VOL.
4

Azadi Ka Amrit Mahotsav

Agriculture and Allied Sciences

Restructured and Revised Syllabi of Post-graduate Programmes

- Dairy Science and Technology
- Agricultural Engineering & Technology
- Food Sciences Technology

भाकृअनुप
ICAR

Education Division
Indian Council of Agricultural Research
New Delhi

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सत्यमेव जयते

त्रिलोचन महापात्र, पीएच.डी.
एफ एन ए, एफ एन ए एस सी, एफ एन ए ए एस
सचिव एवं महानिदेशक

TRILOCHAN MOHAPATRA, Ph.D.
FNA, FNASc, FNAAS
SECRETARY & DIRECTOR GENERAL

भारत सरकार
कृषि अनुसंधान और शिक्षा विभाग एवं
भारतीय कृषि अनुसंधान परिषद
कृषि एवं किसान कल्याण मंत्रालय, कृषि भवन, नई दिल्ली 110 001

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Foreword

THE ICAR has been continuously striving to bring necessary reforms for quality assurance in agricultural education. The Council has appointed National Core Group and BSMA Committees for revision and restructuring of Post-graduate and Doctoral syllabi in consultation with all the stakeholders to meet the challenges and harness opportunities in various disciplines of agriculture and allied sciences. It has been observed that a paradigm shift is necessary in academic regulations to comply with various provisions of National Education Policy-2020. It is heartening to note that the respective Committees have taken due care by following flexible, multi-disciplinary and holistic approach while developing the syllabus and academic regulations. The students are given opportunities to select the courses to support their planned research activities, to register for online courses and to pursue internship for development of entrepreneurship during Masters' programme. Further, the Teaching Assistantship has been introduced to provide experience to the Ph.D. scholars on teaching, evaluation and other related academic matters. This is an important part of doctoral training all over the world and it is expected to address the shortage of faculty in many institutions/universities. By intensive discussion with the subject experts and based on the feedback from the faculty and students, the syllabus of Masters' and Doctoral programmes in 79 disciplines was restructured and new courses were introduced. The syllabus has been revised suitably with the view to equip the students to gain knowledge, enhance their employability and skill sets to mould towards entrepreneurship and build themselves to prepare for global competitiveness. The opinions and suggestions invited from the concerned institutions, eminent scientists and other stakeholders were also reviewed by the Committees.

The Council sincerely thanks Dr Arvind Kumar, Chairman of the National Core Group and its members for the guidance to develop the syllabus in line with contemporary and projected national and global agricultural trends. The Council acknowledges the dedicated efforts and contribution of all the Chairpersons and members of 19 BSMA Committees for preparation of the syllabus. It gives me immense pleasure to express profuse thanks to the Agricultural Education Division for accomplishing this mammoth task under the guidance of Dr N.S. Rathore, former DDG and Dr R.C. Agrawal, DDG. I compliment Dr G. Venkateshwarlu, former ADG (EQR) for his sincere efforts and overall coordination of the meetings. Special thanks to DKMA for bringing out the entire syllabus in six volumes.

(T. Mohapatra)

Date: 13th August 2021
Place: New Delhi-110 001

Preface

THE curricula development is a part of the continued process and effort of the ICAR in this direction for dynamic improvement of national agricultural education system. In this resolve, the ICAR has constituted a National Core Group (NCG) for restructuring of Master's and Ph.D. curriculum, syllabi and academic regulations for the disciplines under agricultural sciences. On the recommendations of the NCG, 19 Broad Subject Matter Area (BSMA) Committees have been constituted by the ICAR for revising the syllabus. These Committees held discussions at length in the meetings and workshops organized across the country. The opinions and suggestions invited from institutions, eminent scientists and other stakeholders were also reviewed by the Committees. The respective BSMA Committees have examined the existing syllabus and analysed carefully in terms of content, relevance and pattern and then synthesized the new syllabus.

The revised curricula of 79 disciplines has been designed with a view to improve the existing syllabus and to make it more contextual and pertinent to cater the needs of students in terms of global competitiveness and employability. To mitigate the concerns related to agriculture education system in India and to ensure uniform system of education, several changes have been incorporated in common academic regulations in relation to credit load requirement and its distribution, system of examination, internship during Masters programme, provision to enrol for online courses and take the advantage of e-resources through e-learning and teaching assistantship for Ph.D. scholars. As per recommendations of the National Education Policy-2020, the courses have been categorized as Major and Minor/Optional courses. By following the spirit of Choice Based Credit System (CBCS), the students are given opportunity to select courses from any discipline/department enabling the multi-disciplinary approach.

We place on record our profound gratitude to Dr Trilochan Mohapatra, Director General, ICAR, New Delhi, for providing an opportunity to revise the syllabi for PG and Ph.D. programs in agriculture and allied sciences. The Committee is deeply indebted to Dr R.C. Agrawal, DDG (Agri. Edn), and to his predecessor Dr N.S. Rathore for their vision and continuous support. Our thanks are due to all Hon'ble Vice Chancellors of CAUs/SAUs/DUs for their unstinted support and to nominate the senior faculty from their universities/institutes to the workshops organized as a part of wider consultation process.

The revised syllabi encompass transformative changes by updating, augmenting, and revising course curricula and common academic regulations to achieve necessary quality and need-based agricultural education. Many existing courses were upgraded with addition and deletion as per the need of the present situation. The new courses have been incorporated based on their importance and need both at national and international level. We earnestly hope that this document will meet the needs and motivate different stakeholders.

G. Venkateshwarlu
Member-Secretary

Arvind Kumar
Chairman, National Core Group

Overview

A National Core Group has been constituted by ICAR for development of Academic Regulations for Masters and Ph.D. programmes, defining names and curricula of Masters' and Ph.D. disciplines for uniformity and revision of syllabi for courses of Masters' and Ph.D. degree disciplines. On the recommendations of the members of National Core Group, 19 Broad Subject Matter Area (BSMA) Committees have been constituted for revising the syllabus. These committees have conducted several meetings with the concerned experts and stakeholders and developed the syllabus for their respective subjects. While developing the syllabi, various provisions of National Education Policy-2020 have also been considered and complied to provide quality higher education and develop good, thoughtful, well-rounded, and creative individuals. Necessary provisions have been made in the curricula to enable an individual to study major and minor specialized areas of interest at a deep level, and also develop intellectual curiosity, scientific temper and creativity.

I express my gratefulness to Dr Arvind Kumar, Vice-Chancellor, Rani Lakshmi Bai Central Agricultural University, Jhansi and Chairman, National Core Group under whose guidance the syllabi for Master's and Doctoral programme is completed. His vast experience in agricultural education and research helped in finalising the syllabi. I wish to place on record the suggestions and directions shown by Dr N.S. Rathore, former Deputy Director General (Education) and Dr G. Venkateswarlu, ADG (EQR) and Member Secretary, National Core Group throughout the period without which the present target could not have been achieved. I am extremely thankful to 19 BSMA Committees for their stupendous job in restructuring and articulating curricula in the light of technological developments and employability prospects in agriculture and allied sciences. I also appreciate and acknowledge the efforts made by Dr S.K. Sankhyan, Principal Scientist (EQR), Dr S.K. Singh, Project Director (DKMA), Mr Punit Bhasin, Incharge, Production Unit (DKMA), Dr Kshitij Malhotra and Dr Sumit Saini, Research Associates to take up the work of editing, proof reading, finalizing and bringing out these six volumes of BSMA in this shape.

I also take this opportunity to express a deep sense of gratitude to Dr Trilochan Mohapatra, Secretary, DARE and Director General, ICAR for his guidance, cordial support and valuable input throughout the revision of the syllabus by BSMA, which helped in completing this task through various stages. The support and help extended by all Deputy Director Generals and the staff of Education Division is also greatly acknowledged.

During this comprehensive exercise of upgrading the course contents, the much-needed academic support, hospitality and participation rendered by Hon'ble Vice-Chancellors of CAUs/SAUs/DUs is greatly acknowledged. My deep sense of gratitude goes to Deans, Directors, Professors, Heads, faculty members and students at the universities who contributed by their effective participation and interaction.

R.C. Agrawal

Contents

Common Academic Regulations for PG and Ph.D. Programmes

1. Academic Year and Registration

- An academic year shall be normally from July to June of the following calendar year otherwise required under special situations. It shall be divided into two academic terms known as semesters. Dates of registration, commencement of instructions, semester end examination, end of semester and academic year, etc. The Academic Calendar shall be developed by the concerned University from time to time and notified accordingly by the Registrar in advance.
- An orientation programme shall be organized by the Director (Education)/ Dean PGS for the benefit of the newly admitted students immediately after commencement of the semester.
- On successful completion of a semester, the continuing students shall register for subsequent semester on the date specified in the Academic/ Semester Calendar or specifically notified separately. Every enrolled student shall be required to register at the beginning of each semester till the completion of his/ her degree programmes.

2. Credit requirements

2.1 Framework of the courses

The following nomenclature and Credit Hrs need to be followed while providing the syllabus for all the disciplines:

		Masters' Programme	Doctoral Programme
(i)	**Course work**		
	Major courses	20	12
	Minor courses	08	06
	Supporting courses	06	05
	Common courses	05	–
	Seminar	01	02
(ii)	**Thesis Research**	30	75
	Total	70	100

Major courses: From the Discipline in which a student takes admission. Among the listed courses, the core courses compulsorily to be taken may be given *mark

Minor courses: From the subjects closely related to a student's major subject

Supporting courses: The subject not related to the major subject. It could be any subject considered relevant for student's research work (such as Statistical Methods, Design of Experiments, etc.) or necessary for building his/ her overallcompetence.

Common Courses: The following courses (one credit each) will be offered to all students undergoing Master's degree programme:

1. Library and Information Services
2. Technical Writing and Communications Skills
3. Intellectual Property and its management in Agriculture
4. Basic Concepts in Laboratory Techniques
5. Agricultural Research, Research Ethics and Rural Development Programmes

Some of these courses are already in the form of e-courses/ MOOCs. The students may be allowed to register these courses/ similar courses on these aspects, if available online on SWAYAM or any other platform. If a student has already completed any of these courses during UG, he/ she may be permitted to register for other related courses with the prior approval of the Head of Department (HoD)/ Board of Studies (BoS).

2.2 Supporting Courses

The following courses are being offered by various disciplines (The list is only indicative). Based on the requirement, any of the following courses may be opted under the supporting courses. The syllabi of these courses are available in the respective disciplines. If required, the contents may be modified to suit the individual discipline with approval of the concerned BoS:

Code	Course Title	Credit Hours
STAT 501	Mathematics for Applied Sciences	2+0
STAT 502	Statistical Methods for Applied Sciences	3+1

Course Code	Course Title	Credit Hours
STAT 511	Experimental Designs	2+1
STAT 512	Basic Sampling Techniques	2+1
STAT 521	Applied Regression Analysis	2+1
STAT 522	Data Analysis Using Statistical Packages	2+1
MCA 501	Computers Fundamentals and Programming	2+1
MCA 502	Computer Organization and Architecture	2+0
MCA 511	Introduction to Communication Technologies, Computer Networking and Internet	1+1
MCA 512	Information Technology in Agriculture	1+1
BIOCHEM 501	Basic Biochemistry	3+1
BIOCHEM 505	Techniques in Biochemistry	2+2

2.3 Syllabus of Common Courses for PG programmes

LIBRARY AND INFORMATION SERVICES (0+1)

Objective

To equip the library users with skills to trace information from libraries efficiently, to apprise them of information and knowledge resources, to carry out literature survey, to formulate information search strategies, and to use modern tools (Internet, OPAC, search engines, etc.) of information search.

Practical

Introduction to library and its services; Role of libraries in education, research and technology transfer; Classification systems and organization of library; Sources of information- Primary Sources, Secondary Sources and Tertiary Sources; Intricacies of abstracting and indexing services (Science Citation Index, Biological Abstracts, Chemical Abstracts, CABI Abstracts, etc.); Tracing information from reference sources; Literature survey; Citation techniques/ Preparation of bibliography; Use of CD-ROM Databases, Online Public Access Catalogue and other computerized library services; Use of Internet including search engines and its resources; e-resources access methods.

TECHNICAL WRITING AND COMMUNICATIONS SKILLS (0+1)

Objective

To equip the students/ scholars with skills to write dissertations, research papers, etc. To equip the students/ scholars with skills to communicate and articulate in English (verbal as well as writing).

Practical (Technical Writing)

- Various forms of scientific writings- theses, technical papers, reviews, manuals, etc.;
- Various parts of thesis and research communications (title page, authorship contents page, preface, introduction, review of literature, material and methods, experimental results and discussion);
- Writing of abstracts, summaries, précis, citations, etc.;

- Commonly used abbreviations in the theses and research communications;
- Illustrations, photographs and drawings with suitable captions; pagination, numbering of tables and illustrations;
- Writing of numbers and dates in scientific write-ups;
- Editing and proof-reading;
- Writing of a review article;
- Communication Skills - Grammar (Tenses, parts of speech, clauses, punctuation marks);
- Error analysis (Common errors), Concord, Collocation, Phonetic symbols and transcription;
- Accentual pattern: Weak forms in connected speech;
- Participation in group discussion;
- Facing an interview;
- Presentation of scientific papers.

Suggested Readings

1. Barnes and Noble. Robert C. (Ed.). 2005. *Spoken English: Flourish Your Language*.
2. *Chicago Manual of Style*. 14th Ed. 1996. Prentice Hall of India.
3. *Collins' Cobuild English Dictionary*. 1995.
4. Harper Collins. Gordon HM and Walter JA. 1970. *Technical Writing*. 3rd Ed.
5. Holt, Rinehart and Winston. Hornby AS. 2000. *Comp. Oxford Advanced Learner's Dictionary of Current English*. 6th Ed. Oxford University Press.
6. James HS. 1994. *Handbook for Technical Writing*. NTC Business Books.
7. Joseph G. 2000. *MLA Handbook for Writers of Research Papers*. 5th Ed. Affiliated East-West Press.
8. Mohan K. 2005. *Speaking English Effectively*. MacMillan India.
9. Richard WS. 1969. *Technical Writing*.
10. Sethi J and Dhamija PV. 2004. *Course in Phonetics and Spoken English*. 2nd Ed. Prentice Hall of India.
11. Wren PC and Martin H. 2006. *High School English Grammar and Composition*. S. Chand & Co.

INTELLECTUAL PROPERTY AND ITS MANAGEMENT IN AGRICULTURE (1+0)

Objective

The main objective of this course is to equip students and stakeholders with knowledge of Intellectual Property Rights (IPR) related protection systems, their significance and use of IPR as a tool for wealth and value creation in a knowledge-based economy.

Theory

Historical perspectives and need for the introduction of Intellectual Property Right regime; TRIPs and various provisions in TRIPS Agreement; Intellectual Property and Intellectual Property Rights (IPR), benefits of securing IPRs; Indian Legislations for the protection of various types of Intellectual Properties; Fundamentals of patents, copyrights, geographical indications, designs and layout, trade secrets and traditional knowledge, trademarks, protection of plant varieties and farmers' rights and biodiversity protection; Protectable subject matters, protection in biotechnology, protection of other biological materials, ownership and period of protection; National

Biodiversity protection initiatives; Convention on Biological Diversity; International Treaty on Plant Genetic Resources for Food and Agriculture; Licensing of technologies, Material transfer agreements, Research collaboration Agreement, License Agreement.

Suggested Readings

1. Erbisch FH and Maredia K.1998. *Intellectual Property Rights in Agricultural Biotechnology*. CABI.
2. Ganguli P. 2001. *Intellectual Property Rights: Unleashing Knowledge Economy*. McGraw-Hill.
3. *Intellectual Property Rights: Key to New Wealth Generation*. 2001. NRDC and Aesthetic Technologies.
4. Ministry of Agriculture, Government of India. 2004. *State of Indian Farmer*. Vol. V. Technology Generation and IPR Issues. Academic Foundation.
5. Rothschild M and Scott N. (Ed.). 2003. *Intellectual Property Rights in Animal Breeding and Genetics*. CABI.
6. Saha R. (Ed.). 2006. *Intellectual Property Rights in NAM and Other Developing Countries: A Compendium on Law and Policies*. Daya Publ. House.

The Indian Acts - Patents Act, 1970 and amendments; Design Act, 2000; Trademarks Act, 1999; The Copyright Act, 1957 and amendments; Layout Design Act, 2000; PPV and FR Act 2001, and Rules 2003; The Biological Diversity Act, 2002.

BASIC CONCEPTS IN LABORATORY TECHNIQUES (0+1)

Objective

To acquaint the students about the basics of commonly used techniques in laboratory.

Practical

- Safety measures while in Lab;
- Handling of chemical substances;
- Use of burettes, pipettes, measuring cylinders, flasks, separatory funnel, condensers, micropipettes and vaccupets;
- Washing, drying and sterilization of glassware;
- Drying of solvents/ chemicals;
- Weighing and preparation of solutions of different strengths and their dilution;
- Handling techniques of solutions;
- Preparation of different agro-chemical doses in field and pot applications;
- Preparation of solutions of acids;
- Neutralisation of acid and bases;
- Preparation of buffers of different strengths and pH values;
- Use and handling of microscope, laminar flow, vacuum pumps, viscometer, thermometer, magnetic stirrer, micro-ovens, incubators, sandbath, waterbath, oilbath;
- Electric wiring and earthing;
- Preparation of media and methods of sterilization;
- Seed viability testing, testing of pollen viability;
- Tissue culture of crop plants;
- Description of flowering plants in botanical terms in relation to taxonomy.

Suggested Readings

1. Furr AK. 2000. *CRC Hand Book of Laboratory Safety*. CRC Press.

2. Gabb MH and Latchem WE. 1968. *A Handbook of Laboratory Solutions*. Chemical Publ. Co.

AGRICULTURAL RESEARCH, RESEARCH ETHICS AND RURAL DEVELOPMENT PROGRAMMES (1+0)

Objective

To enlighten the students about the organization and functioning of agricultural research systems at national and international levels, research ethics, and rural development programmes and policies of Government.

Theory

UNIT I History of agriculture in brief; Global agricultural research system: need, scope, opportunities; Role in promoting food security, reducing poverty and protecting the environment; National Agricultural Research Systems (NARS) and Regional Agricultural Research Institutions; Consultative Group on International Agricultural Research (CGIAR): International Agricultural Research Centres (IARC), partnership with NARS, role as a partner in the global agricultural research system, strengthening capacities at national and regional levels; International fellowships for scientific mobility.

UNIT II Research ethics: research integrity, research safety in laboratories, welfare of animals used in research, computer ethics, standards and problems in research ethics.

UNIT III Concept and connotations of rural development, rural development policies and strategies. Rural development programmes: Community Development Programme, Intensive Agricultural District Programme, Special group – Area Specific Programme, Integrated Rural Development Programme (IRDP) Panchayati Raj Institutions, Co-operatives, Voluntary Agencies/ Non-Governmental Organisations. Critical evaluation of rural development policies and programmes. Constraints in implementation of rural policies and programmes.

Suggested Readings

1. Bhalla GS and Singh G. 2001. *Indian Agriculture - Four Decades of Development*. Sage Publ.
2. Punia MS. *Manual on International Research and Research Ethics*. CCS Haryana Agricultural University, Hisar.
3. Rao BSV. 2007. *Rural Development Strategies and Role of Institutions - Issues, Innovations and Initiatives*. Mittal Publ.
4. Singh K. 1998. *Rural Development - Principles, Policies and Management*. Sage Publ.

2.4 Mandatory requirement of seminars

- It has been agreed to have mandatory seminars one in Masters (One Credit) and two in Doctoral programmes (two Credits).
- The students should be encouraged to make presentations on the latestdevelopments and literature in the area of research topic. This will provide training to the students on preparation for seminar, organizing the work, critical analysis of data and presentation skills.

3. Residential requirements

- The minimum and maximum duration of residential requirement for Masters'

Degree and Ph.D. Programmes shall be as follows:

P.G. Degree Programmes	Duration of Residential Requirement	
	Minimum	Maximum
Masters' Degree	2 Academic Years (4 Semesters)	5 Academic Years (10 Semesters)
Ph.D.*	3 Academic Years (6 Semesters)	7 Academic Years (14 Semesters)

*Student may be allowed to discontinue temporarily only after completion of course work

In case a student fails to complete the degree programme within the maximum duration of residential requirement, his/ her admission shall stand cancelled. The requirement shall be treated as satisfactory in the cases in which a student submits his/ her thesis any time during the 4^{th} and 6^{th} semester of his/ her residentship at the University for Masters' and Ph.D. programme, respectively.

4. Evaluation of course work and comprehensive examination

- For M.Sc., multiple levels of evaluation (First Test, Midterm and Final semester) is desirable. However, it has been felt that the comprehensive examination is redundant for M.Sc. students.
- For Ph.D., the approach should be research oriented rather than exam oriented. In order to provide the student adequate time to concentrate on the research work and complete the degree in stipulated time, the examination may have to be only semester final. However, the course teacher may be given freedom to evaluate in terms of assignment/ seminar/ first test.
- For Ph.D., the comprehensive examination (Pre-qualifying examination) is required. As the students are already tested in course examinations, the comprehensive examinationshould be based onoral examinationby an external expert and the evaluation should cover both the research problem and theoretical background to execute the project. This shall assess the aptitude of the student and suitability of the student for the given research topic. The successful completion of comprehensive examination is to obtain the "Satisfactory" remark by the external expert.

5. Advisory System

5.1 Advisory Committee

- There shall be an Advisory Committee for every student consisting of not fewer than three members in the case of a candidate for Masters' degree and four in the case of Ph.D. degree with the Advisor as Chairperson. The Advisory Committee should have representatives from the major and minor fields amongst the members of the Post-graduate faculty accredited for appropriate P.G. level research. However, in those departments where qualified staff exists but due to unavoidable reasons Post-graduate degree programmes are not existing, the staff having Post-graduate teaching experience of two years or more may be included in the Advisory Committee as member representing the minor.
- At any given time, a P.G. teacher shall not be a Chairperson, Advisory Committee (including Master's and Ph.D. programmes) for more than five students.

- The Advisor should convene a meeting of the Advisory Committee at least once in a Semester. The summary record should be communicated to the Head of Department, Dean of the College of concerned, Director (Education)/ Dean PGS and Registrar for information.

Advisor/ Co-guide/ Member, Advisory Committee from other collaborating University/ Institute/ Organization

- In order to promote quality Post-graduate research and training in cutting edge areas, the University may enter into Memorandum of Understanding (MOU) with other Universities/ Institutions for conducting research. While constituting an Advisory Committee of a student, if the Chairperson, Advisory Committee feels the requirement of involving of a faculty member/ scientist of such partnering university/ Institute/ Organization, he/ she may send a proposal to this effect to Director (Education)/ Dean PGS along with the proposal for consideration of Student's Advisory Committee (SAC).
- The proposed faculty member from the partnering institution can be allowed to act as Chairperson/ Co-guide/ Member, SAC, by mutual consent, primarily on the basis of intellectual input and time devoted for carrying out the research work at the particular institution. The faculty member/ scientist of partnering institutions in the SAC shall become a temporary faculty member of the University by following the procedure approved by the Academic Council.

Allotment of students to the retiring persons

Normally, retiring person may not be allotted M. Sc. Student if he/ she is left with less than 2 years of service and Ph.D. student if left with less than 3 years of service. However, in special circumstances, permission may be obtained from the Director (Education)/ Dean PGS, after due recommendation by the concerned Head of the Department.

Changes in the Advisory Committee:

(i) Change of the Chairperson or any member of the Advisory Committee is not ordinarily permissible. However, in exceptional cases, the change may be effected with due approval of the Director of Education/ Dean PGS.

(ii) Normally, staff members of the university on extra ordinary leave or on study leave or who leave the University service will cease to continue to serve as advisors of the Post-graduate students of the University. However, the Director (Education)/ Dean PGS may permit them to continue to serve as advisor subject to the following conditions:

(a) The concerned staff member must be resident in India and if he/ she agrees to guide research and must be available for occasional consultations;

(b) An application is made by the student concerned duly supported by the Advisory Committee;

(c) In case of a Ph.D. student, he/ she must have completed his/ her comprehensive examinations and the research work must be well in progress and it is expected that the student will submit the thesis within a year;

(d) The Head of the Department and the Dean of the College concerned agree to the proposal;

(e) The staff member, after leaving the University service is granted the status of honorary faculty's membership by the Vice-Chancellor on the recommendation of the Director (Education)/ Dean PGS for guiding as Chairperson or Member, Advisory Committee the thesis/ theses of the student(s) concerned only.

(iii) In case the Chairperson/ member of a Student's Advisory Committee retires, he/ she shall be allowed to continue provided that the student has completed his course work and minimum of 10 research credits and the retiring Chairperson/ member stays at the Headquarters of the College, till the thesis is submitted.

(iv) If the Chairperson/ member proceeds on deputation to another organization, he/ she may be permitted to guide the student provided his/ her new organization is at the Headquarters of the College and his/ her organization is willing for the same.

(v) The change shall be communicated to all concerned by the Head of Department.

6. Evaluation of research work

- It is highly desirablefor Ph.D. programme and this should be done annually as an essential part of research evaluation. The Student Advisory Committee shallreview the progress of research and scrutinize annual progress reports submitted by the student.
- Midterm evaluation of Ph.D. (to move from JRF to SRF) is a mandatory requirement for all the funding agencies. Hence, the second review of annual progress report need to be done after completion of two years. The successful completion enables the students to become eligible for SRF.

6.1 Prevention of plagiarism

- An institutional mechanism should be in place to check the plagiarism. The students must be made aware that manipulation of the data/ plagiarism is punishable with serious consequences.

7. Learning through online courses

- In line with the suggestion in new education policy and the initiatives taken by ICAR and MHRD in the form of e-courses, MOOCs, SWAYAM, etc. and also changes taking place globally in respect of learning through online resources it has been agreed to permit the students to enrol for online courses. It is expected that the provision of integrating available online courses with the traditional system of education would provide the students opportunities to improve their employability by imbibing the additional skills and competitive edge.

The Committee recommends the following points while integrating the online courses:

1. Board of Studies (BoS) of each Faculty shall identify available online courses and a student may select from the listed courses. The interested students may provide the details of the on-line courses to the BoS for its consideration.
2. A Postgraduate student may take up to a maximum of 20% credits in a semester through online learning resources.
3. The host institute offering the course does the evaluation and provide marks/ grades. The BoS shall develop the conversion formula for calculation of GPA and it may do appropriate checks on delivery methods and do additional evaluations, if needed.

8. Internship during Masters programme

Internship for Development of Entrepreneurship in Agriculture (IDEA)

Currently, a provision of 30 credits for dissertation work in M.Sc./ M.Tech/ M.F.Sc./ M.V.Sc. programmes helps practically only those students who aspire to pursue their career in academic/ research. There is hardly any opportunity/ provision under this system to enhance the entrepreneurship skills of those students who could start their own enterprise or have adequate skills to join the industry. Therefore, in order to overcome this gap, an optional internship/ in-plant training (called as IDEA) in lieu of thesis/ research work is recommended which will give the students an opportunity to have a real-time hands-on experience in the industry.

It is envisaged that the internship/ in-plant training would enhance the interactions between academic organizations and the relevant industry. It would not only enable the development of highly learned and skilled manpower to start their-own enterprises but also the industry would also be benefitted through this process. This pragmatic approach would definitely result in enhancedpartnerships between academia and industry.

The main objectives of the programme:

1. To promote the linkages between academia and industry
2. To establish newer University – Cooperative R&D together with industry for knowledge creation, research and commercialization
3. Collaboration between Universities and industries through pilot projects
4. To develop methods for knowledge transfer, innovation and networking potential
5. To enhance skill, career development and employability

Following criteria for IDEA will be taken into consideration:

- At any point of time there will not be more than 50% of students who can opt under IDEA
- Major Advisor will be from Academia and Co-advisor (or Advisory Committee member) from industry
- Total credits (30) will be divided into 20 for internship/ in-plant training and10 for writing the report followed by viva-voce similar to dissertation
- Work place will be industry; however, academic/ research support would be provided by the University or both. MoU may be developed accordingly
- The IPR, if any, would be as per the University policy

9. Teaching assistantship

- Teaching assistantship shall be encouraged. This will give the required experience to the students on how to conduct courses, practical classes, evaluation and other related academic matters. This is an important part of Ph.D. training all over the world and it is expected to address the shortage of faculty in many institutions/ universities.
- The fulltime doctoral students of the University with or without fellowship may be considered for award of Teaching Assistantships in their respective Departments. The Teaching Assistantship shall be offered only to those doctoral students who have successfully finished their course work. Any consideration for award of Teaching Assistantships must have the consent ofthe supervisor concerned.
- Teaching Assistantships shall be awarded on semester to semester basis on the recommendation of a screening/ selection committee to be constituted by the

ViceChancellor. All classes and assignments given to the Teaching Assistants, including tutorials, practicals and evaluation work shall be under the supervision of a faculty member who would have otherwise handled the course/ assignment.

- Each Ph.D. student may be allowed to take a maximum of 16 classes in a month to UG/ Masters students.
- No additional remuneration shall be paid to the students who are awarded ICAR JRF/ SRF. The amount of fellowship to be paid as remuneration to other students (who are receiving any other fellowship or without any fellowships) may be decided by the concerned universities as per the rules in force.However, the total amount of remuneration/ and fellowship shall not exceed the amount being paid as JRF/ SRF of ICAR.
- At the end of each term, Teaching Assistants shall be given a certificate by the concerned Head of the Department, countersigned by the School Dean, specifying the nature and load of assignments completed.

10. Registration of project personnel (SRF/ RA) for Ph.D.

- A provision may be made to enable the project personnel (SRF/ RA) to register for Ph.D. However, this can be done only if they are selected based on some selection process such as walk-in-interview. The prior approval of PI of the project is mandatory to consider the application of project personnel (SRF/ RA) for Ph.D. admission
- The candidates need to submit the declaration stating that the project work shall not be compromised because of Ph.D. programme. Further, in order to justify the project work and Ph.D. programme, the number of course credits should not be more than 8 in a semester for the project personnel (SRF/ RA) who intend to register for Ph.D.

11. Compliance with the National Education Policy-2020

- While implementing the course structure and contents recommended by the BSMA Committees, the Higher Education Institutions (HEIs) are required to comply with the provisions of National Education Policy-2020, especially the following aspects:
- Given the 21st century requirements, quality higher education must aim to develop good, thoughtful, well-rounded, and creative individuals. It must enable an individual to study one or more specialized areas of interest at a deep level, and also develop character, ethical and Constitutional values, intellectual curiosity, scientific temper, creativity, spirit of service, and 21st century capabilities across a range of disciplines including sciences, social sciences, arts, humanities, languages, as well as professional, technical, and vocational subjects. A quality higher education must enable personal accomplishment and enlightenment, constructive public engagement, and productive contribution to the society. It must prepare students for more meaningful and satisfying lives and work roles and enable economic independence (9.1.1. of NEP-2020).
- At the societal level, higher education must enable the development of an enlightened, socially conscious, knowledgeable, and skilled nation that can find and implement robust solutions to its own problems. Higher education must form the basis for knowledge creation and innovation thereby contributing to a growing national economy. The purpose of quality higher education is, therefore, more than the creation of greater opportunities for individual employment. It represents the key to more vibrant, socially engaged, cooperative communities and a happier,

cohesive, cultured, productive, innovative, progressive, and prosperous nation (9.1.3. of NEP-2020).

- Flexibility in curriculum and novel and engaging course options will be on offer to students, in addition to rigorous specialization in a subject or subjects. This will be encouraged by increased faculty and institutional autonomy in setting curricula. Pedagogy will have an increased emphasis on communication, discussion, debate, research, and opportunities for cross-disciplinary and interdisciplinary thinking (11.6 of NEP-2020).
- As part of a holistic education, students at all HEIs will be provided with opportunities for internships with local industry, businesses, artists, crafts persons, etc., as well as research internships with faculty and researchers at their own or other HEIs/ research institutions, so that students may actively engage with the practical side of their learning and, as a by-product, further improve their employability (11.8 of NEP-2020).
- HEIs will focus on research and innovation by setting up start-up incubation centres; technology development centres; centres in frontier areas of research; greater industry-academic linkages; and interdisciplinary research including humanities and social sciences research (11.12. of NEP-2020).
- Effective learning requires a comprehensive approach that involves appropriate curriculum, engaging pedagogy, continuous formative assessment, and adequate student support. The curriculum must be interesting and relevant, and updated regularly to align with the latest knowledge requirements and to meet specified learning outcomes. High-quality pedagogy is then necessary to successfully impart the curricular material to students; pedagogical practices determine the learning experiences that are provided to students, thus directly influencing learning outcomes. The assessment methods must be scientific, designed to continuously improve learning and test the application of knowledge. Last but not least, the development of capacities that promote student wellness such as fitness, good health, psycho-social well-being, and sound ethical grounding are also critical for high-quality learning (12.1. of NEP-2020).

Definitions of Academic Terms

Chairperson means a teacher of the major discipline proposed by the Head of Department through the Dean of the College and duly approved by the Director of Education/ Dean Post Graduate Studies (or as per the procedure laid down in the concerned University regulations) to act as the Chairperson of the Advisory Committee and also to guide the student on academic issues.

Course means a unit of instruction in a discipline carrying a specific number and credits to be covered in a semester as laid down in detail in the syllabus of a degree programme.

Credit means the unit of work load per week for a particular course in theory and/ or practical. One credit of theory means one class of one clock hour duration and one credit practical means one class of minimum two clock hoursof laboratory work per week.

Credit load of a student refers to the total number of credits of all the courses he/ she registers during a particular semester.

Grade Point (GP) of a course is a measure of performance. It is obtained by dividing the per cent mark secured by a student in a particular course by 10, expressed and rounded off to second decimal place.

Credit Point (CP) refers to the Grade point multiplied by the number of credits of the course, expressed and rounded off to second decimal place.

Grade Point Average (GPA) means the total credit point earned by a student divided by total number of credits of all the courses registered in a semester, expressed and rounded off to second decimal place.

Cumulative Grade Point Average (CGPA) means the total credit points earned by a student divided by the total number of credits registered by the student until the end of a semester (all completed semesters), expressed and rounded off to second decimal place.

Overall Grade Point Average (OGPA) means the total credit points earned by a student in the entire degree programme divided by the total number of credits required for the P.G. degree, expressed and rounded off to second decimal place.

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Dairy Science and Technology

- Dairy Technology
- Dairy Engineering
- Dairy Chemistry
- Dairy Microbiology

Contents

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Preamble

The contents of the master's and doctoral courses were critically examined for introducing new dimension to the curriculum in light of the advances made in the scientific knowledge in thefour major disciplines of Dairy Processing and allied disciplines during the last ten years. In Dairy Technology discipline, two new courses at Master's Levelhavebeen added.The course on Production and Applications of Dairy Ingredients covers the principles of conventional and novel approaches for separation, concentration and fractionation of milk components and the second course on Advances in Cheese Technology primarily focuses on the new developments in rennet and acid coagulated cheeses. For doctoral level program in this discipline, Advances in Carbohydrate Technology has been added as a new course. Two other courses namely Advances in Food Processing and Non-Conventional Processes for Dairy and Food Industry have been significantly modified while minor changes have been incorporated in the contents and titles of the other courses. In Dairy Microbiology discipline, two old courses 'Methods in Microbiology' and 'Feed and Rumen Microbiology' have been removed and three new courses 'Microbiology of Fluid Milk and Dairy Products'; 'Microbiology of Cheese and Fermented Dairy Foods' and 'Research Techniques' have been introduced in Masters' Degree Programme to make the students abreast with the emerging trends and scope of microbiology of milk and milk products along with the conventional and innovative analytical instrumentationsrelevant during the research work.In doctoral programme, the course 'Microbiology of Food-borne Pathogens' has been replaced with two new courses 'Advances in Food Safety of Dairy Products' and 'Advances in Probiotics and Functional Foods' to address the recent development in rapid changing fields of food safety and functional foods. In Dairy Engineering discipline, five new courses for Master level program, viz. Industrial Automation and Robotics, Unit Operations, Engineering Properties of Dairy and Food Products, Mechanization in Manufacturing of Indigenous Dairy Products and Energy Management and Auditing in Dairy and Food Plants and two new courses for doctoral program, viz. Advances in Food Process Engineering and Package Permeability and Shelf-Life Modelling have been added in the course curriculum. The idea for inclusion of these courses was conceived based on the feedback from the students working in the industry and educational institutions. In addition to their relevance to the dairy operations, thesenew courses would cover a wide spectrum of application of engineering principles and would be particularly helpful to the students in comprehensive understanding of the subject and in several competitive examinations which require sound basic engineering knowledge. In Dairy Chemistry discipline, although no new course has been introduced; significant changes in the course content were made in the existing courses. The course on Physico-chemical Aspects of Milk Constituents has been modified to better understand the physico-chemical properties of milk constituents in light of the emergence of new analytical techniques, along with the addition of topics related to their recent application in food processing, storage and quality assurance. The courseon Chemistry of Food Constituents has been restructured in such a way that different constituents both major and minor are covered with their specific properties for better applications in the food processing. Additionally, the credit load and the nomenclature of many other courses have been suitably revised for their better understanding and applications.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 4

Dairy Science and Technology
– Dairy Technology

Course Title with Credit Load
M.Tech. in Dairy Technology

Course Code	Course Title	Credit Hours
	Major Courses	
DT-511*	Advances in Dairy Processing	3+1
DT-512	Advances in Food Processing	3+1
DT-513*	Rheology of Dairy and Food Products	2+1
DT-514	Biotechnology for Dairy Applications	2+1
DT-515	Advances in Traditional Indian Dairy Products	2+1
DT-516	Non-conventional Processes for Dairy and Food Industry	2+1
DT-521*	Membrane Processing for Dairy Applications	2+1
DT-522*	Advances in Dairy and Food Packaging	2+1
DT-523	Technology of Food Emulsions, Foams and Gels	2+1
DT-524	Functional Foods and Nutraceuticals	3+1
DT-525	Production and Applications of Dairy Ingredients	2+1
DT-526	Advances in Cheese Technology	2+1
DT-591	Master’s Seminar	1+0
DT-599	Master’s Research	0+30

Course Contents
M. Tech. in Dairy Technology

I. Course Title : Advances in Dairy Processing
II. Course Code : DT 511
III. Credit Hours : 3+1

IV. Why this course?

The basic principles of dairy processing have been understood at undergraduate level. Any dairy plant has to be abreast with the latest developments taking place in the arena of dairy processing, dairy product preservation, quality assurance and public health safety, automation, mechanization, etc. Knowledge of such aspects will help in controlling milk solids losses, aid in process optimization and help in catering to quality dairy products to the consumers.

V. Aim of the course

To provide in-depth knowledge about the various unit operations and basic concepts in dairy processing

VI. Theory

Unit I

Use of bio-protective factors for preservation of raw milk: effects on physico-chemical, micro-bial and nutritional properties of milk and milk products; Present status of preservation of raw milk.

Unit II

Methods of determining lethality of thermal processing; UHT processed milk products, their properties and prospects, types of UHT plants, aseptic fillers, heat stability and deposit formation aspects, effect on milk quality; techno-economic considerations; Nutritional aspects of UHT treated milk vis-à-vis retort sterilized/ HTST treated milk.

Unit III

Principles and equipment for bactofugation and bactotherm processes; Partial homogenization and its application in dairy industry, Low pressure homogenization; Microfluidization of milk: Principle, equipment, effects and applications.

Unit IV

Concentration processes and their impact on quality of finished products; Dehydration: advances in drying of milk and milk products; Freeze dehydration: physico-chemical changes and in-dustrial developments; Glass Transition Temperature and its relevance to dried milks.

Unit V

Water activity; Sorption behaviour of foods, energy of binding water, control of water activity of different milk products in relation to their chemical, microbiologi-cal and textural properties; Hurdle technology and its application in development of shelf-stable and intermediate-moisture foods; Use of carbonation in extending the shelf life of dairy products.

Unit VI

Current trends in cleaning and sanitization of dairy equipment; Automation, Ultrasonic techniques in cleaning; Bio-films; Bio-detergents, innovations in sanitizers - chemical, radiation; Mechanism of fouling and soil removal; Assessing the effectiveness of cleaning and sanitization of dairy equipment, Water conservation methods.

VII. Practical

- Measurement of thiocyanate in milk system
- LP system for extending the keeping quality of raw milk
- Determination of HCT-pH profile of milk
- Determination of water activity and sorption isotherms of milk products
- Determination of WPNI of milk powders
- Functional properties of milk powders
- Determination of HMF content in dried milks
- Freeze drying of milk and milk products
- Homogenization efficiency
- Cleaning and sanitization efficiency of dairy equipment
- Visit to a UHT Processing plant.

VIII. Teaching Methods/Activities

- Lecture
- Assignment (Reading/Writing)
- Student's Book/Publication Review
- Student presentation
- Group Work and Group Discussion
- Visit to various dairy plants

IX. Learning outcome

After undergoing this course, the students are expected to deliver the following:

- To have knowledge to ensure delivery of safe and quality product from the dairy plant to the consumers
- To process the milk and dairy products in such a manner that losses of milk solids are minimal
- Be able to suggest to the dairy plant personnel, the latest type of tools that can be harnessed to produce quality products, without impairing the nutritive value of milk
- To suggest the dairy industry personnel regarding the formulation of detergent and/or acid and sanitizers which would help in efficient cleaning and sanitization of dairy equipment?

X. Suggested Reading

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- IndiaDairy.com-https://indiaDairy.com
- Scherjon Dairy Equipment Holland: Dairy processing equipment-https://scherjon.eu/
- National Dairy Council-https:/nationaldairycouncil.org/
- Alfa Laval – Dairy Processing-https://alfalaval.in/industries/food-dairy-and-beverage/dairy-processing/

I. Course Title : Advances in Food Processing

II. Course Code : DT 512

III. Credit Hours : 3+1

IV. Why this course?

The basic principles of food processing, including dairy processing has been understood at undergraduate level. Any food plant has to be abreast with the latest developments taking place in the sphere of food processing, food product preservation, quality assurance and public health safety, automation, mechanization, etc. Information on composite foods may give an idea about foods formed using amalgamation of dairy foods with other food materials and ingredients. Knowledge of such aspects will help in developing value-added food products, cater to functional (health promoting) foods, adopting non-thermal processing methods to obtain food products having freshness and preserved nutrients and colour, etc.

V. Aim of the course

To provide in-depth understanding of advances in theoretical and practical aspects of food processing keeping in mind the nutritive value of product and its perishability

VI. Theory

Unit I

Status of food processing industry in India and abroad; Prospects and constraints in development of Indian food industry.

Unit II

Development in Post-harvest management of Fruits and Vegetables (Controlled and Modified Atmospheric Storage, Designing aspects of CAS/MAS, Components of CAS/MAS), hypobaric storage, harvesting indices for fruits and vegetables.

Unit III

Newer methods of drying of foods (Super-heated steam drying, Freeze drying, infra-red drying and microwave drying; Osmodrying process), Concepts of UHT and retort sterilization of food products, packaging materials for thermally processed foods.

Unit IV

Basic principles involved in fermentation, Technological aspects of pickled vegetables like sauerkraut, cucumbers, Technology of wine, beer and distilled alcoholic beverages, defects in alcoholic beverages.

Unit V

Advances in milling of rice (solvent extractive milling) and Turbo milling of wheat. Emerging concepts in cereal processing including gluten free products, Low calories bakery products, Technologies for breakfast cereals, Utilization and importance of dairy ingredients in bakery products.

Unit VI

Definition, classification and technologies of fabricated and formulated foods and their nutritional aspects. Imitation dairy products and dairy analogues; meat analogues. Principle of extrusion processing, design and working of extruder, classification, application in food and dairy processing. Food additives, including stabilizers, emulsifiers, antioxidants, preservatives, etc. for formulated foods. Fortification of staples.

Unit VII

Non-thermal processing technologies for food: Principles, Effect on food constituents and Salient application in food sector/industry.

Unit VIII

Enzymes in food processing; newer concepts in food processing including organic foods; Processing of organic raw material; Genetically modified foods; Space foods, Nutrigenomics, metabolomics and other Omics concepts in food processing.

VII. Practical

- Experiments on MAS of fruits and vegetables
- Application of microwave for blanching and drying of foods
- Osmoair drying of fruits and vegetables

- Retort processing of food products
- Application of milk ingredients in caramel, egg-less cake, mayonnaise
- Enzymatic extraction and clarification of fruit juices
- Preparation of soymilk and tofu, Manufacture of sauerkraut/ fermented vegetables
- Preparation of protein isolates
- Application of extrusion processing for breakfast cereal and meat analogue manufacture
- Application of hydrocolloids in stabilization of proteins in acidified beverages
- Manufacture of low calorie and gluten-free cereal products.

VIII. Teaching Methods/Activities

– Lecture
– Assignment (Reading/Writing)
– Student's Book/Publication Review
– Student presentation
– Group Work and Group Discussion
– Visit to various food plants

IX. Learning outcome

After undergoing this course, the students are expected to deliver the following:

– To have knowledge on the latest post-harvest management of fresh produce with limited shelf life
– To have an idea about the processing methods that do not diminish the quality attributes of food being processed
– To know about the recent packaging methodologies that can enhance the shelf life of fresh as well as processed produce/food.
– To have any idea about the enzymes that can be used as processing aids.

X. Suggested Reading

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- *Welcome to APEDA*-https//*apeda.gov.in/*
- *Food safety and quality: Chemical risks and JECFA-FAO-https//fao.org/food/food-safety-quality/scientific-advice/jecfa/en/*
- HACCP and GHP: Standards in Food Industry: (EUFIC)-https://eufic.org/en/food-safety/article/food-industry-standards-focus-on-haccp

I. Course Title : Rheology of Dairy and Food Products

II. Course Code : DT 513

III. Credit Hours : 2+1

IV. Why this course?

The mouth feel of processed food product is one of the parameters for the acceptance of foods. The sensory textural quality of food is closely related to the rheology of that pertinent food product. Any technological treatment meted out to dairy/food product leads to change in its rheological characteristics. Such treatment can be specifically practiced to improve the textural quality of food product. Rheology can be used as a quality control tool to monitor the quality of food product being processed or manufactured.

V. Aim of the course

To explain the basics of food rheology, and to familiarize the students with rheological instruments and their use in relation to dairy and food products

VI. Theory

Unit I

Introduction to rheology of foods: Definition of texture, rheology and psychophysics – their structural basis; Physical considerations in study of foods; Salient definitions of stress tensor and different kinds of stresses.

Unit II

Rheological classification of Fluid Foods: Shear-rate dependence and time dependence of the flow-curve; Non-Newtonian fluids; Mechanisms and relevant models for non-Newtonian flow; Effect of temperature on rheology; Compositional factors affecting flow behaviour; Viscosity of food dispersions: dilute and semi-dilute systems, concentration effects.

Unit III

Viscometers; Types (Co-axial cylinders, Spindle or Impeller type, Cone-plate, Capillary, Falling sphere, Vibratory, Extrusion, and Orifice), comparative assessment, merits and limitations; Rheometer: principles and operational features.

Unit IV

Rheological characterization of semi-solid and solid foods; Mechanical models for viscoelastic foods (Maxwell, Kelvin, Burgers and generalized models) and their application; Dynamic measurement of viscoelasticity.

Unit V

Large Deformations and failure in foods: Definitions of fracture, rupture and other related phenomena; Texture Profile Analysis; Instrumental measurements: Empirical and fundamental methods; Rheometers and Texture Analyzers; Measurement of extensional viscosity; Acoustic measurements on crunchy foods.

Unit VI

Rheological and textural properties of selected dairy products; Measurement modes and techniques; Effect of processing and additives (stabilizers and emulsifiers) on food product rheology; Relationship between instrumental and sensory data; Microstructure of dairy products; Tribology and its applications.

VII. Practical

- Study of different types of viscometers.
- Flow behaviour of fluid dairy products.
- Thixotropy in ice-cream mix.
- Force-deformation study in selected dairy products using Texture Analyzer.
- Effect of test conditions on the texture profile parameters of dairy products.
- Stress relaxation studies in solid foods.
- Use of Cone Pen-etrometer and FIRA-NIRD extruder for measurement of butter texture.
- Assessment of pasting profile of starch/flours using viscoanalysers.
- Oscillatory measurements using Rheometer.

VIII. Learning outcome

After undergoing this course, the students are expected to deliver the following:

– Classify food products based on their rheological characteristics
– Understand the relationship between instrumental rheology and sensory perception of food
– To recommend use of textural analysis of dairy and food product for its quality control aspect
– To recommend specific type of instrument for textural analysis of specific type of food (fluid or solid)

IX. Suggested Reading

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I. Course Title : Biotechnology for Dairy Applications

II. Course Code : DT-514

III. Credit Hours : 2+1

IV. Why this course?

Biotechnology is a tool for the value addition to dairy foods. Genetic techniques have been employed to manipulate bacteria that have significance to the dairy industry. Biotechnological means can be used to regulate the production of flavour enhancing metabolites and to develop starter cultures that are resistant to bacteriophage and bacteriocins. Genetic engineering will be able to deliver dairy foods that can be tolerated by lactose intolerant persons or for persons who are allergic to milk proteins too.

V. Aim of the course

To project the importance of biotechnology in dairy processing and imparts knowledge on all aspects of dairy process biotechnology in production and preservation of dairy products employing the principles of biotechnology.

VI. Theory

Unit I

Introduction to process biotechnology; Principles of recombinant DNA technique; Development and impact of biotechnology on dairy and food industry.

Unit II

Microbial rennet and recombinant chymosin - characteristics and applications in cheese making; exogenous free and microencapsulated enzymes. Immobilized enzymes - their application in continuous coagulation of milk in cheese making; Enzyme modified cheeses (EMC) - their utilization in various food formulations.

Unit III

Technological requirements of modified micro-organisms for applications in cheese, Probiotic and fermented milk products; physiologically active bio-peptides/ nutraceuticals.

Unit IV

Protein hydrolysates - production, physico-chemical, therapeutic properties and application in food formulations; Enzymatic hydrolysis of lactose for preparation of whey and UF-permeate beverages; Continuous lactose hydrolysis of whey.

Unit V

Microbial polysaccharides - their properties and applications in foods; Production of alcoholic beverages; Bio-sweeteners - Types, properties and their applications in dairy and food industry.

Unit VI

Bio-preservatives - characteristics and their applications in enhancing the shelf life of dairy and food products.

VII. Practical

- Effect of exogenous enzymes on hydrolysis of protein and fat in culture containing milk sys-tems
- Factors affecting the coagulation of milk by microbial and vegetable rennets
- Manu-facture and evaluation of probiotic cheese and fermented milks
- Preparation of Enzyme Modified Cheese
- Determination of glycolysis, proteolysis and lipolysis in cheese and fermented milks
- Enzymatic process for manufacture of low lactose milk/whey products
- Preparation of casein hydrolysates
- Visit to a bio-processing unit.

VIII. Learning outcome

After undergoing this course, the students are expected to deliver the following:

– To have any idea about the enzymes that can be used as processing aids.
– Have knowledge on the latest biotechnological approaches to add value to the dairy product
– Ability to produce protein hydrolysates
– Application of biotechnology for bio-preservation of dairy foods

IX. Suggested Reading

- Aluko RE. (Ed.). 2012. *Functional Foods and Nutraceuticals*. Springer.
- Bhat R, Alias AK and Paliyath G. 2012. *Progress in Food Preservation*. John Wiley and Sons Ltd. (Print ISBN: 9780470655856. Online ISBN: 9781119962045) DOI: 10.1002/9781119962045.
- Coffey AG, Daly C and Fitzgerald G. 1994. The impact of biotechnology on the dairy industry. Biotechnology Advances, 12(4): 625-633. Elsevier Pub. doi.org/10.1016/0734-9750(94)90003-5

I. Course Title : Advances in Traditional Indian Dairy Products

II. Course Code : DT 515

III. Credit Hours : 2+1

IV. Why this course?

Traditional Indian dairy products (TIDP) especially the sweetmeats have its own significance in Indian diet and have tremendous export potential. The application of strict hygiene in manufacture of such TIDPs is the need of the day and its technology up gradation (especially mechanization and automation) from research level to industry level needs to be harnessed. Even there is an urgent need to have knowledge about the 'Techno-economic aspects for establishing commercial units for traditional dairy products'. Enhancement in the shelf life of TIDPs has been still a challenging task in the dairy industry.

V. Aim of the course

To project the present status, modernization and globalization of production of traditional Indian dairy products with a focus on process innovation, shelf life, quality and functionality enhancement.

VI. Theory

Unit I

Global prospects and export potential of traditional Indian dairy products.

Unit II

Differences in quality of traditional dairy products from cow, buffalo, goat, camel, and sheep milks; Process innovations in commercial production of heat-desiccated, coagulated and fermented traditional dairy products; Mechanized production of traditional milk based sweets; Automation for manufacture of ghee, *paneer*, *dahi*, *lassi*and traditional sweetmeats.

Unit III

Composite traditional milk products; Application of membrane technology and microwave processing for industrial production of traditional Indian dairy products.

Unit IV

Technologies for region specific traditional Indian dairy products and their value addition, their application as a vehicle for delivering functional ingredients; Manufacture of dietetic traditional dairy products.

Unit V

Techno-economic aspects for establishing commercial units for traditional products.

Unit VI

Convenience traditional dairy products; Food safety issues; Shelf life extension of food using newer techniques; Novel packaging and preservatives.

VII. Practical

- Production of reduced calorie, composite and functional traditional Indian dairy products.
- Microwave heating of traditional Indigenous milk delicacies for shelf life extension.
- Membrane technology for improving the quality of traditional Indigenous products made from cow and buffalo milk.
- Preparation of feasibility report for establishing commercial units for traditional dairy products.

VIII. Learning outcome

After undergoing this course, the students are expected to deliver the following:

– Have an idea about the global prosper and export potential of TIDPs.
– Be an entrepreneur in delivering mechanized production of certain TIDPs including automation, wherever feasible.
– Be able to recommend the methods to enhance the shelf life of perishable TIDPs and recommend the type of packaging technology to be used for safety and shelf life extension.

IX. Suggested Reading

- Aneja RP, Mathur BN, Chandan RC and Banerjee AK. 2002. *Technology of Indian dairy products*. A Dairy India Publication.

- Goyal MR, Kumar A and Gupta AK. 2018. *Novel Dairy Processing Technologies: Techniques, Management, and Energy Conservation*. CRC Press.
- Puniya AK. 2015. *Fermented Milk and Dairy Products;* CRC Press/Taylor and Francis (ISBN 9781466577978)
- Shrott C and O'Brien. 2003. *Handbook of Functional Dairy Products*. CRC Press
- *TetraPak Dairy Processing Handbook*. 2015. www.dairypeocessinghandbook.com.

Websites

- Indian Dairy Product Market–Indian Council of Food and Agriculture– https//icfa.org.in/assets/doc/reports/Indian_Dairy_Product_Market.pdf
- Mechanized production of Indian Dairy Products–AMEFT– https//download.ameft.com/MechanisedProduction.pdf
- Indian Dairy Industry–Aavin – https//aavinmilk.com/dairyprofile.html
- Present Status of Traditional Dairy Products–Technische–TIB– https://www.tib.eu/en/search/id/./Present-Status-of-Traditional-Dairy-Products/

I. Course Title : Non-Conventional Processes for Dairy and Food Industry

II. Course Code : DT 516

III. Credit Hours : 2+1

IV. Why this course?

Unravelling the truths based on the knowledge of 'science and technology' has paved the way for development of several non-conventional technologies. These when used judiciously can have advantage in minimizing the changes in the colour, nutritive value and textural quality of dairy and food products. Certain non-conventional processes may be used as adjunct to the conventional processing technology to reap the benefits from use of such synergistic effects.

V. Aim of the course

To develop an understanding of the basic principles underlying the novel/non-conventional food processing techniques, equipment required, features and actual and potential applications

VI. Theory

Unit I

Irradiation: sources and properties of ionizing radiation; Mechanism of interaction with microorganisms and food components; Chemi-cal effects; Industrial irradiation systems, benefits and limitations; UV pasteurization of milk; Safety aspects in radiation processing; National and international regulations in relation to radiation processing; Cold plasma processing.

Unit II

High frequency heating (Microwave and Radio frequency processing): Principles, merits and demerits; Design and working of processing units; Applications in dairy and food processing; Microwavable packaging; Safety aspects.

Unit III

Infra-red (IR) heating and Ohmic heating: Principle, equipment and applications.

Unit IV

Ultrasonic treatment of food: Mechanism of ultrasound induced cell damage, generation of ultrasound, design of power ultrasonic system, types of ultrasonic reactors, application of power ultrasound in food processing, effects on food constituents, ultrasound in amalgamation with other food processing operations – thermo-sonication, manosonication, thermo-manosonication, advantages and future prospects.

Unit V

High hydrostatic pressure (HHP) processing: Principle of microbial inactivation, barotolerance of microorganisms, effect on food constitu-ents; equipment; dairy and food applications; Merits and demerits of HHP.

Unit VI

Pulsed electric field processing; Description/ mechanism and factors affecting microbial inactivation; effects on food com-ponents; Present status and future scope for food applications.

Unit VII

Super-critical Fluid Extraction; Principle, instrumentation and applications.

VII. Practical

- Market survey of food products processed using non-conventional technologies
- Pasteurization and concentration of milk using ohmic heating
- Degassing of fluids using ultrasound
- Determination of power output and temperature profile of a microwave oven
- Effect of chemical composition on heating behaviour of milk and milk products
- Microwave pasteurization of milk
- Effect of shape and size of container on microwave heating
- Preparation of 'instant' products in a microwave oven
- Visit to a commercial food processing facility.

VIII. Learning outcome

After undergoing this course, the students are expected to deliver the following:

- To recommend use of feasible non-conventional technology for processing and shelf life extension of food
- Application of non-conventional processing technology as adjunct processing for accomplishing hurdle technology for dairy and food products
- To visualize the difference in the physico-chemical properties and microbial changes in dairy/food product when adopting traditional vs. non-conventional technology

IX. Suggested Reading

- Chen D, Sharma SK and Mudhoo A. 2012. *Handbook on applications of ultrasound-sonochemistry for sustainability*. Boca Raton: Taylor and Francis Group, LLC, 273-739.
- Delgado A, Kulisiewicz L, Rauh C and Wiersche A. 2012. *Novel thermal and non-thermal technologies for fluid foods*. New York: Academic Press.
- Monika Willert-Porada. 2001. Advances in Microwave and Radio Frequency Processing. Report from the 8th International Conference on 'Microwave and high frequency heating' held in Bayreuth, Germany, 2001.
- Nanda V and Sharma S. 2017. *Novel food processing technologies*. New India Publishing Agency, New Delhi, India.
- Raso J and Heinz V. 2006. *Pulsed electric fields technology for the food industry fundamentals and applications*. Springer Science + Business Media, LLC, USA.

- Zhang HQ, Barbosa-Canovas GV, Balasubramaniam VM, Dunne CP, Farkas DF and Yuan JT. (Eds.). 2011. *Non-thermal processing technologies for food* (Vol. 45). John Wiley and Sons.

Websites

- Microwave-assisted green extraction technology for sustainable food processing-https://intechopen.com/books/emerging-microwave-technologies-in-industrial-agricultural-medical-and-food-processing/microwave-assisted-green-extraction-technology-for-sustainable-food-processing
- Ultrasound in the food industry– https://hielscher.com/food_01.htm; Microwave assisted extraction (MAE)-https://slideshare.net/Nabiilah/microwave-assisted-extraction

I. Course Title : Membrane Processing for Dairy Applications

II. Course Code : DT 521

III. Credit Hours : 2+1

IV. Why this course?

Amongst non-thermal processes for dairy applications, membrane processing is one of the significant illustrations. Membrane processing has helped the dairy industry, not only to obtain dairy ingredients with high protein and low lactose content, but even to recover the important whey proteins from the by-product – whey. Salient application of use of membrane processed milk concentrate is in cheese making and in concentrated and dried milk manufacture.

V. Aim of the course

To elucidate the basics of membrane technology and its applications in dairy processing

VI. Theory

Unit I

Membrane techniques; Classification and characteristics of filtration pro-cesses; types of commercially available membranes; membrane hardware, design of membrane plants, modelling of ultrafiltration (UF) processes, mass transfer model, resistance model; Membrane fouling-problems and mitigation strategies; Cleaning and sanitization of different types of membranes.

Unit II

Factors affecting permeate flux during ultrafiltration and reverse osmo-sis of milk and sweet/sour whey, energy requirements for membrane processing of milk and whey.

Unit III

Applications of ultrafiltration (UF), reverse osmosis, nanofiltration and microfiltration in the dairy industry: food and pharmaceutical grade lactose, low lactose milk powder, dairy whiteners, WPC, WPI, MPC, MPI, Native micellar casein powder, etc. Preparation, properties and uses of Milk Protein Concentrate (MPC) and Milk Protein Isolate (MPI); Manufacture of some cheeses and fermented milk products and impact of membrane processing on quality of such products. Use of membrane processing techniques for separating prophylactic biological from milk.

Unit IV

Demineralization: principles, processes, equipment and applications.

Unit V

Functional properties of whey proteins (WPC and WPI), micellar casein and UF milk retentate and their modifications.

VII. Practical

- Factors affecting permeate flux during membrane processing (type of feed, temperature, transmembrane pressure, etc.)
- Effect of microfiltration of skim milk and whey on fat content and microbial count
- Preparation of WPC, WPI, MPC, native micellar casein, etc.
- Evaluating the functional properties of milk proteins.

VIII. Learning outcome

After undergoing this course, the students are expected to deliver the following:

- To recommend use of membrane processed milk in manufacture of selected dairy products
- Application of specific membrane processes for milk/whey to prepare certain prophylactic biological
- To recommend the suitable cleaning and sanitization agents to take care of cleaning and sanitization of specific type of membrane used in membrane processing of milk.

IX. Suggested Reading

- Baker RW. (Ed.) 2012. *Membrane Technology and Applications*, 3rd Edn,Wiley Publishers.
- Cooper A.R. (Ed.) 2013. *Ultrafiltration Membranes and Applications* (Vol. 13). Springer Science and Business Media.
- Field RW, Bekassy-Molnar E, Lipnizki F and Vatai G. 2017. *Engineering Aspects of Membrane Separation and Application in Food Processing*. CRC Press.
- Fuquay JW, Fox PF and Mc Sweeney PL. 2011. *Encyclopedia of Dairy Sciences*. Academic Press.
- Hu K and Dickson J. (Eds.). 2015. *Membrane Processing for Dairy Ingredient Separation*. John Wiley and Sons.
- Mohanty K and Purkait M. 2011. *Membrane Technologies and Applications*. CRC Press, Taylor and Francis Group.
- Tamime AY. (Ed.). 2013. *Membrane processing: Dairy and beverage applications*. Wiley-Blackwell Publishers, pp. 1-370.

Websites

- Membrane technology in Dairy Industry – Slideshare-https://slideshare.net/./membrane-technology-in-dairy-industry
- Specialty and Dairy – Products – Toray Membrane-https://toraywater.com/products/specialty/index.html
- Membrane filtration in the dairy industry GEA-https://gea.com/en/binaries/gea-membrane-filtration-brochure-for-dairy-industry_tcm11-17109.pdf

I. Course Title : Advances in Dairy and Food Packaging

II. Course Code : DT 522

III. Credit Hours : 2+1

IV. Why this course?

Packaging of food though carried out towards the end of product manufacture has a great role to play in conserving the processed food in its original state – including freshness of fresh food. Packaging plays a crucial role in acceptance of the food product by the consumer and the extensibility of the shelf life of the food being packaged, especially using advanced techniques such as MAP, active packaging, etc.

V. Aim of the course

To impart basic and advanced knowledge of dairy and food packaging

VI. Theory

Unit I

Trends in packaging industry; designing framework for packaging; Testing of packaging materials.

Unit II

Adhesives; Graphics; Coding (Barcode and Quick Response code), and labeling used in food packaging.

Unit III

Protective packaging of foods; Effect of light, oxygen and moisture on packaged food.

Unit IV

Packaging of dairy products, convenience foods, fresh produce and fruits and vegetable products, Packaging of fats and oils, spices, meat, poultry, fish and other sea foods.

Unit V

Modified atmosphere packaging, Shrink and stretch packaging; Self-heating and self-cooling cans.

Unit VI

Retort pouch technology, microwavable, biodegradable, and edible packages; Principles and applications of Active Packaging, Smart and Intelligent Packaging, Antimicrobial packaging.

Unit VII

Industrial packaging: unitizing, palletizing, containerizing, distribution systems for packaged foods.

Unit VIII

Safety aspects of packaging materials; sources of toxic materials and migration of toxins into food materials, packaging and flavour interaction.

VII. Practical

- Testing of packaging materials for qual-ity assurance: thickness, GSM, grease resistance, bursting strength, tearing resistance, WVTR, puncture resistance
- Estimation and prediction of shelf life of packaged foods
- Development of edible, biodegradable and antimicrobial films
- MAP of perishable foods
- Effect of edible coatings on respiration behaviour of fruits and vegetables
- Application of oxygen scavengers in packaged foods.

VIII. Learning outcome

After undergoing this course, the students are expected to deliver the following:

– To recommend the type of package suitable for specific type of dairy or other food products

- To employ intelligent packaging techniques in food packaging to warn the public in case of impeding health hazard
- Recommending SOPs to the food industry personnel to avoid migration of toxic substances from the package into the food system

IX. Suggested Reading

- Coles R, McDowell D and Kirwan MJ. 2003. *Food Packaging Technology*. Oxford: Oxford Blackwell. Frank, A., Paine, H., and Paine,Y. (1983). *A Handbook of Food Packaging*. Glasgow: Leonard Hill.
- Gordon LR. 2013. *Food Packaging: Principles and Practic*e, 3rd Edn., Florida, USA: CRC Press, Taylor and Francis Group.
- Han JH. 2005. *Innovations in Food Packaging*. Elsevier Science and Technology Books.
- Parry RT. 1993. *Principles and Applications of Modified Atmosphere Packaging of Foods*. Dordrecht: Springer Science+Business Media.
- Piergiovanni L and Limbo S. 2015. Food Packaging Materials. In: *Chemistry of Foods*, Springer Publishers.
- Raija A. 2006. *Novel Food Packaging*. England: Woodland Publishing Co.
- Robertson GL. (Ed.). 2012. *Food Packaging: Principles and Practice*. 3rd Edn.,Florida, US: CRC Press.
- Robertson GL. 2010. *Food Packaging and Shelf Life: A Practical Guide*. Boca Raton: CRC Press.
- Yam KL. 2009. *The Wiley Encyclopedia of Packaging Technology*, 3rd Edn., USA: John Wiley and Sons, Inc.

Websites

- Indian Institute of Packaging-https//iip-in.com/
- The Regulation of Food Packaging-https://www.packaginglaw.com/special-focus/regulation-food-packaging
- Packaging Industry Servies-www.nsf.org/services/by-industry/food-safety-quality/packaging

I. Course Title : Technology of Food Emulsions, Foams and Gels

II. Course Code : DT 523

III. Credit Hours : 2+1

IV. Why this course?

In order to improve the viscosity or rheological characteristics of food systems, certain food additives such as stabilizers, emulsifier and even foaming agents play a significant role. The chances of probability of defect in certain food products can be circumvented through use of such food additives. Emulsifiers play a great role in maintaining emulsion of two or multiple phases in the food system till its consumption. Foaming agents are of significance in ice cream, whipping cream, meringue, certain baked goods, etc.

V. Aim of the course

To impart basic knowledge regarding food dispersion systems, their formation, behaviour, and factors affecting their stability.

VI. Theory

Unit I

Food dispersions, their characteristics and factors affecting food dispersions.

Unit II

Food emulsions; Emulsifiers and their functions in foods; HLB concept for food emulsifiers; Emulsion formation and stability; Surfactants.

Unit III

Dairy based foams and their applications, structure of foams; Egg foams and uses; Foam formation and stability.

Unit IV

Theory of gel formation; Carbohydrate and protein based gels. Gelled milk products. Advances in food gels (organogel, hydrogel and nanogel).

Unit V

Structure of dairy based emulsions, foams and gels; blend of stabilizers and emulsifiers; Effect of stabilizers and/or emulsifiers on functional properties of dairy foods; Aerosols and propelling agents in foamed dairy products.

Unit VI

Techniques for evaluating the structure of food emulsions, foams and gels

VII. Practical

- Determination of emulsifying efficiency and emulsion stability
- Examination of foaming capacity and foam stability
- Gel formation and gel properties
- Preparation of hydrogels and organogels
- Preparation of single and double emulsions.

VIII. Learning outcome

After undergoing this course, the students are expected to deliver the following:

- To be able to recommend specific type of food additive from amongst stabilizers and emulsifiers for stability of the food system
- Be able to recommend solution to the food processor to improve upon the textural quality of food products through use of food additives like stabilizers and/or emulsifiers
- To make the food processors understand how the type of emulsion in question in the food product has a bearing on the functional property of that specific food product

IX. Suggested Reading

- Rajah KK. (Ed.). 2014. Emulsifiers and stabilisers. Chapter 7.Young, N.W.G. *Fats in food technology*.UK: John Wiley and Sons Ltd. (ISBN: 9781405195423).
- Valdez B. (Ed.) 2012. Milani J and Maleki G. Hydrocolloids in food industry. Chapter in Book. *Food industrial processes – Methods and equipment*. InTech Europe, Rijeka, Croatia, pp. 1-418 (www.InTechopen.com)
- Whitehurst RJ. (Ed.). 2004. *Emulsifiers in food technology*. 1st Edn. Wiley-Blackwell Publisher, pp. 1-264. (ISBN-13 978-1405118026).

X. Websites

- Stabilizers – Specialty food ingredients – Federation of European Specialty Food Ingredients Industry-https://specialtyfoodingredients.eu/ingredients-and-benefits/group/stabilizers
- Emulsifier Solutions – Corbion- https://corbion.com/base/DownloadHelper/DownloadFile/8386

I. Course Title : Functional Foods and Nutraceuticals

II. Course Code : DT 524

III. Credit Hours : 3+1

IV. Why this course?

Ingestion of food possessing nutraceuticals can sustain and maintain human health – free from diseases. Today's consumers are aware about the health promoting foods and if the industry launches functional foods, there are takers for such foods. Several herbs and spices are known to contain components that have nutraceutical value. Ayurveda system is built on such naturally available materials. However, consumer does want to seek food that can sustain their health and nutritional requirement – not to rely on medicines. Fermented probiotic foods are the latest prominent functional foods.

V. Aim of the course

To impart knowledge about functional ingredients and nutraceuticals and their utilization in developing physiologically beneficial health foods, functional foods and speciality foods

VI. Theory

Unit I

Classes of functional foods and their status.

Unit II

Functional ingredients; Classification; Dietary and therapeutic significance.

Unit III

Food fortification; Significance and techniques of fortifying foods with functional ingredients.

Unit IV

Infant nutrition; Dietary formulations, special needs, additives; Geriatric Foods: Design considerations, ingredients, special needs; Sports foods: Significance, strategies and design considerations.

Unit V

Reduced calorie foods: Significance, strategies, additives (fat replacers, bulking agents, non-nutritive sweeteners).

Unit VI

Low sodium and low lactose foods: Nutritional and health significance.

Unit VII

Herbs; Classification; Therapeutic potential, applications; Phytochemicals; Classes; Physiological role; Applications; Bioactive ingredients from animal and marine sources.

Unit VIII

Probiotic, prebiotic and synbiotic foods: Concept and applications.

VII. Practical

- Determination of soluble and insoluble fibre
- Determination of antioxidant activity of functional ingredient/food

- Determination *of in vitro* bioavailability of nutrients
- b-galactosidase activity for low-lactose dairy products
- Prebiotic potential of selected plant/milk components
- Probiotic potential of selected microorganisms
- Preparation of functional foods

VIII. Learning outcome

After undergoing this course, the students are expected to deliver the following:

– Be able to identify food in which fortification with necessary nutrients are required
– Be able to evolve Geriatric foods and food for infants based on their requirement and physiological functions
– To make food available to the consumers amalgamated with functional ingredients such as herbs, phytochemicals, etc.

IX. Selected Reading

- Earle M, Earle R and Anderson A. (Eds.). 2001. Food product development.1st Edn., Woodhead Publishing, pp. 1-392 (eBook ISBN: 9781855736399).
- Francesco C. (Ed.). 2017. Advances in dairy products. John Wiley and Sons Ltd. pp. 1-448. Chapter 4.2 - Consumer insight in the process of new dairy products development(ISBN: 9781118906460).
- Kanekanian A. (Ed.). 2014. Milk and dairy products as functional foods. John Wiley and Sons, Ltd., UK: West Sussex, pp. 1-373.
- Leong TSH, Manickam S, Martin GJ, Li W and Ashokkumar M. 2018. Ultrasonic Production of Nano-emulsions for Bioactive Delivery in Drug and Food Applications. Springer.
- Saarela M. (Ed.). 2007. Functional dairy products (2007) Vol. 2, Series in Food Science, Technology and Nutrition, Woodhead Pub., pp. 521-539.
- Shortt C and O'Brien J. (Eds.). 2003. Handbook of functional dairy products – Functional foods and Nutraceuticals, 1st Edn. Boca Raton, FL: CRC Press, pp. 1-312.

Websites

- Foods for Specified Health Uses (FOSHU)-https://mhlw.go.jp/english/topics/foodsafety/fhc/02.html
- A New Definition for Functional Food by FFC-https//functionalfoodscenter.net/files/111174880.pdf
- Food-info.net: Functional Foods-https//food-info.net/uk/ff/intro.htm

I. Course Title : Production and Applications of Dairy Ingredients
II. Course Code : DT 525
III. Credit Hours : 2+1

IV. Why this course?

Milk is a source of several components, which may contribute to nutrients, nutraceuticals, flavour, colour, texture to the food products in which they may be incorporated. Nowadays, we have perfected technologies to separate the dairy components having specified function for use in dairy as well as food products. The by-products such as whey and buttermilk can be salvaged through separation of components, which are of significance to the dairy and food industries alike.

V. Aim of the course

The aim of this course is to give comprehensive information of various milk components used as ingredients in food processing with regard to their separation, properties and applications.

VI. Theory

Unit I

An overview of dairy ingredients for food processing; Composition, nutritive value and health attributes of dairy ingredients; Important quality indices; National and international regulatory standards.

Unit II

Principles of conventional and novel approaches for separation, concentration and fractionation of milk components(Ig, lf, b-Lg): centrifugal separation, concentration, drying, membrane processing, enzyme-assisted separation, supercritical fluid extraction, electric field assisted membrane technique, etc.

Unit III

Chemical, physical and functional characteristics of concentrated and dried dairy ingredients (SMP, WMP, lactose, whey powder, WPC, WPI, MPC, casein and caseinates, cream powder, butter powder, cheese powder, yogurt powder, buttermilk powder, etc.).Miscellaneous dairy ingredients, viz. dairy permeates, hydrolysates, coprecipitates andlactoferrin.

Unit V

Interactions of dairy ingredients with other food components and its effect on product quality.

Unit V

Applications of dairy ingredients in food industry: bakery and confectionery; Infant, adult and sports nutrition; Processed meat products; spreads; functional Foods; edible films and coatings.

VII. Practical

- Manufacture of whey powder, caseinates, whey protein/milk protein concentrates, lactose, sweet cream butter milk powder, cream powder, yogurt powder and cheese powder.
- Determination of functional and nutraceutical properties of dried dairy ingredients.
- Manufacture of enzyme-modified dairy ingredients
- Production of eggless cakes using WPC
- Production of processed meat products incorporating caseinates
- Visit to a dairy ingredients manufacturing industry.

VIII. Learning outcome

After undergoing this course, the students are expected to deliver the following:

- Be able to separate the various important components from milk/dairy byproduct having significance in dairy and food industries
- Be able to recommend the required type of specialized dairy ingredient for use in formulated and composite foods
- To be able to erect a dairy factory producing specialized dairy ingredients with immense value addition

IX. Suggested Reading

- Chandan RC and Kilara A. 2011. *Dairy Ingredients for Food Processing*. Iowa, USA: Blackwell Publishing Ltd.
- Corredig M. 2009. *Dairy Derived Ingredients: Food and Nutraceutical Uses*. Cambridge, UK: Woodhead Publishing Ltd.

- Fox PF. 1985. *Developments in Dairy Chemistry*. Vol.3.Lactose and minor constituents, New York: Elsevier Applied Science.
- Fox PF. 1989. *Developments in Dairy Chemistry*. Vol.4. Functional milk proteins, New York: Elsevier Applied Science.
- McSweeney PLH and Fox PF. 2013. *Advanced Dairy Chemistry*. Vol.1A: Proteins: Basic aspects. 4th Edn. Springer Publication.
- McSweeney PLH and O'Mahony JA. 2016. *Advanced Dairy Chemistry*. Vol.1B: Proteins: Applied Aspects. Springer Science + Business Media.

I. Course Title : Advances in Cheese Technology

II. Course Code : DT 526

III. Credit Hours : 2+1

IV. Why this course?

There is an array of cheese varieties; use of different starter cultures can lead to the development of specific cheese variety too. However, the technological principles involved in Cheddar cheese making are common to several varieties of cheeses with some modifications. Cheese is getting popularized in India, especially the Pizza cheese variety that is preferentially used as a topping on pizza pie. The functional properties of cheese dictate its end use functionality in food system. Basically, some cheese varieties can be produced by two methods – starter culture and direct acidification. Wheyless cheese making from ultra-filtrated milk concentrate is one unique possibility. There has been trend to produce cheeses having low-fat and low salt for the health conscious consumers.

V. Aim of the course

To impart advanced knowledge on milk coagulants, theory of milk coagulation, the technology, biochemistry and microbiology of cheese.

VI. Theory

Unit I

Rennet coagulation: Measurement of milk clotting activity and gelation properties, Catalytic mechanism and milk-clotting properties of rennet and rennet substitutes. Advances in renneting of milk; recombinant rennet.

Unit II

Acid coagulated milk gels: formation, rheology, structural properties, etc.

Unit III

Advances in cheese starters; genetics of Lactic Acid Bacteria (LAB); Exo Polysaccharide (EPS) starters; Genetic engineering of LAB.

Unit IV

Biochemistry of cheese ripening: Metabolism of residual lactose and lactate, protein hydrolysis, lipid hydrolysis, amino acid catabolism; Development of cheese flavour, and body and texture; Cheese microstructure. Accelerated cheese ripening.

Unit V

Mold-ripened cheeses; Starter cultures, technology, ripening process (Blue, Roquefort, Camembert, etc.)

Unit VI

Low fat and low-sodium cheeses: challenges, strategies and advances; Membrane technology in cheese; Cheese as an ingredient in food systems.

Unit VII

Technology of non-bovine cheese: popular varieties, challenges, strategies; Technology of cheeses prepared by coagulation other than rennet and acid (Ricotta, Brown whey cheese, etc.); Advances in cheese packaging; Automation in cheese making; Cheese analogues.

VII. Practical

- Instrumental determination of rennet coagulation time
- Rheology of acid-coagulated milk gels
- Fermentation dynamics of common cheese starters
- Evaluation of cheese ripening behaviour
- Manufacture of mold ripened-, low sodium-, low fat-cheeses
- Manufacture of Goat and Ewemilk cheeses
- Manufacture of Ricotta cheese
- Microstructure of cheese

VIII. Learning outcome

After undergoing this course, the students are expected to deliver the following:

- Be able to manufacture various varieties of cheeses
- Try to employ various non-thermal pre-treatment to milk to obtain value added cheese
- Be able to develop low-calorie and low-salt cheeses
- Recommend the cheese makers for appropriate mechanization

IX. Suggested Readings

- Jana AH and Thakar PN. 1996. Recombined milk cheeses – A review. *Australian Journal of Dairy Technology*, **51**(1), 33-43.
- Jana AH and Tagalpallewar GP. 2017. Functional properties of Mozzarella cheese for its end use application – A Review. *Journal of Food Science and Technology,* **54**(12), 3766-3778.
- Johnson ME, Kapoor R, McMahon DJ, McCoy DR and Narasimmon RG. 2009. Reduction of sodium and fat levels in natural and processed cheeses: Scientific and technological aspects. *Comprehensive Reviews in Food Science and Food Safety*, **8**(3), 252-268.
- Lucey JA and Singh H. 1997. Formation and physical properties of acid milk gels: a review. *Food Research International*, **30**(7), 529-542.
- Mc Sweeney PLH. 2004. Biochemistry of cheese ripening. *International Journal of Dairy Technology*, **57**(2 3), 127-144.
- Mc Sweeney PLH, Fox PF, Cotter PD and Everett DW. (Eds.) 2017. *Cheese: Chemistry, physics and microbiolog*y, 4th Edn, Vol. 1, Academic Press.

Websites

- Cheeses and related cheese products – Proposal to permit the use of ultra-filtered milk-https://federalregister.gov/documents/2005/10/19/05-20874/cheeses-and-related-cheese-products-proposal-to-permit-the-use-of-ultrafiltered-milk
- Go cheese to add new products in its portfolioBW Businessworld-http://businessworld.in/article/GO-Cheese-To-Add-New-Products-In-Its-Portfolio/10-07-2018-154382
- American Cheese Society: Serving the Cheese Industry-https://cheesesociety.org/
- Cheese: Dairy Processing Handbook-https://dairyprocessinghandbook.com/chapter/cheese

Course Title with Credit Load
Ph.D. in Dairy Technology

Course Code	Course Title	Credit Hours
DT 611	Advances in Lipid Technology	3 (3+0)
DT 612**	Advances in Protein Technology	3 (3+0)
DT 621**	Product Monitoring and Process Control	3 (3+0)
DT 622	R and D Management in Dairy Industry	3 (3+0)
DT 623	Advances in Carbohydrates Technology	3 (3+0)
DT 691	Doctoral Seminar-I	1 (1+0)
DT 692	Doctoral Seminar-II	1 (1+0)
DT 699	Doctoral Research	75 (0+75)

Minor Courses

The courses will be selected from the allied disciplines of Dairy Engineering, Dairy Chemistry and Dairy Microbiology to meet the minimum credit requirements.

Supporting Courses

The supporting courses will be picked from the basket of courses offered inagricultural statistics, computer applications and IT, and other related relevant disciplinesto meet the minimum credit requirements.

Common Courses

1. Library and Information Services 1
2. Technical Writing and Communications Skills 1
3. Intellectual Property and its Management in Agriculture 1
4. Basic Concepts in Laboratory Techniques 1
5. Agricultural Research, Research Ethics and Rural Development Programmes 1

*Core courses for Master's programme; **Core courses for Doctoral programme

Course Contents
Ph.D. in Dairy Technology

I. Course Title : Advances in Lipid Technology

II. Course Code : DT 611

III. Credit Hours : 3+0

IV. Why this course?

Fats have multifarious effect on human beings. These are source of saturated fats, unsaturated fats, sterols (including cholesterol), phospholipids, etc. The essential fatty acids have a significant role in human health. There are however, some relations between certain type of fats (i.e. cholesterol, certain saturated fats and trans-fats) and cardiovascular disease in humans. There are several technological means to modify fat such as inter-esterification, fractionation of fat, hydrogenation, bleaching, refining, etc. Repeated frying of fat can lead to formation of toxic substances, unfit for consumption. Consumers have started accepting the modified fats for health reasons.

V. Aim of the course

To study the physico-chemical and nutritional characteristics of fats and oils, their processing and application in food products.

VI. Theory

Unit I

Current trends in the fats and oil industry in India and abroad: Sources and classification of commercial edible fats and oils from animal, vegetable and marine origin; Non-conventional fats/oils for edible purpose – rice bran oil, microbial lipids, etc.

Unit II

Structural aspects of fats and oils in relation to their processing, properties and utilization; Polymorphism and polytypism, crystallization kinetics.

Unit III

PUFA, MUFA, CLA, Medium Chain Triglycerides (MCTs), Omega fatty acids, Trans-fatty acids: Nutritional and technological interventions; Phytosterols and their significance.

Unit IV

Advances in extraction and refining of oils and fats; Application of membrane techniques in oil refining.

Unit V

Physical, chemical and enzymatic modification approaches to tailor-made fats. Cholesterol reducing treatments; structured lipids; Fat replacers; Isolation of emulsifiers.

Unit VI

Applications of fats and oils: Margarine and low-fat table spreads; Bakery and confectionery fats; Coatings; Shortenings; Salad dressings; Technology of cooking oils, salad oils and oil based dressings.

Unit VI

Frying process and systems; Changes in fats and oils during frying; Snack foods - Processing sys-tems; Modified fats and oils for use in bakery and confectionery products, shortenings and spreads; Cocoa butter substitutes.

VII. Learning outcome

After undergoing this course, the students are expected to deliver the following:

– Able to recommend the type of fat suitable for given application (i.e. for frying).
– Prepare modified fats with reduced cholesterol, reduced long chain saturated fats, etc.
– Make the food processor understand the principle of polymorphic transformation of fat for texture development in fatty food system.
– Can modify the fat to suit physiological needs of the people.

VIII. Suggested Reading

- Garti, N.andSato, K. (Eds.). 2001.Hartel, R.W., and Kaylegian, K.E. Chapter 11. Advances in milk fat fractionation – Technology and applications. In: *Crystallization processes in fats and lipid systems*, 1[st]Edn,Boca Raton: Taylor and Francis Group (eBook ISBN 9781482270884).
- Hartel, R. W., and Kaylegian, K. E. 2001. Advances in milk fat fractionation – Technology and applications. In: *Crystallization Processes in Fats and Lipid Systems*. Garti, N., and Sato, K. (Eds.), Chapter 11, Taylor and Francis Group.
- Rajah, K.K. (Ed.). 2014. *Fats in food technology*. John Wiley and Sons Ltd., UK(**ISBN:** 9781405195423)
- Tamime, A.Y. (Ed.). 2009. *Dairy fats and related products*. Oxford, UK: Blackwell Publishing Ltd., pp. 1-315.

Websites

- **AOCS Lipid Library**-http://lipidlibrary.aocs.org/human-nutrition/trans-fat-replacements-in-foods-(pg2)
- **Fats and Cholesterol - USDA**-https://nal.usda.gov/fnic/fats-and-cholesterol
- **Fats and Fatty Acids in Human Nutrition**-http://fao.org/3/a-i1953e.pdf
- **Dietary Guidelines Advisory Committee**-http://www.usda.gov/cnpp/Pubs/DG2000/Full%20Report.pdf

I. Course Code : DT 612

II. Course Title : Advances in Protein Technology

III. Credit Hours : 3+0

IV. Why this course?

Protein is an essential major nutrient in the diets. Essential amino acids play an important role. Cheaper sources of protein are being constantly unearthed possibly from several sources, viz. plants, animals, microbes and mushrooms. Protein malnutrition, especially in children is being tackled today. Use of membrane processing (especially ultrafiltration) and food texturization technologies has led to the development of newer type of high protein food ingredients and products. The state of protein – un-denatured and denatured can play a role in functionality of resultant food as well as in digestion of the nutrient. Protein hydrolysates have their own application even in pharmaceuticals.

V. Aim of the course

To study the characteristics of food proteins and to familiarize the students with their nutritional role, implications in processing and their interactions in food systems

VI. Theory

Unit I

Characteristics, functional properties and applications of proteins from plant, animal, microbial and non-conventional sources.

Unit II

Denaturation of proteins: effect of processing parameters on denaturation; effect of denatur-ation on the physico-chemical and biological properties of proteins in food systems.

Unit III

Structure-functional relationship of food proteins; Protein interactions with food constituents and their significance: protein-protein interactions. Protein--lipid interactions, protein-polysaccharide interactions, protein-ion interactions.

Unit IV

Nutritional aspects of dietary proteins: Protein nutrition and digestion; protein quality evaluation methods; effect of processing on nu-tritive value of proteins.

Unit V

Food protein concentrates and isolates: types, production, characterization and applications Protein hydrolysates: production and processing; de-bittering; bioactive peptides: classification, production and properties.

Unit VI

Texturization of proteins; Selection of ingredients and processes; Microstructure of texturized foods, Protein based fat substitutes; Protein engineering; Protein genetic polymorphism.

VII Learning outcome

After undergoing this course, the students are expected to deliver the following:

- Tackle the problem of protein malnutrition.
- Adopt some recent technological means to produce high protein food ingredients such as WPC, WPI, MPC, Micellar casein powder, etc.
- Modify the native protein (i.e. protein hydrolysate) to have specific applications in composite food products

IX. Suggested Reading

- Boland M, Singh H and Thompson A. (Eds.). 2014. *Milk proteins: From expression to food*. Academic Press.
- Consultation FE. 2011. Dietary protein quality evaluation in human nutrition. *FAO Food Nutrition Papers*, 92, 1-66.
- Damodaran S. 1997. *Food proteins and their applications*. CRC Press.

- Fox Patrick F and McSweeney PLH. (Eds.) 2013. *Advanced Dairy Chemistry: Volume 1: Proteins, Parts A&B*, New York: SpringerScience+Business Media.
- Hayes M. 2018. *Food Proteins and Bioactive Peptides: New and Novel Sources*, Characterisation Strategies and Applications. *Foods*, **7**(3):E38. (doi: 10.3390/foods7030038).
- Hettiarachchy NS, Sato K, Marshall MR and Kannan A. (Eds.). 2012. *Food proteins and peptides: Chemistry, functionality, interactions and commercialization*. CRC Press.
- Maskan M and Altan A. 2016. *Advances in Food Extrusion Technology*. CRC press.
- Phillips GO and Williams PA. (Eds.). 2011. *Handbook of Food Proteins*. Elsevier Pub.
- Sims S. (Ed.). 2019. Protein Hydrolysates: Uses, Properties and Health Effects. Nova Publishers.
- Yada RY. (Ed.). 2017. *Proteins in Food Processing*. Woodhead Publishing.

Websites

- Protein energy malnutrition-FAO-http://fao.org/DOCREP/W0073e/w0073e05.htm
- Dietary Protein EU Science Hub European Commission-https://ec.europa.eu/jrc/en/health-knowledge-gateway/promotion-prevention/nutrition/protein
- High and Low Biological Value Protein Foods: (EUFIC)-https://www.eufic.org/en/whats-in-food/article/the-basics-proteins

I. Course Title : Product Monitoring and Process Control

II. Course Code : DT 621

III. Credit Hours : 3+0

IV. Why this course?

Whatever food products are processed at the food plant needs to be monitored for product quality and safety. Recent developments in advanced control techniques have opened up novel possibilities for food process control. Food processes have been particularly difficult to automate and control owing to non-uniformity and variability in raw-materials, and lack of sensors for real-time monitoring of key process variables and quality attributes. Model-based control, distributed control systems together with field communication protocols, and other computer-aided advanced control strategies have proven themselves in selected food processing applications. The benefits of advanced control techniques include reduced costs, increased quality and improved food safety.

V. Aim of the course

To develop the understanding of the concept of monitoring and optimization of food quality/characteristics and familiarize the students with the techniques involved.

VI. Theory

Unit I

The concept of Product-Process Monitoring in dairy and food industries; Definition of 'quality', optimization paradigm, quality-prediction model based on quality kinetics and process state equations, simulation modelling; Process/Product Optimization: optimization procedures – search methods, Response surface, differentiation and programming methods; neural networks, optimization software.

Unit II

Process Control: objectives, control loop, loop elements and their functions; Modes of process control; Control techniques; Control equipment.

Unit III

Real-time instrumentation: sensors, their classification based on proximity, working principle, examples of applications in process control; Requirements of on-line sensors; Biosensors – construction, types, working principles, applications, merits and limitations; Time-temperature indicators – partial-history and full-history indicators; Commercial devices; Applications and limitations; E-Nose and E-Tongue – Simulation of natural organs, components and their functions, applications.

Unit IV

Flavour analysis: flavour bioassays – Gas Chromatography-Olfactometry techniques; Isolation, separation and detection/identification of flavour compounds – GC-MS, LC-MS, NMR, FTIR; Analysis of chiral compounds.

Unit V

Formation of flavour compounds in milk and milk products during heat processing (including UHT processing, caramelization and extrusion cooking), fermentation and ripening (cultured products and cheese flavour, with special reference to bitterness) and storage (Maillard browning); Aroma losses/retention during the drying process (in rela-tion to milk powder, cheese powder and dry cultured products); Industrial processes for extraction of desirable and undesirable volatile components from fresh and/or stored products by supercritical fluid (SCF) technique.

Unit VI

Monitoring of food structure: Application of analytical techniques (Differential Thermal Analysis, Differential Scanning Calorimetry, X-ray crystallography, circular dichroismspectroscopy, dynamic light scattering, laser diffraction, image analysis and Nuclear Magnetic Resonance) to monitor the effect of processing and storage on structure of foods.

Unit VII

Emerging spectroscopic techniques in assessment of foods: Raman Spectroscopy and Electron Spin Spectroscopy – working principles and applications; Monitoring of irradiated foods, detection of lipid auto-oxidation, etc.; Microwave and NIR absorption/reflection methods for Compositional analyses; Automated milk analysers; Proximate principles in cheese and milk powder.

Unit VIII

Colour Characterization: colour and appearance (gloss and translucence) monitoring through visual colorimeter, tri-stimulus colorimeters and reflectance spectrophotometer, CIE, Hunter-Lab, Munsel and other systems of three-dimensional expression of colour; Colour-based sorting of foods; Computer vision – principles, applications and benefits.

VII. Learning outcome

After undergoing this course, the students are expected to deliver the following:

- Prepare a protocol for specific food industry in which all critical processes are to be monitored
- Avoid chances of occurrence of structure defect in food product through monitoring of the food structure using latest methodologies (i.e. DSC, NMR, etc.)
- Improve and stabilize the color of the food system through color characterization methods

– Elucidate the development of flavor for flavor rich foods (i.e. cheese, Enzyme modified cheese, fermented dairy products, etc.)

VIII. Suggested Reading

- Acree TE and Teranishi R. 1993. *Flavour Science: Sensible Principles and Techniques*. Washington: Amer. Chem. Soc.
- Bartlett PN, Elliott JM and Gardner JW. 1997. Electronic noses and their application in the food industry. *Food Technology*, **51**(12), 44-48.
- Kress-Rogers E and Brimelow CJB. (Eds.). 2001. *Instrumentation and Sensors for the Food Industry*. CRC Press, Woodhead Pub. Ltd.
- Nollet LML. (Ed.) 2020. *Mass Spectrometry Imaging in Food Analysis*, CRC Press.
- Pomeranz Y. (Ed.). 2013. *Food analysis: Theory and Practice*. Springer Science and Business Media.
- Schaertel BJ and Firstenberg-Eden R. 1988. Biosensors in the food industry: present and future. *Journal of Food Protection*, **51**(10), 811-820.

IX. Websites

- Quality Management Tools-Including TQM, Six Sigma, Cost of Quality and EFQM-https://cgma.org/resources/tools/essential-tools/quality-management-tools.html
- Process Control Solutions: Berthhold Technologies-https://berthold.com/en/pc/home?gclid=EAIaIQobChMIl-uQ4—K4gIVQyUrCh0P_gqvEAMYASAAEgJfcPD_BwE
- Laboratory Quality Management System – World Health Organization-https://who.int/ihr/publications/lqms_en.pdf
- Real Time Process Monitoring in Food and Beverage Manufacturing-https://manufacturing.net/article/2016/02/real-time-process-monitoring-food-and-beverage-manufacturing

I. Course Title : R&D Management in Dairy Industry

II. Course Code : DT 622

III. Credit Hours : 3+0

IV. Why this course?

Several dairy industries have separate R and D cell to carry out product innovation or to bring in more returns to the organization. Managing the R&D in a planned manner helps to deliver the goods to reap its benefit. Once patenting procedure is known, those research findings of extreme utility in dairy industry can be filed for patenting. The researches that have far reaching impact value should be taken for transfer of technologies within the limited time frame.

V. Aim of the course

To provide in-depth knowledge to students about selection and management of research projects and in patenting and transfer of technology processes.

VI. Theory

Unit I

Global scenario of R&D efforts in dairy processing; Determinants of Consumer Preferences; Competitive positioning and value chain configuration in global market.

Unit II

Management of human resources in dairy Industry: Structure and design of Research and Development organization; Analysis of organization behaviour – Transactional analysis; Personnel management – Typology analysis, individual and the organization, team building, human behaviour at work, motivation.

Unit III

Skill requirements of an R and D manager; New product development: strategies, models and life cycle analysis.Food innovation dynamics; innovation opportunities; innovations in traditional and functional foods; consumer driven food innovation; implementation of latest technology and assessment.

Unit IV

Management of R&D functions: Criterion for selection of R&D projects; Technology development process, Techniques for monitoring R and D functions.

Unit V

Patenting Laws; Indian Patenting Act/International Protocols for technology transfer; Transfer of technology from Lab to Plant, ISO 9001, ISO 14001, ISO 22000, ISO 50001, OHSAS; Laboratory Quality Management System- ISO 17025, Retailer Standards -BRC Food and BRC/IoP Standards, International Food Standard (IFS), SQF 1000 and SQF 2000, Global GAP and India GAP., Six-Sigma concept.

Unit VI

Project proposal writing for research funding, Development of feasibility and technical report for dairy plant establishment, Report writing of projects and its evaluation

VII. Learning outcome

After undergoing this course, the students are expected to deliver the following:
– Identify whether the researches carried out are suitable for patenting
– Help in selecting proper R and D projects for the benefit of the industry as well as for the consumers
– Can write Project proposals to bring in Research funding from external agencies for mutual benefit

VIII. Suggested Reading

- Basu CR. 2017. *Business Organization and Management*. Tata-McGraw Hill Publication.
- Early R, Early M and Anderson A. 2009. *Food Product Development*. Woodhead Publishing Ltd.
- Robbins SP, Judhe, TA and Vorha N. 2013. *Organization Behaviour*. 15th Edn, Pearson Education Publishing Inc.
- Tetra Pak Dairy Processing Handbook. 2015. www.dairyprocessinghandbook.com.

Websites

- World Intellectual Property Organization-https//wipo.int
- IPR and Patents CEN CENELEC-https://cencenelec.eu/ipr/Pages/default.aspx
- ISO-International Standardization for Organization-https://iso.org/home.html
- ISO-45001 Occupational Health and Safety-https://iso.org/iso-45001-occupational-health-and-safety.html

I. Course Title : Advances in Carbohydrate Technology
II. Course Code : DT 623
III. Credit Hours : 3+0
IV. Why this course?

Besides proteins and fats, carbohydratesareother important nutrients. The flavour, colour and structure of food product also depend on the type and amount of carbohydrates present and their reactivity with other constituents during processing. Modified starches have been the recent addition to the list of stabilizers available for the food industry. Lactose – the carbohydrate of milk origin has a special role to play in dairy and food industry. Modifications of carbohydrates such as inversion, enzymic hydrolysis, maillard reaction can lead to value-addition in some food products.

V. Aim of the course

To study the physico-chemical and nutritional characteristics of carbohydrates, and their applications in food processing and health

VI. Theory

Unit I

Introduction to Carbohydrates: Classification, Sources of carbohydrates, Structure of major groups, Non-conventional sources of carbohydrates.

Unit II

Characterization and functional properties of Carbohydrates; Various classes of sweeteners; Production technologies for Corn Syrup Solids (CSS), High fructose corn syrup (HFCS); Maltodextrins; Phenomenon of retrogradation of starch and interventions in foods and methods to control it.

Unit III

Milk Carbohydrates: Manufacturing technologies and their functional, nutritional and technological properties; Lactose hydrolysed dairy products.

Unit IV

Nutritional and therapeutic aspects of carbohydrates: Role in dental caries, obesity, cardiovascular diseases (CVD), colon health, diabetes; resistant starches, Prebiotics, Non-digestible carbohydrates (NDC) and their health benefits.

Unit V

Modified starches: Technologies for starch modification; Properties, applications, safety and toxicity. Carbohydrate based edible packaging films.

Unit VI

Hydrocolloids: Classification, structures, functional properties, and applications.

Unit VII

Cyclodextrins; Carbohydrates as fat replacers/fat substitutes; microencapsulating agents; Techniques for production of protein-polysaccharide conjugates and their applications.

VII. Learning outcome

After undergoing this course, the students are expected to deliver the following:

– Unravel the unconventional sources of carbohydrate for human nutrition
– To produce dairy foods free of allergenicity i.e. lactose-free for lactose intolerant persons
– Able to ameliorate defects in food product through knowledge about interaction of carbohydrates with other constituents in food during processing and/or storage
– To recommend reducing calorie in food (formulate dietetic food) through use of carbohydrate source to mimic properties of fat

VIII. Suggested Reading

- Eliasson AC. 2006. *Carbohydrates in Food*, 2nd Edn, CRC Press, Taylor and Francis group.
- Biliaderis CG and Izydorczyk MS. 2007. *Functional Food Carbohydrates.* CRC Press, Taylor and Francis group.
- Mc Sweeney PLH and Fox PF. 2009. *Advanced Dairy Chemistry*. Volume 3, Lactose, water, salts and minor constituents. USA: Springer Science and Business Media.
- Paques M and Lindner C. (Eds.). 2019. Lactose: Evolutionary Role, Health Effects, and Applications. Academic press.
- Steve W Cui. 2005. *Food Carbohydrates: Chemistry, Physical Properties and Applications.* CRC Press, Taylor and Francis group.

Websites

- Effect of Food Processing on Dietary Carbohydrates-http://fao.org/3/W8079E/w8079e0j.htm
- Carbohydrates: Uses, health benefits, and risks – Medical News Today-https://www.medicalnewstoday.com/articles/161547.php

Potential Areas for Research

1. Active, intelligent and biodegradable packaging
2. Application of non-thermal processes for value-added dairy products
3. Bioactives from plant/plant bio-waste for human nutrition
4. By-products from agri-food industry: Recovery, utilization and revalorization
5. Composite dairy foods
6. Dairy based analogues
7. Dairy derived ingredients and their applications
8. Green technologies for dairy and food products
9. Health foods for conferring physiological benefits
10. Innovations in fermented dairy and food products
11. Nanotechnology in dairy and food applications
12. Non-bovine milk and milk products
13. Novel extruded food based on dairy and cereal/legume based solids.
14. Novel products utilizing membrane processed dairy solids.
15. Sensory characterization, technology standardization, value addition and shelf life extension of traditional Indian dairy products
16. Target delivery of nutraceuticals/active functional ingredients through dairy matrices
17. Technology of novel and exotic cheeses
18. Utilization of dairy by-products

List of Journals

1. *Australian Journal of Dairy Technology*
2. *British Food Journal*
3. *Cereal Chemistry*
4. *Cereal Foods World*
5. *Comprehensive Reviews in Food Science and Food Safety*
6. *Critical Reviews in Food Science and Nutrition*
7. *CyTA - Journal of Food (Ciencia Y TecnologiaAlimentaria)*
8. *Dairy Science and Technology (formerly Le Lait)*
9. *Drying Technology: An International Journal*
10. *Emirates Journal of Food and Agriculture*
11. *European Food Research and Technology*
12. *European Journal of Nutrition and Food Safety*

13. *Food and Bioprocess Technology*
14. *Food and Bioproducts Processing*
15. *Food and Function*
16. *Food Bioscience*
17. *Food Hydrocolloids*
18. *Food Quality and Preference*
19. *Food Research International*
20. *Food Reviews International*
21. *Indian Journal of Dairy Science*
22. *Innovative Food Science and Emerging Technologies*
23. *International Dairy Journal*
24. *International Journal of Dairy Technology*
25. *International Journal of Fermented Foods*
26. *International Journal of Food Properties*
27. *International Journal of Food Science and Technology*
28. *Irish Journal of Agricultural and Food Research*
29. *Journal of Dairy Research*
30. *Journal of Dairy Science*
31. *Journal of Food Measurement and Characterization*
32. *Journal of Food Processing and Preservation*
33. *Journal of Food Science and Technology*
34. *LWT - Food Science and Technology*

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 4

Dairy Science and Technology
– Dairy Engineering

Course Title with Credit Load
M.Tech. in Dairy Engineering

Course Code	Course Title	Credit Hours
	Major Courses	
DE-511*	Dairy and Food Engineering-I	3+0
DE-512	Analytical Heat and Mass Transfer	2+1
DE-513	Transport Phenomena	3+0
DE-514	Advances in Refrigeration Engineering	2+1
DE-515*	Design of Dairy and Food Process Equipment	3+0
DE-516	Engineering Properties of Dairy and Food Products	2+1
DE-517	Mechanization in Manufacture of Indigenous Dairy Products	3+0
DE-521*	Dairy and Food Engineering-II	3+0
DE-522	Bio-Thermal Process Engineering	3+0
DE-523*	Industrial Instrumentation and Process Control	2+1
DE-524	Industrial Automation and Robotics	2+1
DE-525	Unit Operations	2+1
DE-526	Environmental Engineering	2+0
DE-527	Energy Management and Auditing in Dairy and Food Plants	2+1
DE-591	Masters' Seminar	1+0
DE-599	Masters' Research	0+30

Course Contents
M.Tech. in Dairy Engineering

I. **Course Title : Dairy and Food Engineering-I**

II. **Course Code : DE 511**

III. **Credit Hours : 3+0**

IV. **Why this course?**

The development in mechanization and automation of the dairy and food processing are dependent on deeper knowledge of rheological, thermal and physical properties of the dairy and food products. Energy conservation and preservation of food quality during processing using emerging and non-thermal processes are the need of the hour. Therefore, this course is designed to provide the students a deeper understanding of the role of rheology and other food properties in the design, handling and operation of various processing equipment. Also, newer and emerging technologies are introduced to reduce the impact of processing on food quality.

V. **Aim of the course**

- To familiarize with the study of rheological properties of food and their measurements.
- To introduce the developments in thermal and non-thermal processing of foods

VI. **Theory**

Unit I

Viscoelastic characterisation of materials, stress-strain behaviour, creep, stress relaxation, solving problems on creep and stress relaxation of foods, non-Newtonian fluids; Viscometry-capillary and rotational viscometers, derivation on principle of operation of capillary and rotational viscometers, fitting of flow models; Rheometers: types and applications, temperature sweep, amplitude sweep and frequency sweep; identification of LV region.

Unit II

Freezing: IQF, Cryogenic freezing- process and equipment details, freezing curves, freezing time calculations, design of freezing equipment, freeze drying, freeze concentration.

Unit III

Design of single and multi-effect evaporators, design of TVR and MVR, design and selection of evaporator pumps, calculation of wetting rate, concept of condenser free design of evaporator, design of condenser (barometric and surface), flash vessel, preheater design for bacterial destruction, DSI, vacuum pump, concept of fanless cooling tower, aroma recovery unit.

Unit IV

Design of spray drier and its components, design of three stage drier, selection of fans, roots blower, selection of nozzle, HPP cum homogeniser used for automation, CIP, cleanable bag filter, concept of cyclone free spray drier operation, use of computer software in design of evaporators and spray driers.

Unit V

Novel processing methods and equipment: high pressure processing, ohmic heating, ultraviolet light, pulsed electric field, pulsed light field, micro and nano-encapsulation, microwave heating, cold plasma, ultrasound processing and low dose e-beams.

Unit VI

Ultra-high temperature processing (UHT): concept, process, system; Design: plate and tubular type, their merits and demerits and selection; heat balances and concept of differential temperature; steam cleaning systems. Analysis of sterilization performance and validation, determination of residence time distribution.Pouch forming, can and carton filling systems for UHT. Cleaning and sterilization of UHT processing plants

VII. Teaching Methods

- Lecture
- Assignment Writing
- Student presentation
- Case Analysis and case studies
- Guest Lectures
- Industry Visit

VIII. Learning outcome

The students will be more confident in design and operation of dairy and food process equipment. They will also be familiar with non-thermal processes and emerging processing methods in the manufacture of dairy and food products.

IX. Suggested Reading

- Burton H. 2012. *Ultra-High-Temperature Processing of Milk and Milk Products*. Springer Science.ISBN-13: 978-1461359012.
- Chauhan OP. 2019. *Non-thermal Processing of Foods*. 1st Edition, CRC Press. ISBN-13: 978-1138035843.
- Das SK and Das M. 2019. *Fundamentals and Operations in Food Process Engineering*. 1st Edition, CRC Press. ISBN-13: 978-1466560901.
- Gunasekaran S and Mehmet MAK. 2002. *Cheese Rheology and Texture*. 1st Edition, Taylor and Francis. ISBN-13: 978-1138198425.
- Heldman RD, Daryl BL and Sabliov C. 2019. *Handbook of Food Engineering*. 3rd Edition, CRC Press. ISBN-13: 978-1466563124.
- Kessler HG. 1981. *Food Engineering and Dairy Technology*. Verlag A. Kessler.
- Bourne M. 2002. *Food Texture and Viscosity: Concept and Measurement* 2nd Edition, Academic Press. ISBN-13: 978-0121190620.
- McCabe WL, Smith JC and Harriott P. 2017. *Unit Operations of Chemical Engineering*. 7th Edition, McGraw Hill Education. ISBN-13: 978-8184959635.
- Mohsenin NN. 1970. *Physical Properties of Plant and Animal Materials*. 1st Edition, Routledge. ISBN-13: 978-0677023007.
- Singh RP and Heldman DR. 2013. *Introduction of Food Engineering*. 5th Edition, Bio-Green Elsevier. ISBN-13: 978-9351073499.
- Toledo RT, Singh RK and Kong F. 2000. *Fundamentals of Food Process Engineering*. 2nd Edition, CBS. ISBN-13: 978-8123915517.

I. Course Title : Analytical Heat and Mass Transfer

II. Course Code : DE 512

III. Credit Hours : 2+1

IV. Why this course?

Heat and mass transfer are the basic transport processes occurring in all the unit operations. These are complex processes because these occur mostly simultaneously and under unsteady state conditions with continuous changes in product characteristics. These also affect the efficiency and productivity of food processing lines. Deeper analytical solutions to heat and mass transfer operations are therefore needed. This course is aimed to provide solutions to such complex heat and mass transport processes, which will help in the design of efficient process equipment.

V. Aim of the course

- To introduce two dimensional and unsteady state of heat transfer.
- To introduce the forced convective heat transfer and relationships with dimensionless numbers.
- To learn appropriate design and analytical tools to investigate heat and mass transport phenomena
- To apply various computational techniques to obtain numerical solutions of these phenomena

VI. Theory

Unit I

One-dimensional steady state heat conduction through fins (Extended surfaces): actual and approximate solution. Efficiency, effectiveness and design of profile area of fins.

Unit II

Two-dimensional steady state heat conduction: analytical and numerical solution.

Unit III

Unsteady state heat conduction: Concept of Biot number, Lumped parameter analysis, transient heat flow in semi-infinite solids, use of Heisler charts.

Unit IV

Forced convection heat transfer in flow over a flat surface: hydrodynamic and thermal boundary layer, continuity equation, momentum equation and energy equation, heat transfer coefficient/ Nusselt number in laminar and turbulent region of boundary layer. Stanton number; Colburn analogy; empirical co-relations.

Unit V

Forced convection heat transfer in flow through tubes: Nusselt number in the entrance region and fully developed laminar and turbulent region.

Unit VI

Condensation and boiling heat transfer: Film wise condensation on vertical surface; Nusselt equation, regimes of boiling, boiling heat transfer.

Unit VII

Performance analysis of parallel flow and counter flow heat exchangers. LMTD and effectiveness NTU approach. Application of computational software for process heat transfer applications.

Unit VIII

Mass transfer - Fick's law of diffusion, diffusion of gases and liquids through solids, equimolar diffusion, isothermal evaporation of water into air, mass transfer coefficients. Governing equation for mass transfer; boundary conditions. Various non-dimensional numbers and their analogy to heat transfer. Examples of simultaneous heat and mass transfer

VII. Practical Topics

- Steady state heat conduction through fins
- Two-dimensional steady state heat conduction
- Solving problems in unsteady state heat conduction and use of Heisler charts
- Experiments on forced convection heat transfer
- Experiments on drop and film-wise condensation
- Determination of heat transfer coefficient
- Solving problems in condensation and boiling heat transfer
- Solving problems on mass transfer in diffusion and evaporation
- Experiments in parallel flow/ counter flow heat exchanger test rig
- Determination of mass transfer coefficient
- Design of engineering systems involving thermofluid phenomena.

VIII. Teaching Methods

– Lecture
– Assignment Writing
– Student presentation
– Solving problems
– Familiarising with relevant software

IX. Learning outcome

Students have better understanding of heat and mass transfer processes and the skills to obtain solutions to such complex problems. They will develop competence in the design of process equipment using the analytical solutions of heat and mass transfer.

X. Suggested Reading

- Cengel YA. 2020. *Heat and Mass Transfer*. Tata McGraw Hill Education, New Delhi, 6th Edition, ISBN: 978-9390185283.
- Domkundar S and Arora SC. 2007. *A Course in Heat and Mass Transfer*. Dhanpat Rai and Co., Ltd. ISBN-13: 978-8177000290.
- Holman JP and Bhattacharyya S. 2017. *Heat Transfer*. 10th Edition, McGraw Hill. ISBM-13: 978-0071069670.
- Majumdar P. 2017. *Computational Methods for Heat and Mass Transfer*. T&F India. ISBN-13: 978-1138044869.
- Muralidhar and Sundararajan. 2009. *Computational Heat and Mass Transfer*. Narosa.
- Nag P K. 2011. *Heat and Mass Transfer*. 3rd Edition, McGraw Hill Education. ISBN-13: 978-0070702530.
- Rajput RK. 2018. *A Textbook of Heat and Mass Transfer SI Units*. S. Chand Publishing. ISBN-13: 978-9352533848.

I. Course Title : Transport Phenomena

II. Course Code : DE 513

III. Credit Hours : 3+0

IV. Why this course?

An understanding of uniform approach to mass, energy and momentum transfer is necessary in modelling and predicting the above phenomena in food processing operations. This course provides engineering students advance methods to solve problems involving transports of momentum, energy and mass in biological, mechanical and chemical systems using a unified approach. Emphasis is given on developing the mathematical models to describe the flow phenomena.

V. Aim of the course

- To introduce the transport phenomena of mass, energy and momentum.
- To study the transport phenomena with the help of dimensional analysis.

VI. Theory

Unit I

Introduction to vector analysis, dot product and cross product and its physical significance, Stress tensor, total and partial derivatives, total acceleration, Eulerian and Lagragian frames of reference, Reynolds transport theorem, Different three-dimensional co-ordinate systems (Cartesian and Polar).

Unit II

Introduction to transport phenomena - transport processes and similarities in momentum, energy and mass transfer; Application of transport phenomena in CFD, practical examples in food engineering. Classification of flows and flow visualization; vorticity and potential and stream function, Potential flow, Cauchy Reimann equations.

Unit III

Steady-state equations - Momentum transport equations for Newtonian and non-Newtonianfluids, continuity equation in different co-ordinates; Derivation for Cartesian, cylindrical and spherical coordinate system.

Unit IV

Equations of motion - Navier-Stokes equations and their application in viscous fluid flow between parallel plates and through pipes.

Unit V

Turbulent transport mechanism - Mathematical analysis; Eddy viscosity and eddy diffusivity; Velocity, temperature and concentration distribution; time smoothing equations. Inter-phase transport in isothermal system -friction factors for various geometries.

Unit VI

Dimensional analysis- Buckingham Pi-theorem and matrix method, application to transport phenomena, analysis among mass, heat and momentum transfer, Reynolds' and Chilton –Colburn analogy.

Unit VII

Non-dimensional numbers in transport phenomena- definition, mathematical relation and physical significance; Boundary layer concept - Theoretical and exact solutions for heat, mass and momentum transfer. Governing equations, Blassius solution and Von-Karmen integral equation

VII. Teaching Methods

- Lecture
- Assignment Writing
- Student presentation
- Solving problems
- Familiarising with relevant software
- Industry Visit

VIII. Learning outcome

Student will obtain the knowledge and analytical skills to modelling and predicting the action of mass, energy and momentum transfer. They will be able to solve, using rigorous mathematics, fundamental and elucidating problems involving momentum, energy, and mass transport phenomena and apply this knowledge in design and operation of processing equipment.

IX. Suggested Reading

- Bird RB, Stewart WE and Lightfoot EN. 2006. *Transport Phenomena*. 2nd Edition. Wiley. ISBN-13: 978-8126508082.
- Deen WM. 2013. *Analysis of Transport Phenomenon.* Oxford University Press. ISBN-13: 978-0198098584.
- Foust AS, Wenzel LA, Clump CW, Maus L and Andersen LB. 2015. *Principles of Unit Operations*. 2nd Edition, Wiley.ISBN-13: 978-8126518296.
- Geankoplis CJ, Herse AA and Lepek DH. 2018. *Transport Processes and Separation Process Principles*. 4th Edition. Pearson Education India Prentice-Hall Private Ltd.ISBN-13: 978-9332549432.
- McCabe WL, Smith JC and Harriott P. 2017. Unit Operations of Chemical Engineering. 7th Edition, McGraw Hill Education.ISBN-13: 978-8184959635.
- Raj B. 2012. *Introduction to Transport Phenomena: Momentum, Heat and Mass*. Prentice Hall India Learning Private Limited.ISBN-13: 978-8120345188.
- Yanniotis, S. 2008. *Solving Problems in Food Engineering*. 2008th Edition. Springer. ISBN-13: 978-0387735139.

I. Course Title : Advances in Refrigeration Engineering

II. Course Code : DE 514

III. Credit Hours : 2+1

IV. Why this course?

Refrigeration engineering is an essential technology to preserve the food products. It is an integral part of dairy industry as milk and milk products have very short shelf life. This course is intended to impart knowledge on design aspects of refrigeration and air conditioning systems, system analysis and load calculations. Troubleshooting techniques are explained with the use of wiring diagrams, schematics and 3D sketches.

V. Aim of the course

- To study the various components and the parameters that affect the performance of vapour compression refrigeration
- To study the vapour absorption refrigeration systems

- To study heat pumps and their applications in dairy industry
- To study design and maintenance of cold stores.
- To study controls of refrigeration systems

VI. Theory

Unit I

Vapour compression refrigeration system: major components and their different types; Theoretical vapour compression cycle, theoretical COP; Effect of operating parameters on COP; actual vapour compression cycle; Multi-pressure commercial refrigeration systems.

Unit II

Vapour absorption refrigeration system; Ammonia-water system, lithium bromide - water system, vapour absorption refrigeration cycle and its representation on enthalpy-concentration diagram; Absorption system calculations.

Unit III

Heat Pumps: different heat pump circuits; analysis of heat pump cycle; Use of heat pumps in dairy plant for energy conservation.

Unit IV

Non-conventional refrigeration systems; Steam jet refrigeration, thermoelectric refrigeration, vortex tube, cooling by adiabatic demagnetization.

Unit V

Design elements of refrigeration equipment: compressor, condenser, evaporator, cooling tower, spray pond, etc. Balancing of different components. Design of brazed PHE for condensers

Unit VI

Design of cold storage and air-conditioning systems: types of cooling loads and their calculation, design of cold storage for food products, construction of cold storage, equipment selection, insulating materials, vapour barriers, ice bank tank. Concept of Ice silos, centralised distribution of ammonia through pump, PUF panel design.

Unit VII

Control and maintenance of a commercial refrigeration plant: Pressure regulating valves, Thermostatic valves, LP/ HP cut-outs, high to low side bypass valve, condenser water regulating valve, capacity control devices, pump down control, defrosting methods, liquid charging, advanced intelligent control systems; General preventive maintenance of refrigeration plant.

VII. Practical

- To find and compare the theoretical and actual COP of a small refrigeration unit on Refrigeration Tutor.
- Study and design of refrigeration components of a bulk milk chiller.
- Visit to a commercial refrigeration plant for cold storage/ ice bank unit and calculation of its theoretical COP by making cycle on P-h chart.
- Calculation of theoretical work and comparing it with actual work for some specified cooling job in a commercial plant.
- Study of various control and safety devices in a commercial refrigeration plant.

- Design problems on cold storage for different food/ dairy products.
- Use of computer software specific to cold store AC design
- Study the working of heat pump system.
- Study and design of refrigeration components of a walk-in-cooler
- Evaluate actual performance of a heat pump on heat pump tutor.
- Study of compressors used in vapour compression refrigeration system.
- Study of condensers and expansion devices used in vapour compression refrigeration system
- Study of cooling towers used in vapour compression refrigeration system.
- Industry visit

VIII. Teaching Methods

- Lecture
- Assignment Writing
- Student presentation
- Case Analysis and case studies
- Guest Lectures
- Industry Visit

IX. Learning outcome

The students will be familiar with newer technologies like heat pumps, improved VAR systems and cold store prefabricated designs. Students will also be familiar with improved application of energy efficiencies and automation in refrigeration systems. They can apply this knowledge to perform cooling load calculations and service and troubleshoot commercial refrigeration systems.

X. Suggested Reading

- Arora CP. 2017. *Refrigeration and Air-Conditioning*. 3rd Edition, McGraw Hill Education. ISBN-13: 978-9351340164.
- Arora SC and Domkundwar S. 2018. *A Course in Refrigeration and Air- Conditioning*. Dhanpat Rai and Sons.
- *ASHRAE Handbook*. 2018. American Society of Heating and Refrigeration. ISBN-13: 978-1939200983.
- Hundy GF, Trott AR and Welch T. 2008. *Refrigeration and Air-Conditioning*. 4th Edition. Butterworth Heinemann. ISBN-13:9780750685191.
- Dincer I. 2017. *Refrigeration Systems and Applications*. 3rd Edition, Wiley. ISBN-13: 978-1119230755.
- Khurmi RS. 2006. *Textbook of Refrigeration and Air-conditioning*. S. Chand. ISBN-13:9788121927819.
- New-Comer JL. 1981. *Refrigeration and Air-Conditioning*. Venus Trading Co.
- Wang S. 2000. *Handbook of Air Conditioning and Refrigeration*. 2nd Edition, McGraw Hill Education. ISBN-13:9780070681675.
- Whitman WC, Johnson WM, John A and Silberstein E. 2016. *Refrigeration and Air Conditioning Technology*. 8th Edition, Delmar Publications. ISBN-13: 978-0357001059.

I. Course Title : Design of Food and Dairy Processing Equipment

II. Course Code : DE 515

III. Credit Hours : 2+1

IV. Why this course?

The knowledge of various design codes and steps are needed to understand the design and fabrication of dairy and food processing equipment. These are also essential to design new equipment as well as prevent equipment failure. The challenges are to develop machines/gadgets that are responsive to the customer with high quality and low cost. This course is aimed to provide the students with working knowledge of design principles as applied in food and dairy processing operations. In this course, the students will learn how to design major equipment common to most unit operations using relevant CAD/CAM software.

V. Aim of the course

To study design and various codes for pressure vessels, heat exchangers and reactors

VI. Theory

Unit I

Design of vessels: codes and regulations, Design for pressure and temperature, loading; allowable stress, minimum thickness after forming, design for internal and external pressure, cylindrical and spherical shells, formed heads, reinforcement openings; fabrication requirements, inspection, tests and non-destructive examination, pressure tests, design and stress evaluation, design problem.

Unit II

Design of storage vessels/ tanks, horizontal and vertical tanks, design of insulated and un-insulated tanks, nozzles and mountings, Design problems.

Unit III

Design of high-pressure vessels: constructional features, material for high pressure, multi shell construction, solid walled vessel.

Unit IV

Supports for vessel: bracket support or Lug support, web (gusset plates), skirt support, skirt design, skirt bearing plate, saddle support, Design problems.

Unit V

Heat exchangers: shell and tube heat exchangers, construction codes, general design considerations, U- tube heat exchangers, double pipe exchanger, scraped surface exchanger, spiral tube exchangers, joints; welded tube joints, baffles and tube bundles, tube sheet, double tube sheet construction; plate type heat exchanger; air cooled heat exchangers; Computer software for design of heat exchanger, Design problems.

Unit VI

Design of reactor vessel: material of construction, agitation, classification, heating systems, design consideration, tank coils, design of agitation system components, baffles, power requirement for agitation, Hygienic engineering design.

Unit VII

Fundamentals of CAD/ CAM for design of dairy and food processing equipment.

VII. Practical

- Design of storage tanks and silos
- Design of supports for silos and tanks
- Design of high pressure vessels
- Design of plate heat exchanger
- Design of scraped surface heat exchanger

- Design of air cooled heat exchangers
- Computation of power requirement of agitators
- Exercises on use of CAD/CAM software for design of heat exchangers
- Use of computational software for design of heat exchangers

VIII. Teaching Methods

- Lecture
- Assignment Writing
- Student presentation
- Case Analysis and case studies
- Guest Lectures
- Industry Visit

IX. Learning outcome

The students will understand the impact of various constraints on product design and process planning. The knowledge and understanding of design codes and procedures would help to understand, operate the processing equipment as well as design new equipment that are efficient and safe to operate. The students can analyse structures using computer software and expedite the design process of various equipment used in the dairy and food industry.

X. Suggested Reading

- Evans FL. 2016. *Equipment Design Handbook for Refineries and Chemical Plants*. Gulf Publishing, Houston, Texas. ISBN-13: 978-0872012660.
- Farrall AW. 2018. *Engineering for Dairy and Food Products*. 3rd Edition, MedTech. ISBN-13: 978-9386800718.
- Kessler HG. 1981. *Food Engineering and Dairy Technology*. Verlag A. Kessler.
- Mahajani VV and Umarji SB. 2016. *Joshi's Process Equipment Design*. 5th Edition, Laxmi Publications. ISBN-13: 978-9351380191.
- Saravacos GD and Kostaropoulos AE. 2012. *Handbook of Food Processing Equipment*. Springer. ISBN-13: 978-1461352129.

I. Course Title : Engineering Properties of Dairy and Food Products

II. Course Code : DE 516

III. Credit Hours : 2+1

IV. Why this course?

The successful and efficient design and operation of process equipment depend on the information and knowledge of engineering properties of dairy and food products. This course is to acquaint the students with different techniques of measurement of engineering properties of biological materials and their importance in the design of food processing equipment. The student will be taught to design and conduct experiments for measuring different properties of biological materials, as well as to analyze and interpret data. Also, the students will acquire knowledge on the application of physical properties to design a system, component, or engineering process to meet desired needs.

V. Aim of the course

- To familiarize with the engineering properties of food products and their measurement.
- To study the application of the properties in design of food process equipment.

VI. Theory

Unit I

Geometrical Properties; Shape, size, volume, density, porosity, surface areas, friction, rolling resistance, angle of repose, specific surface area, mean diameter, sphericity, particle size analysis, Hausner's ratio, Carr's index.

Unit II

Aerodynamic, Hydrodynamic and Frictional Properties; Drag coefficient, terminal velocity, Relation between drag coefficient and Reynolds number, terminal velocity from time distance relation. Pressure drop through packed beds.

Unit III

Thermal properties; Specific heat, thermal conductivity, thermal diffusivity, methods of determination, steady state and transient heat flow, enthalpy, surface heat transfer coefficient freezing point. Measurement of thermal properties and prediction techniques.

Unit IV

Electrical conductivity, capacitance, inductance, Dielectric properties, viz. dielectric and microwave, dielectric constant, Dielectric loss factor, loss tangent, energy absorption, heating; Optical properties, colorimetry, transmittance and reflectance.

Unit V

Non-destructive quality evaluation techniques; Measurement techniques and instruments for food quality determination, destructive and non-destructive quality evaluation, UV-VIS NIR spectroscopy, X-ray, CT, NMR, machine vision system. FTIR, DSC, machine vision system, particle size determination by laser diffraction, e-nose, biosensors, etc.

Unit VI

Application of engineering properties in equipment design, processing and handling of dairy and food products.

VII. Practical

- Determination of geometric mean diameter, sphericity and surface area
- Determination of angle of repose and coefficient of internal friction
- Determination of bulk density, tapped density, true density, porosity, Hausner's ratio and Carr's index
- Particle size distribution analysis
- Determination of aerodynamic properties such as terminal velocity, lift and drag force for grains and particulates.
- Use of empirical equations for determination of thermal properties
- Determination of thermal conductivity, thermal resistivity and specific heat of food materials
- Estimation of surface heat transfer coefficient
- Measurement of electrical conductivity and dielectric properties
- Colour measurement and determination of CIELAB colour parameters
- Study of machine vision system

VIII. Teaching Methods

– Lecture

– Assignment Writing
– Student presentation
– Solving problems
– Familiarising with relevant software

IX. Learning outcome

The student will be familiar with engineering properties of food products and methods to determine these properties. They will be able to apply the fundamentals of engineering sciences to characterize the physical and rheological properties of biological materials. The students can apply the physical, aerodynamic and rheological data in the design of agricultural and food processing machines and processing systems and to various unit operations in the food industry.

X. Suggested Reading

- Arana I. 2016. *Physical Properties of Foods: Novel Measurement Techniques and Applications*. 1st Edition, CRC Press. ISBN-13: 978-1138627130.
- Gunasekaran S. 2000. *Non-destructive Food Evaluation: Techniques to Analyze Properties and Quality*. 1st Edition, CRC Press. ISBN-13: 978-0824704537.
- Heldman DR and Singh PR. 2012. *Food Process Engineering*. 2nd Edition, Springer Science and Business Media. ISBN-13: 978-0870553806
- Mohsenin NN. 1970. *Physical Properties of Plant and Animal Materials*. 1st Edition, Routledge. ISBN-13: 978-0677023007.
- Mohsenin NN. 2020. *Thermal Properties of Food and Agricultural Materials*. Gordon and Breach Science Publishers (CRC Press). ISBN: 0677054505.
- Rahman MS. 2016. *Food Properties Handbook*. 2nd Edition, CRC press. ISBN-13: 978-1138627598.

I. Course Title : Mechanization in Manufacturing of Indigenous Dairy Products

II. Course Code : DE 517

III. Credit Hours : 3+0

IV. Why this course?

The focus of the industry today is now on hygienic, mechanized and mass production of indigenous dairy products. This trend is due to the greater urbanization and higher disposable income and life style change. This course is going to cover all these aspects.

V. Aim of the course

- To design equipment suitable for manufacture of indigenous dairy products.
- To adopt, modify SSHE for continuous manufacture of indigenous dairy products.
- To upscale these equipment for a large scale, hygienic and safe production of indigenous dairy products

VI. Theory

Unit I

Present status of mechanization in manufacture of indigenous dairy products.

Unit II

Preliminary design calculations and material selection, design considerations like force alignment and vibration. Analysis of stresses and strains in rectangular and polar coordinates; Cauchy's formula, principal stresses and principal strains. Failure modes and effects analysis. Manufacturing system types and principles, manufacturing models- physical and mathematical models, realistic model building and design of prototypes.

Unit III

Design of liquid-filled SSHE for preheating applications; Design of equipment for batch and continuous mechanized manufacture of khoa, khoa-based sweets, chhana and chhana-based sweets; Conical process vat, single SSHE, triple SSHE, etc. Equipment for manufacture of batch and continuous manufacture of fermented dairy products, paneer, butter and ghee. Sizing and optimization. Cooling systems for viscous products. Machining standards for stainless steel.

Unit IV

Instrumentation and automation in manufacturing of indigenous dairy products. Automatic filling machines. Changes in engineering properties of milk during manufacture of indigenous dairy products.

Unit V

Design, layout and preparation of project report for establishing unit for the manufacture of indigenous dairy products. Scaling up of prototypes to commercial capacity.

VII. Teaching Methods

- Lecture
- Assignment Writing
- Student presentation
- Familiarising with relevant software
- Industry visit

VIII. Learning outcome

The student familiarizes with equipment manufacture suitable for the typical indigenous dairy products. Also the ability to adopt heat exchanger design suitable to manufacture these products in large scale, continuous manufacture under hygienic condition

IX. Suggested Reading

- Aneja RP, Mathur BN, Chandan RC and Banerjee AK. 2002. *Technology of Indian Milk Products*. Dairy India Publications, New Delhi. ISBN-13: 978-8190160308.
- Askin RG. and Standridge CR. 1993. *Modeling and Analysis of Manufacturing System*. John Wiley and Sons. ISBN-13: 978-0471514183.
- Gupta V. 2018. *Dairy India*. 7th Edition. Dairy India Year Book.ISBN-13: 978-8190160339.
- Haik Y, Sivaloganathan S and Shahin MT. 2009. *Engineering Design Process*. 3rd Edition, Cengage Learning.ISBN-13: 978-8131510599.
- Kessler HG. 1981. *Food Engineering and Dairy Technology*. Verlag A. Kessler.
- Kutz M. 2019. *Handbook of Farm, Dairy and Food Machinery Engineering*. 3rd Edition, Academic Press Inc. ISBN-13: 978-0128148037.
- Pahl G, Beitz W, Feldhusen J and Grote KH. 2014. *Engineering Design- A Systematic Approach*. 3rd Edition, Springer. ISBN-13: 978-1447160250.
- Sukumar De. 2001. *Outlines of Dairy Technology*, 1st Edition, Oxford University Press. ISBN-13: 978-0195611946.

I. Course Title : Dairy and Food Engineering-II

II. Course Code : DE 521

III. Credit Hours : 3+0

IV. Why this course?

Shelf life of a food is governed by internal and external factors and the type of packaging used. Thus, water activity, package permeability and temperature determine the shelf life of a food. This course is aimed to acquaint the students to integrate these factors to evaluate, model and validate the shelf life of a food product. Also newer methods of non-thermal preservation process like membrane technology and also some of the efficient thermal processes like microwave heating to be better understood and applied.

V. Aim of the course

- To study role of water activity in food preservation.
- To study different packaging material, their properties and effect on shelf life of food products
- To study membrane processing and microwave heating of food products

VI. Theory

Unit I

Water activity and states: a thermodynamic quantity, water sorption isotherms, hysteresis, theories of sorption hysteresis, water activity measurement methods, water binding, control of water activity and moisture; Relationship between water activity and glass transition. Diffusion and sorption kinetics of water in foods

Unit II

Different types of packaging materials, their key properties and applications, Plastic packaging, different types of polymers used in food packaging and their barrier properties. Recent innovations in packaging, identification and testing of packaging materials

Unit III

Permeability and shelf-life: theoretical considerations, permeability to gases and vapours, measurement methods, permeability of multiplayer materials, permeability in relation to packaging requirements of food products. Development of shelf-life models based on moisture gain, lipid oxidation and light.

Unit IV

Calculation of shelf life and requirements for packaging, deteriorative reactions accelerated testing, relationship between transport properties of the package and shelf life of packaged products, simulation of product package- environment interaction, shelf life simulation for moisture, oxygen and light sensitive products.

Unit V

Theory of ultra-filtration, reverse osmosis and electrodialysis, selection and types of membrane and properties, concentration polarization, mathematical description of flow through membrane, application and use in dairy industry. Design calculation and selection of various membrane systems.

Unit VI

Microwave energy absorption, physical parameters in microwave heating processes, heat transfer phenomena, equipment and application in dairy food industry. Types of waveguides, electromagnetic resonators and microwave tubes.

VII. Teaching Methods

- Lecture
- Assignment Writing
- Student presentation
- Solving problems
- Familiarising with relevant software
- Industry visit

VIII. Learning outcome

Students can design and select packaging material to achieve desired shelf life of a wide variety of food and dairy products. An understanding of application of newer technologies such as Membrane processing, and Microwave heating is also achieved.

IX. Suggested Reading

- Barbosa-Cánovas GV, Fontana AJ, Schmidt SJ and Labuza TP. 2020. *Water Activity in Foods. Fundamentals and Applications*. 2nd Edition, Blackwell Publishing. ISBN-13: 978-0813824086.
- Brennan JG. 2012. *Food Processing Handbook*. 2nd Edition, Wiley-VCH. ISBN-13: 978-3527307197.
- Cheryan M. 2016. *Ultrafiltration and Microfiltration Handbook*. Technomic Publishing. ISBN-13: 978-1498771139.
- Collin RE. 2007. *Foundations for Microwave Engineering*. 2nd Edition. Wiley. ISBN-13: 978-8126515288.
- Karel M and Lund DB. 2003. *Physical Principles of Food Preservation*. 2nd Edition, CRC Press.ISBN-13: 978-0824740634.
- Robertson GL. 2016. *Food Packaging-Principles and Practice*. CRC Press, 3rd Edition, ISBN-13: 9781138628052.
- Varzakas T and Tzia C. 2015. *Handbook of Food Processing*. 1st Edition, CRC Press. ISBN-13: 978-1466582309.

I. Course Title : Bio-Thermal Process Engineering

II. Course Code : DE 522

III. Credit Hours : 3+0

IV. Why this course?

The trend towards longer shelf life milk products is necessitating a closer look at the reaction kinetics and the areas of thermo-bacteriology and fermenters for controlled reaction studies. Also, the field of bioprocessing is developing very rapidly and needs skilled engineers with the background to design, build, control, and operate bioreactors and fermenters. This course provides students with advanced concepts and prepares them to meet the challenges of the new and emerging area of bioprocessing in the food industry.

V. Aim of the course

- To study biochemical reaction kinetics, reaction vessel design and operation.
- To study thermal effects on the UHT processed food products.

VI. Theory

Unit I

Introduction to biochemical engineering: biochemical kinetics, kinetics of substrate utilization, enzyme reaction, growth of microorganisms, fermenters, pasteurization and sterilization and thermal destruction.

Unit II

Design and analysis of fermentation vessels: residence time distribution, reactors in food processing, reactor types, analysis of reactor systems.

Unit III

Mixing in reactors: mixing equipment, power consumption, gas-liquid mixing, liquid-liquid dispersion, solids suspension and solid-liquid mass transfer. Scale-up of mixers and alternative mixing devices.

Unit IV

UHT systems and recent advances: factors affecting spoilage of food, Aseptic packaging systems and conditions.

Unit V

Thermo-bacteriology: Survivor curve, thermal death curve, Arrhenius curve, techniques for determination of heat resistance of microorganisms, analysis of thermal resistance data, processing in containers, process time, lethality, design of batch and continuous sterilisation cycles in vat.

VII. Teaching Methods

– Lecture
– Assignment Writing
– Student presentation
– Solving problems
– Familiarising with relevant software

VIII. Learning outcome

Student will be familiar with biochemical reaction kinetics and the design of equipment to study the same. The student will also understand the mixing equipment and their dynamic and scale up relationships. A better understanding of UHT processes in perspective of reactions will be achieved.

IX. Suggested Reading

- Bailey JE and Ollis DF. 2017. *Biochemical Engineering Fundamentals*. 2nd Edition, McGraw Hill Education.ISBN-13: 978-0070701236.
- Blanch HW and Clark DS. 2007. *Biochemical Engineering*. T&F India. ISBN-13: 979-0824700996.
- Das H. 2008. *Food Processing Operations Analysis*. Asian Books. ISBN-13: 978-8186299784.
- Das SK and Das M. 2019. *Fundamentals and Operations in Food Process Engineering*. 1st Edition, CRC Press.ISBN-13: 978-1466560901.
- McNeil B and Harvey LM. 1990. *Fermentation: A Practical Approach*. IRL Press. ISBN-13: 978-0199630455.
- Pauline MD. 2013. *Bioprocess Engineering Principles*. Elsevier Science, 2nd Edition, ISBN-13: 978-9381269831.
- Stumbo. 1965. *Thermobacteriology in Food Processing*. 2nd Edition, Academic Press. ISBN-13: 978-0126753523.

I. Course Title : Industrial Instrumentation and Process Control

II. Course Code : DE 523

III. Credit Hours : 2+1

IV. Why this course?

With the advancements in electronics, automation has become the trend in dairy industry. Automation enables better control of the process operations resulting in improved efficiency. Therefore, understanding of computer control of instrumentation and automation is essential in the rapidly developing field of Automation in Dairy and Food Industry.

V. Aim of the course

- To study microprocessor based instruments used in industries.
- To study various control systems for process control.
- To study computer based control systems.

VI. Theory

Unit I

Introduction; Instrumentation systems and its classification, measuring instruments, characteristics of instruments, intelligent versus dumb instruments, Microprocessor based instrumentation, Function of measurement systems, its elements and applications. Industrial instrumentation, Structure of industrial instrumentation in real time applications

Unit II

Control Systems; Feedback principles. Mechanical, hydraulic and pneumatic system components. Characteristics of liquid system, gas system, thermal system. Mathematical model of liquid process, gas process, flow process, thermal process, mixing process, Chemical reaction, D.C. and A.C. Servomotors, D.C. and A.C. Tachogenerators, Potentiometers and optical encoders, Synchro and stepper motors, Modelling and objectives of modelling for batch and continuous processes, Self-regulation. Pneumatic valves

Unit III

Process Control and Controllers; Principles of automatic process control, Process characteristics, control system parameters, Process control loop, Elements of process control, process variables, Process facility considerations, controller modes, lag time, error signals, and correction signals, Actuators and Control valves; on-off, P, PI, P-I-D, cascade, feed forward, and ratio controllers, Fuzzy controllers. Data loggers and data acquisition, Introduction to computer based control systems, PLC, DCS, SCADA, HMI, etc.

Unit IV

Modern Transducers and Display Devices; Silicon micro transducers, optical transducer principles, types, characteristics of fibres and fibre optic transducers, Introduction to smart transducers and their applications, displays and their classification - Storage CRTs, Flat CRTs, LEDs, LCD display, Gas discharge plasma displays, Incandescent display, Electrophoretic image displays (EPID), Liquid vapour display (LVD).

Unit V

Introduction to computer based control; Computer based controller, data logging, supervisory control, flow chart, control system networks, basic structure and operation of programmable logic controllers (PLCs).

VII. Practical

- Study and analysis of electric switches, networks, electromechanical relays, MCB, SCR etc.
- Study of CRO and digital display devices.
- Study of automation techniques to control temperature by using PID controller.
- Study and application of digital timer to control timing of various processes, working of controllers in constant temperature water baths
- Make ladder diagrams and flow sheet diagrams for control logics in PLC.
- Study programme of a PLC and computer interface of a PLC.
- Study the characteristics of resistance transducer potentiometer and calibration of ammeter, voltmeter using DC potentiometer.
- Characteristics of LDR, photo diode, and phototransistor:
  - Variable illumination.
  - Linear displacement.
- Study of storage oscilloscope and transient response of RLC circuit.
- Study the characteristics of one solid state sensor/ fibre optic sensor
- Design and test a signal conditioning circuit for the transducers.
- Visit to a microprocessor controlled dairy plant

VIII. Teaching Methods

- Lecture
- Assignment Writing
- Student presentation
- Solving problems
- Industry visit

IX. Learning outcome

Students will get an insight on advanced data acquisition, processing and monitoring systems that provide dynamic responses of various systems. The student will learn about various systems and levels of automation involved in operation and control of dairy plant and the link up of computer software to it.

X. Suggested Reading

- Barney GC. 2018. *Intelligent instrumentation: Microprocessor Applications in Measurement and Control*. Prentice Hall International. ISBN-13:978-0134689432.
- Bhargava NN, Kulshreshtha DC and Guptta S. (Eds.). 2017. *Basic Electronics and Linear Circuits*. 2nd edn, McGraw Hill Publication.
- Harriot P. 2012. *Process Control*, Tata McGraw Hill Publishing Co Ltd., New Delhi. ISBN: 9780070993426.
- Johnson CD. 2015. *Process Control Instrumentation Technology*, 8th Edition, Pearson Education India. ISBN-13: 978-9332549456.
- Kalsi HS. 2019. *Electronic Instrumentation and Measurements*, 4th Edition, McGraw-Hill Education. ISBN-13: 978-9353162511.
- Sawhney AK. 2015. *A Course in Electronic Measurements and Instrumentation*, Dhanpat Rai and Co. ISBN-13: 978-8177001006.
- Stephanopoulos G. 2008. *Chemical Process Control: An Introduction to Theory and Practice*, Prentice Hall India, ISBN-13: 978-8120306653.

I. Course Title : Industrial Automation and Robotics

II. Course Code : DE 524

III. Credit Hours : 3+0

IV. Why this course?

The understanding of the Microprocessor controls, SCADA and Robotics and their application in material handling, process control and supervision is essential in large food industry. This course is going to cover all these aspects.

V. Aim of the course

- To study automation, role in material handling and manufacturing systems.
- To study computer based industrial automation, SCADA, etc.
- To study elements of Robotics.

VI. Theory

Unit I

Introduction; Automation in Production System, principles and strategies of automation, basic elements of an automated system, advanced automation functions, levels of automation. Flow lines and transfer mechanisms, fundamentals of transfer lines.

Unit II

Material handling and Identification Technologies: Overview of Material Handling Systems, Principles and Design Consideration, Material Transport Systems, Storage Systems, Overview of Automatic Identification Methods.

Unit III

Automated manufacturing systems; Components, classification and overview of manufacturing systems, Manufacturing cells, GT and Cellular manufacturing, FMS, FMS and its planning and implementation. Quality control systems: Traditional and modern quality control methods, SPC tools, inspection principles and practices, inspection technologies.

Unit IV

Control technologies in automation; Industrial control systems. Manufacturing industries, continuous versus discrete control, computer process and its forms.

Unit V

Computer based industrial control; Introduction and automatic process control building blocks of automation systems; LAN, Analog and Digital I/O modules, SCADA systems and RTU. Distributed control system: Functional requirements, configurations and some popular distributed control systems. Industrial control applications in dairy and food processing industry. Microcontroller units (MCU); Arduino, Raspberry Pi sensors compatible with MCUs: temperature- RH, ultrasound and infrared sensors.

Unit VI

Basic principles of robotics, configurations, control. Application of machine vision systems, Image processing and analysis. Typical pick and place, loading and unloading, packaging and palletizing applications.

VII. Teaching Methods

- Lecture
- Assignment Writing
- Student presentation
- Solving problems
- Familiarising with relevant software

VIII. Learning outcome

Student will have knowledge of application of Robotics in the operations of the food processing industry. Also acquire knowledge of microcontroller applications and the components of automation in using them.

IX. Suggested Reading

- Cichocki A, Ansari HA, Rusinkiewicz M and Woelk D. 2012. *Workflow and Process Automation: Concepts and Technology* (Vol. 432). Springer Science and Business Media. ISBN-13: 978-1461375999.
- Groover MP. 2016. *Automation, Production Systems and Computer-Integrated Manufacturing*. 4th Edition, Prentice Hall Press. ISBN-13: 978-9332572492.
- Helfrick AD and Cooper WD. 2015. *Modern Electronic Instrumentation and Measurement Techniques*. Pearson Education India.
- Hollender M. 2012. *Collaborative Process Automation Systems*. ISA.
- Kant K. 2010. *Computer-based Industrial Control*. 2nd Edition, PHI Learning Pvt. Ltd. ISBN-13: 978-8120339880.
- Moore CA. 2012. *Automation in the Food Industry*. Springer Science and Business Media. ISBN-13: 978-1461565109

I. Course Title : Unit Operations

II. Course Code : DE 525

III. Credit Hours : 2+1

IV. Why this course?

Many of processing steps are categorized and studied under independent operations called Unit Operations. It is important to study these individually, so that in the larger context, these can be seamlessly integrated into the industrial operations. Treatment of the process in terms of individual unit operations allows process engineers to move away from product specific operation to one which is general. In order to manufacture a product of desired quality with the maximum yield, each unit operation must be designed correctly. Mathematical treatment of the process can lead to prediction of conditions that give the highest efficiency. This course is specifically designed for students of food processing disciplines, so that these can be exposed to various unit operations that would enable them to improve the design and operation of food processing plants.

V. Aim of the course

- To study various unit operations in food processing.
- To study crystallization and distillation in food processing.
- To study extrusion, extraction, expelling in food processing.

VI. Theory

Unit I

Grading, cleaning, washing, sorting, shelling, dehusking, decortication, milling, polishing, pearling, drying (evaporative, osmotic and freeze drying), Mixing, clarification, coagulation, mechanical separation, sedimentation.

Unit II

Handling of food products; Mechanics of bulk solids, selection of bulk handling equipment, operation and construction of conveyors and elevators, viz. belt conveyors, screw/auger conveyors, bucket elevators and drag/chain conveyors. Estimation of energy requirement, damage to products during mechanical handling. Operation and maintenance of conveying equipment.

Unit III

Mechanical cleaning and sizing of food products – size reduction, size characteristics, particle geometry, energy for size reduction of granular materials and dry powders, size- reduction equipment, performance characteristics of size reducers. Different milling methods, cryogenic grinding.

Unit IV

Crystallization; Material and energy balance in crystallizers, Principles of crystal growth, super saturation and nuclei formation, operation of batch and continuous crystallizers.

Unit V

Distillation; Flash-off distillation, binary mixtures, differential distillation, steam distillation.

Unit VI

Flow through porous media, adsorption, pressing, expelling, extraction, palletizing, and extrusion.

VII. Practical

- Performance evaluation of cleaning and sorting equipment- destoners, spiral separators, graders, etc.
- Performance evaluation of size reduction equipment- disc grinders, hammer mill, ball mill, etc.
- Calculation of energy for size reduction through Kick's, Bond's and Rittinger's laws.
- Determination of particle size distribution of powders by ASTM sieve analysis
- Application of rotary and vacuum evaporator for concentration of liquid foods
- Use of distillation for solvent extraction of oleoresins and essential oils
- Performance evaluation of conveying equipment- screw conveyors, belt conveyors, bucket elevators, etc.

VIII. Teaching Methods

– Lecture
– Assignment Writing
– Student presentation
– Solving problems
– Industry visit

IX. Learning outcome

Student will have good understanding of the unit operations like size reduction, crystallization, distillation, material handling and the energies involved in these operations. This course serves to integrate the fundamental concepts learned with various industrial operations of manufacturing of food products. Also the knowledge gained in the treatment of one process can be used to a completely new process.

X. Suggested Reading

- Berk Z. 2018. *Food Process Engineering and Technology*. 3rd Edition, Academic Press. ISBN-13: 978-0123736604.
- Earle RL. 2013. *Unit Operations in Food Processing*. 2nd Edition, Pergamon press, ISBN-13: 978-1483293103.
- Fellows P. 2016. *Food Processing Technology: Principles and Practice*. 4th Edition, Woodhead Publishing, ISBN-13: 978-0081019078.
- Foust AS, Wenzel LA, Clump CW, Clump CW and Andersen LB. 2008. *Principles of Unit Operations*. 2nd Edition, John Wiley and Sons. ISBN-13: 978-8126518296.
- Geankoplis CJ, Hersel AA and Lepek DH. 2018. *Transport Processes and Separation Process Principles*. 5th EditionPearson. ISBN-13: 978-0134181028.
- Ibarz and Barbosa-Carnovas GV. 2003. *Unit Operations in Food Engineering*. 1st Edition, CRC Press. ISBN-13: 978-6610546282.
- McCabe WL, Smith JC and Harriott P. 2017. *Unit Operations of Chemical Engineering*. 7th Edition, McGraw Hill Education. ISBN-13: 978- 8184959635.
- Sahay KM and Singh KK. 2004. *Unit Operations of Agricultural Processing*. 2nd Edition, Vikas Publishing House Pvt. Ltd. ISBN-13: 978-8125911425
- Singh RP and Heldman DR. 2013. *Introduction to Food Engineering*. 5th Edition, Academic press. ISBN-13: 978-0123985309.

I. Course Title : Environmental Engineering

II. Course Code : DE 526

III. Credit Hours : 2+0

IV. Why this course?

There is a continuous change in the environmental norms and regulatory standards of the country and all industries including dairy and food industry have to follow them. This requires up gradation of techniques for treatment of wastewater and solid waste from the industries. Hence, it is important to have good understanding of the latest methods of treatment of the dairy industry effluents and their safe, economic and legal disposal.

V. Aim of the course

- To study waste water characteristics, measurement and its treatment methods.
- To study air pollution and methods to control it.

VI. Theory

Unit I

Waste water sources, characteristics, standards for disposal of dairy waste water.

Unit II

Physical, chemical and biological characteristics of waste water, measurement of organic content in waste water

Unit III

Physical unit operations in waste water treatment: screening, racks, mixing, flocculation, sedimentation, floatation, elutriation, vacuum filtration and incineration.

Unit IV

Chemical unit operations in waste water treatment: reaction kinetics, chemical precipitation, aeration and gas transfer process, rate of gas transfer, adsorption and disinfection.

Unit V

Biological unit operations- aerobic and anaerobic cycles, kinetics of biological growth, application of kinetics to treatment systems, aerobic waste treatment, anaerobic waste treatment

Unit VI

Air conditioning systems: clean – room air conditioning; important pollutants of air; properties of particulate matter and air pollution control methods. Dairy plant fire hazards.

VII. Teaching Methods

- Lecture
- Assignment Writing
- Student presentation
- Solving problems
- Industry visit

VIII. Learning outcome

Student will be able to learn the advances in physical, chemical and biological operations of dairy waste treatment and effluent disposal. This will enable them to identify and implement scientific and technological solutions to various environmental problems. Also, they will learn about control methods to provide clean and conditioned air for enclosures in dairy plant operations.

IX. Suggested Reading

- Davis M and Cornwell D. 2017. *Introduction to Environmental Engineering*. 5th Edition, McGraw Hill Education ISBN-13: 978-9339204037.
- Hussain A and Ahmed S. 2018. *Advanced Treatment Techniques for Industrial Wastewater (Advances in Environmental Engineering and Green Technologies)*.1st Edition, IGI Global. ISBN-13: 978-1522557548.
- Karia GL. 2013. *Wastewater Treatment: Concepts and Design Approach*. 2nd Edition, Prentice Hall India Learning Private Limited.ISBN-13: 978-8120347359.
- Kuehn T, Ramsey J and Threlkeld J. 1998. *Thermal Environmental Engineering*. 3rd Edition, Prentice Hall of India. ISBN-13: 978-0139172205.
- Metcalf and Eddy, Tchobanoglous G, Burton F and H David Stensel. 2017. *Wastewater Engineering*: *Treatment Disposal Reuse*. Tata McGraw Hill. ISBN-13: 978-0070495395.
- Peavy HS, Rowe DR and Tchobanoglous G. 2017. *Environmental Engineering*. McGraw Hill Education. 1st Edition, ISBN-13: 978-9351340263.
- Rao MN. 2020. *Waste Water Treatment* 3rd Revised Edition. Oxford and IBH Publishing. ISBN-13: 978-8120417120.
- Syed R. Qasim and Guang Zhu. 2018. *Wastewater Treatment and Reuse Theory and Design Examples*. 1st Edition, Volume 2: Post-Treatment, Reuse, and Disposal. CRC Press. ISBN-13: 978-1138300941.

I. Course Title : Energy Management and Auditing in Dairy and Food Plants

II. Course Code : DE 527

III. Credit Hours : 3+0

IV. Why this course?

The energy cost is increasing as fossil fuels are being depleted. Lot of energy is used for heating and refrigeration purpose in the dairy industry. Therefore, there is a need for understanding and implementing various methods of 'Energy Conservation and Management' in the dairy industry. This is important in view of reducing environmental pollution too.

V. Aim of the course

- To study methods of identifying various Energy Conservation opportunities in dairy and food plants.
- To study various methods involved in Energy Management in dairy and food plants
- To study methods and steps involved in Energy Auditing in dairy and food plants.

VI. Theory

Unit I

Energy audit; its need and types. Bench marking of energy costs. Matching energy use to requirement. Optimizing the input energy requirements. Fuel and energy substitution. Energy Balance and computation of efficiency of energy.

Unit II

High efficiency boilers, improved combustion techniques, energy conservation in steam distribution systems, upkeep and maintenance of steam auxiliaries and fittings.

Unit III

Electrical load management; Demand management, Energy saving controllers, Power factor and its improvement. Transformer; Energy saving in transformers.

Unit IV

Electric motor; Selection and application, energy efficient motors. Variable speed drives and Variable Frequency drives. Industrial lighting

Unit V

Energy conservation in Refrigeration and Cold storages, cooling towers, pumps and pumping systems, fans, blowers, air compressors, Maintenance and upkeep of vacuum and compressed air pipelines.

Unit VI

Processing equipment; Improving efficiency and energy conservation opportunities in kettles, PHEs, Evaporators and Driers. Hot air generator, thermic fluid heater, steam radiator, waste heat recovery and thermal energy storage in food processing facilities, condensate recovery and reuse.

VII. Practical

- Bench marking for various dairy plant operations
- Computation of energy conservation in boilers and steam distribution
- Computation of energy demand management of a dairy plant
- Computation of energy savings in induction motors and transformers
- Exercise on variable frequency drive applications
- Computation of cooling load and energy savings in refrigeration plant and cold stores
- Computation of energy savings in air compressor and compressed air distribution
- Computation of energy savings in counter-current plate heat exchangers and HTST pasteurizer

- Computation of energy saving in multiple effect evaporators and modern dryers
- Energy audit of a dairy plant

VIII. Teaching Methods

- – Lecture
- – Assignment Writing
- – Student presentation
- – Solving problems
- – Industry visit

IX. Learning outcome

Student will gain knowledge of different types of Energy Auditing, Energy Conservation and substitution with Renewable Energy. Important aspects of Electrical load management and selection and up gradation of equipment to higher energy efficiency to save energy will be covered.

X. Suggested Reading

- Abbi YP and Jain S. 2009. *Handbook on Energy Audit and Environment Management*, The Energy and Resources Institute (TERI), New Delhi. ISBN-13: 978-8179930922.
- *Bureau of Energy Efficiency*, 4th floor, Sewa Bhavan, R.K. Puram, New Delhi. Guide Books No. 1 to 4. for National Certification Examination for Energy Managers and Energy Auditors. Pub. 2015.
- Klemes J, Smith R and Kim JK. 2008. *Handbook of Water and Energy Management in Food Processing* (Woodhead Publishing series in Food Science, Technology and Nutrition). 1st Edition, Woodhead Publishing, CRC Press. ISBN-13: 978-1420077957.
- *Practical Guide to Energy Conservation in Dairy Industry*. 2011. Petroleum Conservation Research Association, Sanrakshan Bhawan, 10 Bhikaiji Cama Place, New Delhi. Pub. ISBN 978-81-908167-1-7
- Roosa SA, Doty S and Turner WC. 2018. *Energy Management Handbook*. 9th Edition, River Publishers. ISBN-13:978-1138666979.

Course Title with Credit Load
Ph.D. in Dairy Engineering

Course Code	Course Titles	Credit Hours
Major Courses		
DE 611**	Advances in Dairy Process Engineering	3+1
DE 612	Advances in Heat Transfer	3+0
DE 613	Physicochemical Processes	3+0
DE 621**	Computational Methods and Simulation in Dairy and Food Engineering	2+1
DE 622	Package Permeability and Shelf-Life Modelling	3+0
DE 624	Special Problems	0+2
DE 691	Doctoral Seminar I	1+0
DE 692	Doctoral Seminar II	1+0
DE 699	Doctoral Research	0+75

Minor Courses

The courses will be selected from the allied disciplines of Dairy Technology, Dairy Chemistry and Dairy Microbiology to meet the minimum credit requirements.

Supporting Courses

The supporting courses will be picked from the basket of courses offered in agricultural statistics, computer applications and IT, and other related relevant disciplines to meet the minimum credit requirements.

Common Courses

1.	Library and Information Services	1
2.	Technical Writing and Communications Skills	1
3.	Intellectual Property and its Management in Agriculture	1
4.	Basic Concepts in Laboratory Techniques	1

*Core courses for Master's programme;

**Core courses for Doctoral programme

Course Contents
Ph.D. in Dairy Engineering

I. Course Title : Advances in Dairy Process Engineering
II. Course Code : DE 611
III. Credit Hours : 3+1
IV. Why this course?

To provide the latest methodologies of simulation and modelling for designing of process equipment, problem solving in operation and maintenance of evaporators, driers and mixing equipment. This course is going to cover all these aspects.

V. Aim of the course

To impart knowledge on design and analysis of selected dairy equipment.

VI. Theory

Unit I

Evaporator designs and selection, piping and instrumentation diagrams of evaporator systems, heat and mass balance in single effect system, vapour recompression and impact on efficiency, layout and design calculations of multiple effect evaporator, estimation of residence time in film evaporators, fouling of evaporators and cleaning, entrainment separators.

Unit II

Drying; Design data, performance and selection and design of dryers: tray dryer, drum dryer, freeze dryer, fluidized bed dryer. Design of powder recovery systems; Automation in spray dryers, management of explosions and fire hazards in spray dryers.

Unit III

Mixing of materials; Factors in mixing, types of mixers, operation, mixing gas, liquid and solid; heat transfer in mixers, power requirement, transmission, scale-up of models.

Unit IV

Material handling; System and devices, design and applications of screw, belt, flight, apron conveyors, bucket elevators; power requirements, feeding and discharge mechanisms.

Unit V

Mathematical modelling in food processing operations; Process modelling and optimisation approaches, framework and challenges, transport phenomena models for food process simulation for optimal design and operation. Stochastic finite element analysis of thermal food processes. Neural networks approach to modelling food processing operations.

VII. Practical

- Problems on design of evaporators- effect of temperature and pressure on heat

transfer and efficiency
- Effect of boiling point rise and enthalpy of concentration on heat transfer in evaporators
- Study of vacuum pan
- Reading Piping-Instrumentation diagrams of evaporator systems
- Analysis of drying rate curves of different types of dryers
- Design of tray, drum and fluidized bed dryers
- Design of agitators for liquid systems
- Analysis of heat transfer in agitated vessels
- Effectiveness of mixing of liquids, dispersions and emulsions
- Design of belt, bucket and screw conveyors

VIII. Learning outcome

Students will acquire thorough understanding of recent advances in the design and operation of Evaporators, driers, Mixers and material handling equipment, using Modelling and optimization techniques.

IX. Suggested Reading

- Ahmed J and Shafi-ur-Rahman M. 2012. Handbook of Food Process Design. Wiley-Blackwell Publishing Ltd. ISBN-13: 978-1444330113.
- Chaudhary C, Rai D and Kumar D. (Eds.). 2018. *Advances in Food Processing Techniques*. Kalyani Publishers.
- Chen XD and Mujumdar AS. 2008. Drying Technologies in Food Processing, Blackwell Publishing Ltd. ISBN-13: 978-8126549788.
- Das H. 2008. Food Processing Operation and Analysis. Asian Books. ISBN-13: 978-8186299784.
- Geankoplis CJ, Hersel AA and Lepek DH. 2018. Transport Processes and Separation Process Principles, 5th Edition, Pearson. ISBN-13: 978-0134181028.
- Saravacos GD and Kostaropoulos AE. 2016. Handbook of Food Processing Equipment, 2nd Edition, Springer International. ISBN-13: 978-3319250182.
- Valentas KJ, Rotstein E and Paul Singh R. 1997. Handbook of Food Engineering Practice. CRC Press. ISBN-13: 978-0849386947.
- Zeki Berk. 2018. Food Process Engineering and Technology, 3rd Edition, Academic Press. ISBN: 9780128120187.

I. Course Title : Advances in Heat Transfer

II. Course Code : DE 612

III. Credit Hours : 3+0

IV. Why this course?

To enable the students to solve problems on heat transfer under steady and unsteady state conditions in 1, 2 and 3 dimensional geometries and turbulent flow conditions. This course is going to cover all these aspects.

V. Aim of the course

To develop analytical and numerical approaches for heat transfer operation

VI. Theory

Unit I

Steady state one - dimensional problems, Bessel functions, composite structures, Principal of superposition, Heterogeneous solids, Power series solutions, Properties of Bessel functions, Extended surfaces, Approximate solutions for extended surfaces.

Unit II

Steady state two- and three- dimensional problems, Separation of Variables; Orthogonal functions; Boundary value problems; Characteristic value problems; Orthogonality of characteristics functions; Fourier series. Separation of variables; Steady two-dimensional Cartesian geometry, selection of coordinates, steady two-dimensional spherical geometry, Legendre polynomials, Steady three-dimensional geometry.

Unit III

Unsteady problems - Separation of Variables, Orthogonal functions, Distributed systems having stepwise disturbances, Use of one-dimensional chart, Time - dependent boundary conditions, Duhamel's superposition integral, Laplace transforms.

Unit IV

Heat transfer in turbulent flow: turbulent flow, boundary layer, Prandtl analogy, temperature distribution in turbulent flow, empirical and practical correlation for convection heat transfer, heat transfer in packed beds. Use of computational software for modelling heat and moisture transfer in various unit operations.

VII. Learning outcome

The students will learn problem solving skills on heat transfer under steady and unsteady state conditions encountered in unit operations such as frying, baking, cooling, freezing, evaporation, drying, etc.

VIII. Suggested Reading

- Arora SC, Domkundwar S and Domkundwar AV. 2007. *A Course in Heat and Mass Transfer*. Dhanpat Rai and Co. (P) Ltd. ISBN-13: 978-8177000290.
- Bergman TL, Lavine AS, Incropera FP and DeWitt DP. 2016. *Fundamentals of Heat and Mass Transfer*. 8th Edition, Wiley Publishers. ISBN-13: 978-1119337683.
- Cengel YA and Ghajar AJ. 2017. *Heat and Mass Transfer*. 5th Edition, Tata McGraw-Hill Education Pvt. Limited. ISBN-13: 978-9339223199.
- Geankopolis CJ, Hersel AA and Lepek DH. 2018. *Transport Processes and Separation Process Principles*. 5th Edition, Prentice-Hall Private Ltd. ISBN-13: 978-0134181028.
- Holman JP. 2017. *Heat Transfer*. 10th Edition, McGraw-Hill Higher Education Publishers. ISBN-13: 978-0071069670.
- Kreith F and Manglik RM. 2017. *Principles of Heat Transfer*. 8th Edition, Cengage Learning Publishers. ISBN-13: 9781305387102.
- Kumar DS. 2013. *Basics of Heat and Mass Transfer*. S K Kataria and Son Publishers. ISBN-13: 978-9350140604.

I. Course Title : Physicochemical Processes

II. Course Code : DE 613

III. Credit Hours : 3+0

IV. Why this course?

Physicochemical processes are like cog in the wheels of various unit operations. These help in deeper understanding of the various chemical unit operations and mass separation processes in the industry. This course will impart advance knowledge of mass transfer in various chemical engineering processes, which form the backbone of dairy and food engineering operations.

V. Aim of the course

- To develop understanding of advanced physical and chemical processes, their unit operations and design.

VI. Theory

Unit I

Types of separation processes; Adsorption process; Relationship between surface tension and adsorption, adsorption equilibrium and adsorption isotherm; Commercial adsorbents; Sorption kinetics in continuous flow reactors, factors influencing adsorption; Design of fixed adsorption columns and breakthrough adsorption curve.

Unit II

Membrane processing-computation of osmotic pressure of various solutions; Mathematical description of mass transport through reverse osmosis membrane; Water and solute diffusion, mechanisms of membrane transport, membrane transport models; Factors affecting membrane performance: membrane properties, concentration polarization; Types of flow: difference between gas and liquid permeation processes; Extraction: Liquid-solid extraction, single and multi-stage extraction, liquid-liquid extraction, supercritical fluid extraction, classification and properties of supercritical fluids, design and applications.

Unit III

Electrodialysis: Minimum energy requirements, selective ion transport, power requirement of electrodialysis, design of an electrodialysis systems; Ion-exchange process: exchange resins, kinetics of exchange and resin capacity, equilibrium relations in ion exchange, ion-selectivity: Design of fixed bed ion exchange columns.

Unit IV

Aeration and gas transfer, gas transfer processes, rates of gas transfer, power requirement of aerations systems, film transfer, theories of gas transfer, liquid-phase transport involving chemical reactions.

VII. Learning outcome

The students will learn mass transfer in various physical and chemical processes which will help them to better understand dairy and food processing unit operations.

VIII. Suggested Reading

- Das H. 2008. *Food Processing Operation and Analysis*. Asian Books. ISBN-13: 978-8186299784.
- Don Green and Southard MZ. 2018. *Perry's Chemical Engineers' Handbook*, 9th Edition, McGraw-Hill Education. ISBN-13: 978-0071834087.
- Geankoplis CJ, Hersel AA and Lepek DH. 2018. *Transport Processes and Separation Process Principles*, 5th Edition, Pearson. ISBN-13: 978-0134181028.
- Martinez JL. 2007. *Supercritical Fluid Extraction of Nutraceuticals and Bioactive Compounds*, 1st Edition.CRC Press. ISBN -13: 978-0849370892.
- McCabe W, Smith J and Harriot P. 2017. *Unit Operations of Chemical Engineering*, 7th Edition, McGraw Hill Education, ISBN-13: 978-9339213237.
- Rao MA, Rizvi SSH. and Datta AK. 2014. *Engineering Properties of Foods*, 4th Edition, CRC Press, ISBN-13: 978-1466556423.
- Ruthven D M. 1984. *Principles of Adsorption and Adsorption Processes*. John Wiley and Sons.
- Sinnot RK and Towler G. 2019. *Coulson and Richardson's Chemical Engineering: Chemical Engineering Design*. (Coulson and Richardson's Chemical Engineering). Elsevier. ISBN-13: 978-9351073932.

I. Course Title : Computational Methods and Simulation in Dairy and Food Engineering

II. Course Code : DE 621

III. Credit Hours : 2+1

IV. Why this course?

With the advent of powerful computers and software, there is a paradigm shift in the computation and simulation methods used to solve complex and advanced problems in the field of dairy and food engineering. This is a mathematical course for engineers and scientists designed to solve various engineering and natural problems. It deals with the approximate solution formations of various mathematical models. This course is aimed to impart knowledge on the recent developments in Computational and Simulation techniques, with practical applications in the field of Dairy and Food Engineering.

V. Aim of the course

To develop competence in developing statistical/theoretical models.

VI. Theory

Unit I

Taylor's series expansion in development of numerical differentiation; numerical differentiation procedures, forward difference, backward difference, central difference.

Unit II

Numerical integration trapezoidal rule, Simpson's rule, improper integrals, Gauss-Legrendre Quadretuse method, numerical methods to solve ordinary differential equations.

Unit III

Euler method, improved Euler method, Runge-Kutta method, Adam's P-C method, initial value problems, numerical solution of partial differential equation: explicit method, implicit method.

Unit IV

Simulation concept, simulation methods and their limitations, statistical and theoretical models.

Unit V

Problem formulation and development of models; solution and validation of models; data collection; processing and analysis; basic modeling problems on unit operations involved in dairy and food processing.

VII. Practical

- Solution to Taylor's series approximation
- Exercises on numerical differentiation – central difference, forward difference and backward difference
- Numerical integration by Simpson's rule, trapezoidal rule, Gauss-Legrendre approximation
- Exercises on Euler's method approximation
- Exercises on Runge-Kutta method
- Numerical solution to partial differential equations

- Problem solving on unit operations in dairy and food processing
- Application of computational software for solving numerical integration, differentiation and boundary layer problems
- Concepts of simulation and validation

VIII. Learning outcome

The skills and knowledge taught in this course are fundamentally useful to students who do simulations and research in computational engineering. The students will be trained on solving complex and advanced problems in the field of dairy and food engineering using computational and simulation approaches in software such as MATLAB, CFD, COMSOL Multiphysics, etc.

IX. Suggested Reading

- Balagurusamy E. 2017. *Numerical Methods*. McGraw Hill Education. ISBN-13: 978-0074633113.
- Bober W. 2013. *Introduction to Numerical and Analytical Methods with MATLAB for Engineers and Scientists*. CRC Press. ISBN-13: 978-1466576025.
- Franks and Roger GE. 1972. *Modeling and Simulation in Chemical Engineering*. Wiley-Interscience.
- Gerald CF and Wheatley PO. 2007. *Applied Numerical Analysis*. 7th Edition. Addison Wesley. ISBN-13: 978-8131717400.
- Hamming RW. 1987. *Numerical Methods for Scientists and Engineers*. Dover Publications Inc. ISBN-13: 978-0486652412.
- Jain MK, Iyengar SR, Kanchi MB and Jain. 1993. *Computational Methods for Partial Differential Equations*, New Age Publishers. ISBN-13: 9788122404296.
- Kandaswamy P, Thilagavathy K and Gunavathi K. 2006. *Numerical Methods*. S. Chand and Company. ISBN-13: 978-8121914383.
- Kiusalaas J. 2015. *Numerical Methods in Engineering with MATLAB*. 3rd Edition, Cambridge University Press.
- Kobayashi H. 1978. *Modeling and Analysis: An Introduction to System Performance Evaluation Methodology*. Addison-Wesley Publishing. ISBN-13: 978-0201144574.
- Fausett LV. 2009. *Applied Numerical Analysis Using MATLAB*. 2nd Edition. Pearson Education India. ISBN-13: 978-8131728536.
- Sastry SS. 2015. *Introductory Methods of Numerical Analysis- Theory and Applications*. 9th Edition, Cengage learning, New Delhi.

X. Software

1. MATLAB version 9.6
2. CONSOL multi-physics version 5.4
3. CFD software like ANSYS, Fluidyn

I. Course Title : Package Permeability and Shelf-Life Modelling

II. Course Code : DE 622

III. Credit Hours : 3+0

IV. Why this course?

Traditional dairy products have very short shelf life due to poor packaging. Their shelf life can be improved by designing appropriate tailor made packaging. This course will impart the required knowledge on deteriorative reactions, their kinetics that affect the shelf life of the food and the design/ selection of appropriate flexible packaging materials for dairy products. Also, integration of water activity, deteriorative reactions and package permeability will be covered to predict the shelf life of foods.

V. Aim of the course

To impart knowledge on design of specific packaging for indigenous dairy products and to determine their shelf life.

VI. Theory

Unit I

Thermodynamics of water activity; Composition based water activity prediction models; determination of sorption isotherms; Moisture sorption types and hysteresis: Theory and Everett's classification of hysteresis, models for prediction of sorption isotherms; Composition based moisture sorption isotherm models.

Unit II

Temperature and moisture control in foods; Moisture management systems; Importance of temperature control and temperature management; Adiabatic saturation of air and its applications.

Unit III

Protective packaging of foods: Cushioning and G-factor, Use of moisture vapours permeability rates in design for a definite shelf-life; Design problems; Rates of deteriorative reactions and factors influencing them, prediction and simulation of shelf-life of foods; Validation of predictive shelf-life models.

Unit IV

Iterative procedures for moisture sensitive products, oxygen sensitive products; error analysis, water vapour permeability and oxygen barrier properties of composite packaging materials and fabricated package systems.

Unit V

Nanocomposites from biopolymers: production, mechanical properties and applications; Influence of nanocomposites and clays on barrier properties of packaging materials.

VII. Learning outcome

The students will acquire knowledge on design of packaging for indigenous dairy products and understand the intricacies among deteriorative reaction kinetics and package permeability affecting the shelf life of food. Also the students will learn about testing, prediction and validation of shelf life of dairy products in various packaging environment.

VIII. Suggested Reading

- Advani S. 2007. *Processing and Properties of Nanocomposites*. World Scientific. ISBN-13: 978-9812703903.
- Barbosa-Canovas G, Fontana AJ, Schmidt SJ and Labuza TP. 2007. *Water Activity in Foods-Fundamentals and Applications*. Blackwell Publishing.ISBN-13: 978-0-813-82408-6.
- Brennan JG. 2011. *Food Processing Handbook*. 2nd Edition, Wiley-VCH Verlag GmbH and Co. KGaA, Wienheim. Germany.ISBN-13:9783527324682.
- Karel M and Lund DB. 2003. *Physical Principles of Food Preservation*. 2nd Edition, CRC Press. ISBN-13: 978-0824740634.
- Fennema OR. 1976. *Principles of Food Science*. Part I and II. Marcel Dekker Inc. ISBN-13: 9780824763503.
- Robertson GL. 2015. *Food Packaging- Principles and Practice*. CRC Press. ISBN-13: 9781439862421.

- Simatos D and Multon JL. 2011. *Properties of Water in Foods in Relation to Quality and Stability*. Dordrecht: Martinus Nijhoff. ISBN-13: 9789401087568.

Suggested Broad Topics of Research

- Application of high pressure processing in indigenous dairy products
- Pulsed electric field and pulsed light treatment of milk and indigenous dairy products
- Studies on irradiation of dairy products
- Application of thermo and manosonification during manufacture of dairy products
- Micro- and nanoencapsulation of active food ingredients
- Energy and exergy performance evaluation of evaporators and dryers.
- Performance evaluation of agitated tanks and solids blenders
- Performance evaluation of conveyor systems
- Design modifications and upgradation of process equipment for better performance
- Hygienic design solutions
- Design of evaporators and dryers
- Freezing of dairy products
- Simultaneous momentum, heat and mass transfer analysis of thermal processing of dairy products
- Application of computational methods for heat and mass transfer analysis and simulation of dairy process equipment
- Development of computer software for the performance analysis and design of heat exchange equipment.
- Biosensors, E-nose, machine vision and non-destructive analysis and evaluation of dairy products
- Application of MATLAB in design of biothermal processes and equipment
- Recovery of heat energy and reuse for improvement of efficiency in dairy plant
- Studies on use of heat pumps in dairy plant for energy conservation
- Water activity characterization of milk products
- Shelf life simulation and modelling of moisture and oxygen sensitive products
- Design of fermenters and aeration systems
- Design of improvised wastewater treatment techniques
- Model-based fault-detection for process engineering instrumentation
- Instrumentation for measurement of engineering properties of dairy and food materials
- Controlled atmosphere storage for enhancing the shelf-life of foods
- Non-thermal processing of dairy products
- Development of simulation models for various unit operations in dairy and food processing.
- Engineering and rheological properties of food materials and characterization of food powders
- Extrusion technologies and sub-baric frying of dairy products
- Supercritical extraction of bioactive compounds
- Small scale milk processing equipment and farm level cooling and chilling systems
- Novel, edible and biodegradable packaging for dairy products
- Enhancement of thermal performance of dairy equipment by nanocoatings

List of Journals

- *Journal of Food Engineering*
- *Drying Technology*

- *Journal of Food Process Engineering*
- *Journal of Food Processing and Preservation*
- *International Dairy Journal*
- *LWT – Food Science and Technology*
- *Trends in Food Science and Technology*
- *Agricultural Engineering International*
- *Journal of Food Science and Technology*
- *Indian Journal of Dairy Science*
- *Indian Journal of Agricultural Engineering*
- *Food Research International*
- *European Food Research and Technology*
- *International Journal of Food Science and Technology*
- *Applied Thermal Engineering*
- *Heat and Mass Transfer*
- *International Heat and Mass Transfer*
- *Journal of Food Measurement and Characterization*
- *Industrial Crops and Products*
- *Industrial and Engineering Chemistry Research*
- *Powder Technology*
- *Advanced Powder Technology*
- *Journal of Encapsulation*
- *Biosystems Engineering*
- *International Journal of Dairy Technology*
- *Journal of Dairy Science*
- *Computers and Electronics in Agriculture*

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 4

Dairy Science and Technology
– Dairy Chemistry

Course Title with Credit Load
M.Tech. in Dairy Chemistry

Course Code	Course Title	Credit Hours
DC 511	Physico-chemical Aspects of Milk Constituents	2+1
DC 512*	Milk Carbohydrates, Minerals and Water Soluble Vitamins	2+1
DC 513*	Chemistry of Milk Lipids	2+1
DC 514	Chemistry of Food Constituents	2+1
DC 521*	Chemistry of Milk Proteins	3+1
DC 522*	Chemistry of Processed Dairy Foods	3+1
DC 523	Chemical Quality Assurance and Management Tools	2+1
DC 524	Research Techniques	1+2
DC 591	Master's Seminar	1+0
DC 599	Master's Research	0+30

Course Contents
M.Tech. in Dairy Chemistry

I. Course Title : Physico-Chemical Aspects of Milk Constituents

II. Course Code : DC 511

III. Credit Hours : 2+1

IV. Why this course?

This course will help the students while working in dairy industry/research institutes for better understanding of behaviour of milk constituents with respect to their chemical reactions and physical state. This course is going to cover all these aspects.

V. Aim of the course

To impart knowledge on the physico-chemical aspects of milk and milk products with special reference to their processing and quality assurance.

The course is organized as follows:

No.	Blocks	Units
1.	Reaction Kinetics	I Chemical and Enzymatic reactions
		II Electrochemistry
2.	Surface and colloidal Chemistry	III Surface Chemistry
		III Foams and Emulsions
		V Micelles and Gelation

VI. Theory

Block 1: Reaction Kinetics

Unit I: Chemical and Enzymatic reactions

Basics of chemical reaction kinetics, Order and molecularity of a reaction. Kinetics of denaturation of whey proteins and Maillard browning. Kinetics of enzymatic reactions; the role of enzymes as biological catalysts; factors affecting the rate of enzyme reaction: concentration of substrate, concentration of enzyme, concentration of reaction products, pH, temperature, time, activators and inhibitors. Thermal inactivation of enzymes present in milk. Concept of activation energy

Unit II: Electrochemistry

Electrolytic dissociation: activity, ionic strength and dissociation constants of acids and bases; effect of ionic strength on dissociation constants. Buffer, buffer capacity and buffer index of milk and milk products. Redox reactions and photo-oxidation of milk.

Block 2: Surface and colloidal Chemistry

Unit III: Surface Chemistry

Adsorption at solid – vapour interphase; Monolayer and multilayer adsorption; capillary condensation; adsorption isotherms; Hysteresis. Sorption of water on milk constituents and milk products and its relation to stability of dairy products.

Unit IV: Foams and Emulsions

Colloidal and surface phenomena in milk; adsorption at solid-liquid and liquid-liquid interphases; Gibb's equations. Interfacial tension, surface tension, surface active agents, general aspects of foaming, churning and whipping of cream; emulsion and emulsion stability; coalescence and dispersion; an introduction to the concept of Nano emulsion and Nano micelles.

Unit V: Micelles and Gelation

Micelles: definition, critical micelle concentration, formation and stability; Colloidal stability of casein micelles in milk, zeta potential, size distribution of casein micelles and fat globules. Gels and their formation, structure and stability; acid and rennet gels.

VII. Practical

- Determination of the order of hydrolysis of an ester and measurement of activation energy.
- Measurement of the order of hydrolysis of a carbohydrate and measurement of activation energy.
- Assessment of the progress curve obtained during the hydrolysis of p-nitrophenyl phosphate by milk alkaline phosphatase.
- Analysis of effect of substrate concentration on hydrolysis of p-nitrophenyl phosphate by milk alkaline phosphatase.
- Study of effect of enzyme concentration on hydrolysis of p-nitrophenyl phosphate by milk alkaline phosphatase.
- Michaelis constant determination for the digestion of casein by trypsin.
- Measurement of pH and buffering capacity of different types of milk.
- Preparation of a buffer of a given molarity/ionic strength and pH and determination of pH of the buffer.
- Stability analysis of an oil-in-water emulsion stabilised by milk proteins
- Foaming capacity and foam stability of caseins/whey proteins.
- Study of the gel formation and gel stability of milk proteins.
- Drawing of an adsorption isotherm of water on casein.
- Measurement of thermal inactivation of enzymes (Alkaline phosphatase, Lactoperoxidase).

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/Writing)
- Student's Book/Publication Review
- Student presentation
- Group Work
- Guest Lectures

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Apply basics of reaction kinetics in understanding different phenomenon in milk during processing and storage.
- Role of different constituents of milk in formation and stability of emulsions, foams and gel

X. Suggested Reading

- Ancheyta J. 2017. *Chemical Reaction Kinetics: Concepts, Methods and Case Studies*. John Wiley and Sons.
- Dickinson E. 1995. *Food Macromolecules and Colloids*, RSC Special Publication.
- Dickinson E. 2005. *Food Colloids: Interactions, Microstructure and Processing*, RSC advancing chemical series.
- Fox PF, Uniacke-Lowe T, McSweeney PLH and O'Mahony JA. 2015. *Dairy Chemistry and Biochemistry*. Springer International Publishing-Switzerland.
- McClements DJ. 2016. *Food Emulsions: Principles, Practices and Techniques*, 3rd Edn, CRC press Taylor and Fracis group.
- Puri BR, Sharma LR, Pathania MS. 2016. *Principles of Physical Chemistry,* 47th Edition Vishal Publishing Co.
- Rockland LB and Beuchat LR. 1987. *Water Activity: Theory and Applications to Food*, Marcel Dekker Inc, NY.
- Walstra P and Jenness R. 1984. *Dairy Chemistry and Physics*. John Wiley and Sons.

I. Course Title : Milk Carbohydrates, Minerals and Water Soluble Vitamins

II. Course Code : DC-512

III. Credit Hours : 2+1

IV. Why this course?

This coursewill givean overview of carbohydrates, minerals and vitamins present in milk. This knowledge will help the students to understand the various physicochemical reactions occur during processing and storage of dairy foods.

V. Aim of the course

To impart basic knowledge on aspects of milk carbohydrates, minerals and water soluble vitamins and to project the importance of these milk constituents on the quality of milk and milk products as well as in human health.

The course is organized as follows:

No.	Blocks	Units
1.	Lactose	I. Chemistry of lactose
		II. Physical properties of lactose
		III. Chemical properties of lactose
2.	Mineral	IV. Minerals in milk
		V. Physical equilibrium amongst milk salts
		VI. Effect of Processing on Minerals
3.	Vitamins	VII. Water soluble vitamins:

VI. Theory

Block 1: Lactose

Unit I: Chemistry of lactose

Lactose: occurrence, isomers, molecular structure, levels in milk of different species.

Unit II: Physical properties of lactose

Physical properties of lactose: crystalline habits, hydrates, lactose glass, specific rotation, equilibrium of different isomers in solution, solubility, density, sweetness.

Unit III: Chemical properties of lactose

Chemical properties of lactose: hydrolysis; Pyrolysis; Oxidation; Reduction; Degradation with strong bases; Derivatives; Dehydration and Fragmentation; Browning reaction; Oligosaccharides in milk-health significance.

Block 2: Mineral

Unit IV: Mineral in Milk

Minerals: major and minor minerals; Factors affecting variation in salt composition of milk; Distribution and importance of trace elements in milk.

Unit V: Physical equilibrium amongst milk salts

Physical equilibrium amongst milk salts; Effect of various treatments on salt equilibrium; Partitioning of salts and factors affecting them.

Unit VI: Effect of Processing on Minerals

Salt balance and its importance in the processing of milk; Protein-mineral interactions.

Block 3: Vitamins

Unit VII: Water soluble vitamins

Water soluble vitamins: molecular structure, levels in milk and milk products; factors affecting their levels; Biological significance; Ascorbic acid structure; Relation with redox potential (Eh) of milk and milk products.

VII. Practical

- Estimation of lactose in milk by volumetric method
- Estimation of lactose in milk by gravimetric method
- Estimation of lactose in milk by polarimetric method
- Estimation of lactose in milk by colorimetric methods
- Determination of sodium and potassium by (flame photometry)
- Determination of calcium and magnesium by EDTA method
- Determination of phosphorus by colorimetric method (Fiske and Subba Rao)
- Estimation of citric acid by colorimetric methods
- Determination of iron by colorimetric methods
- Estimation of vitamin C in milk by volumetric method
- Determination of HMF content in heated milk

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/Writing)
- Student's Book/Publication Review
- Student presentation
- Group Work
- Guest Lectures

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Appreciate the significance of milk as a source of carbohydrates, minerals and water soluble vitamins.
- Understand the importance of these constituents in chemical, physical, technological, nutritional and physiological properties of milk.

X. Suggested Reading

- Fox PF, Uniacke-Lowe T, McSweeney PLH and O'Mahony JA. 2015. *Dairy Chemistry and Biochemistry*. Springer International Publishing-Switzerland.
- Jennes RG. 1995. *Handbook of Milk Composition*. Academic Press.
- McSweeney PLH and Fox PF. 2009. *Advanced Dairy Chemistry Volume 3: Lactose, Water, Salts and Minor Constituents*. Springer-Verlag New York.
- Paques M and Lindner C. (Eds.). 2019. Lactose: Evolutionary Role, Health Effects, and Applications. Academic press.
- Walstra P and Jenness R. 1984. *Dairy Chemistry and Physics*. John and Wiley.
- Watson RR, Collier RJ and Preedy VR. (Eds.). 2017. Nutrients in dairy and their implications for health and disease. Academic Press.
- Young W. Park and George F.W. Haenlein. 2013. *Milk and Dairy Products in Human Nutrition*. John Wiley and Sons, UK.
- Zadow JG. 1992. *Whey and Lactose Processing*. Elsevier Science Publishers Ltd- Springer Netherlands.

I. Course Title : Chemistry of Milk Lipids

II. Course Code : DC 513

III. Credit Hours : 2+1

IV. Why this course?

The course will provide in-depth coverage of milk lipids. It makes the students capable to understand various chemical reactions occur during processing and storage of milk and milk products. This course is going to cover all these aspects.

V. Aim of the course

To impart the basic knowledge on different aspects of milk lipids and to project the importance of milk lipids in the quality of dairy products as well as in human health.

The course is organized as follows:

No.	Blocks	Units
1.	Milk Lipids	I. Classification of milk lipids II. Properties of milk lipids III. Unsaponifiable matter
2.	Chemical properties of milk lipids	IV. Chemical Reaction of milk fat V. Oxidation of milk fat

VI. Theory

Block 1: Milk Lipids

Unit I: Classification of milk lipids

Milk lipids: General classification, neutral and polar lipids (phospholipids) in milk, gross composition of milk lipids in different species, physico-chemical properties of milk lipids; role of major milk lipids in milk and milk products and biological significance of milk lipids; Composition of milk fat globule membrane.

Unit II: Properties of milk lipids

Fatty acid profile of milk lipids; factors affecting the profile of fatty acids; Different properties of fatty acids

Unit III: Unsaponifiable matter

Unsaponifiable matter and its importance; Composition of unsaponifiable matter; Chemistry, levels and physiological functions of sterols; Fat soluble vitamins and carotenoids in milk.

Block 2: Chemical properties of milk lipids

Unit IV: Chemical Reaction of milk fat

Chemical properties of milk lipids: hydrolysis by alkali, water and enzymes; hydrogenation, halogenation, transesterification, inter-esterification and fractionation.

Unit V: Oxidation of milk fat

Autoxidation: Definition, theories, induction period, secondary products of autoxidation, factors affecting, prevention and measurement; various methods for evaluating primary and secondary oxidation products; Antioxidants: Definition, types, reaction mechanism and estimation. Thermal oxidation of fat

VII. Practical

- Determination of melting point/slip point and B.R reading of milk fat.
- Determination of conjugated dienes, peroxide value and anisidine value of milk fat.
- Analysis of milk fat for its thiobarbituricacid-(TBA) value.
- Estimation of carbonyl value of milk fat
- Determination of unsaponifiable matter in milk fat.
- Total cholesterol estimation in milk fat.
- Determination of vitamin A and D in milk fat
- Estimation of total phospholipids and free fatty acids in milk fat.
- Preparation of fatty acid methyl esters and their analysis by GLC.
- Quantitative determination of butylatedhydroxylanisole (BHA) in milk fat.

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/Writing)
- Student’s Book/Publication Review
- Student presentation
- Group Work
- Guest Lectures

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Understand the basic aspects of milk lipids in terms of quality of dairy products and human health
- Understand the different reactions taking place during processing and storage of milk fat

X. Suggested Reading

- Akoh CC and Min DB. 1997. *Food Lipids: Chemistry, Nutrition and Biotechnology*. Marcel Dekker.
- Fox PF and McSweeney PLH. 2006. *Advanced Dairy Chemistry Volume 2: Lipids*. Springer-US.
- Fox PF, Uniacke-Lowe T, McSweeney PLH and O’Mahony JA. 2015. *Dairy Chemistry and*

Biochemistry. Springer International Publishing-Switzerland.
- Mathur MP, Datta Roy D and Dinakar P. 1999. *Text Book of Dairy Chemistry*. ICAR.
- Truong T, Lopez C, Bhandari B and Prakash S. 2020. *Dairy Fat Products and Functionality*.
- Walstra P and Jenness R. 1984. *Dairy Chemistry and Physics*. John Wiley and Sons.
- Wong NP, Jenness R, Keeney M and Elmer HM. 1988 *Fundamentals of Dairy Chemistry*. Van Nostrand Reinhold Co.

I. Course Title : Chemistry of Food Constituents

II. Course Code : DC 514

III. Credit Hours : 2+1

IV. Why this course?

This course will help the students to get more insight into chemistry of food constituents such as water, carbohydrates, protein, lipids, phytochemicals and food additives. This course will also enrichthe knowledge of students for working in food industry/research institutes for better understanding of processed food products development.

V. Aim of the course

To impart knowledge on different chemical aspects of food components

The course is organized as follows:

No.	Blocks	Units
1.	Major Constituents of Foods	I. Water II. Carbohydrates III. Proteins IV. Food Lipids
2.	Minor constituent of foods	V. Phyotchemicals VI. Food Additives

VI. Theory

Block 1: Major Constituents of Foods

Unit I: Water

Water: Forms of water in foods; water- solute interactions, and food stability in relation to water activity; solute mobility; property of ice crystals; role of ice in the stability of food at sub-freezing temperatures.

Unit II: Carbohydrates

Carbohydrates: Starch; Types, swelling behaviour, gelatinization and their role in bread making; modification of starches for industrial applications, physico-chemical changes taking place during malting. Oligosaccharides: Structural units of commercially available oligosaccharide, their properties and preparation methods, Hydrocolloids, their properties and utilization in different food preparations; mutual interactions among hydrocolloids and interactions with proteins.

Unit III: Proteins

Proteins: Classification, distribution and physico-chemical properties of food proteins from various sources; structure-function relationship and their modifications; denaturation of food proteins. Application of enzymes in food Industry; Immobilized enzymes, Browning reactions in foods: enzymatic browning and non-enzymatic browning (caramelization and maillard reaction).

Unit IV: Food Lipids

Food Lipids: Physico-chemical properties of food lipids and their modifications; Composition of various types of edible oils/fats with special reference to their quality; auto-oxidation of food lipids.

Block 2: Minor constituent of foods

Unit V: Phyotchemicals

Phytochemicals: Chemistry of polyphenols, phenolic acid, flavonoids, phytosterols, phytostanol.

Unit VI: Food Additives

Food Additives: Sweeteners, anticaking agents, antioxidants, humectants, preservatives, neutralizers, stabilizers, emulsifiers, texture modifiers, flavours and colours etc.

VII. Practical

- Estimation of fat content in cereal products by Soxhlet method.
- Determination of total nitrogen in cereal products.
- Determination of gluten content in wheat flour.
- Analysis of starch in flour by polarimetric method.
- Estimation of crude fibre in food product.
- Determination of polyphenol content in tea and coffee.
- Determination of antioxidant activity in various foods using DPPH/FRAP methods
- Detection of adulteration of mustard oil with argemone oil.
- Detection of artificial colours in various spices.
- Determination of level of artificial sweeteners (saccharin and aspartame)
- Visit to a food plant.

VIII. Teaching Methods/ Activities

– Lecture
– Assignment (Reading/Writing)
– Student's Book/Publication Review
– Student presentation
– Group Work
– Guest Lectures

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Forms of water in food and its role in stability of food during storage at low temperature
– Types of carbohydrates, proteins, lipids in various types of foods, changes in such constituents during processing, interaction of carbohydrates and proteins, application of enzymes in food industry including immobilization of enzymes
– Types of phytochemicals in foods and role of additives to impart various functions in foods.

X. Suggested Reading

- Belitz HD, Grosch W and Schieberle P. 2004. *Food Chemistry*. 3rd Ed. Springer.

- Connie M. Weave. 2017. *The Food Chemistry Laboratory: A Manual for Experimental Foods*, Dietetics, and Food Scientists, Second Edition CRC Press.
- Damodaran S, Parkin KL and Feenema OR. 2008. *Fennema's Food Chemistry*. 4th Ed. CRC Press.
- Dwidvedi A. 2016. *Enzyme Immobilization: Advances in Industry, Agriculture, Medicine, and the Environment*. 1st edition. Springer.
- Fennema OR. 1985. *Food Chemistry*. Marcer Dekker.
- Peter CK and Bhavbhuti M. 2015. *Handbook of Food Chemistry*. Springer-Verlag Berlin Heidelberg.
- Srinivas D and Alan Praf. 1997. *Food Proteins and their Applications*. Marcel Dekker.
- Velisek J, Koplik R and Cejpek K. 2020. *The Chemistry of Food*. John Wiley and Sons.

I. Course Title : Chemistry of Milk Proteins

II. Course Code : DC 521

III. Credit Hours : 3+1

IV. Why this course?

This course will help the students of dairying to get more insight into chemistry of milk proteins and in understanding the various physicochemical reactions occur during milk processing. This course is going to cover all these aspects.

V. Aim of the course

To impart knowledge on different aspects of milk proteins
The course is organized as follows:

No.	Blocks	Units
1.	Milk proteins	I. Basic concept of milk proteins
		II. Major milk proteins
		III. Whey proteins
		IV. Minor milk proteins
2.	Properties of milk proteins	V. Denaturation of proteins
		VI. Enzymes

VI. Theory

Block 1: Milk proteins

Unit I: Basic concept of milk proteins

Milk proteins of different species and their variability. Distribution and fractionation of different nitrogen fractions of milk proteins; nomenclature of milk proteins; genetic polymorphism and biological significance of milk proteins.

Unit II: Major milk proteins

Major milk proteins: caseins (acid and micellar), methods of isolation; Fractionation of casein and heterogeneity; Physico-chemical properties; amino acid composition; Casein micelle models; Primary structure of different caseins; Modification of casein: Physical, chemical (glycosylation, phosphorylation) and enzymatic.

Unit III: Whey proteins

Alpha-lactalbumin and beta-lactoglobulin, bovine serum albumin: distribution and methods of isolation and their physico-chemical properties.

Unit IV: Minor milk proteins

Minor milk proteins: Proteose-peptone, immunoglobulins, lactoferrin, and fat globule membrane proteins.

Block 2: Properties of milk proteins

Unit V: Denaturation of proteins

Denaturation of milk proteins, various factors affecting denaturation; Casein-whey protein interactions.

Unit VI: Enzymes

Indigenous milk enzymes: Properties and their significance with particular reference to lipases, proteases, phosphatases, catalase, peroxidase, xanthine oxidase, lysozyme, lactoperoxidase and galactosyltransferase

VII. Practical

- Estimation of different nitrogen fractions of milk by Kjeldahl method.
- Preparation of acid and rennet casein; urea fractionation of acid casein; isolation of alpha-lactalbumin and beta-lactoglobulin by ammonium sulphate precipitation.
- Milk protein estimation by Folin method.
- Polyacrylamide gel electrophoresis of milk proteins.
- Assay of indigenous milk enzyme activity like protease, lipase, alkaline phosphatase and lactoperoxidase.
- Estimation of hexoses and sialic acid in casein.
- Measurement of degree of hydrolysis of milk proteins.
- Measurement of denaturation of whey proteins.

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/Writing)
- Student's Book/Publication Review
- Student presentation
- Group Work
- Guest Lectures

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Understand the basic aspects of milk proteins in terms of major and minor milk proteins
- Understand the effect of different processing of milk on interaction of milk proteins

X. Suggested Reading

- Boland M and Singh H. (Eds.). 2019. Milk proteins: from expression to food. Academic Press.
- Fox PF, Uniacke-Lowe T, McSweeney PLH and O'Mahony JA. 2015. *Dairy Chemistry and Biochemistry*. Springer International Publishing-Switzerland.
- Mathur M, Datta Roy D and Dinakar P. 1999. *Text Book of Dairy Chemistry*. ICAR.
- McSweeney PLH, O'Mahony and James A. 2013. *Advanced Dairy Chemistry Volume 1A: Proteins: Applied Aspects*. Springer-Verlag, New York.
- McSweeney PLH, O'Mahony and James A. 2016. *Advanced Dairy Chemistry Volume 1B: Proteins: Applied Aspects*. Springer-Verlag, New York.
- Robert G Jensen 1991. *Handbook of Milk Composition*. Academic Press.

- Wong NP, Jenness R, Keeney M and Elmer HM. 1988 *Fundamental of Dairy Chemistry*. 3rd Ed. Van Nostrand Reinhold Co.

I. Course Title : Chemistry of Processed Dairy Foods

II. Course Code : DC 522

III. Credit Hours : 3+1

IV. Why this course?

To gain insights in the underlying chemical changes during processing of milk for preparation of concentrated, dried, fermented and fat rich dairy products and frozen desserts. This course is going to cover all these aspects.

V. Aim of the course

To understand the physico-chemical changes and effects of various milk constituents of milk products during manufacture and storage of processed dairy foods.

The course is organized as follows:

No.	Blocks	Units
1.	Concentrated and Dried milks and dried milks	I. Process induced changes in concentrated II. Human milk and infant food III. Heat induced changes in milk
2.	Chemistry of Dairy Products	IV. Cheese and other fermented dairy products V. Cream, butter and ghee VI. Ice cream and frozen desserts

VI. Theory

Block 1: Concentrated and Dried milks

Unit I: Process induced changes in concentrated and dried milks

Process induced changes in milk constituents during preparation and storage of concentrated and dried milks.

Unit II: Human milk and infant food

Role of biologically active components in human milk; Standards, composition and properties of infant milk and infant food formulations

Unit III: Heat induced changes in milk

Heat induced changes in milk leading to coagulation; Heat stability of concentrated milk as affected by different process variables, Milk constituents and additives; Age gelation: Mechanism and control.

Block 2: Chemistry of Dairy Products

Unit IV: Cheese and other fermented dairy products

Biochemical changes during ripening of different varieties of cheese; Lactic acid fermentation in cheese and other fermented dairy products; chemical defects in cheese.

Unit V: Cream, butter and ghee

Storage stability of cream, butter and ghee. Physico-chemical properties of ghee; Ghee flavour, texture (grains) and colour in ghee.

Unit VI: Ice cream and frozen desserts

Role of different ingredients during processing and storage of ice cream/ frozen desserts; Concept of antifreeze protein/ice structuring protein in ice cream

VII. Practical

- Determination of lactose and sucrose in condensed milk and ice-cream.
- Determination of weight per litre of ice-cream.
- Determination of heat stability of milk and concentrated milks.
- Determination of WPNI of skim milk powder.
- Determination of fat in cream and butter by Mojonnier method.
- Determination of salt in butter.
- Determination of diacetyl and acetyl methyl carbinol in butter/ cultured products.
- Determination of RM, Polenske value, iodine value, saponification value of ghee.
- Determination of soluble proteins, salt and free fatty acids in cheese.
- Determination of rennet clotting time of milk.

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/Writing)
- Student's Book/Publication Review
- Student presentation
- Group Work
- Guest Lectures

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Understand the basic aspects of dairy chemistry in terms of processing of different dairy products
- Understand the different reactions taking place during storage of dairy products

X. Suggested Reading

- Fox PF, Uniacke-Lowe T, McSweeney PLH and O'Mahony JA. 2015. *Dairy Chemistry and Biochemistry*. Springer International Publishing-Switzerland.
- Koca N. (Ed.). 2018. *Technological Approaches for Novel Applications in Dairy Processing*. BoD–Books on Demand.
- Mathur MP, Roy DD and Dinakar P. 1999. *Textbook of Dairy Chemistry*. ICAR.
- Official methods of AOAC. 11th and 15th Eds.
- Walstra P and Jenness R. 1984. *Dairy Chemistry and Physics*. John Wiley and Sons.
- Wong NP, Jeness R, Keeney M and Elmer HM. 1988. *Fundamentals of Dairy Chemistry*. Van Nostrand Reinhold Co.

I. Course Title : Chemical Quality Assurance and Management Tools

II. Course Code : DC 523

III. Credit Hours : 2+1

IV. Why this Course?

The course will provide in depth knowledge in preparing the reagents, testing methodologies and quality tools to understand the concept of 'Quality Assurance' in dairy industries. This course is going to cover all these aspects.

V. Aim of the course

To project the importance of chemical quality assurance and safety in relation to dairy industry and impart basic knowledge on all aspects of chemical quality and safety assurance

The course is organized as follows:

No.	Blocks	Units
1.	Quality Management Tools and Quality Assurance Organizations	I. Quality Tools and Management System II. International and National organisations
2.	Analytical Methods	III. Assessment of Quality of milk and milk products IV. Contaminants and Food Traceability

VI. Theory

Block1: Quality Management Tools and Quality Assurance Organizations

Unit I: Quality Tools and Management System

Concept of quality assurance and quality control in relation to dairy industry; Quality management systems - good manufacturing practices (GMP); HACCP certification; ISO 9001, ISO 22000, FSSC, total quality management (TQM); Lean and Six sigma, Five –S, Kaizen, Kanban and other quality tools; Good laboratory practices (GLP), laboratory accreditation

Unit II: International and National Organisations

Role of international organisations such as ISO, IDF, CAC, AOAC, WTO and national organisations like BIS, FSSAI, AgMark and APEDA in dairy industry, Quality Council of India (QCI), Export Inspection Council (EIC); Guidelines for setting up quality control laboratory and chemical safety aspects; sampling of milk and milk product; Food labeling guidelines.

Block 2: Analytical Methods

Unit III: Assessment of Quality of milk and milk products

Detergents, sanitizers and disinfectants; Calibration of milk testing glassware; Preparation of standard reagents; Detection of adulterants in milk and milk products; Quality of packaging material for dairy products; Instrumentation in analysis of milk and milk products.

Unit IV: Contaminants and Food Traceability

Agro-chemicals/veterinary drug residues; occurrence of pesticide residues, antibiotic residues, heavy metals etc. in dairy products and their testing methods, Laboratory auditing, Food traceability systems, Food recall and withdrawal

VII. Practical

- Preparation of standard solutions
- Testing of available chlorine content in hypochlorites/ bleaching powder
- Determination of purity of common salt to be used for butter and cheese making
- Detection of common adulterants in milk and foreign fat/ oil in ghee
- Checking the accuracy of calibration of hydrometers/ lactometers, butyrometers, milk pipette and thermometer
- Qualitative colour tests to distinguish between azo dyes and natural dyes in butter

- Maintenance of records as per NABL and ISO criteria.
- Visit to a food analytical laboratory.

VIII. Teaching Methods/ Activities
- Lecture
- Assignment (Reading/Writing)
- Student's Book/Publication Review
- Student presentation
- Group Work
- Guest Lectures

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:
- Understand the requirements and policy relating to implementation of various quality management tools.
- Apply the food safety standards to specific situations

X. Suggested Reading

- Hoorfar J. 2012. *Case Studies in Food Safety and Authenticity*. 1st Ed. Woodhead Publishing
- IDF. 1993. *Quality Assurance (QA) and Good Lab. Practices (GLP) in Dairy Laboratories.* Special Issue No. 9302.
- IDF. 1997. *Monograph on Residues and Contaminants in Milk and Milk Products.* Special Issue No. 9701.
- Konieczka P and Namiesnik J. 2018. *Quality Assurance and Quality Control in The Analytical Chemical Laboratory: A Practical Approach*. CRC Press.
- Ralph Early. 1995. *Guide to Quality Management System for Food Industry*. Blackie.
- Schrenk D and Cartus A. 2017. *Chemical Contaminants and Residues in Food.* 2nd Ed. Woodhead Publishing.
- Young W. Park and George FW. Haenlein 2013. *Milk and Dairy Products in Human Nutrition*. John Wiley and Sons, UK.

I. Course Title : Research Techniques

II. Course Code : DC 524

III. Credit Hours : 1+2

IV. Why The Course?

This course concentrates on instrumental methods of analysis. The course will beof importance to all the students, who rely on the use of instrumental analysis in their field of research while conducting research as part of their postgraduate studies.

V. Aim of the course

To impart the advanced knowledge on the use of analytical techniques in Dairy Chemistry

The course is organized as follows:

No.	Blocks	Units
1.	Separation and Purification of Biomolecules	I. Electrophoresis II. Chromatography III. Membrane processing and centrifugation
2.	Laboratory Analytical Techniques	IV. Instrumental Techniques V. ELISA and lateral flow assay

VI. Theory

Block1: Separation and Purification of Biomolecules

Unit I: Electrophoresis

Electrophoresis: principles and types, isoelectric focussing

Unit II: Chromatography

Chromatographic techniques: Principles and types (Paper and Column Chromatography, TLC, GLC, HPLC, gel-permeation, ion-exchange, affinity).

Unit III: Membrane processing and centrifugation

Separation of bio-molecules using membranes; Centrifugation: principle, types and applications.

Block 2: Laboratory Analytical Techniques

Unit IV: Instrumental Techniques

Spectrophotometry: UV, visible, IR and flame photometry; Potentiometry: principles, ion-selective electrodes; buffers. Measurement of size and zeta potential of colloidal solution or emulsion using dynamic light scattering/ particle size analyser

Unit V: ELISA and lateral flow assay

Immuno based analytical techniques such as ELISA and Lateral flow assay.

VII. Practical

- Paper chromatography, TLC separation of amino acids.
- Gel-filtration of biomolecules.
- Preparation of a buffer and measurement of its pH electro-metrically and using indicators.
- SDS gel electrophoresis and molecular weight determination.
- Plotting of UV-visible absorption spectra of a standard analyte.
- Demonstration of Beer's law using standard protein.
- Estimation of minerals using AAS.
- Separation of milk proteins using ion-exchange chromatography and affinity chromatography.
- Detection of analytes using ELISA and lateral flow assay.
- Separation of biomolecules using HPLC.
- Preparation of methyl esters of fatty acids of milk fat and analysis by GLC.
- Separation of fat/casein using centrifugation.

VIII. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Provides a sound foundation to the theory and application of modern analytical techniques.

– Impart the concept of good laboratory practice and protocol, and hands-on experience of modern analytical instrumentation.

IX. Suggested Reading

- Christian GD, Dasgupta PS and Schug K. 2014. *Analytical Chemistry*, 7th Edition Wiley Global Education.
- Clark JM and Switzer RL. 1977. *Experimental Biochemistry*. WH Freeman and Co.
- Cooper TG. 1977. *The Tools of Biochemistry*. John Wiley and Sons.

- Frank A Settle. 1997. *Handbook of Instrumental Techniques for Analytical Chemistry*. Prentice Hall.
- Leo ML and Toldra NF. *Handbook of Dairy Foods Analysis*. 1st Ed. CRC Press.
- Nielsen S Suzanne 1994. *Introduction to the Chemical Analysis of Foods*.Jones and Barlett Publ.
- Sawhaney SK and Singh R. 1985. *An Introduction to Practical Biochemistry*. Narosa Publ.
- Stock R and Rice F. 1974. *Chromatographic Methods*. Chapman and Hall.
- Su W. 2018. *Trends in Food Authentication*: Wen-Hao Su; Ioannis S. Arvanitoyanni; Da-Wen, Sun. In Modern Techniques for Food Authentication (Second Edition).
- Wilson K and Walker J. 2000. *Practical Biochemistry: Principles and Techniques*. Cambridge Univ. Press.

Course Title with Credit Load
Ph.D. in Dairy Chemistry

Major Courses

Course Code	Course Title	Credit Hours
DC 611	Advances in Chemistry of Milk Proteins	3+0
DC 612	Advances in Chemistry of Milk Lipids	3+0
DC 621	Advances in Chemistry of Dairy Processing	3+0
DC 622	Advances in Analytical Techniques in Dairy Chemistry	3+0
DC 691	Doctoral Seminar-I	1+0
DC 692	Doctoral Seminar-II	1+0
DC 699	Doctoral Research	0+75

Minor Courses

The courses will be selected from the major courses of the allied disciplines of Dairy Technology, Dairy Microbiology, Dairy Engineering and Animal Biochemistry to meet the minimum credit requirements.

Supporting Courses

The supporting courses will be picked from the basket of courses offered in agricultural statistics, computer applications and IT, and other related relevant disciplines to meet the minimum credit requirements.

Common Courses

1. Library and Information Services	1
2. Technical Writing and Communications Skills	1
3. Intellectual Property and its Management in Agriculture	1
4. Basic Concepts in Laboratory Techniques	1
5. Agricultural Research, Research Ethics and Rural Development Programmes	1

Course Contents
Ph.D. in Dairy Chemistry

I. Course Title : Advances in Chemistryof Milk Proteins
II. Course Code : DC-611
III. Credit Hours : 3+0

IV. Why this course?

To gain insights in the underlying structure-function aspects of milk proteins, biological role of bioactive milk proteins, properties of bioactive peptides and allergy aspects of milk proteins.

V. Aim of the course

To understand the advances in area of functionality of milk proteins
The course is organized as follows:

No.	Blocks	Units
1.	Biosynthesis and Structure Function relationship of milk Proteins	I. Biosynthesis of milk proteins II. Structure of milk protein with respect to function III. Modification of milk proteins with respect to function
2.	Biological role of milk proteins	IV. Antimicrobial protein in milk V. Significance of bioactive peptides VI. Nutritive and therapeutic aspects of milk proteins

VI. Theory

Block 1: Biosynthesis and structure Function relationship of milk Proteins

Unit I: Biosynthesis of milk proteins

Biosynthesis of milk proteins, milk fat globule membrane (MFGM) proteins.

Unit II: Structure of milk protein with respect to function

Primary structure of casein, structural properties of casein and whey proteins and their structure-functional relationship

Unit III: Modification of milk proteins with respect to function

Physical, chemical and enzymatic modification of milk proteins and their functional characteristics

Block 2: Biological roles of milk proteins

Unit IV: Antimicrobial protein in milk

Mechanism of action and biological role of specific and non-specific antimicrobial factors in milk- immunoglobulins, lactoferrin, lactoperoxidase and lysozyme

Unit V: Significance of bioactive peptides

Milk protein derived bioactive peptides – their properties; significance and application; bitter peptides in cheese; growth factors in milk.

Unit VI: Nutritive and therapeutic aspects of milk proteins

Nutritive and therapeutic aspects of milk proteins and peptides;
Milk protein allergy: mechanism and method of their reduction in dairy products

Teaching Methods/ Activities

- Lecture
- Assignment (Reading/Writing)
- Student's Book/Publication Review
- Student presentation
- Group Work
- Guest Lectures

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Understand the basic mechanism on functionality of major milk proteins and bioactive milk proteins
- Understand the aspects on biosynthesis of milk proteins, bioactive peptides and nutritive properties of milk proteins

VIII. Suggested Reading

- Damodaran S and Paraf A. 1997. *Food Proteins and their Applications*. Marcel Dekker.
- Gigli I. (Ed.). 2016. *Milk Proteins: From Structure to Biological Properties and Health Aspects*. BoD–Books on Demand.
- Hettiarachchy NS, Sato K, Maurice R, Marshall MR and Kannan A. 2016. *Bioactive Food Proteins and Peptides: Applications in Human Health*. CRC Press.
- Deeth HC and Bansal N. 2018. *Whey Proteins from Milk to Medicine*. 1st Edition, Academic Press
- McSweeney PLH, O'Mahony and James A. 2013. *Advanced Dairy Chemistry Volume 1A: Proteins: Applied Aspects*. Springer-Verlag, New York.
- McSweeney PLH, O'Mahony and James A. 2016. *Advanced Dairy Chemistry Volume 1B: Proteins: Applied Aspects.* Springer-Verlag, New York.
- Popay AI and Prosser CG.1997. *Biotech in Agric*. Series No. 18, CABI.
- Visser Hans. 1992. *Protein - Interactions*. VCS.
- Welch RAS, Burns DJW and Davis SR. 1997. *Milk Composition, Production and Biotechnology*. CABI.

I. Course Title : Advances in Chemistry of Milk Lipids

II. Course Code : DC-612

III. Credit Hours : 3+0

IV. Why this course?

This is an advanced course for in-depth understanding of milk fat including recent research work in the area of milk fat. This course is going to cover all these aspects.

V. Aim of the course

To impart the students with the in-depth understanding of various facets of milk fat including synthesis, changes during processing, various constituents of milk fat including minor components. The course also gives the opportunity to learn the

recent research work being done in the area of milk fat.
The course is organized as follows:

No.	Blocks	Units
1.	Composition and Structure	I. Origin, composition, structure and physical chemistry of milk fat globule membrane II. Lipolytic enzymes in milk of different species III. Fatty acids and other components in milk fat
2.	Stability and Health Significance	IV. Deterioration of milk fat due to oxidization and heating V. Significance of milk fat in human health

VI. Theory

Block 1: Composition and Structure

Unit I: Origin, composition, structure and physical chemistry of milk fat globule membrane

Origin, composition, structure and physical chemistry of milk fat globule membrane; Comparative aspects of milk lipids from different species such as human, bovine, buffalo, sheep, goat, and camel. Changes in milk fat globule membrane during processing and its effect on digestion.

Unit II: Lipolytic enzymes in milk of different species

Lipolytic enzymes in milk of different species including human; Bile salt stimulated lipase and esterases, induced and spontaneous lipolysis in milk. Assay for lipase activity; Biosynthesis of fatty acids, glycerol, neutral lipids, phospholipids, sphingolipids and cholesterol.

Unit III: Fatty acids and other components in milk fat

Essential fatty acids, prostaglandins and flavour compounds. Conjugated linoleic acids – different isomers, factors affecting their levels in dairy products and their significance.

Unit IV: Deterioration of milk fat due to oxidization and heating

Chemistry of oxygen in relation to autoxidation of milk fat including effect of milk components and environmental factors; Types of oxidations; Thermal oxidation; Chemical and biological properties of heated and oxidized fats.

Unit V: Significance of milk fat in human health

Significance of milk lipids in human health. Role of milk lipids in consumer acceptance of dairy products. Polymorphism and milk fat crystallization

VII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/Writing)
- Student's Book/Publication Review
- Student presentation
- Group Work
- Guest Lectures

VIII. Learning outcome

After successful completion of this course, the students are expected to be able to:
- Have in-depth understanding of milk fat including its origin in mammary gland
- Lipolytic enzyme in milk of various species including lipolysis
- Types of minor milk components and their structure
- Deterioration of milk fat due to oxidation
- Significance of milk fat in human health.

IX. Suggested Reading

- Fox PF. 1995. *Advanced Dairy Chemistry*. Vol. II. *Lipids*. 2nd Ed. Chapman and Hall.
- Fox PF and McSweeney PLH. 2006. *Advanced Dairy Chemistry Volume 2: Lipids*. Springer-US.
- Fox PF, Uniacke-Lowe T, McSweeney PLH and O'Mahony JA. 2015. *Dairy Chemistry and Biochemistry*. 2nd Edition. Springer.
- Jensen RG. 2018. The lipids of human milk. CRC Press.
- Nollet LML and Toldra F. 2009. *Handbook of Dairy Foods Analysis*. CRC Press. Taylor and Francis Group.
- Truong T, Palmer M, Bansal N and Bhandari B. 2016. *Effect of Milk Fat Globule Size on the Physical Functionality of Dairy Products*. Springer International Publishing.
- Truong T, Lopez C, Bhandari B and Prakash S. 2020. *Dairy Fat Products and Functionality*.
- Walstra P and Jenness R. 1984. *Dairy Chemistry and Physics*. John Wiley and Sons.
- Wong NP, Jenness R, Keeney M and Elmer HM. 1988. *Fundamental of Dairy Chemistry*. 3rd Ed. Van Nostrand Reinhold Co.

I. Course Title : Advances in Chemistry of Dairy Processing

II. Course Code : DC 621

III. Credit Hours : 3+0

IV. Why this course?

This course covers the physicochemical changes during processing of milk and chemistry of different additives and ingredients with respect to their effect on functional properties of dairy foods. This course is going to cover all these aspects.

V. Aim of the course

To highlight the impact of processing parameters on the milk constituents with special reference to chemical changes involved and also to impart the basic knowledge on the chemistry and significance of bio active compounds and additives

The course is organized as follows:

No.	Blocks	Units
1.	Physicochemical changes during processing	I. Heat induced changes and interactions II. Physical changes in the fat globules after homogenisation III. Specific and non-specific enzymatic coagulation of milk IV. High Pressure Processing of milk
2.	Food additives/ ingredients	V. Encapsulation of bioactive compounds VI. Micronutrients, Stability of sweeteners and Milk fat replacers

VI. Theory

Block 1: Physicochemical changes during processing

Unit I: Heat induced changes and interactions

Heat induced changes and interactions between protein, lipids, carbohydrates and minerals during processing of milk. Effect of heat on the proteins of concentrated milk systems. Inactivation of indigenous milk enzymes during processing.

Unit II: Physical changes in the fat globules after homogenisation

Physical changes in the fat globules in unhomogenized and homogenized milk; cold agglutination – its mechanisms and role.

Unit III: Specific and non-specific enzymatic coagulation of milk

Specific and non-specific enzymatic coagulation of milk.

Unit IV: High Pressure Processing of milk

Physico-chemical and structural changes occurring in milk constituents during high pressure processing of milk.

Block 2: Food additives/ ingredients

Unit V: Encapsulation of bioactive compounds

Chemistry involved in encapsulation of bioactive compounds and factors affecting their stability during processing.

Unit VI: Micronutrients, Stability of sweeteners and Milk fat replacers

Chemistry involved in the fortification of milk with vitamins, minerals and nutraceuticals. Stability of high intensity sweeteners during processing of milk and milk products. Milk fat replacers.

VII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/Writing)
- Student's Book/Publication Review
- Student presentation
- Group Work
- Guest Lectures

VIII. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Understand the effect of processing on milk constituents
- Analyse the stability of different additives including micronutrients added to milk as affected by different processing treatments

IX. Suggested Reading

- Shortt C and Brien JO. 2004. *Handbook of Functional Dairy Products*. CRC Press.
- Deeth HC and Lewis MJ. 2017. *High Temperature Processing of Milk and Milk Products*. Wiley-Blackwell.
- Fox PF and McSweeney PLH. 1998. *Dairy Chemistry and Biochemistry*.Blackie Academic Professional, Chapman and Hall.
- IDF. 1995. Special issue. *Heat Induced Changes in Milk*. Intern. Dairy Fed.,Brussels.
- Koca, N. (Ed.). 2018. Technological Approaches for Novel Applications in Dairy Processing. BoD–Books on Demand.

- Leo ML Nollet. 2004. *Intense Sweeteners. Handbook of Food Analysis*. 2ndEd. Marcel Dekker.
- Minj, J., Sudhakaran, A. and Kumari, A. 2020. Dairy Processing: Advanced Research to Applications. Springer Singapore.
- Walstra P, Walstra P, Wouters JTM and Geurts TJ. 2005. *Dairy Science and Technology*. CRC Press

I. Course Title : Advances in Analytical Techniques in Dairy Chemistry

II. Course Code : DC 622

III. Credit Hours : 3+0

IV. Why this course?

To gain insights in the underlying principle of newer instrumental techniques and their application in the dairy science research. This course is going to cover all these aspects.

V. Aim of the course

To highlight the application of advance analytical techniques used for analysis of milk and milk products

The course is organized as follows:

No.	Blocks	Units
1.	Electrophoresis and Chromatographic techniques	I. Isoelectric focusing, 2-D gel electrophoresis, Immuno assays
		II. High performance liquid chromatography
		III. Mass spectroscopy
2.	Protein structure determination and Spectroscopy	IV. Protein sequencing
		V. X-ray crystallography
		VI. Circular dichroism spectroscopy
		VII. Atomic spectroscopy
		VIII. Infrared, Fluorescence
		IX. Differential scanning calorimetry, NMR and FTIR

VI. Theory

Block 1: Electrophoresis and Chromatographic techniques

Unit I: Isoelectric focusing, 2-D gel electrophoresis, Immuno assays

Electrophoresis: Isoelectric focusing and 2-D polyacrylamide gel electrophoresis; Capillary zone electrophoresis, Enzyme linked immune-sorbentassay, blotting techniques

Unit II: High performance liquid chromatography

High performance liquid chromatography; Theory, instrumentation and application in analysis of dairy foods

Unit III: Mass spectroscopy

Mass spectroscopy: Principle, instrumentation and application in milk proteins/ milk fat analysis

Block 2: Protein structure determination and Spectroscopy

Unit IV: Protein sequencing

Protein sequencing; Chemical reactions involved in analysis of primary structure of proteins.

Unit V: X-ray crystallography

Circular dichroism spectroscopy; Theory and application for determination of secondary structure of proteins.

Unit VI: Circular Dichroism Spectroscopy

X-ray crystallography; Theory and application for determination of tertiary structure of milk proteins.

Unit VII: Atomic spectroscopy

AAS (Atomic Absorption Spectroscopy, Atomic Emission Spectroscopy, ICPS (Inductively coupled plasma spectroscopy); Principle and application in analysis of milk and milk products.

Unit VIII: Infrared, Fluorescence

Infrared Spectroscopy, Fluorescence Spectroscopy: principle and application.

Unit IX: Differential scanning calorimetry, NMR and FTIR

Differential scanning calorimetry: principle and application for milk fat and protein analysis.
NMR (Nuclear Magnetic Resonance), FTIR (Fourier Transform Infrared). Principle, application for quality analysis of milk and milk products.

VII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/Writing)
- Student's Book/Publication Review
- Student presentation
- Group Work
- Guest Lectures

VIII. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Understand the basic principle on advance analytical techniques for quality assessment of milk and milk products
- Understand the aspects on structure determination of milk proteins

IX. Suggested Reading

- Blundell TL and Johnson LN. 1976. *Protein Crystallography*. Academic Press.
- Calter P. 2004. *Methods in Molecular Biology*. Vol. 244 2nd Ed. *Protein Purification Protocols*. Humana Press.
- FL Creighton T. 1998. *Protein Structure*. 2nd Ed. Portland Press.
- Nielsen SS. 1994. *Introduction to Chemical Analysis of Foods*. Part IV.Jones and Bertlett Publ.
- Leo ML and Toldra NF. *Handbook of Dairy Foods Analysis*. 1st Ed. CRC Press.
- Wilson K and Walker J. 2000. *Practical Biochemistry: Principles and Techniques*. Cambridge University Press.

- Christian GD, Dasgupta PS, Schug K. 2014. Analytical Chemistry, 7th Edition Wiley Global Education.
- Nollet, L. M. (Ed.). 2020. *Mass Spectrometry Imaging in Food Analysis*. CRC Press.
- Nordén, B., Rodger, A., and Dafforn, T. 2019. *Linear Dichroism and Circular Dichroism: A Textbook on Polarized-Light Spectroscopy*. Royal Society of Chemistry.
- Singh, D. B., and Tripathi, T. 2020. *Frontiers in Protein Structure, Function, and Dynamics*.

Suggested Broad Topics for Master's and Doctoral Research

1. Profiling of milk from indigenous breeds of cattle, buffalo, goat and other minor species for their composition, physico-chemical properties and health benefits.
2. Encapsulation of bioactive compounds using milk and food grade constituents for their use in functional foods.
3. Physico-chemical changes in milk and milk products on fortification with micronutrients and nutraceuticals.
4. Flavour profiling of indigenous dairy products.
5. Shelf life enhancement of dairy products using natural and synthetic additives.
6. Development and evaluation of new generation methods for detection of adulterants and contaminants in milk and milk products based on biotechnological and nanotechnological approaches.
7. Development and validation of methods for detection of emerging contaminants and adulterants.
8. Validation of existing methods for quantification of different claimed constituents in various dairy products.
9. Stability of newer additives in milk and milk products and development of methods for their quantification.
10. Migration from food contact materials into food products.
11. Development of methods for detection of mixed milk and ghee-species and breeds.
12. Physico-chemical changes in milk proteins and lipids during processing and storage of dairy products.
13. Isolation and purification of growth factors and bioactive peptides from colostrum, milk and whey.
14. Enzymatic modification of milk proteins and incorporation of biopeptides into food system.
15. Incorporation of whey/whey constituents in milk and milk products for enhancement of biofunctional properties.
16. Evaluation of microstructure of dairy products.

List of Journals

1. *Indian Journal of Dairy Science*
2. *International Dairy Journal*
3. *International Journal of Dairy Technology*
4. *Journal of Dairy Research*
5. *Journal of Dairy Science*
6. *Comprehensive Reviews in Food Science and Food Safety*
7. *Critical Reviews in Food Science and Nutrition*
8. *Food Additives and Contaminants: Part A and Part B*
9. *Food Analytical Methods*
10. *Food Hydrocolloids*
11. *Food Chemistry*

12. *Food Research International*
13. *Food Reviews International*
14. *Food Science and Technology - Lebensmittel-Wissenschaft and Tech*
15. *Food Science and Technology International*
16. *Food Science and Technology Research*
17. *Food and Chemical Toxicology*
18. *Indian Journal of Dairy Science*
19. *International Journal of Food Properties*
20. *International Journal of Food Science and Technology*
21. *IDF Bulletins*
22. *Journal of Agricultural and Food Chemistry*
23. *Journal of Food Biochemistry (Journal of Food Lipids)*
24. *Journal of Food Composition and Analysis*
25. *Journal of Food Processing and Preservation*
26. *Journal of Food Quality*
27. *Journal of Food Safety*
28. *Journal of Food Science*
29. *Journal of Food Science and Technology*
30. *Journal of Functional Foods*
31. *Journal of the Science of Food and Agriculture*

Restructured and Revised
Syllabi of Postgraduate Programmes

Vol. 4

Dairy Science and Technology
– Dairy Microbiology

Course Title with Credit Load
M.Tech. in Dairy Microbiology

Course Code	Course Title	Credit Hours
	Major Courses	
DM 511*	Microbial Physiology	2+1
DM 512*	Microbiology of Processed Dairy Foods	3+1
DM 513	Microbial Morphology and Taxonomy	2+1
DM 514	Microbiology of Fluid Milk and Dairy Products	2+1
DM 515	Microbial Genetics	2+1
DM 516	Environmental Microbiology	2+1
DM 517	Biotechnology in Dairy Industry	2+1
DM 521*	Dairy Starter Cultures	2+1
DM 522*	Microbial Safety and Quality	2+2
DM 523	Microbiology of Cheese and Fermented Dairy Foods	2+1
DM 524	Probiotics and Prebiotics	2+1
DM 525	Research Techniques	2+1
DM 526	Microbial Fermentation Technology	2+1
DM 591	Credit Seminar	1+0
DM 599	Master’s Research	0+30

Course Contents
M.Tech. in Dairy Microbiology

I. Course Title : Microbial Physiology
II. Course Code : DM 511
III. Credit Hours : 2+1

IV. Why this course?

Microbial physiology is the study of how microbial cell structures, growth and metabolism function in living organisms. It covers the study of nutritional transport system of bacteria, electron transport chain in prokaryotes and nutritional requirements of bacteria for their growth.

V. Aim of the course

To familiarize the student with various aspects of growth and energy generating activities of bacteria for the betterment of human life.

VI. Theory

Unit I

Bacterial growth: Growth phases and kinetics; synchronous, continuous, and associative growth; factors affecting bacterial growth; growth measurement; sporulation.

Unit II

Effect of environment on the growth of bacteria: Temperature, air, osmotic pressure, pH, hydrostatic pressure, surface tension, metals, electromagnetic and other waves, sonics, various chemicals, their application in dairy industry; mechanism of action of antimicrobials.

Unit III

Bacterial nutrition; Nutrient media; Nutritional groups of bacteria; Role of growth factors; Active and passive transport.

Unit IV

Energy metabolism: Electron transport chain, fermentation, respiration and photosynthesis.

VII. Practical

- Measurement of bacterial growth by direct methods (cell number, SPC, DMC) and indirect methods (turbidometric methods, MPN, cell mass).
- Preparation of growth curve; determination of generation time.
- Determination of cell activity; Carbohydrate fermentation; Acid production/pH alteration; Starch, lipid, casein and gelatin hydrolysis.
- Effect of different factors, viz. physical (temperature, pH, osmotic pressure, surface tension), chemical (dyes, antibiotics, phenol) and nutritional (amino acid supplements, vitamin supplements, protein hydrolysates, casamino acids) on bacterial growth.

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/Writing)
- Student's Book/Journal Articles
- Student presentation
- Group Work
- Routine Practical as per the schedule
- Visit to the relevant industry or Laboratory

IX. Learning outcome

After undergoing this course, the students are expected to deliver the following:

- To have knowledge on the effect of environmental factors on microbial growth of bacteria
- To have an idea about nutritional transport system of bacteria
- To know about the electron transport chain in prokaryotes.
- To have any idea about the nutritional requirements of bacteria during their growth using various growth measurement techniques.

X. Suggested Reading

- Dean Watson. 2017. *Microbial Physiology*.
- Seaman GR and Mary JD. 2012. *Experiments in Microbial Physiology and Biochemistry*. Literary Licensing, LLC, USA.
- Willey J, Sherwood L and Woolverton CJ. 2017. *Prescott's Microbiology*, 10th Edition.
- Madigan MT, Martinko JM and Parker J. 2020. *Brock Biology of Microorganisms*. 16th edition, Prentice Hall, London, UK.
- Moat AG, Foster JW and Spector MP. 2002. *Microbial Physiology*. 4th Ed. Wiley-Liss.
- Poole RK. 2006. *Advances in Microbial Physiology*. Apple Academic Press (CRC Press), USA
- Rose AH. 2009. *Chemical Microbiology: An Introduction to Microbial Physiology*. Plenum Pub. Corp.
- Tortora GJ, Funke BR and Case CL. 2020. *Microbiology: An Introduction*, 13th Edn, Pearson, Harlow, UK.

I. Course Title : Microbiology of Processed Dairy Foods

II. Course Code : DM 512

III. Credit Hours : Credit: 3+1

IV. Why this course?

Different types of processing are done in dairy and foods industry for improving the quality and shelf life of the products. Each processing step affects microbial quality. Students should have idea about such changes. Course will also coverbio-preservation system of processed dairy foods, antimicrobial or bioactive packaging systems and GMO and their regulatory systems.

V. Aim of the course

To understand the microbiology of processed foods, types of processing and their effect on microbiological quality, significance of different food microorganisms, their control and other related aspects.

VI. Theory

Unit I

Introduction to microbes in foods, history and development of food microbiology, microorganisms important in foods, microbial ecology of processed foods and food ecosystem, factors influencing microbial growth in foods; Intrinsic factors and extrinsic factors.

Unit II

High temperature food preservation, factors affecting heat resistance in microorganisms, thermal destruction of microorganisms, low temperature food preservation, food preservation by irradiation, food preservation by drying and fermentation, modern processing techniques-ohmic heating, high pressure processing, infra-red heating, cold plasma, pulsed electric field, ultra sound etc., bio preservation of foods - concepts: metabolites of lactic acid bacteria; Bacteriocins, Antifungal substances etc., protective cultures and other antimicrobials (herbs, spices and other natural antimicrobial compounds), Nanoscience in food preservation; microencapsulation.

Unit III

Microbial stress response in the food environment; Stress adaptation, sublethal stress and injury, antibiotic resistance in food bacteria, predictive modelling for food spoilage, industrial strategies for ensuring safe foods, HACCP; GMP, GHP

Unit IV

Antimicrobial packaging; concepts and development, modified atmosphere packaging (MAP), intermediate moisture foods (IMF), and hurdle technology in processed foods.

Unit V

New prospects and problems in processed dairy foods. Genetically modified foods

VII. Practical

- D and Z-value calculation of common food pathogens.
- Production of antimicrobial substances-bacteriocins.
- Production of antifungal substances.
- Application of bacteriocins for bio preservation of foods.
- Application of hurdle concepts for enhanced shelf stability of processed foods.
- Induction of bacterial cell injury and recovery of injured cells.
- Antibiotic resistance of food pathogens.
- Shelf life enhancement using antimicrobial packaging.

VIII. Teaching Methods/ Activities

- Lectures
- Assignment (Reading/Writing)
- Student's Book/Journal Articles
- Student presentation
- Group Work
- Routine Practical as per the schedule
- Visit to the relevant industry or Laboratory

IX. Learning outcome

After undergoing this course, the students are expected to deliver the following:

- To have knowledge on the latest technologies for processing of foods, biopreservation system of processed dairy foods
- To have an idea about the processing methods that do not diminish the quality attributes of food being processed
- To know about the recent antimicrobial or bioactive packaging systems that can enhance the shelf life of fresh as well as processed produce/food.
- To have any idea about the GMO and their regulatory systems.

X. Suggested Reading

- Ozer B and Evrendilek GA. 2014. *Dairy Microbiology and Biochemistry: Recent Developments*. CRC Press.
- Silva ND, Taniwaki MH, Junqueira VC, Silveira N, Nascimento MDSD and Gomes RAR. 2012. *Microbiological Examination Methods of Food and Water: A Laboratory Manual*. CRC Press, USA.
- Erkmen O and Bozoglu TF. 2016. *Food Microbiology: Principles into Practice*, 2 Volume Set. Wiley Publishing.
- Papademas P. 2014. *Dairy Microbiology: A Practical Approach*. CRC Press.
- Prajapati JB and Behare PV. 2018. *Textbook of Dairy Microbiology*. Directorate of Knowledge Management in Agriculture, ICAR, ISBN: 978-81-7164-182-6.
- Ray RC and Didier M. 2014. *Microorganisms and Fermentation of Traditional Foods*. CRC Press, USA.
- Ray B. 2003. *Fundamental Food Microbiology*. CRC Press.
- Hutkins RW. 2019. *Microbiology and Technology of Fermented Foods*, 2nd Ed, Wiley Blackwell, New Jersey, USA.

I. Course Title : Microbial Morphology and Taxonomy

II. Course Code : DM 513

III. Credit Hours : 3+1

IV. Why this course?

Morphology is the study of the form of bacteria. This covers morphological features such as shape, size, cell structure, motility (ability to move in a liquid), and spore and capsule formation, different staining methods and micrometry etc.

V. Aim of the course

To educate the students about the morphological features and taxonomy of the various microorganisms, viz. bacteria, fungi and viruses

VI. Theory

Unit I

Evolution of life on earth, history and diversity of microorganisms

Unit II

Principles of classification and taxonomy of Eubacteria (Bacteria and Archaea); Major characteristics used in taxonomy; Cultural, Morphological, Biochemical; Physiological, Genetic and Molecular; Numerical Taxonomy (Taxometrics) and Chemotaxonomy. Assessing Microbial Phylogeny: Chronometers; Phylogenetic trees, r-RNA, DNA and proteins as indicators of phylogeny.

Unit III

Cell ultra-structure (prokaryotes and eukaryotes); Cell wall- structure, chemical composition, synthesis and inhibition; cell membrane, cytoplasmic inclusions, cytoskeleton, cell appendages- capsule, flagella, pili; sporulation - structure of endospore, composition and function of spore constituents, induction and germination.

Unit IV

Fungi: Distribution, importance and recent classification, study of yeasts and moulds in dairy foods

Unit V

History, development and scope of virology; classification and nomenclature, characteristics of viruses (acellular organization and viral genome), viral reproduction, brief account of viroidsand prions

VII. Practical

- Staining: Simple staining; differential staining - Gram's staining, spore staining, acid fast staining; special staining - cell wall staining, flagella staining, nucleoids staining, capsule staining, inclusion/storage bodies staining
- Preparation of bacterial protoplasts and spheroplasts
- Measuring dimensions of microorganisms (bacteria) using micrometry
- Morphology of fungi: yeast and moulds
- Application of computer software in bacterial identification

VIII. Teaching Methods/ Activities

- Lectures
- Assignment (Reading/Writing)
- Student's Book/Journal Articles
- Student presentation
- Group Work
- Routine Practical as per the schedule
- Visit to the relevant industry or Laboratory

IX. Learning outcome

After undergoing this course, the students are expected to deliver the following:

- To have knowledge on the Principles of classification and taxonomy of Eubacteria
- To have knowledge on the advanced techniques help in classification of organisms
- To know about the ultrastructure of microorganisms.
- To acquire the knowledge on different staining methods and micrometry.

X. Suggested Reading

- Cowan MK. 2012. *Microbiology: A Systems Approach*, 3rd Edition. The McGraw Hill Companies, New York, USA.
- Holt JG, Krieg NR, Sneath PHA, Staley JT and Williams ST. 1997. *Bergey's Manual of Determinative Bacteriology* (9th edition). Williams and Wilkins, Baltimore, Maryland, USA.
- Krejer van-Rij NJW. 1998, *The Yeasts: A Taxonomic Study*, 4th edn, Elsevier Science Publishers, Amsterdam, The Netherlands.
- Madigan MT, Martinko JM and Parker J. 2020. *Brock Biology of Microorganisms*. 16th edition, Prentice Hall, London, U.K.
- Prescott LM, Harley JP and Klein DA. 2002, *Microbiology*, 5th edn, McGraw Hill, New York, USA.

- Tolaro KP. 2011. *Foundations in Microbiology*, 8th Edn. The McGraw Hill Companies, New York, USA.
- Tortora GJ, Funke BR and Case CL. 2020. *Microbiology: An Introduction*, 13^{th} Edn, Pearson, Harlow, UK.

I. Course Title : Microbiology of Fluid Milk and Dairy Products

II. Course Code : DM-514

III. Credit Hours : 2+1

IV. Why this course?

Milk is a complex biological fluid secreted in the mammary glands of mammals. It contains all the nutrients which help the organisms to grow well. For the safe processing and production of milk and milk products, student should have good knowledge of various handling and processing practices on market milk. Novel technologies must be applied in milk and milk product processing for the inactivation of food borne microorganisms or toxins produced by the organisms during transportation or storage or raw milk.

V. Aim of the course

To familiarize the students with microbes in milk and milk products, microbiological aspects of processing, microbiology of milk products and safety aspects

VI. Theory

Unit I

Common microbes in milk and their significance, Microflora of mastitis milk and its importance in dairy industry, Sources of microbial contamination of raw milk and their relative importance in influencing quality of milk during production, collection, transportation and storage; Clean milk production and natural antimicrobial systems in raw milk, Microbial changes in raw milk during long storage, Microbiological grading of raw milk.

Unit II

Microbiological aspects of processing techniques like bactofugation, thermization, pasteurization, sterilization, boiling, UHT, non-thermal processes (pulsedelectric field) and membrane filtration of milk; Role of psychrotrophic, mesophillic, thermophilic and thermoduric bacteria in spoilage of processed milks, their sources and prevention; Heat induced damage in bacteria and role of resuscitation in recovery of injured microbial cells. Microbiological standards (BIS/ FSSAI) of heat-treated fluid milks

Unit III

Microbiological quality of dairy products; fat rich (cream and butter), frozen (ice cream), concentrated (evaporated and condensed milk), dried milks (roller and spray dried), infant dairy foods and legal standards; Sources of contamination and factors affecting microbial quality of these products during processing, storage and distribution; Microbiological defects associated with these products and their control.

Unit IV

Microbiological quality of traditional dairy products in India; heat desiccated (khoa, burfi, peda, kheer, etc.), acid coagulated (paneer, chhana, rasogolla, etc.), fermented (dahi, lassi, srikhand, etc.) and frozen (kulfi); Sources of microbial contaminants and their role in spoilage; Importance of personnel and environmental hygiene on quality of traditional milk products; Microbiological standards for indigenous dairy foods.

Unit V

Food poisoning- Food intoxications, Food infections and Toxi-infections, pathogens associated with fluid milks, dairy products and their public health significance; Sources of pathogens and their prevention; Importance of biofilms, their role in transmission of pathogens in dairy products and preventive strategies.

VII. Practical

- Grading of raw milk based on SPC, coliforms and dye reduction tests.
- Effect of different storage temperatures on microbiological quality of fluid milk.
- Tests for mastitic milk and brucellosis.
- Microbiological quality evaluation of cream and butter for coliforms, yeasts and moulds, lipolytic and proteolytic bacteria.
- Detection of *Cronobacter sakazakii* in infant dairy foods.
- Microbial evaluation of burfiand pedafor SPC, *S. aureus*, yeast and mould counts.
- Detection of *Bacillus cereus, Salmonella,Shigella* and coagulase positive staphylococci in milk powder.
- Evaluation of ice cream for coliforms and *Escherichia coli*.
- Microbiological quality of paneer.
- Enumeration of aerobic and anaerobic spores in condensed, sterilized and dried milks.
- Line testing for determining the source of contamination of dairy products.
- Detection of toxins (staphylococcal, aflatoxins/mycotoxins) in dairy foods

VIII. Teaching Methods/ Activities

- Lectures
- Assignment (Reading/Writing)
- Student's Book/Journal Articles
- Student presentation
- Group Work
- Routine Practical as per the schedule
- Visit to the relevant industry or Laboratory

IX. Learning outcome

After undergoing this course, the students are expected to deliver the following:

- To have knowledge on the novel technologies applied in milk and milk product processing for the inactivation of food borne microorganisms.
- To have an idea about the latest standards formulated by FSSAI on milk and milk products (Microbiological Standards).
- To know about the different toxins produced by microorganisms in milk and milk products.
- To have knowledge on Microbiological quality of traditional dairy products in India.

X. Suggested Reading

- Eozer B. 2014. *Dairy Microbiology and Biochemistry: Recent Developments*. CRC Press, USA.
- Law BA. 2012. *Microbiology and Biochemistry of Cheese and Fermented Milks*. Springer Publisher.
- Quin M. 1989. *Applied Microbiology in the Dairy Industry*. Hobsons Publishing PLC.

- Osei G. 2017. *Handbook of Dairy Microbiology*. AGri-Horti Press.
- Poltronieri P (Editor). 2017. *Microbiology in Dairy Processing: Challenges and Opportunities* John Wiley and Sons Inc.
- Prajapati JB and Behare PV. 2018. *Textbook of Dairy Microbiology*: Directorate of Knowledge Management in Agriculture, ICAR, ISBN: 978-81-7164-182-6.
- Fernandes R (Editor). 2009. *Microbiology Handbook: Dairy Products*. RSC Publishing.

I. Course Title : Microbial Genetics

II. Course Code : DM 515

III. Credit Hours : Credit: 2+1

IV. Why this course?

Microbial genetics is a subject area within microbiology and *genetic* engineering. *Microbial genetics* provides powerful tools for deciphering the regulation, as well as the functional and pathway organization, of cellular processes.

V. Aim of the course

To understand the fundamentals of structure, functions and synthesis of macromolecules and their genetic manipulation.

VI. Theory

Unit I

Macromolecules: DNA, RNA and their structure, types, organization, function and properties of macromolecules, DNA replication.

Unit II

Regulation and Gene Expression: Gene Expression and its regulation in Prokaryotes-Transcription, Genetic Code, Translation, Negative and Positive regulation in gene expression, Operon Models - Lac, Trp.

Unit III

Mutations: Mutations - Spontaneous and Induced, Type of mutations, Mutagenic agents – physical and chemical, Damage and repair system operating in Prokaryotes.

Unit IV

Plasmids and gene transfer systems: Plasmids and their properties, transposable elements, bacterial recombination, transformation, transduction and conjugation.

Unit V

Recombinant DNA technology, Fundamental aspects of genetic engineering/ recombinant DNA technology, restriction enzymes, plasmid vectors (cloning as well as expression vectors), PCR and real time PCR.

VII. Practical

- Isolation and quantitative estimation of chromosomal DNA from *E. coli* and *Lactobacillus* by mini prep method.
- Isolation of plasmid DNA from *E. coli* by miniprep method.
- Calcium chloride induced transformation of *E. coli* hosts with plasmids.
- Digestion of plasmid DNA with restriction enzymes and ligation into plasmid vector for transformation
- PCR based detection of microorganisms
- Demo of real time PCR machine

VIII. Teaching Methods/ Activities

- Lectures
- Assignment (Reading/Writing)
- Student's Book/Journal Articles
- Student presentation
- Group Work
- Routine Practical as per the schedule
- Visit to the relevant industry or Laboratory

IX. Learning outcome

After undergoing this course, the students are expected to deliver the following:

- To have knowledge on the macrostructure of DNA and RNA
- To have an idea about the genetic expression and regulation in Prokaryotic system
- To know about the recent advancements in genetic engineering/recombinant DNA technology.
- To have exposure on different types of PCR and their applications.

X. Suggested Reading

- Bansal MP. 2012. *Molecular Biology and Biotechnology: Basic Experimental Protocols*. Teri Press - New Delhi.
- Hofmann A and Clokie S. (Eds.). 2018. *Wilson and Walker's principles and techniques of biochemistry and molecular biology*. Cambridge University Press.
- Watson JD, Tania AB, Stephen PB, Alexander G, Michael L and Richard L. 2017. *Molecular Biology of the Gene*.
- Russell J. Peter. 2014. *IGenetics: a molecular approach*. Pearson.
- Synder L and Champness W. 2003. *Molecular Genetics of Bacteria*. ASM Publ.
- Uldis N Streips and Ronald E Yasbin (Eds.). 2004. *Modern Microbial Genetics*. John Wiley and Sons.
- Watson JD. 2003. *Molecular Biology of Genes*. W.A. Benjamin.

I. Course Title : Environmental Microbiology

II. Course Code : DM 516

III. Credit Hours : 2+1

IV. Why this course?

Environmental microbiology is the study of the composition and physiology of microbial communities in the environment. This includes: structure and activities of microbial communities, processing of waste water using microbes, microbial interactions with bioecosytem, environmentally transmitted microbial pathogens, various bio-geochemical cycles etc.

V. Aim of the course

To understand the fundamentals of environmental microbiology for overall effects of microorganisms in combating the pollution in the environment.

VI. Theory

Unit I

Environmental microbiology; Aero-microbiology; Airborne pathogens, toxins, aerosols, nature and control of bio-aerosols, aquatic environments and microbial habitats; Soil as a microbial environment; Microbes in extreme environments.

Unit II

Bio-geochemical cycles; Carbon cycles (fixation, energy flow and respiration), nitrogen cycle (fixation, ammonia assimilation, nitrification and nitrate reduction) sulphur cycle (assimilatory sulphate reduction, sulphur mineralization, oxidation and reduction), iron cycle; microbial influenced metal corrosion, acid mine drainage, metal recovery and desulfurization.

Unit III

Environmentally transmitted microbial pathogens (*Salmonella*, *E. coli*, *Campylobacter, Yersinia* etc.) and viruses (enteric and respiratory); indicator microorganisms (concept, total and faecal coliforms, faecal streptococci, bacteriophage etc.); Biofouling and biofilms; microorganisms as indicators of environment pollution; microbial toxicants and bio-organic pollutants.

Unit IV

Waste water treatment: physical - screening, racks, mixing, flocculation, sedimentation, floatation, elutriation, vacuum filtration and incineration; biological unit operations- aerobic and anaerobic cycles; kinetics of biological growth, application of kinetics to treatment systems, aerobic waste treatment, anaerobic waste treatment; waste water utilization for value addition, disposal and reuse of Waste water after treatment, solid wastes management; environment laws.

VII. Practical

- Determination of composite microflora (i.e. total bacteria, coliforms, yeasts and moulds etc.) of soil, water, air.
- Determination of BOD in dairy and food industrial wastes.
- Determination of composite microflora of waste water samples.
- Detection of residual antibiotics/pesticides in waste water samples.
- Isolation of bacteria capable of degrading organic and microbial pollutants from waste water samples.
- Isolation and characterization of bio-indicators from environmental samples.
- Utilization of waste water for production of ethanol, microbial and biomass.
- Visit to a sewage and sludge treatment plant.

VIII. Teaching Methods/ Activities

– Lectures
– Assignment (Reading/Writing)
– Student's Book/Journal Articles
– Student presentation
– Group Work
– Routine Practical as per the schedule
– Visit to the relevant industry or Laboratory

IX. Learning outcome

After undergoing this course, the students are expected to deliver the following:
– To have knowledge on the environmental bioecosytem (aero-microbiology).
– To have an idea about the processing of waste water using microbes
– To know about the various bio-geochemical cycles
– To have idea on environmentally transmitted microbial pathogens.

X. Suggested Reading

- Hurst CJ, Crawford RL, Garland JL, Lipson DA and Mills AL. 2007. *Manual of Environmental Microbiology*. 3rd Ed. ASM Press.
- Madsen, Eugene L. 2016. *Environmental microbiology: from genomes to biogeochemistry*.
- Maier RM, Pepper IL and Gerba CP. 2000. *Environmental Microbiology*. Elsevier.
- Maier RM, Pepper IL and Gerba CP. 2009. *Environmental Microbiology*. Elsevier Academic press, USA.
- Mitchell R and Gu JD. 2010. *Environmental Microbiology*. Wiley Blackwell.
- Varnam AH and Evans MG. 2000. *Environmental Microbiology*. Manson Publishing Ltd.

I. Course Title : Biotechnology in Dairy Industry

II. Course Code : DM 517

III. Credit Hours : 2+1

IV. Why this course?

Biotechnology is a tool for value addition to dairy foods. Genetic techniques have been employed to manipulate bacteria that have significance to the dairy industry. Biotechnological means can be used to regulate the production of flavour enhancing metabolites and to develop starter cultures that are resistant to bacteriophage and bacteriocins. Genetic engineering will be able to enhance the technological functions of Lactic acid bacteria for industrial applications using genetic approaches.

V. Aim of the course

To impart knowledge in the application of biotechnology in dairy/ food Industries

VI. Theory

Unit I

History and development of biotechnology; Status of biotechnology industries in India to meet the demands of dairy and food Industries.

Unit II

Genetic improvement of lactic starters to enhance their technological functions for industrial applications, e.g. acid, flavour, EPS, probiotic functions; Metabolic engineering of lactic acid bacteria; Production of recombinant dairy/ food enzymes/ proteins, e.g. chymosin, lactoferrin, lysozyme, lipases, proteases, immunoglobulins etc. Detection of GMOs and GM foods and their safety from public health point of view.

Unit III

Dairy based functional foods/ health foods and nutraceuticals. Value addition in dairy products through fortification/supplementation with bioactive components and probiotic cultures, Nutrigenomics.

Unit IV

Application of molecular tools, biosensors, etc. for detection of foodborne pathogens and spoilage microorganisms.

Unit V

Molecular tools for studying biodiversity; Regulatory standards, value added products for GMOs and GM foods.

VII. Practical

- Plasmid isolation from *E. coli*.
- Agarose gel electrophoresis.
- Transformation of *E. coli* with plasmid (Amp^r).
- Growth of starter cultures on MRS for "lac" marker.
- Induction of "lac"mutation using UV rays or ethidium bromide
- PCR assays for identification of LAB and foodborne pathogen detection
- Production of enzymes:protease/ â galactosidase
- Preparation of value added dairy products: fruit and probiotic based dahi/yoghurt/ lassi.

VIII. Teaching Methods/ Activities

- Lectures
- Assignment (Reading/Writing)
- Student's Book/Journal Articles
- Student presentation
- Group Work
- Routine Practical as per the schedule
- Visit to the relevant industry or Laboratory

IX. Learning outcome

After undergoing this course, the students are expected to deliver the following:

- To have knowledge on the nutrigenomics.
- To have knowledge on how to enhance the technological functions of Lactic acid bacteria for industrial applications using genetic approaches.
- To know about the advanced molecular tools for the detection of pathogens.
- To have knowledge on Biosensor and its application on dairy industry

X. Suggested Reading

- Pometto A, Shetty K, Paliyath G and Levin RE. 2005. *Food Biotechnology*. CRC Press, USA.
- Ratledge C and Kristiansen B. 2001. *Basic Biotechnology*. Cambridge University Press, USA.
- Bagchi D, Lau FC and Ghosh DK. 2010. *Biotechnology in Functional Foods and Nutraceuticals*. CRC Press, USA.
- Rai RV. 2015. *Advances in Food Biotechnology*. John Wiley and Sons Ltd.

I. Course Title : Dairy Starter Cultures

II. Course Code : DM 521

III. Credit Hours : 2+1

IV. Why this course?

Starter cultures are those microorganisms that are used in the production of cultured dairy products such as dahi, yogurt, cheese etc. A starter culture can provide particular characteristics in a more controlled and predictable fermentation. This study covers isolation and characterization of Lactic acid bacteria, methods for selection and preservation, preparation of DVS cultures, control of starter slowness and control of phage in dairy industry.

V. Aim of the course

To familiarize the students with the starter organisms, their metabolism and genetics; different types of starters, propagation, preservation and applications of starters

VI. Theory

Unit I

Taxonomy and characteristics of starter cultures: Taxonomy and natural habitat of starter cultures, Desirable properties of starter cultures with respect to various fermented milk products, Characteristics of starter organisms, bacteria (*Lactococcus, Leuconostoc, Streptococcus, Pediococcus*, *Lactobacillus*, *Bifdobacterium, Enterococcus, Propionibacterium, Brevibacterium*), yeasts and moulds.

Unit II

Carbohydrate, citrate and protein metabolism; Lactose, galactose and glucose metabolism-transport of sugars across the cell boundaries, homolactic and heterolactic fermentations, other pathways of sugar metabolism, formation of flavouring agents from citrate fermentation, proteolytic systems and protein metabolism in lactic acid bacteria: Genetics of starter bacteria: Plasmids and plasmid instability; Industrially significant genes; Genetic modification of lactic acid bacteria, transposons and insertion sequences. Genetics of flavor formation in starter bacteria; Major enzymes and pathways involved.

Unit III

Classification of starters: Single, mixed and multiple strain, mesophilic and thermophilic starter cultures; propagation and preservation of starter cultures; factors affecting propagation of starter, functional starters producing exopolysaccharides, vitamins and antimicrobial compounds, commercial starter preparations: concentrated and super concentrated starters; Production systems for bulk cultures: Lewis, Jones and Tetra-pack systems; growth media: nutritional requirements of lactic acid bacteria, growth media formulations; PIM/PRM, pH control during culturing- external and internal pH control systems; preservation of bulk starter cultures- frozen and freeze dried, spray dried cultures; direct vat starter cultures.

Unit IV

Growth inhibition of lactic acid bacteria by antibiotics, bacteriocins, bacteriophages, cleaning and sanitizing agents and naturally occurring antimicrobial systems in raw milk; sources, types and characteristics of phages associated with starters, morphology and taxonomy, phage host interaction, prevention and control of phages during starter handling and fermented milk products manufacturing, mechanisms of phage resistance in lactic acid bacteria, inhibitory substances produced by lactic acid bacteria.

VII. Practical

- Morphological examination of dairy starter cultures.
- Isolation of lactic acid bacteria from fermented milk products.
- Examination of purity and activity of starter cultures.
- Effect of physical and chemical factors on starter cultures.
- Evaluation of homo and hetero fermentation by starter cultures.
- Production of bulk starter culture.
- Preservation of starter cultures by liquid, freeze drying and other methods.
- Preparation and quality evaluation of concentrated starters.

- Inhibition of starters by antibiotic residues and other inhibitors.
- Production of bacteriocins by lactic acid bacteria.
- Production of exopolysaccharides by lactic acid bacteria.
- Detection of bacteriophages in cheese whey.

VIII. Teaching Methods/ Activities

- Lectures
- Assignment (Reading/Writing)
- Student's Book/Journal Articles
- Student presentation
- Group Work
- Routine Practical as per the schedule
- Visit to the relevant industry or Laboratory

IX. Learning outcome

After undergoing this course, the students are expected to deliver the following:

- To have knowledge on the isolation and characterization of Lactic acid bacteria
- To have an idea about biochemical pathways of Lactic acid bacteria for carbohydrate metabolisms
- To know about the freeze drying and preparation of DVS cultures.
- To have idea about causes of slowness of starter and control of phage.

X. Suggested Reading

- Speranza B, Bevilacqua A, Corbo MR and Sinigaglia M. 2017. *Starter Cultures in Food Production*. Wiley Black Well, John Wiley and Sons, Ltd, UK.
- Marth EH and Steele JL. 2001. *Applied Dairy Microbiology*. Marcel Dekker Inn. New York.
- Prajapati JB and Behare PV. 2018. *Textbook of Dairy Microbiology: Microbiology of Starter Culture* 147-183. Directorate of Knowledge Management in Agriculture, ICAR, ISBN: 978-81-7164-182-6.
- Puniya AK. 2015. *Fermented Milk and Dairy Products*; CRC Press/ Taylor and Francis (ISBN 9781466577978).
- Hutkins RW. 2019. *Microbiology and Technology of Fermented Foods*, 2nd Ed, Wiley Blackwell, New Jersey, USA.
- Gabriel V, Ouwehand A, Salminen S and Wright AV. 2019. *Lactic acid bacteria: microbiological and functional aspects*. CRC Press.
- Wood BJ and Warner PJ. (Eds.). 2003. *Genetics of Lactic Acid Bacteria*. Springer Verlag.

I. Course Title : Microbial Safety and Quality

II. Course Code : DM 522

III. Credit Hours : 2+1

IV. Why this course?

Food Quality and Standards Service is committed to the enhancement of *food safety and quality* along the *food* chain to prevent diseases and trade disruptions. This course covers principles of safety in a food microbiological laboratory, conventional and rapid methods for detection of hygiene indicators or pathogens, antibiotic resistance in bacteria etc.

V. Aim of the course

To impart knowledge pertaining to quality and safety functions in dairy processing unit and measure to control quality and safety of dairy products.

VI. Theory

Unit I

Principles of quality and safety functions in dairy processing unit:
Introduction to ISO standards– ISO: 9000:2000; ISO: 9004:2000; ISO: 9001:2000: Brief concept and principles of QMS and standard requirements for certification HACCP, Hazard Analysis and Risk-Based Preventive Controls (HARPC), SAFE, GMP, SSOP, FSMS, personnel hygiene and food handling in dairy industry.
Principles of safety in a food microbiological laboratory-Bio-safety concept, Biosafety level-1-4 containment design and layout; Standard microbiological practices for safe handling in food laboratory, safety equipment, facility design.

Unit II

General principles for establishment of microbiological criteria
Definition, purpose and components of microbiological criteria; mandatory and advisory criteria
Sampling methods - two and three class sampling plan as per International council for microbiological standards for foods (ICMSF)
Establishment of microbiological standards, guidelines and specifications for different dairy foods as recommended by ICMSF, CODEX, FSSAI

Unit III

Conventional and rapid methods for detection of hygiene indicators;
definition, selection criteria of indicator organisms as an index of food quality
Conventional detection methods for indicator organisms – Standard plate count (SPC), coliforms, *E. coli*, yeast and mould Counts (YMC), spore counts; enterobacteriaceae count; Faecal streptococci count; Dye reduction tests
Rapid techniques like D-count, petrifilm, ATP bioluminance including commercial kits for monitoring hygiene indicators

Unit IV

Conventional and rapid methods for detection of safety indicators;
definition, selection criteria of indicator Organisms as an index of food safety;
Conventional detection methods for detection of pathogenic organisms as per ISO protocol specified by FSSAI – *Staphylococcus aureus*; *Bacillus cereus*; Pathogenic *E.coli*; *Salmonella*; *Shigella*; *Listeria monocytogenes*; *Enterobacter sakazakii*; Sulphite reducing clostridia (SRC), *Campylobacter jejuni*;
Rapid techniques like–VIDAS, SPR, RT-PCR including commercial kits, for monitoring safety indicators.

Unit V

Bio-sensors and micro-techniques for rapid monitoring of contaminants;
definition, history, basic characteristics of bio-sensors; classification based on bio-recognition molecule - Microbial, spore, Aptamer, DNA, immune and enzyme etc. Biosensors based on Transducers - electrochemical, optical, mechanical and calorimetric etc.
Bio-sensors for rapid detection of hygiene indicators, pathogenic bacteria, antibiotics, pesticides, heavy metal, aflatoxin M1 in milk.

VII. Practical

- Demonstration of safety principles in a food microbiological laboratory.

- Aseptic technique for ensuring safety of personnel, product and environment.
- Conventional and rapid methods for hygienic assessment of milk for SPC, coliforms, *E. coli*, YMC, Spore counts, Enterobacteriaceae count, faecal streptococci count, Dye reduction tests
- Conventional ISO methods for enumeration of safety indicators in dairy foods for *S. aureus*; *B. cereus*; *E.coli*; *Salmonella*; *Shigella*; *L. monocytogenes*; *E. sakazakii*; SRC; *Campylobacter jejuni* as per FSSAI standards.
- Rapid tests for detection of antibiotics, aflatoxin M1 and pesticides in milk.
- Determination of antibiotic resistance in bacteria using phenotypic methods.
- Shelf life studies of dairy products; effect of storage condition and packaging material on microflora of dairy foods.
- Determination of efficacy of detergents and sanitizers using capacity and suspension tests.

VIII. Teaching Methods/ Activities

– Lectures
– Assignment (Reading/Writing)
– Student's Book/Journal Articles
– Student presentation
– Group Work
– Routine Practical as per the schedule
– Visit to the relevant industry or Laboratory

IX. Learning outcome

After undergoing this course, the students are expected to deliver the following:
– To have knowledge on principles of safety in a food microbiological laboratory
– To have an idea about the principles for establishment of microbiological criteria
– To know about the conventional and rapid methods for detection of hygiene indicators/pathogens
– To have knowledge on antibiotic resistance in bacteria.

X. Suggested Reading

- M. Brown and M Stringer. 2012. *Microbiological: Risk Assessment in Food Processing*. Woodhead Publishing 1st Edition
- Patel P. (Ed.). (2012). *Rapid Analysis Techniques in Food Microbiology*. Springer Science and Business Media.
- Borough LM. 2004. *Food Microbiology Laboratory*, CRC Press, USA
- Nordenfelt, Pontus, Collin, Mattias. 2017. *Bacterial Pathogenesis* (1st edition) Springer.
- Arvanitoyannis IS. 2012. HACCP and ISO 22000: *Application to Foods of Animal Origin* (Institute of Food Science and Technology Series). Wiley Blackwell
- Osiemo O. 2012. *Food Safety Standards in International Trade: The Case of the EU and the COMESA*. Routledge Publisher.
- Bhunia AK. 2016. *Sensors for Food Safety and Quality*. eBook

I. Course Title : Microbiology of Cheese and Fermented Dairy Foods
II. Course Code : DM 523
III. Credit Hours : 2+1

IV. Why this course?

There are several types of cheeses in the world; use of different starter culture can lead to development of specific cheese variety too. However, the technological principles involved in Cheddar cheese making are common to several varieties of cheeses, with some modifications. Cheese is getting popularized in India, especially the Pizza cheese variety that is preferentially used as a topping on pizza pie. The functional properties of cheese depend on the starter cultures used and ripening of cheeses. Specific cheese has its own typical flavour and aroma depending on type of starter cultures used for particular ripening conditions.

V. Aim of the course

To impart knowledge on basic and applied aspects of cheese and fermented dairy foods

VI. Theory

Unit I

Evolution and classification of cheeses and fermented Dairy foods; Introduction, classification and types of cheeses and fermented dairy foods. Market share and recent market trends

Unit II

Microbiology of cheese, Cheese starter cultures involved in the manufacture, their types, roles, Current classification and metabolic pathways. Rennet, rennet substitutes; Microbial and recombinant rennet used in cheese preparation. Bacteriophages of cheese starters. Microbes associated with spoilage, defects, causative organisms and preventive measures. Health aspects of cheese.

Unit III

Microbiology of cheese ripening
Microbiological changes, Factors Influencing Growth of Microorganisms, Flavour development, Role of starter flora and supplementary flora in cheese ripening.
Accelerated cheese ripening through biotechnological approaches, Cheese with high linoleic acid content, Enzyme-modified cheese, GMO
Microbiological and biochemical aspects of major cheese varieties - Cheddar, Swiss-Type Cheeses - Emmental, Very hard cheese - Parmesan, Dutch cheese varieties - Edam, Gouda, Pasta Filata/Pizza Cheese - Mozzarella, Unripened cheese - Cottage, Internal mould ripened cheese - Roquefort, Surface mould ripened cheese - Camembert, Bacterial surface ripened cheese- Limburger; Microbiology of processed cheese.

Unit IV

Microbiology of Fermented dairy foods; Dahi, lassi, yoghurt, Kefir, Koumiss, functional fermented dairy based beverages, fermented whey drinks, and dairy based fermented cereal foods, fortified fermented dairy foods - Microbes associated with spoilage and preventive measures. Safety and standards of fermented foods.

Unit V

Functional cheeses, Cheese as matrix for probiotic delivery.
Health aspects of cheese and fermented foods: nutritional value, and therapeutic benefits.

VII. Practical

- Preparation and evaluation of ethnic fermented dairy products
- Preparation of cheese with mesophilic dairy starter cultures and different microbial rennets.

- Preparation of functional/probiotic cheese
- Microbial analysis of cheeses
- Identification and characterization of specific starter cultures from different varieties of cheeses (*Leuconostoc* for Dutch type cheese, *Propioni bacterium* for Swiss type cheese).
- Determination of ß-galactosidase activity of microorganisms
- Accelerated cheese ripening using different interventions

VIII. Teaching Methods/ Activities

- Lectures
- Assignment (Reading/Writing)
- Student's Book/Journal Articles
- Student presentation
- Group work
- Routine practical as per the schedule
- Visit to the relevant industry or laboratory

IX. Learning outcome

After undergoing this course, the students are expected to deliver the following:

- Be able to manufacture various varieties of cheeses using cheese specific starter cultures
- To have knowledge on Bacteriophages of cheese starters
- Be able to develop different fermented milk products, particularly traditional fermented milk products
- To develop the probiotic cheese using probiotic cultures

X. Suggested Reading

- Speranza B, Bevilacqua A, Corbo MR and Sinigagli M. 2017. *Starter Cultures in Food Production*. Wiley Black Well, John Wiley and Sons, Ltd, UK.
- FatihYildiz. 2009 *Development and Manufacture of Yogurt and Other Functional Dairy Products*, CRC Press, USA.
- El-Mansi EMT, Bryce CFA, Arnold L. Demain and Allman AR. (Edited). 2012. *Fermentation Microbiology and Biotechnology*, Third Edition CRC.
- McSweeney P, Fox P, Cotter P and Everett D. (Eds.) 2017. *Cheese -Chemistry, Physics and Microbiology*, 4^{th} Edn. Academic Press.
- Puniya AK. 2015. *Fermented Milk and Dairy Products*; CRC Press/ Taylor and Francis (ISBN 9781466577978).
- Hutkins RW. 2019. *Microbiology and Technology of Fermented Foods*, 2^{nd} Ed, Wiley Blackwell, New Jersey, USA.
- Wood BJ and Warner PJ. (Eds.). 2003. *Genetics of Lactic Acid Bacteria*. Springer Verlag.

I. Course Title : Probiotics and Prebiotics

II. Course Code : DM 524

III. Credit Hours : 2+1

IV. Why this course?

Probiotics are live microorganisms intended to provide health benefits when consumed, generally by improving or restoring the gut flora. This study covers Gut microbiota and its role in human health, mechanism of action of probiotics/prebiotics, safety and regulations on probiotics or probiotic food products.

V. Aim of the course

To understand the concept of probiotics and prebiotics in relation to food formulations and health effects.

VI. Theory

Unit I

Probiotics, Prebiotics and Synbiotics: Concepts, definitions and history. Gut microbiota and its role in human health and disease

Unit II

Identification of probiotic strains isolated from different niches by polyphasic approach using phenotypic, biochemical and genotypic tools/techniques. Characterization and selection of candidate probiotic strains on the basis of FAO/WHO or ICMR/DBT guidelines.

Unit III

Mechanism of action of probiotics: Colonization in the gut; Adhesion to intestinal mucosal surface – role of surface proteins; Antimicrobial/antagonistic activity of probiotics, Pathogen exclusion; Immuno-modulatory action; Impact on gut homeostasis; Host microbe interaction and their cross talk; Role of biomarkers for probiotic functionality.

Unit IV

Mechanism of action of prebiotics and synbiotics: Selective stimulation of beneficial bacteria in the gut microbiota; Effect on gastric emptying and intestinal transit rate; Production of short chain fatty acids (SCFA); Effect of SCFA on host metabolism and immunomodulation; Anti-adhesive prebiotics. Synbiotics and their action through improved viability of probiotic microorganisms and provision of specific health benefits

Unit V

Dairy based foods as carrier of probiotics: Dairy based products as delivery vehicles – Stability towards manufacturing conditions, enhancing stability through encapsulation or drying strategies for lyophilized formulations etc., co-culture compatibility with starters, minimum effective dose, and large-scale production of probiotic biomass through fermentation for application in foods and as drugs/supplements.

Unit VI

Designer probiotics: Genetically modified probiotics as oral vaccines, enhanced adhesion properties and health promoting functions.

Unit VII

Safety, human trials and regulatory guidelines: *In vitro* and *in vivo* safety assessment of probiotics; designing human trials; regulatory guidelines - US, Canada, Europe and India.

VII. Practical

- Isolation of probiotic organisms from human milk and faecal samples.
- Tentative identification by microscopic examination, catalase and biochemical tests.
- Identification of isolates by genus and species-specific PCR.
- Evaluation of bacterial isolates for probiotic properties.

- Acid tolerance; Bile tolerance; Hydrophobicity; Antimicrobial activity.
- Specific utilization of prebiotics by probiotic bacteria.
- Survival of probiotic culture in fermented dairy products.
- Microencapsulation of probiotic bacteria.

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/Writing)
- Student's Book/Journal Articles
- Student presentation
- Group Work
- Routine Practical as per the schedule
- Visit to the relevant industry or Laboratory

IX. Learning outcome

After undergoing this course, the students are expected to deliver the following:

- Have knowledge on the Gut microbiota and its role in human health
- To have knowledge on identification, characterization and selection of probiotic strains using phenotypic, biochemical and genotypic tools/techniques
- To know about the different mechanism of action of probiotics/prebiotics establishing through in vitro and in vivo studies.
- To have any idea about the safety and regulations on probiotics or probiotic food products.

X. Suggested Reading

- Sungsoo C and Finocchiaro ET. 2010. *Handbook of prebiotics and probiotics ingredients: health benefits and food applications*. Boca Raton: Taylor and Francis.
- Ipek G, Vijay JK and Mohamed A. 2006. *Probiotics in Food Safety and Human Health*.
- Huffnagle GB. 2008. *The Probiotics Revolution: The Definitive Guide to Safe, NaturalHealth Solutions Using Probiotic and Prebiotic Foods and Supplements*. Bantam,USA.
- Venema K. 2015. *Probiotics and Prebiotics: Current Research and Future Trends*.
- Min-TzeLiong. 2011. *Probiotics: Biology, Genetics and Health Aspects*. Springer.
- Prajapati JB and Behare PV. 2018. *Textbook of Dairy Microbiology:* Directorate of Knowledge Management in Agriculture, ICAR, ISBN: 978-81-7164-182-6.
- Di Gioia, Diana. -Biavati, Bruno. 2018. *Probiotics and Prebiotics in Animal Health and Food Safety*
- Wallace RK and Wallace S. 2017. *Gut Crisis: How Diet, Probiotics, and Friendly Bacteria Help You Lose Weight and Heal Your Body and Mind*. Dharma Publication, Fairfield, USA.

I. Course Title : Research Techniques

II. Course Code : DM-525

III. Credit Hours : 2+1

IV. Why this course?

Research techniques are required to study the tools and techniques that are used in quantitative and qualitative methods. This study covers microscopic analysis of different types of bacteria, activities of enzyme using spectrophotometric based assays, identification and characterization of microorganisms by PCR etc.

V. Aim of the course

To impart knowledge and skills related to microbiological analytical systems in microbiology and related sciences.

VI. Theory

Unit I

Microscopy: Principles, design and application of bright field, dark field, phase contrast, fluorescence, atomic force, confocal laser and electron microscopes.

Unit II

Cell fractionation: Physical and chemical methods of microbial cell lysis: Ultrasonication, glass bead lysis, micro-fluidization, enzymatic and solvent induced techniques.

Unit III

Molecular separation: Ultrafiltration, crystallography, isoelectric focusing, chromatography, SDS-PAGE, micro and ultracentrifugation.

Unit IV

Assay methods: Spectrophotometric methods, ELISA, protein and enzyme assays, microbiological assay, and microbial receptor assay.

Unit V

Studying nutritional and therapeutic attributes of microorganisms and fermented dairy foods - Use of cell culture and small animal models.

VII. Practical

- Familiarization with the construction and design of a compound microscope; use of light microscope accessories; microscopic analysis of different types of bacteria by bright field, dark field, phase contrast and fluorescence microscopes
- Disruption of bacterial cells by ultra-sonification
- Demonstration of chromatographic techniques and SDS-PAGE
- Demonstration of aerobic and anaerobic culturing techniques
- Demonstration of use of animal models in toxicity studies
- Identification and characterization of microorganisms by PCR

VIII. Teaching Methods/ Activities

– Lectures
– Assignment (Reading/Writing)
– Student's Book/Journal Articles
– Student presentation
– Group Work
– Routine Practical as per the schedule
– Visit to the relevant industry or Laboratory

IX. Learning outcome

After undergoing this course, the students are expected to deliver the following:
– Be able to do the microscopic analysis of different types of bacteria
– To measure the activities of enzyme using spectrophotometric based assays
– To know about the identification and characterization of microorganisms by PCR

X. Suggested Reading

- Murphy DB. 2001. *Fundamentals of Light Microscopy and Electronic Imaging*, Wiley-Liss, Inc., USA.
- Harisha S. 2010. *Biotechnology Procedures and Experiments Handbook*. Infinity science press LLC, Hingham, MA 02043, USA.

- Hofmann A and Clokie S. (Eds.). 2018. *Wilson and Walker's principles and techniques of biochemistry and molecular biology*. Cambridge University Press.
- Spencer JFT & Ragout AL, Nollet LML and Toldra F. 2013. *Food analysis* HPLC, Third edition, CRC press, Taylor and Francis group, Florida, USA.
- Nollet LML and Toldra F. 2013. *Food analysis* HPLC, Third edition, CRC press, Taylor and Francis group, Florida, USA.
- Nasser Hajibagheri MA.1999. *Electron Microscopy Methods and Protocols, Methods in Molecular Biology Series*, # 117.Humana Press Inc., Totowa, New Jersey, USA.
- Singer S. 2001. *Experiments in Applied Microbiology*, Academic Press, New York, USA.

I. Course Title : Microbial Fermentation Technology

II. Course Code : DM-526

III. Credit Hours : 2+1

IV. Why this course?

Fermentation technology is the use of organisms to produce food, pharmaceuticals and alcoholic beverages on a large scale industrial basis. The basic principle involved in the industrial fermentation technology is that organisms are grown under suitable conditions, by providing raw materials meeting all the necessary requirements such as carbon, nitrogen, salts, trace elements and vitamins in a suitably designed bioreactor.

V. Aim of the course

To disseminate recent information on basic and applied aspects of fermentation technology and its industrial application to the students.

VI. Theory

Unit I

Fermentation for enhancing shelf life of foods, types of fermentation - submerged/ solid state and semi-solid.

Unit II

Microbial growth, metabolism, death, membrane transport, fermentation kinetics and fermentation modelling, batch, fed batch, continuous culture systems.

Unit III

Bioreactor design, measurement and control in fermentation.
Different types of fermenters, scaling up of fermentation, sterilization, agitation; pH, Eh, temperature measurement and control, downstream processing and product recovery, immobilization in fermentation

Unit IV

Biosensors in fermentation applications
Biosensors, basic principles; application in detection of sugars, alcohol, amino acids

Unit V

Industrial production of microbial cell biomass, organic acids, enzymes, antibiotics, micro-nutrients, amino acids, vitamins, ethanol, SCP and alcoholic beverages

VII. Practical

- Bacterial growth in batch culture.
- Different methods of microbial cultivation.

- Fermenter operation and measurement.
- Production of antimicrobial substances/ bacteriocins
- Production of microbial enzymes
- Production of baker yeast, SCP/microbial biomass.
- Production of alcohol, lactic acid.
- Production of alcoholic beverages and whey beverage

VIII. Teaching Methods/ Activities

- Lectures
- Assignment (Reading/Writing)
- Student's Book/Journal Articles
- Student presentation
- Group Work
- Routine Practical as per the schedule
- Visit to the relevant industry or Laboratory

IX. Learning outcome

After undergoing this course, the students are expected to deliver the following:

- To have knowledge on the Bioreactor design, measurement and control in fermentation
- Be able to produce the microbial cell biomass, organic acids, enzymes, antibioticsetc. using fermenter
- To have an idea about the construction, design and application of biosensor
- Be able to produce alcoholic and whey beverages.

X. Suggested Reading

- Kulandaivelu S and Janarthanan S. 2012. *Practical Manual on Fermentation Technology*. I K International Publishing House Pvt. Ltd.
- PF Stanbury Dr Whitaker. 2008. *Principles of Fermentation Technology*, Elsevier; 2editions.
- Okafor N, Okeke BC. 2017. *Modern Industrial Microbiology and Biotechnology* (Text Book), Second Edition published by CRC press, USA.
- ArindamKuila and Vinay Sharma. 2019. *Principles and Applications of Fermentation Technology* John Wiley and Sons.
- Hutkins RW. 2019. *Microbiology and Technology of Fermented Foods*, 2nd Ed, Wiley Blackwell, New Jersey, USA.
- Gabriel V, Ouwehand A, Salminen S and Wright AV. 2019. *Lactic acid Bacteria: Microbiological and Functional Aspects*. CRC Press.

Course Title with Credit Load
Ph.D. in Dairy Microbiology

Course Code	Course Title	Credit Hours
DM 611**	Advances in Microbial Physiology	3+0
DM 612	Advances in Microbial Genetics	3+0
DM 621**	Advances in Dairy and Food Microbiology	3+0
DM 622	Advances in Food Safety of Dairy Products	3+0
DM 623	Advances in Probiotics and Functional Foods	3+0
DM 691	Credit Seminar-I	1+0
DM 692	Credit Seminar-II	1+0
DM 699	Doctoral Research	0+75

Minor Courses

The courses will be selected from the major courses of the allied disciplines of Dairy Chemistry, Dairy Technology, Dairy Engineering and Animal Biochemistry to meet the minimum credit requirements.

Supporting Courses

The supporting courses will be picked from the basket of courses offered in agricultural statistics, computer applications and IT, and other related relevant disciplines to meet the minimum credit requirements.

Common Courses

1. Library and Information Services 1
2. Technical Writing and Communications Skills 1
3. Intellectual Property and its Management in Agriculture 1
4. Basic Concepts in Laboratory Techniques 1
5. Agricultural Research, Research Ethics and Rural Development Programmes 1

*Core courses for Master's programme; **Core courses for Doctoral programme

Course Titles with Credit Load
Ph.D. in Dairy Microbiology

I. Course Title : Advances in Microbial Physiology
II. Course Code : DM 611
III. Credit Hours : 3+0

IV. Why this course?

Microbial physiology deals with metabolism and energy provision; reproduction and death; and regulation of vital activity on the intracellular level and on the level of microbe-microbial interactions and interactions of microorganisms with plants, animals, and man. This study covers growth kinetics of microorganisms, genetical changes during endospore formation, interactions of bacterial communities and diversity in natural eco-systems

V. Aim of the course

To understand the advances in microbial physiology and diversity for its interface with all other branches of microbiology.

VI. Theory

Unit I

Microbial growth and stress response; Mathematics and kinetics of bacterial growth, Continuous culture system (chemostat and turbidostat), Diauxic and synchronous growth, Unrestricted versus nutrient-limited growth; Advances in growth measurement, counting viable but non-culturable microbes, Growth in natural environments and limitations. Osmotic stress and osmoregulation, high and low osmolality, osmotic control of gene expression, Aerobic to anaerobic transitions, oxidative stress, regulation of the oxidative stress response,pH stress and acid tolerance,Thermal stress and heat shock response, Nutrient stress and starvation stress response, starvation protecting proteins.

Unit II

Peptidoglycans of bacterial cell walls; peptidoglycan hydrolases and synthesis; teichoic and lipo-teichoic acids, Outer membranes of Gram-negative bacteria; lipo-polysaccharide biosynthesis; Outer membranes of Gram-negative bacteria, Bacterial flagella; Chemotaxis; Swarming motility; motility in spirochetes, Endospore formation in bacillus; molecular design of a spore; Stages, physiological changes and genetic aspects of sporulation; Sporulating genes; initiation, transition, forespore development and final stages of sporulation; spore cortex and coat synthesis; Biochemical changes during sporulation, heat resistance in spores; Activation, germination, and outgrowth of bacterial endospores.

Unit III

Energy generation and transport of metabolites: Substrate-level and oxidative phosphorylation; Measurement of proton motive force; Electron transport systems;

Anaerobic respiration; Conversion of proton motive force to energy; Structure of F1F0 and the ATP operon; Energy yield; Generating ATP in alkalophiles; Energetics of chemolithotrophs; Metabolite transport; Facilitated diffusion; Mechanosensitive channels; ATP-binding cassette transporter family; Chemiosmotic-driven transport; Establishing ion gradients; New insight into Respiration and fermentation mechanism in Lactic Acid bacteria, specific transport systems; ATP-linked ion motive pumps, the histidine permease, iron, phosphotransferase system. Sugar transport in Lactic Acid bacteria.

Unit IV

Metabolic Pathways: Alternate pathways of carbohydrate metabolism; Fructose bisphosphatealdolase pathway; Alternate pathways of glucose utilization; Entner-doudoroff or ketogluconate pathway; phosphoketolase pathway; oxidative pentose phosphate cycle; Gluconeogenesis, regulation, glycogen synthesis, tricarboxylic acid cycle, glyoxylate cycle. Utilization of sugars other than glucose, lactose, galactose; maltose, mannitol, fucose and rhamnose, melibiose, raffinose, stachyose; Cellulose degradation; metabolism of starch and glycogen.

Unit V

Microbial (bacterial, archaeal, fungal and viral) diversity, Bacterial communities and diversity in natural eco-systems with special reference to Lactic Acid bacteria. Extremophiles: hyperthermophiles, extreme acidophiles, psychrophiles, barophiles halophiles, alkaliphiles, oligotrophs, radiation-resistant microorganisms, extremophiles habitats and microorganisms, Biochemistry and physiology of adaptation, biotechnology of extremophiles.

VII. Teaching Methods/ Activities

- Lectures
- Assignment (Reading/ Writing)
- Student's Book/ Journal Articles
- Student presentation
- Group Work
- Visit to the relevant industry or Laboratory

VIII. Learning outcome

After undergoing this course, the students are expected to deliver the following:

- To have knowledge on the growth kinetics of microorganisms
- To have an idea about the genetical changes during endospore formation
- To know about the energy generation using electron transport chains
- To have idea on interaction of bacterial communities and diversity in natural eco-systems.

IX. Suggested Reading

- Cowan MK. 2012. *Microbiology: A Systems Approach*, 3rd Edn. The McGraw Hill Companies, New York, USA.
- Madigan MT, Martinko JM and Parker J. 2012. *Brock Biology of Microorganisms*, 13th Edn. Prentice Hall, London, UK. Edition, Prentice Hall, London, UK.
- Moat AG, Foster JW and Spector MP. 2004. *Microbial Physiology*. 4th Ed. John Wiley and Sons, USA.
- Ogunseitan O. 2005. *Microbial Diversity: Form and Function in Prokaryotes* Blackwell Publishing, Malden, USA.

- Poole RK. (Ed.). 2020. *Advances in microbial physiology*. Academic Press.
- Xie *et al*. 2011. *Bacterial Flagellum as a Propeller and as a Rudder for Efficient Chemotaxis*. PNAS108 (6): 2246-51.

I. Course Title : Advances in Microbial Genetics

II. Course Code : DM 612

III. Credit Hours : 3+0

IV. Why this course?

Microbial genetics is the study of inheritance in microorganisms, including bacteria and fungi. This study covers the advancement of genetic expression and regulation in Prokaryotic system, genetic engineering/recombinant DNA technology, mutations, gene editing using advanced tools, etc. The course will also highlight applications of genetic tools.

V. Aim of the course

To familiarize the students with basic concepts of Microbial Genetics and impart them knowledge in advancements of Microbial Genetics and Genetic Engineering

VI. Theory

Unit I

Nucleic Acids: Structure of DNA – A, B and Z and triplex DNA, Function of DNA, RNA, DNA Replication models, Protein-Nucleic acid Interactions and helix-turn-helix (HTH) motif, Genetic Code.

Unit II

Mutations – Spontaneous and Induced mutations, Types of mutations; Mutagenic agents (Physical and Chemical), Molecular basis of Mutagenesis, DNA Damage and Repair – Molecular Mechanisms, Photoreactivation, Excision repair, mismatch repair, post replication repair and SOS repair. Site Directed Mutagenesis, Directed evolution, Targeted Genome Editing and CRISPR/Cas9.

Unit III

Prokaryotic Transcription; Promoters- Constitutive and Inducible; Operators; Regulatory elements; Initiation; Attenuation; Termination-Rho-dependent and independent; Transcriptional regulation-positive and negative; Operon models, -Lac, Gal and Trp. Translation: Translation machinery, translation process, Initiation, elongation, termination, factors of Protein Synthesis, peptide bond formation and translocation, Regulation of prokaryotic translation.

Unit IV

Plasmid - Structure and replication, types of plasmids, moveable genetic elements: Transposons, IS and Tn elements, molecular mechanism of transposition, Recombination in bacteria, homologous and non-homologous, 'illegitimate' recombination, and site-specific recombination; Transformation and competence factors, Transduction and Conjugation, structure of F plasmids, Hfr, Recombination methods as a tool for Gene mapping.

Unit V

Genetic Engineering/ rDNA–Restriction Enzymes – Types, Mode of action and application as a tool for gene manipulation, Vectors – Cloning and expression vectors, Construction of genomic and cDNA library, construction of full length cDNA, Microarray, Gene Silencing, Gene knock out.

Unit VI

Intracellular Signaling in microorganisms, cell-cell communication (quorum sensing), Signal transduction mechanism or pathways

Unit VII

Pyrosequencing, Illumina, Ion torrent, Nanopore sequencing technologies for whole genome and metagenome sequencing.

VII. Teaching Methods/ Activities

- Lectures
- Assignment (Reading/Writing)
- Student's Book/Journal Articles
- Student presentation
- Group Work
- Visit to the relevant industry or Laboratory

VIII. Learning outcome

After undergoing this course, the students are expected to deliver the following:

- To have knowledge on the biological significance of DNA and RNA
- To have an idea about the genetic expression and regulation in Prokaryotic system
- To know about the recent advancements in genetic engineering/recombinant DNA technology.
- To have exposure on gene editing using advanced tools.

IX. Suggested Reading

- Dyson MR and Durocher Y. 2007. *Expression Systems*. Scion Publ.
- Hartl D, Jones L and Elizabeth W. 2000. *Genetic Analysis of Genes and Genomes*. Jones Bartkett Publ.
- Watson JD, Tania AB, Stephen PB, Alexander G, Michael L and Richard L. 2017. *Molecular Biology of the Gene*. Pearson.
- Keuzer H and Massey A. 2001. *Recombinant DNA and Biotechnology*. 2nd Ed. ASM Press.
- Russell Peter J. 2014. *IGenetics: a molecular approach*. Pearson
- Streips UN and Yasbin RE. 2002. *Modern Microbial Genetics*. 2nd Ed. John Wiley and Sons.
- Synder L and Champness W. 2003. *Molecular Genetics of Bacteria*. 2nd Ed. ASM Publ.

I. Course Title : Advances in Dairy and Food Microbiology

II. Course Code : DM 621

III. Credit Hours : 3+0

IV. Why this course?

Functional foods have potentially positive effects on health beyond basic nutrition and promote optimal health and help to reduce the risk of life style diseases. This course covers biochemical pathways of Lactic acid bacteria for carbohydrate metabolisms or protein metabolisms, bacteriocins and their application as biopreservatives, encapsulation of microorganisms and enzymes for the delivery to the target site etc.

V. Aim of the course

To study and understand the current trends and recent concepts related to microbiology of dairy and other foods products.

VI. Theory

Unit I

Lactic acid bacteria in food fermentations, Important metabolic pathways of microorganisms, Current status of metabolism of starters cultures; Antibiotic resistance in lactic acid bacteria, Current trends in lactic starter for industrial applications and functional foods, Special additional cultures, Biofilm and their remedies, Future aspects in research and development of LAB.

Unit II

Current concepts in starter technology, Novel starter preservation techniques, DVS, Improving starter cultures for food fermentation by genetic manipulation/metabolic engineering, Development/formulation of new products based on dairy by-products, Bioactive metabolites and biogenic amines, Designer milk, Modern concepts in cheese ripening, Nutraceuticals and functional foods, Genetically modified foods/ products, Safety aspects of genetic engineered foods.

Unit III

Bacteriocins of lactic acid bacteria, Structure, function, transport and mode of action, Application of bacteriocins in food bio preservation, Non-bacteriocin antimicrobial compounds- reuterin, antifungal compounds, milk and food derived bioactive peptides and other antimicrobial compounds, Protective cultures, Antimicrobial packaging system, active packaging.

Unit IV

Newly emerging pathogens, Concepts in food toxicology, Food borne toxins, Rapid methods for detection in food borne pathogens, Current concepts in food quality and safety management, Control of food borne pathogens, Pasteurization, dehydration, freezing, fermentation, irradiation and chemical additives, microwave processing, microfiltration, bactofugation, Hurdle technology, modified atmosphere packaging and storage, novel technology in control of food based pathogens, Use of non-thermal technologies (ultra-high voltage electric fields, thermosonication hydrostatic pressure technology, cold plasma etc.) alternate-thermal technologies (ohmic heating, dielectric heating, infrared and induction heating etc.), Biological technologies (antibacterial enzymes, proteins and peptides) in food processing.

Unit V

Encapsulation as a means for delivery of bacteria and functional ingredients-microencapsulation and nanoencapsulation, nanotechnology, Immobilization of cell and enzymes and their use in dairy and food industry.

VII. Teaching Methods/ Activities

- Lectures
- Assignment (Reading/Writing)
- Student's Book/Journal Articles
- Student presentation
- Group Work
- Visit to the relevant industry or Laboratory

VIII. Learning outcome

After undergoing this course, the students are expected to deliver the following:
- Have knowledge on the functional dairy foods
- To have an idea about biochemical pathways of Lactic acid bacteria for carbohydrate metabolisms or protein metabolisms
- To know about the Bacteriocins and their application as biopreservatives.
- To have any idea about the encapsulation of microorganisms and enzymes for the delivery to the target site.

IX. Suggested Reading

- Ozer B and Evrendilek GA. 2014. *Dairy Microbiology and Biochemistry: Recent Developments*. CRC Press
- Bagchi D, Lau FC and Ghosh DK. 2010. *Biotechnology in Functional Foods and Nutraceuticals* (1st Edition, 2010) CRC Press, USA.
- Kwak HS. 2015. *Nano- and Microencapsulation for Foods*. Wiley Publishing
- Erkmen O and Bozoglu TF. 2016. *Food Microbiology: Principles into Practice*, 2 Volume Set. Wiley Publishing.
- Suvendu Bhattacharya. 2014. *Conventional and Advanced Food Processing Technologies*. Wiley Publishing.

I. Course Title : Advances in Food Safety of Dairy Products

II. Course Code : DM 622

III. Credit Hours : 3+0

IV. Why this course?

Food safety is used as a scientific discipline describing handling, preparation, and storage of food in ways that prevent food-borne illness. This study covers principles of safety in advanced food microbiological laboratory, general mechanism of microbial pathogenesis, emerging food borne pathogens, antimicrobial resistance in bacteria etc.

V. Aim of the course

To develop knowledge, understanding and application of foodborne pathogens at an advanced level to ensure safety of dairy products.

VI. Theory

Unit I

Milk borne diseases, public health concern and epidemiology Trends in food borne disease and implication; Methods of diseases transmission; Changing patterns in epidemiology of milk borne diseases; Impact of agricultural and modern food manufacturing practices in transmission of food borne diseases. Public health concern associated with milk and milk products; type of microbial spoilage, defects and control measures.

Unit II

General mechanism of microbial pathogenesis: Food borne infection by colonization and adhesion factors like Pilli or fimbriae, adhesion proteins, Food borne infection by biofilm formation; invasion and intracellular residence factors; Food borne infection by phagocytosis, invasion mediated induced phagocytosis; Food borne infection by iron acquisition; motility and chemotaxis; Food borne infection by invasion of immune system; Intoxication; Toxi-infection. Structure and function of exotoxins and endotoxin; Genetic regulation and secretary system for virulence factors.

Unit III

Growth, survival characteristics, virulence and infectivity of dairy pathogens; Growth and survival characteristics of *E. coli, Enterobacter sakazaki*, Salmonella, Shigella, *Yersinia enterocolitica,* Streptococcus sp., *L. monocytogenes*, *Mycobacterium avium* subsp. *paratuberculosis*, *Brucella* sp., *Campylobacter jejuni*, *Staph.aureus*, *B. cereus, Clostridium perfringens*, toxigenic fungi and viruses in milk and milk products, their pathology of illness, mode of transmission, incidence of illness, virulence and infectivity.

Unit IV

Microbiological risk assessment of dairy foods: Risk analysis principle and concept; Hazard identification and characterization; Exposer assessment;Risk characterization in dairy products; Risk assessment models (dose response/ exposer assessment models);Risk factors affecting microbial safety of raw and processed dairy foods; Risk profiling of pathogens in milk and milk products; Risk management issues and control strategies for dairy products.

Unit V

Antimicrobial resistance in dairy animals and public health concern: Global and national perspective of AMR in dairy sector; WHO priority list/ guidelines on AMR bacteria; National action plan on AMR. Surveillance/ Incidence of AMR bacteria in dairy food chain and public health concern Mechanisms of resistance development in AMR bacteria; Conventional and rapid diagnostics for detection of AMR bacteria in dairy foods.

VII. Teaching Methods/ Activities

– Lectures
– Assignment (Reading/ Writing)
– Student's Book/ Journal Articles
– Student presentation
– Group Work
– Visit to the relevant industry or Laboratory

VIII. Learning outcome

After undergoing this course, the students are expected to deliver the following:

– To have knowledge on principles of safety in advanced food microbiological laboratory
– To have an idea about the general mechanism of microbial pathogenesis
– To know about the emerging food borne pathogens
– To have knowledge on antimicrobial resistance in bacteria

IX. Suggested Reading

Schwarz S, Cavaco LM, Shen J and Aarestrup FM. 2018. *Antimicrobial Resistance in Bacteria from Livestock and Companion Animals* ASM Press.

- Haas CN, Rose JB and Gerba CP. *Quantitative Microbial Risk Assessment*. John Wiley and Sons.
- Kudva IT and Nicholson T. 2016. *Virulence Mechanisms of Bacterial Pathogens*. ASM Press.

- McVey DS, Kennedy M and Chengappa MM. 2013. *Veterinary Microbiology* John Wiley and Sons.
- Yoe C. 2016. *Principles of Risk Analysis: Decision Making Under Uncertainty*. Publisher - Technology and Engineering.
- Bhunia AK. 2019. *Foodborne Microbial Pathogens: Mechanisms and pathogenesis*. Springer-Verlag New York.

I. Course Title : Advances in Probiotics and Functional Foods

II. Course Code : DM 623

III. Credit Hours : 3+0

IV. Why this course?

Probiotics are live microbial food supplements that provide several health benefits, as they help in maintaining excellent stability and composition of the intestinal microbiota and boost the resistance against infection by pathogens. The requirement for probiotic functional foods is rapidly and progressively because of increased awareness of the public regarding the impact of food on health. This study covers prebiotics, synbiotics and postbiotics, functional food ingredients and their role in human health and nutrition, different mechanism of action of probiotics establishing through in vitro and in vivo studies, scientific assessment of probiotics/functional foods, next generation probiotics etc.

V. Aim of the course

To familiarize the student with the advancements in probiotics and functional foods

VI. Theory

Unit I

Probiotics: Characteristics of probiotics for selection, Stability during storage and passage to gastrointestinal tract.

Unit II

Probiotic mode of action and disease control: Homeostasis of disturbed commensal microbial flora in the gut, pathogen exclusion, production of antimicrobial substances, modulation of immune system, alteration of intestinal bacterial metabolite action, alteration of microecology of healthy humans and patients.

Unit III

Prebiotics, synbiotics and postbiotics: Concept and definitions, criteria, types and sources of prebiotics, prebiotics and gut microbiota.

Unit IV

Functional foods; Nutraceuticals, medical/health foods, functional foods ingredients and their role in human health and nutrition.

Unit V

Dairy based functional foods: Dahi, lassi, yoghurt, kefir, cheese, koumiss, functional fermented dairy beverages, and dairy based cereal foods, fortified fermented dairy foods.

Unit VI

Cereals, soya, plant based and other functional foods; Miso, Kimchi, Sauerkraut, Sake, Ogi, Gundruk, Natto, Doenjang, Tempeh, Douchi, Cheonggukjang, and Soy milk based fermented foods:(yoghurt, dahi, beverages and cheese), fermented meat products.

Unit VII

Microbial production of Bioactive compounds: Bacteriocins, Bioactive peptides, Conjugated Linoleic Acids, gamma-Aminobutyric acid, Vitamins (Folate, Riboflavin, Vitamin B12), Low calorie sugars (Xylitol, Sorbitol, Mannitol, Trehalose), Micronutrients (Selenium, Zinc).

Unit VIII

Health benefits of probiotics/functional foods: Gastrointestinal disorders, metabolic syndrome including cardiovascular diseases, diabetes and obesity, Brain health, Immunological disorders, cancer, health and wellbeing in Ageing, alcoholic and non-alcoholic liver disease, Reproductive and Hormonal disorders, mental health.

Unit IX

Scientific Assessment of probiotics/functional foods: Role of Biomarkers, Application of Proteomics, Metabolomics, Nutrigenetics and Nutrigenomics in establishing scientific evidence of functional foods for imparting health benefits.

Unit X

Regulations and Future prospects of probiotics and functional foods: Legal status of probiotics, safety and regulatory aspects and Future prospects.

Unit XI

Next generation probiotics (Designer probiotics): Robust probiotic strains with stress survival systems, enhanced adhesion ability and surface markers etc. and for mucosal delivery of vaccines.

VII. Teaching Methods/ Activities

- Lectures
- Assignment (Reading/Writing)
- Student's Book/Journal Articles
- Student presentation
- Group Work
- Visit to the relevant industry or Laboratory

VIII. Learning outcome

After undergoing this course, the students are expected to deliver the following:

- To have knowledge on the Prebiotics, synbiotics and postbiotics
- To have knowledge on functional food ingredients and their role in human health and nutrition
- To know about the different mechanism of action of probiotics establishing through *in vitro* and *in vivo* studies.
- To have any idea about the Scientific Assessment of probiotics/functional foods.

IX. Suggested Reading

- Huffnagle GB. 2008. *The Probiotics Revolution: The Definitive Guide to Safe*, Natural Health Solutions Using Probiotic and Prebiotic Foods and Supplements. Bantam, USA.
- Robert Keith Wallace (Author) and Samantha Wallace. 2017. *Gut Crisis: How Diet, Probiotics, and Friendly Bacteria Help You Lose Weight and Heal Your Body and Mind*. Dharma Publication, Fairfield, USA.
- Hae-Soo Kwak. 2015. *Nano- and Microencapsulation for Foods*. Wiley Publishing

- Edward R. (Ted) Farnworth. 2008. *Handbook of Fermented Functional Foods*. CRC Press
- Prajapati JB and Behare PV. 2018. *Textbook of Dairy Microbiology*. Directorate of Knowledge Management in Agriculture, ICAR, ISBN: 978-81-7164-182-6.
- Puniya AK. 2015. *Fermented Milk and Dairy Products*; CRC Press/ Taylor and Francis (ISBN 9781466577978)
- Frias J, Villaluenga CM and Peñas E. (Ed.). 2016. *Fermented Foods in Health and Disease Prevention*. Elsevier Inc.
- Sungsoo C, and Finocchiaro ET. 2010. *Handbook of prebiotics and probiotics ingredients: health benefits and food applications*. Boca Raton: Taylor and Francis.
- Owen Judith A and Janis Kuby. 2013. *Kuby immunology*. New York: W.H. Freeman.
- Tamang Jyoti Prakash. 2020. *Ethnic fermented foods and beverages of India: science history and culture*. Singapore: Springer.

Suggested Broad Topics for Master's and Doctoral Research

- Application of predictive microbiology:Modeling microbial responses in foods
- A process approach to quality management system
- Air micro-flora as spoilage and infectious agents in dairy industry
- Alternative methods of microbial quantification
- Animal studies of functional attributes of dairy organisms
- Anti-microbial packaging and MAP of foods
- Bioactive peptides and Nutraceuticals
- Biodegradation of pollutants and packaging of food materials in the environment
- Biodiversity of Indian probiotic cultures/ LAB
- Biofilms in dairy industry
- Bioprospecting of dairy foods for identification, characterization and classification of prevailing microbiota
- Bioremediation of food industry wastes and metabolic engineering
- Biosensor Based assays for the detection of pathogens
- Cloning and Expression of prokaryotic and Eukaryotic genes in *E. coli* and yeast systems
- Defined strain cultures for indigenous fermented milks
- Detection and enumeration of conventional and emerging pathogenic organisms and other contaminants in dairy foods
- Detection and enumeration of indicator organisms in dairy foods
- Detection of phages in dairy and food environment
- Development of direct-fed microbial for ruminants
- Development of indicators and biosensors from microbial metabolites
- Development of synbiotic products
- Effect of different nutrients on the growth and production of microorganisms
- Effect of natural environment on microbial growth and production
- Studies on bacterial growth kinetics in batch and continuous culture systems
- Emerging Foodborne pathogens
- Enhancing shelf life of foods through microbial fermentation
- Enrichment of poor-quality roughages by solid-state fermentation
- Evaluation lactic acid bacteria for production of functional biomolecules
- Fermentation Studies for cultivation of lactic acid bacteria
- Food toxins- bioremediation
- Formulation of novel pharmaceuticals and neutraceuticals
- Genetic improvement of starter cultures
- Genetic manipulation of lactic starter cultures
- Genetic modification of dairy cultures by rDNA technology

- Genetic modification of food through the use of food grade vectors
- Genetic modification of LAB
- Genomics and Proteomics of lactic acid bacteria
- Genotypic heterogeneity and diversity of microorganisms in fermented dairy foods
- Harnessing the potential of microbial growth in environmental depollution
- Improving functionality of probiotics through metabolic engineering
- Industrial production of metabolites such as recombinant proteins/enzyme in a bioreactor and downstream processing
- Manipulation of rumen microbial ecosystem
- Metabolic engineering of LAB
- Microbial stress metabolism and ecosystem
- Microorganisms as indicators of environment pollution
- Molecular diagnostics for detection and identification of food pathogens and dairy micro-organisms
- Molecular diagnostics in dairy/food industry
- Molecular techniques for detection of foodborne pathogens and their toxins
- Metagenomic analysis of gut microbiome
- Newly emerging pathogens- rapid method of identification
- Novel bacteriocins of LAB
- Novel bacteriocins of lactic acid bacteria
- Nutrient transport systems through cell-membrane of yeast and bacteria
- Nutritional and therapeutic value of probiotic products
- PCR based identification of dairy cultures and probiotic cultures
- PCR based identification of pathogens
- Phage resistance in lactic acid bacteria
- Plasmid borne genes, chromosomal integration and technological properties of LAB
- Preservation of leguminous/ non-leguminous fodder crops by ensiling
- Principles of bio-safety in establishment of pathogen testing laboratory in food industry
- Principles of food safety control programme on HACCP, standard sanitary operating procedures (SSOP) and GMP for dairy industry
- Probiotics: characterization, product formulations, novel probiotics, validation of health claims through animal and clinical trials
- Production of microbial biomass as single cell protein
- Rapid method for detection and identification of food pathogens
- Rapid methods for detection and identification of pathogens in milk and milk products.
- Recombinant proteins/ enzymes for application in food/ dairy industry
- Recombinant proteins/enzymes for application in dairy industry
- Regulation of metabolism for lactic acid and flavour production
- Resistance of Foodborne pathogens to emerging food processing technologies.
- Role of extremophiles in microbial ecology and industry
- Screening of prebiotics
- Stress induced injury: mechanism and application in hurdle technology
- Biofilms formation in milk handling and dairy processing environment
- Mode of action of antibacterial substances on cellular organelles
- Plasmid linked properties of dairy cultures
- Probiotic organisms by growing them under anaerobic conditions and their identification by PCR method
- Study of production of functional biomolecules by lactic acid bacteria
- Ultra-structure of spore forming and non-spore forming dairy/food microorganisms with

the help of electron microscopy
- Transformation of gene of interest in the bacterial hosts
- Trends in food borne diseases and implications; method of diseases transmission; principles of safety in a food microbiological laboratory
- Understanding probiotic functionality at molecular level and role as potential probiotic markers
- Use of microorganisms in conversion of food wastes in preparation of newer foods
- Whole genome shuffling/ DNA/ Family shuffling

List of Journals

- *Advances in Applied Microbiology*
- *Advances in Bioscience and Biotechnology*
- *Advances in Genetics*
- *Advances in Microbial Physiology*
- *Annals of Microbiology*
- *Annual Review of Microbiology*
- *Antonie van Leeuwenhoek*
- *Applied and Environmental Microbiology*
- *Applied Biochemistry and Microbiology*
- *Applied Microbiology and Biotechnology*
- *Archives of Animal Nutrition*
- *Archives of Microbiology*
- *Bioscience, Biotechnology and Biochemistry*
- *BMC Microbiology*
- *BMC Molecular Biology*
- *Brazilian Journal of Microbiology*
- *British Food Journal*
- *British Journal of Nutrition*
- *Canadian Journal of Microbiology*
- *Cellular Microbiology*
- *Clinical Microbiology*
- *Comparative Immunology Microbiology and Infectious Diseases*
- *Comprehensive Reviews in Food Science and Food Safety*
- *Critical Reviews in Environmental Science and Technology*
- *Critical Reviews in Food Science and Nutrition*
- *Critical Reviews in Microbiology*
- *Current Genetics*
- *Current Microbiology*
- *Current Opinion in Biotechnology*
- *Current Science*
- *Current Topics in Microbiology and Immunology*
- *Dairy Science and Technology (Le Lait)*
- *Environmental Microbiology*
- *Enzyme and Microbial Technology*
- *Eukaryotic Cell*
- *European Food Research and Technology*
- *European Journal of Clinical Microbiology and Infectious Diseases*
- *FEMS Microbiology Ecology*
- *FEMS Microbiology Letters*
- *FEMS Microbiology Reviews*

- *Food Analytical Methods*
- *Food and Function*
- *Food Bioscience*
- *Food Biotechnology*
- *Food Control*
- *Food Microbiology*
- *Food Microbiology and Food Safety*
- *Food Quality and Preference*
- *Food Research International*
- *Food Reviews International*
- *Food Science and Technology - Lebensmittel-Wissenschaft and Tech*
- *Food Science and Biotechnology*
- *Food Science and Technology International*
- *Food Technology and Biotechnology*
- *Foodborne Pathogens and Disease*
- *Frontiers in Cellular and Infection Microbiology*
- *Frontiers in Microbiology*
- *Frontiers in Molecular Biosciences*
- *Fungal Genetics and Biology*
- *Future Microbiology*
- *Gene*
- *Indian Journal of Animal Sciences*
- *Indian Journal of Dairy Science*
- *Indian Journal of Medical Microbiology*
- *Indian Journal of Microbiology*
- *Indian Journal of Veterinary Science*
- *Innovative Food Science and Emerging Technologies*
- *International Dairy Journal*
- *International Journal of Dairy Technology*
- *International Journal of Fermented Foods*
- *International Journal of Food Microbiology*
- *International Journal of Food Properties*
- *International Journal of Food Science and Nutrition*
- *International Journal of Food Science and Technology*
- *International Journal of General and Molecular Microbiology*
- *International Journal of Probiotics and Prebiotics*
- *Journal of Agricultural and Food Chemistry*
- *Journal of Animal and Feed Sciences*
- *Journal of Animal Science*
- *Journal of Applied Animal Research*
- *Journal of Applied Microbiology*
- *Journal of Bacteriology*
- *Journal of Basic Microbiology*
- *Journal of Biological Chemistry*
- *Journal of Biotechnology*
- *Journal of Dairy Research*
- *Journal of Dairy Science*
- *Journal of Food and Drug Analysis*
- *Journal of Food Biochemistry*

- *Journal of Food Composition and Analysis*
- *Journal of Food Processing and Preservation*
- *Journal of Food Protection*
- *Letters in Applied Microbiology*
- *Journal of Food Quality*
- *Journal of Food safety*
- *Journal of Food Science*
- *Journal of Food Science and Technology*
- *Journal of Functional Foods*
- *Journal of General and Applied Microbiology*
- *Journal of Industrial Microbiology and Biotechnology*
- *Journal of Industrial Microbiology and Biotechnology*
- *Journal of Medicinal Food*
- *Journal of Microbial Food Safety Standards*
- *Journal of Microbiology*
- *Journal of Microbiology and Biotechnology*
- *Journal of Microscopy*
- *Journal of Molecular Microbiology and Biotechnology*
- *Journal of Rapid Methods and Automation in Microbiology*
- *Journal of The Science of Food and Agriculture*
- *Journal of Virology*
- *Methods in Microbiology*
- *Microbial Ecology in Health and Disease*
- *Microbial Pathogenesis*
- *Microbiological Research*
- *Microbiology*
- *Microbiology and Molecular Biology Reviews*
- *Microbiology: Bacteriology, Mycology, Parasitology and Virology*
- *Molecular Biology*
- *Molecular Genetics, Microbiology, virology*
- *Nature*
- *Nature Biotechnology*
- *Nature Reviews Microbiology*
- *Plasmid*
- *PNAS*
- *Probiotics and Antimicrobial Proteins*
- *Process Biochemistry*
- *Quality Assurance and Safety of Crops and Foods*
- *Research in Microbiology*
- *Science*
- *Science of the Total Environment*
- *Systematic and Applied Microbiology*
- *The Lancet*
- *Trends in Food Science and Technology*
- *Trends in Microbiology*
- *Veterinary Microbiology*
- *Veterinary Research*
- *World Journal of Dairy and Food Sciences*
- *World Journal of Microbiology and Biotechnology*

ANNEXURE I

List of BSMA Committee Members for Dairy Science and Technology

(Dairy Technology/Dairy Engineering/Dairy Microbiology/Dairy Chemistry)
(Constituted by ICAR vide Office order No. F.No. 7/6/2017-EQR)

Name and designation	Address	Specialization
Dr R.R.B. Singh Director	ICAR-National Dairy Research Institute, Karnal, Haryana Present Address: Joint Director (Academics), ICAR-National Dairy Research Institute, Karnal, Haryana	Chairman
Dr Anil K. Puniya Dean	College of Dairy Science and Technology, Guru Angad Dev Veterinary and Animal Sciences, University, Ludhiana Present Address: Principal Scientist and Head, Dairy Microbiology Division, ICAR-National Dairy Research Institute, Karnal, Haryana	Convener
Dr J.B. Prajapati Professor and Dean	Dairy Microbiology Division, SMC College of Dairy Science, Anand Agricultural University, Anand, Gujarat	Dairy Microbiology
Dr Bimlesh Mann Principal Scientist and Head	Dairy Chemistry Division, ICAR-National Dairy Research Institute, Karnal, Haryana	Dairy Chemistry
Dr Atanu Jana Professor and Head	Dairy Technology Division, SMC College of Dairy Science, Anand Agricultural University, Anand, Gujarat	Dairy Technology
Dr S. Ravi KumarProfessor and Head (Rtd.)	Department of Dairy Engineering, College of Dairy Technology, Sri Venkateswara Veterinary University, Tirupati, Andhra Pradesh	Dairy Engineering
Dr Savita Sharma Professor	Department of Food Science and Technology, Punjab Agricultural University, Ludhiana, Punjab	Food Technology

Restructured and Revised
Syllabi of Post-graduate Programmes
Vol. 4

Agricultural Engineering

- Farm Machinery and Power Engineering
- Processing and Food Engineering
- Irrigation and Drainage Engineering
- Renewable Energy Engineering
- Soil and Water Conservation Engineering

Contents

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 4

Agricultural Engineering
– Farm Machinery and Power Engineering

Preamble

Three major points were kept in mind while preparing course curricula related to Farm Machinery and Power Engineering (1) the syllabus and courses taught at UG level as recommended by 6^{th} Dean committee (2) preparing students to keep pace with future requirement of the human resource in institutions and industry (3) to align the syllabus with ARS/NET examination.

Course curricula and course outlines in Farm Machinery and Power Engineering have been designed keeping in view the courses offered by the faculties from associated/ closely related disciplines, viz. Mechanical Engineering, Mathematics, Renewable Energy Engineering, Electrical, Electronics and Computer Engineering, Processing and Food Engineering, Civil Engineering, etc.

It becomes more important for the post graduate students to not only learn the recent advances but have also to be trained/ hands on experience in the modern and latest techniques in their major disciplines so that they can participate and contribute in the development and advancement in their related fields. Further, the shrinking job opportunities in the National Agricultural Research System (ICAR/SAUs) have put additional pressure on our education system to prepare students in tune with the demands of the corporate sector.

All courses are designed to cover all basic topics and by taking into consideration demands of corporate sector harnessing commercial aspects, modern research tools and their applications, supplementary skills required and enhancing the global competitiveness and employability of students. To meet these objectives new courses were added which covers areas: Machinery for Precision Agriculture, Automation and Control, Machinery for Horticulture and Protected Agriculture, Advance Manufacturing Technologies, Principles of Hydraulic and Pneumatic Systems, Ergonomics in Working Environment, Machinery for Special Farm Operations, Mechanics of Traction and its Application.

Further, existing courses were suitably modified and restructured by deleting topics already covered in UG, removing overlapping topics in different courses, adding topics/ courses to cover ARS/NET exam syllabus and topic important to the farm machinery industry and emerging trends in Farm Machinery & Power Engineering. The modified/revised courses cover the areas: Advances in farm machinery, Computer aided Design of Machinery, Design of Farm Machinery, Ergonomics in Working Environment, Machinery for Special Farm Operations, Mechanics of Traction and its Application.

The course content and syllabus upgraded make it more of practical oriented and as per ARS/NET Syllabus.

The ICAR recommendations for PG courses have been taken into consideration in framing these courses. It is hoped that these will prove very useful to the future students.

Course Title with Credit Load
M.Tech in Farm Machinery and Power Engineering

Major Courses (Requirement: 20 Credits)

Course Code	Course Title	Credit Hours
FMPE 501*	Soil Dynamics in Tillage and Traction	2+1
FMPE 502*	Testing and Evaluation of Agricultural Equipment	2+1
FMPE 503*	Ergonomics and Safety in Farm Operations	2+1
FMPE 504	Design of Tractor systems	2+1
FMPE 505	Design of Farm Machinery-I	2+1
FMPE 506	Design of Farm Machinery-II	1+1
FMPE 507*	Management of Farm Power and Machinery System	2+1
FMPE 511	Principles of Automation and Control	2+1
FMPE 512	Principles of Hydraulic and Pneumatic Systems	2+1
FMPE 513	Applied Instrumentation in Farm Machinery	2+1
FMPE 514	Systems Simulation and Computer Aided Problem Solving in Engineering	1+1
FMPE 515	Computer Aided Design of Machinery	0+2
FMPE 516	Advance Manufacturing Technologies	2+0
FMPE 517	Machinery for Precision Agriculture	2+1
FMPE 518	Machinery for Horticulture and Protected Agriculture	2+0

*Compulsory Course

Minor Courses (Requirement: 08 Credits)

Course Code	Course Title	Credit Hours
PFE 511	Engineering Properties of Biological Materials	2+1
ME 501	Mechatronics and Robotics in Agriculture	2+0
ME-504	Vibrations	2+1
ME-507	Fatigue Design	2+1
ME-515	Computer Aided Design	2+1
REE 503	Biomass Energy Conversion Technologies	2+1
REE 516	Agro Energy Audit and Management	2+1
CE 501	Dimensional Analysis and Similitude	1+1
CE 510	Experimental Stress Analysis	2+1
MATHS 501	Finite Element Methods	1+1
MATHS 502	Numerical Methods for Engineers	2+0
CSE 501	Big Data Analytics	2+1
CSE 502	Artificial Intelligence	2+1
CSE 505	Database Management System	2+1

Any other course(s) of other department other than course(s) from major can be taken as per recommendations of the student's advisory committee.

Supporting Courses (Requirement: 06 Credits)

Course Code	Course Title	Credit Hours
*STAT 501	Statistical Methods for Research Works	2+1
	Courses from subject matter fields (other than Major and Minor) relating to area of special interest and research problem can be taken as per recommendations of the student's advisory committee.	

*Compulsory Course

Common Courses (Requirement: 05 Credits)

Course Code	Course Title	Credit Hours
*PGS 501	Library and Information Services	0+1
*PGS 502	Technical Writing and Communications Skills	0+1
*PGS 503	Intellectual Property and its management in Agriculture	0+1
*PGS 504	Basic Concepts in Laboratory Techniques	0+1
*PGS 505	Agricultural Research, Research Ethics and Rural Development Programmes	0+1

*Compulsory Course

List of Other Essential Requirements

Course Code	Course Title	Credit Hours
FMPE 591	Masters' Seminar	0+1
FMPE 599	Masters' Research	0+30

Course Contents
M.Tech in Farm Machinery and Power Engineering

I. Course Title : Soil Dynamics in Tillage and Traction

II. Course Code : FMPE 501

III. Credit Hours : 2+1

IV. Aim of the course

To have an understanding of the principles of soil mechanics as applied to interaction of tillage tools and traction devices with soil in terms of soil forces and deformation during for soil cutting and generation of traction.

V. Theory

Unit I

Characterization of state of stress in a point: Derivation, representation by Mohr's Circle. Coulomb's law of friction and cohesion. Measurement of soil resistance properties: Direct shear box, torsion shear apparatus, tri-axial apparatus. Soil behaviour considerations: Soil water pressure and movement. Critical state soil mechanics: Soil stress-strain behaviour, shear rate effects.

Unit II

Soil cutting forces: The universal earthmoving equation, two dimensional cases, smooth vertical blade, smooth and rough raked blades in cohesive soil, unconstrained tool to soil adhesion. The shape of failure surfaces. Hettiaratchi's calculations, effect of soil weight. Soil cutting force by method of trial wedges.

Unit III

Extension of theory to three dimension: Hettiaratchi, Reece-Godwin and Spoor. Three dimensional wedges: McKyes and Ali, Grisso models. Dynamic effect: Inertial forces, change in soil strength. Concept of critical depth. Complex tool shapes: Curved tools-shank and foot tools-mould board plough. Soil Loosening and manipulation: Measurement of soil loosening and its efficiency. Draft force efficiency: Loosening and pulverization efficiency. Soil mixing and inversion: Soil properties, tool shape, tool speed and tool spacing.

Unit IV

Traction devices: Tyres, type, size, selection mechanics of traction devices. Maximum traction force: Soil deformation and slip, estimation of contact areas. Sinkage in soil: Rolling resistance, Bekker's formulae, McKyes formulae. Soil compaction by agricultural vehicles and machines.

VI. Practical

Measurements of soil shear strength by in-situ shear box apparatus and soil friction by friction plate. Measuring cone penetrometer resistance and working out tractive coefficients for tyres. Measurement of in-situ shear strength of soil by torsional vane shear apparatus. Solving problems on stress in soil. Solving problems on soil properties. Solving problems of tool forces. Problems on tillage tool forces, wheel slippage, tyre deflection, design and performance of traction devices.

VII. Learning outcome

The student will be able to understand the principles that govern manipulation of soil by tillage tools.

The student will be able to apply the principles of soil mechanics to theoretically calculate the forces on tillage tools during soil cutting and forces generated by tractor wheels.

VIII. Lecture schedule

S.No.	Topic	No of Lectures
1.	**Unit I** Characterization of state of stress in a point: Derivation, representation by Mohr's Circle.	2
2.	Coulomb's law of friction and cohesion.	**1**
3.	Measurement of soil resistance properties: Direct shear box, torsion shear apparatus, tri-axial apparatus.	2
4.	Soil behaviour considerations: Soil water pressure and movement.	1
5.	Critical state soil mechanics: Soil stress-strain behaviour, shear rate effects	2
6.	**Unit II** Soil cutting forces: The universal earthmoving equation, two dimensional cases, smooth vertical blade, smooth and rough raked blades in cohesive soil, unconstrained tool to soil adhesion.	3
7.	The shape of failure surfaces.	2
8.	Hettiaratchi's calculations, effect of soil weight.	2
9.	Soil cutting force by method of trial wedges.	2
10.	**Unit III** Extension of theory to three dimensions: Hettiaratchi, Reece-Godwin and Spoor.	2
11.	Three dimensional wedges: McKyes and Ali, Grisso models. Dynamic effect: Inertial forces, change in soil strength.	2
12.	Concept of critical depth.	1
13.	Complex tool shapes: Curved tools-shank and foot tools-mould board plough.	1
14.	Soil Loosening and manipulation: Measurement of soil loosening and its efficiency.	1
15.	Draft force efficiency: Loosening and pulverization efficiency.	1
16.	Soil mixing and inversion: Soil properties, tool shape, tool speed and tool spacing.	2
17.	**Unit IV** Traction devices: Tyres, type, size, selection mechanics of traction devices.	1
18.	Maximum traction force: Soil deformation and slip, estimation of contact areas.	1
19.	Sinkage in soil: Rolling resistance, Bekker's formulae, McKyes formulae.	2
20.	Soil compaction by agricultural vehicles and machines.	1
		32

IX. List of Practicals

S.No.	Topic	No of Practicals
1.	Measurements of soil shear strength by *in-situ* shear box apparatus and soil friction by friction plate.	3
2.	Measuring cone penetrometer resistance and working out tractive coefficients for tyres.	2
3.	Measurement of *in-situ* shear strength of soil by torsional vane shear apparatus.	1
4.	Solving problems on stress in soil.	2
5.	Solving problems on soil properties.	2
6.	Solving problems of tillage tool forces.	1
7.	Problems on wheel slippage and tyre deflection.	3
8.	Problems on design and performance of traction devices.	1
9.	Practical examination	1
	Total	**16**

X. Suggested Reading

- Gill WR and Van den Berg GE. 1968. *Soil Dynamics in Tillage and Traction.*
- Handbook 316, *Agricultural Research Service*, US Department of Agriculture, Washington DC, 1968.
- John BL, Paul KT, David WS and Makoto H. 2012. *Tractors and their Power Units.* 4th Edition. Springer Science & Business Media, ISBN: 81-239-0501-7, ASAE ISBN: 0-929355-72-5.
- Koolen AJ and Kuipers H. 1983. *Agricultural Soil Mechanics.* Springer-Verlag ISBN 13:978-3-642-69012-9.
- McKyes E. 1989. *Agricultural Engineering Soil Mechanics*, Elsevier science publishers B.V., P.O. Box 211, 1000 AE Amsterdam, the Netherlands.
- McKyes E. 2016. *Soil Cutting and Tillage: Vol 7.* Developments in Agricultural Engineering Elsevier R Science Publisher SBV.

I. Course Title : Testing and Evaluation of Agriculture Equipment

II. Course Code : FMPE 502

III. Credit Hours : 2+1

IV. Aim of the course

To enable the student to learn the procedure for testing of different farm machinery and the concept behind evaluation of different performance parameters of farm machinery and the standards adopted therein.

V. Theory

Unit I

Importance and significance of testing and types of testing. Test equipment, usage and limitations. Test procedures and various test codes: National and International.

Unit II

Laboratory and field testing of tillage and sowing machinery: Sub-soiler, laser land leveler, mould board Plough, disc plough, rotavator, cultivator, disc harrow, seed cum fertilizer drill and planter.

Unit III

Laboratory and field testing of manual and power operated intercultural machinery and plant protection machine.

Unit IV

Laboratory and field testing of reaper, thresher and chaff cutter.

Unit V

Laboratory and field testing of straw combine and combine harvester. Review and interpretation of test reports. Importance and need of standardization of components of agricultural equipment.

VI. Practical

Laboratory and field testing of selected farm equipment: Tillage, sowing and planting. Material testing of critical components. Accelerated testing of fast wearing components.

VII. Learning outcome

The student will be able to test farm machinery, prepare performance reports and also analyze the performance reports to find the suitability of a machinery for a given farm operation.

VIII. Lecture Schedule

S.No	Topic	No. of Lectures
1.	Introduction, various test codes, Test programs, testing terminology, procedures and type of testing systems	2
2.	Study of different types of Dynamometer	2
3.	Stationary diesel engine performance testing	2
4.	Tractor Test Codes and Data Interpretation Estimation of error	2
5.	Testing and evaluation of tillage machinery	2
6.	Testing and evaluation of seed-cum-fertilizers drills/planters	3
7.	Testing and evaluation of manually and power operated Sprayers	3
8.	Testing and evaluation of reapers and straw combines	1
9.	Testing and evaluation of combine harvester and threshers	3
10.	Testing and evaluation of manually and power operated chaff cutters	2
11.	Testing and evaluation of advanced machinery	2
12.	Reliability in Engineering with emphasis on agricultural machinery	2
13.	Discussion on Farm machinery codes	2
14.	Interpretations of the information given in different codes on farm machinery	1
15.	Formulation of test-code for machines that do not have any code.	2
16.	Current topics/discussion	1
	Total	**32**

IX. List of Practicals

S.No.	Topic	No of Practicals
1.	Lab testing of Stationary diesel engine for full load, variable load and governor test	2
2.	Lab Testing and evaluation of seed-cum-fertilizers drills	1
3.	Lab Testing and evaluation of seed-cum-fertilizers planters	1
4.	Lab Testing and evaluation of knapsack Sprayers	1

S.No.	Topic	No of Practicals
5.	Lab Testing and evaluation of nozzles	1
6.	Field testing of rotavators	1
7.	Lab testing of rotavators for soil sample analysis	1
8.	Testing and evaluation of reapers	1
9.	Testing and evaluation of combine harvester and threshers	1
10.	Testing and evaluation of chaff cutters	1
11.	Testing and evaluation of laser land leveler	1
12.	Case study of test reports of different agricultural implements	3
	Total	**15**

X. Suggested Reading

- Barger E L, Liljedahl J B and McKibben E C. 1967. *Tractors and their Power Units*. Eastern Wiley 4th Edition.
- *Indian Standard Codes for Agricultural Implements*. Published by BIS, New Delhi.
- Inns F M. 1986. *Selection, Testing and Evaluation of Agricultural Machines and Equipment*. FAO Service Bull. No.115.
- Mehta M L, Verma S R, Rajan P and Singh S K 2019. *Testing and Evaluation of Agricultural Machinery*. Daya Publishing House, Delhi.
- *Nebraska Tractor Test Code for Testing Tractor*, Nebraska, USA.
- Smith D W, Sims B G and O'Neill D H 2001. *Testing and Evaluation of Agricultural Machinery and Equipment -Principle and Practice*. FAO Agricultural Services Bull. 110.

I. Course Title : Ergonomics and Safety in Farm Operations

II. Course Code : FMPE 503

III. Credit Hours : 2+1

IV. Aim of the course

To understand the principles of the science of Ergonomics and its application to farm machinery in order to reduce drudgery in the use of tools and equipment and also make them safe and comfortable to operate.

V. Theory

Unit I

Description of human-machine systems. Ergonomics and its areas of application in the work system. History of ergonomics. Modern ergonomics.

Unit II

Anthropometry: Its role in daily life, principles in workspace and equipment design, design of manual handling tasks and application in equipment design. Human postures: Postural stress and its role in design of farm machinery.

Unit III

Human factors in tractor seat design: Entry system, controls, shape, colour coding, dial and indicators. Modern technology for comfort in driving places.

Unit IV

Physiological parameters: Psychological and mental stresses and their measurement techniques. Human energy expenditure: Calibration of subjects, human workload and its assessment.

Unit V

Safety considerations and operators protective gadgets in farm operations. Standards/codes for tractors and agricultural machinery safety.

VI. Practical

Identifying role of ergonomics in our daily life. Measurement of anthropometric dimensions of agricultural workers and establishing relationship between them. Determination of human requirements for field operation with manually operated equipment. Assessment of psychological/general load for specific agricultural operations. Calibration of human subject on bicycle ergometer and/ or treadmill for its energy output and physiological parameters like heart rate, oxygen consumption rate under laboratory conditions. Case studies of agricultural accidents and safety measure.

VII. Learning outcome

The student will be able to apply the concepts of ergonomics in the design of agricultural tools and equipment and also evaluate the ergonomic suitability of such equipment.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction to ergonomics, definition of ergonomics	1
2.	Operator- machine-environment system approach	1
3.	Relative advantages of man and machine, ergonomics in daily life	1
4.	Importance of ergonomics in agriculture and farm machinery	1
5.	History of ergonomics, modern ergonomics	1
6.	Man machine environment components, broad objectives of ergonomics	1
7.	Basic issues and processes under ergonomics for design and development of machine	1
8.	Anthropometry and its uses in daily life	1
9.	First hourly examination	1
10.	Principles of applied anthropometry in ergonomics	1
11.	Availability of anthropometric database for Indian agricultural workers	1
12.	Definitions and possible applications of anthropometric dimensions	2
13.	Workspace and equipment design	1
14.	Different modes of force application	1
15.	Design of manual handling tasks	1
16.	Biomechanics aspects in machine design	1
17.	Mid-semester examination	1
18.	Human posture, posture stresses and its role in design of agricultural machinery	1
19.	Work place design for standing and seated workers	2
20.	Human factors in tractor seat design	1
21.	Entry system, controls, shape, colour coding, dial and indicators	1
22.	Modern technology for safety and comfort in driving place	1
23.	Physiological and psychological parameters for ergonomic evaluation	1
24.	Physiological and psychological stresses and measurements techniques	1
25.	Human work load assessment, human energy expenditure	1
26.	Calibration of subjects – concept, importance and techniques	1
27.	Accidents and safety in agriculture operations, general safety guidelines	1
28.	Safety feeding systems for threshers and chaff cutters	1

S.No.	Topic	No. of Lectures
29.	Safety gadgets for tractors and trailers	1
30.	Standard/ codes for agricultural machinery safety	1
	Total	**32**

IX. List of Practicals

S.No.	Topic	No of Practicals
1.	Identify role of ergonomics in our daily life	1
2.	Measurement of anthropometric dimensions of agriculture workers and establishing relation between them	2
3.	Measurement of strength parameters	1
4.	Determination of human requirements of field operation with manual operated equipment	2
5.	Assessment of psychological/ general load for agricultural operations	1
6.	Assessment of stress on eyes by specific agricultural operation	1
7.	Noise measurement in tractors	1
8.	Calibration of human subject on bicycle ergometer	1
9.	Calibration of human subject on treadmill	1
10.	Measurement of physiological parameter, viz. heart/ pulse rate	1
11.	Measurement of oxygen consumption under laboratory conditions	1
12.	Case study of accidents and safety on tractors and trailers	1
13.	Case study of accidents and safety on chaff cutters and threshers	1
14.	Practical examination	1
	Total	**16**

X. Suggested Reading

- Bridger R S 2009. *Introduction to Ergonomics*. CRC Press, Boca Rotan, USA
- Sanders M S and McCormick E J 2000. *Human Factors in Engineering and Design*. McGraw Hill. 7th edition
- Astrand P, Rodahl K, Dahl H A and Stromme S B 2003. *Textbook of Work Physiology - Physiological Basis of Exercise*. McGraw Hill.
- Gite L P 2009. *Anthropometric and Strength Data of Indian Agricultural Workers for Farm Equipment Design*. Central Institute of Agricultural Engineering, Bhopal.
- Gite L P, Agrawal K N, Mehta C R, Potdar R R and Narwariya B S. 2019. *Handbook of Ergonomical Design of Agricultural Tools, Equipment and work Places*. Jain Brothers, New Delhi.

I. Course Title : Design of Tractor Systems

II. Course Code : FMPE 504

III. Credit Hours : 2+1

IV. Aim of the course

To introduce the student to the principles that direct the design of a tractor and its subsystems and enable the student to apply the concept of machine design in designing the subsystems and critical components.

V. Theory

Unit I

Design and types, research, development, design procedure, technical specifications of tractors, modern trends in tractor design and development, special design features of tractors in relation to Indian agriculture.

Unit II

Engine related terminology. Selection of stroke-bore ratio. Design of engine components; Piston, connecting rod, cylinder, cylinder head, crank shaft etc.

Unit III

Design of tractor systems like clutch, gearbox, steering, steering geometry, turning force, hydraulic system & hitching, chassis, operator's seat, work-place area and controls. Tire selection, aspect ratio etc.

Unit IV

Mechanics of tractor stability. Computer aided design and its application in farm tractors.

VI. Practical

Engine design calculations, transmission component design calculations. Extensive practices on the computer aided design packages.

VII. Learning outcome

The student will have an overview of the philosophy guiding the design of a tractor and also design tractor systems and components.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
	Unit I	
1.	Design and types, research, development, design procedure, technical specifications of tractors, modern trends in tractor design and development, special design features of tractors in relation to Indian agriculture.	3
	Unit II	
2.	Engine related terminology. Selection of stroke-bore ratio.	1
3.	Design of engine components: Piston, connecting rod, cylinder, cylinder head, crank shaft etc.	3
	Unit III	
4.	Design of tractor clutch	2
5.	Design of tractor gearbox	3
6.	Tractor steering system, functional requirements, steering geometry, turning force	2
7.	Steering system design parameters and design procedure	2
8.	Hydraulic system & hitching – principles of operation	2
9.	Hydraulic system - Design parameters and design procedures including design of pump, cylinder etc.	2
10.	Design of chassis	2
11.	Human factors in tractor design. Design of operator's seat	2
12.	Work-place area and controls	2
13.	Tire selection, aspect ratio etc.	1
	Unit IV	
14.	Mechanics of tractor stability. Dynamic and static analysis of forces acting on farm tractor, case studies.	3
15.	Computer aided design and its application in farm tractors	2
	Total	**32**

IX. List of Practicals

S.No.	Practical	No. of Practical
1.	Engine design calculations - Stroke-bore ratio determination - Design of radiator - Balancing of crankshaft	2
2.	Engine design calculations - Calculation of volumetric/thermal efficiencies	1
3.	Transmission component design calculations - Design of clutch	1
4.	Transmission component design calculations - Design of gear box and calculation of speed ratios	2
5.	Design of Ackerman steering. Calculation of turning radius.	1
6.	Design of brakes (mechanical and hydraulic)	2
7.	Design of hydraulic system	2
8.	Calculation for determination of centre of gravity of tractor, moment of inertia and stability	3
9.	Practice on the Computer Aided Design (CAD) packages for design of various components	2
	Total	**16**

X. Suggested Reading

- Barger EL Liljedahl JB and McKibben EC. 1967. *Tractors and their Power Units*. Wiley Eastern Pvt. Ltd.
- Macmillan RH. 2002. *The Mechanics of Tractor – Implement Performance and Worked Example*. University of Melbourne, Australia.
- Sharma PC and Agarwal DK. 2000. *Machine Design*. S K Kataria and Sons, Delhi.

I. Course Title : Design of Farm Machinery I

II. Course Code : FMPE 505

III. Credit Hours : 2+1

IV. Aim of the course

To understand the interaction of tillage tools with soil and design the components of the tillage tools based on their requirement and also to learn how the systems of planting machinery are designed.

V. Theory

Unit I

Farm machinery design: Modern trends, tasks and requirements, economic considerations of durability, reliability and rigidity. Physico-mechanical properties of soils. Technological process of ploughing. Wedge. Working process of mould board plough, determination of basic parameters. Design of coulters, shares, mould boards.

Unit II

Constructing of mould board working surface. Design of landside, frog, jointer. Forces acting on plough bottom and their effect on plough balance: Trailed, semi mounted and mounted plough. Draft on ploughs, resistance during ploughing. Design disk ploughs: Concave disk working tools, forces acting.

Unit III

Machines and implements for surface and inter row tillage; Peg toothed harrow, disk harrows, rotary hoes, graders, rollers, cultivators. Design of V shaped sweeps. Rigidity of working tools. Rotary machines: Trajectory of motion of rotary tiller tynes, forces acting, power requirement. Machines with working tools executing an oscillatory motion.

Unit IV

Methods of sowing and planting: Machines, agronomic specifications. Sowing inter-tilled crop. Grain hoppers: Seed metering mechanism, furrow openers and seed tubes. Machines for fertilizer application: Discs type broadcasters. Organic fertilizer application: Properties of organic manure, spreading machines. Liquid fertilizer distributors. Planting and transplanting: Paddy transplanters, potato planters.

VI. Practical

Design of mould board working surface; Coulter, frog, share, jointer, mould board plough. Trailed, semi mounted and mounted ploughs. Design of disc plough, disc harrow, peg tooth harrow, cultivators, sweeps. Design of rotary tiller. Design of traction and transport devices.

Design of seed drills; Metering mechanism, hopper, furrow opener. Fertilizer spreader, liquid fertilizer applicators and design of its sub systems. Design of paddy transplanters and potato planters.

VII. Learning outcome

The student will be able to appreciate the principles behind the design of tillage tools and planting machinery. He will be able to arrive at design configurations for such machines.

VIII. Lecture Schedule

S.No.	Topic	No of Lectures
1.	Farm machinery design: Modern trends, tasks and requirements, economic considerations of durability, reliability and rigidity.	3
2.	Farm machinery design: economic considerations of durability, reliability and rigidity.	2
3.	Physio-mechanical properties of soils.	1
4.	Technological process of ploughing. Wedge. Working process of mould board plough, determination of basic parameters.	2
5.	Design of coulters, shares, mould boards.	2
6.	Constructing of mould board working surface.	1
7.	Design of landside, frog, jointer.	1
8.	Forces acting on plough bottom and their effect on plough balance: Trailed, semi mounted and mounted plough.Draft on ploughs, resistance during ploughing.	2
9.	Design disk ploughs: Concave disk working tools, forces acting.	2
10.	Machines and implements for surface and inter row tillage: Peg toothed harrow, disk harrows, rotary hoes, graders, rollers, cultivators.	2
11.	Design of V shaped sweeps. Rigidity of working tools.	1
12.	Rotary machines: Trajectory of motion of rotary tiller tynes, forces acting, power requirement.	2
13.	Machines with working tools executing an oscillatory motion.	1
14.	Methods of sowing and planting: Machines' agronomic specifications. Sowing inter-tilled crop, Grain hoppers Seed metering mechanism Furrow openers and seed tubes.	2

S.No.	Practical	No. of Lectures
15.	Machines for fertilizer application: Discs type broadcasters.	1
16.	Organic fertilizer application: Properties of organic manure spreading machines. Liquid fertilizer distributors.	2
17.	Planting and transplanting: Paddy transplanters, potato planters.	1
18.	Case studies	2
	Total	**30**

IX. List of Practicals

S.No.	Practical	No of Practicals
1.	Design of mould board: Coulter, frog, share	1
2.	Design of mould board: mould board plough working surface, jointer.	1
3.	Trailed, semi mounted and mounted ploughs.	1
4.	Design of disc plough	1
5.	Design of disc harrow	1
6.	Design of peg tooth harrow	1
7.	Design of cultivators and sweep.	1
8.	Design of rotary tiller.	1
9.	Design of traction and transport devices.	1
10.	Design of seed drills: Metering mechanisms	1
11.	Design of seed drills: hopper and furrow opener.	1
12.	Design of Fertilizer application equipment: fertilizer spreaders	1
13.	Design of Fertilizer application equipment: liquid fertilizer applicators and design of its sub systems	1
14.	Design of paddy transplanters	1
15.	Design of potato planters.	1
	Total	**15**

X. Suggested Reading

- Bernacki C, Haman J and Kanafajski Cz. 1972. *Agricultural Machines Theory and Construction*. Vol.I. U.S. Dept. of Commerce, National Technical Information Service, Springfield, Virginia 22151.
- Bosoi ES, Verniaev OV, Smirnov II and Sultan-Shakh EG. 1990. *Theory, Construction and Calculations of Agricultural Machinery - Vol. I.* Oxonian Press Pvt. Ltd. No.56, Connaught Circle, New Delhi.
- Gill R and Vanden Berg GE. 2013. *Soil Dynamics in Tillage and Traction*. Scientific Publishers (India) ISBN-10: 8172338031.
- Yatsuk EP 1981. *Rotary Soil Working Machines Construction, Calculation and Design.* American Publishing Co. Pvt. Ltd, New Delhi.

I. Course Title : Design of Farm Machinery-II

II. Course Code : FMPE 506

III. Credit Hours : 1+1

IV. Aim of the course

To learn the engineering principles behind application of pesticides and the systems that implements the same. To learn the concepts behind design of crop harvesting and threshing equipment.

V. Theory

Unit I

Pesticide calculation examples. Multidisciplinary nature of pesticide application. Overview of chemical control integrated pest management. Targets for pesticide deposition. Formulation of pesticides.

Unit II

Spray droplets. Hydraulic nozzles. Power operated hydraulic sprayer design principles. Air assisted hydraulic sprayer design principles. Controlled droplet application. Electrostatically charged sprayers. Spray drift and its mitigation. Aerial spraying systems. Use of drones for spraying: Design of spray generation and application issues.

Unit III

Introduction to combine harvesters: Construction, equipment subsystems, power sub systems. Crop harvesting: Plant properties, physical and mechanical properties of plant stem, plant bending modelling. Properties of plant grain: Physical, mechanical, grain damage. Properties of MOG; Mechanical and aerodynamic.

Unit IV

Design of grain header; Orienting and supporting reel. Plant cutting cutter bar: Working process, cutter bar drive. Knife cutting speed pattern area. Design of auger for plant collection. Corn header: Working elements, snapping roll design, stalk grasping and drawing process. Corn ear detachment: Stalk cutting and chopping.

Unit V

Cereal threshing and separation; Design of tangential and axial threshing units. Performance indices of threshing units. Modelling material kinematics in different threshing units. Factors influencing the threshing process and power requirement. Separation process and design of straw walker. Cleaning Unit process and operation. Grain pan; Chaffer and bottom sieve. Blower design and flow orientation. Design of conveying system for grain. Straw choppers and shredders.

VI. Practical

Measurement of spray characters for different nozzles. Problems on sizing of sprayer components. Design of sprayer for special purpose: Orchard and tall trees. Harvesting machine. Problems on design of cutterbars, reels, platform auger, conveyors. Design of threshing drum: Radial and axial flow type. Design of cleaning and grading systems. Design of blowers.

VII. Learning outcome

The student will know the principles behind the design of crop spraying equipments and harvesting and threshing machinery.

VIII. Lecture Schedule

S.No.	Topic	No of Lectures
1.	Overview of chemical control integrated pest management.	1
2.	Targets for pesticide deposition. Formulation of pesticides.	1
3.	Multidisciplinary nature of pesticide application.	1
4.	Pesticide calculation examples.	2

S.No.	Topic	No of Lectures
5.	Spray droplets. Hydraulic nozzles. Power operated hydraulic sprayer design principles.	2
6.	Controlled droplet application. Spray drift and its mitigation.	1
7.	Air assisted hydraulic sprayer design principles. Electrostatically charged sprayers.	2
8.	Aerial spraying systems. Use of drones for spraying:	1
9.	Design of spray generation and application issues.	1
10.	Introduction to combine harvesters; Construction, equipment subsystems, power sub systems.	1
11.	Crop harvesting: Plant properties, physical and mechanical properties of plant stem, plant bending modelling.	1
12.	Properties of plant grain: Physical, mechanical, grain damage.	2
13.	Properties of MOG; Mechanical and aerodynamic.	2
14.	Design of grain header; Orienting and supporting reel. Plant cutting cutter bar.	2
15.	Working process, cutter bar drive. Knife cutting speed pattern area.	1
16.	Design of auger for plant collection.	1
17.	Corn header: Working elements, snapping roll design, stalk grasping and drawing process. Corn ear detachment: Stalk cutting and chopping.	2
18.	Cereal threshing and separation, Design of tangential and axial threshing units. Performance indices of threshing units.	2
19.	Modelling material kinematics in different threshing units. Factors influencing the threshing process and power requirement.	1
20.	Separation process and design of straw walker.	1
21.	Cleaning Unit process and operation. Grain pan: Chaffer and bottom sieve. Blower design and flow orientation.	2
22.	Design of conveying system for grain. Straw choppers and shredders.	2
	Total	**32**

IX. List of Practicals

S.No.	Practical	No of Practicals
1.	Measurement of spray characters for different nozzles.	1
2.	Problems on sizing of sprayer components.	1
3.	Design of spraying units – manual	1
4.	Design of spraying units – powered	1
5.	Design of sprayer for special purpose: Orchard and tall trees.	1
6.	Design of agitation units – mechanical and hydraulic	1
7.	Harvesting machines: Problems on design of shear type cutting mechanism	1
8.	Harvesting machines: Problems on design of impact type harvesting mechanism	1
9.	Harvesting machines: Problems on design of platform auger and conveyors.	1
10.	Harvesting machines: Problems on design of reels	1
11.	Design of threshing drum: Radial flow type.	1
12.	Design of threshing drum: Axial flow type.	1
13.	Design of cleaning systems.	1
14.	Design of grading systems.	1
15.	Design of blowers.	1
	Total	**15**

X. Suggested Reading

- Bernacki C, Haman J and Kanafajski Cz 1972. *Agricultural Machines Theory and Construction.* Vol-I. U.S. Department of Commerce, National Technical Information Service, Springfield, Virginia22151.
- Bindra, OS and Singh H. 1971. *Pesticides Application Equipments.* Oxford & IBH Publishing Co., New Delhi.
- Bosoi ES, Verniaev OV, Smirnov II and Sultan-Shakh EG. 1987. *Construction and Calculations of Agricultural Machinery - Vol.II.* Oxonian Press Pvt. Ltd. New Delhi.
- Miu P. 2016. *Combine Harvesters Modeling and Design.* CRC Press, Boca Raton, USA ISBN 13:978-1-4822-8237-5
- Thornhill EW and Matthews GA. 1995. *Pesticide Application Equipment for Use in Agriculture* Vol II. Mechanically powered equipment FAO Rome.

I. Course Title : Management of Farm Power and Machinery System

II. Course Code : FMPE 507

III. Credit Hours : 2+1

IV. Aim of the course

To understand how principles of management are applied to farm machinery systems to make them more effective and profitable.

V. Theory

Unit I

Importance and objectives of farm mechanization in Indian agriculture, its impact, strategies, myths and future needs. Estimation of operating cost of tractors and farm machinery. Management and performance of power, operator, labour. Economic performance of machinery, field capacity, field efficiency and factors affecting field efficiency.

Unit II

Tractor power performance in terms of PTO, drawbar and fuel consumption. Power requirement problems to PTO, DBHP.

Unit III

Selection of farm machinery, size selection, timeliness of operation, optimum width and problem related to its power selection. Reliability of agricultural machinery. Replacement of farm machinery and inventory control of spare parts.

Unit IV

Systems approach to farm machinery management and application of programming techniques to farm machinery selection and scheduling. Network Analysis: Transportation, CPM and PERT, dynamic programming, Markov chain.

VI. Practical

Study of latest development of different agricultural equipment and implements in India and other developing countries. Size selection of agricultural machinery. Experimental determination of field capacity of different farm machines. Study of farm mechanization in relation to crop yield. Determination of optimum machinery system for field crop and machine constraints. To develop computer program for the selection of power and machinery.

VII. Learning outcome

The student will be able to understand how farm machinery is selected and operated to make them economically viable.

VIII. Lecture Schedule

S.No.	Topic	No of Lectures
1.	Importance and scope of farm mechanization in Indian Agriculture	1
2.	Cost analysis of Farm Machinery and tractor, Breakdown analysis, Inflation.	2
3.	Measurement of power performance (PTO power, drawbar power and fuel consumption) of tractor and power tiller	3
4.	Study of field capacity and field efficiency of different farm machinery and factor affecting them	1
5.	Selection of Farm Machinery size wrt to power source and timeliness of operation	4
6.	Application of programming technique to problem of farm power and machinery selection.	4
7.	Replacement models, spare parts and inventory control	2
8.	Maintenance and scheduling of operations.	2
9.	Network analysis – transportation	2
10.	Network analysis – critical path method, PERT	2
11.	Network analysis – dynamic programming	3
12.	Network analysis – markov chain	3
13.	Linear programming, multivariable system, simplex algorithm. Theory of network.	3
	Total	**32**

IX. List of Practicals

S.No.	Topic	No of Practicals
1.	Introduction to latest development of advanced agricultural equipment's in India	3
2.	Experimental determination of field capacity of different farm machines	3
3.	Case studies on optimum size selection of agricultural machinery	3
4.	Determination of inventory of different farm machines for a farm of size 50 ha as per regional crop rotations	3
5.	To develop computer program regarding selection of farm machinery size and power requirement for a 10, 50 and 100 ha farm size	3
	Total	**15**

X. Suggested Reading

- Carveille LA. 1980. *Selecting Farm Machinery*. Louisiana Cooperative Extn. Services Publication.
- Culpin C. 1996. *Profitable Farm Mechanization*. Lock Wood and Sons, London.
- FAO. 1990. *Agricultural Engineering in Development: Selection of Mechanization Inputs*. FAO, Agri service Bulletin.
- Hunt D. 1979. *Farm Power and Machinery Management*. Iowa State University Press, USA.
- Kapoor VK. 2012. *Operation Research: Concepts, Problems and Solutions*. Sultan Chand and Sons, India.

- Singh S and Verma SR. *Farm Machinery Maintenance and Management*. DIPA, ICAR, KAB-I, New Delhi.

I. Course Title : Principles of Automation and Control

II. Course Code : FMPE 511

III. Credit Hours : 2+1

IV. Aim of the course

To learn the principles behind systems for industrial automation and control especially with respect to electronically implemented systems.

V. Theory

Unit I

Introduction to industrial automation and control: Architecture of industrial automation systems, review of sensors and measurement systems. Introduction to process control: PID control, controller tuning, implementation of PID controllers, special control structures, feed forward and ratio control, predictive control, control of systems with inverse response, cascade control, overriding control, selective control and split range control.

Unit II

Introduction to sequence control: PLCs and relay ladder logic, sequence control, scan cycle, RLL syntax, sequence control structured design approach, advanced RLL programming, the hardware environment, Introduction to CNC machines.

Unit III

Control of machine tools: Analysis of a control loop, introduction to actuators. Flow control valves, hydraulic actuator systems, principles, components and symbols, pumps and motors. Proportional and servo valves. Pneumatic control systems, system components, controllers and integrated control.

Unit IV

Control systems: Electric drives, introduction, energy saving with adjustable speed drives stepper motors, principles, construction and drives. DC motor drives: Introduction to DC-DC converters, adjustable speed drives. Induction motor drives: Introduction, characteristics, adjustable speed drives. Synchronous motor drive-motor principles, adjustable speed and servo drives.

Unit V

Networking of sensors, actuators and controllers, the fieldbus, the fieldbus communication protocol, introduction to production control systems.

VI. Practical

Control system practical: Characteristics of DC servomotor, AC/DC position control system. ON/OFF temperature control system. Step response of second order system, temperature control system using PID level control system. Automation: Introduction to ladder logic, writing logic and implementation in ladder. PLC programming, water level controller using programmable logic controller. Batch process reactor using programmable logic controller. Speed control of AC servo motor using programmable logic controller.

VII. Learning outcome

Understanding of the principles behind implementation of systems for automation and control.

VIII. Lecture Schedule

S.No.	Topic	No of Lectures
1.	Introduction to industrial automation and control	1
2.	Architecture of industrial automation systems	1
3.	Review of sensors and measurement systems-I	1
4.	Review of sensors and measurement systems-II	1
5.	Introduction to process control	1
6.	PID control, controller tuning and implementation of PID controllers,	1
7.	Special control structures, feed forward and ratio control	1
8.	Predictive control and control of systems with inverse response	1
9.	Cascade control, overriding control	1
10.	Selective control and split range control.	1
11.	Introduction to sequence control	1
12.	PLCs and relay ladder logic, sequence control and scan cycle,	1
13.	RLL syntax, sequence control structured design approach,	1
14.	Advanced RLL programming and the hardware environment,	1
15.	Introduction to CNC machines.	1
16.	Control of machine tools	1
17.	Analysis of a control loop	1
18.	Introduction to actuators.	1
19.	Introduction to flow control valves,	1
20.	Hydraulic actuator systems, principles, components and symbols	1
21.	Introduction to hydraulic pumps and motors	1
22.	Introduction about proportional and servo valves.	1
23.	Pneumatic control systems, system components and controllers and integrated control.	1
24.	Introduction about electric control systems	1
25.	Electric drives, energy saving with adjustable speed drives	1
26.	Stepper motors, principles, construction and drives.	1
27.	DC motor drives: Introduction to DC-DC converters, adjustable speed drives.	1
28.	Induction motor drives: Introduction, characteristics, adjustable speed drives	1
29.	Synchronous motor drive-motor principles, adjustable speed and servo drives.	1
30.	Networking of sensors, actuators and controllers,	1
31.	The field bus, the field bus communication protocol,	1
32.	Introduction to production control systems.	1
	Total	**32**

IX. List of Practicals

S.No.	Topic	No of Practicals
1.	Control system including characteristics of DC servomotor.	2
2.	AC/DC position control system	1
3.	Temperature control system	1
4.	Step response of second order system	2
5.	Temperature control system using PID level control system	1
6.	Introduction to ladder logic, writing logic and implementation in ladder.	2

S.No.	Topic	No of Practicals
7.	PLC programming	2
8.	Water level controller using programmable logic controller	1
9.	Batch process reactor using programmable logic controller	1
10.	Speed control of AC servo motor using programmable logic controller	1
	Total	**14**

X. Suggested Reading

- https://nptel.ac.in/downloads/108105063/
- Manesis S and Nikolakopoulos G. 2018. *Introduction to Industrial Automation. 1st Edition*, CRC Press. Textbook-ISBN 9781498705400-CAT#K24766

I. Course Title : Principles of Hydraulic and Pneumatic Systems

II. Course Code : FMPE 512

III. Credit Hours : 2+1

IV. Aim of the course

To understand the principles behind operation of hydraulic and pneumatic systems and their components and design simple hydraulic and pneumatic circuits and select components for the same.

V. Theory

Unit I

Hydraulic power, its advantages, applications, properties of hydraulic fluids, viscosity, bulk modulus, density. Concepts of energy of hydraulic systems, laws of fluid flow.

Unit II

Hydraulic pump and motors, principle, capacity, classifications, working, performance. Design of various types of pumps and motors.

Unit III

Actuators, types, design of linear actuator and rotary actuators. Hydraulic rams, gear motors, piston motors and their performance characteristics. Hose, filters, reservoirs, types of circuits, intensifier, accumulator, valves. Valve types: Direction control, deceleration, flow, pressure control, check valve and their working etc.

Unit IV

Hydraulic circuit design. Applications in farm power and machinery: Tractor, combine, farm machinery systems, hydrostatic system etc.

Unit V

Power pack, pneumatic circuits, properties of air. Compressors, types. Design of pneumatic circuits.

VI. Practical

Study of various hydraulic pumps, motors, valves, directional control valves, cylinder piston arrangements, engineering properties of hydraulic fluids, hydraulic system of tractor, power steering system.

VII. Learning outcome

Ability to design simple hydraulic and pneumatic circuits and to select the components for the same. To design hydraulic and pneumatic systems of farm Machinery.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction to hydraulic power, its advantages, applications.	1
2.	Properties of hydraulic fluids, viscosity, bulk modulus, density.	2
3.	Concepts of energy of hydraulic systems, laws of fluid flow.	1
4.	Introduction to hydraulic pump and motor.	1
5.	Principle of hydraulic pump and motor, capacity, classifications, working, performance.	1
6.	Design of various types of hydraulic pumps.	1
7.	Design of various types of hydraulic motors.	1
8.	Actuators, types, design of linear actuator and rotary actuators.	3
9.	Hydraulic rams, gear motors, piston, motors and their performance characteristics.	3
10.	Hose, filters, reservoirs, types of circuits, intensifier, accumulator, valves.	3
11.	Valve types: Direction control, deceleration, flow, pressure control, check valve and their working etc.	4
12.	Hydraulic circuit design.	2
13.	Applications in farm power and machinery: Tractor, combine, farm machinery systems, hydrostatic system etc.	3
14.	Power pack, pneumatic circuits, components of pneumatic systems, properties of air.	3
15.	Compressors, types. Design of pneumatic circuits.	3
	Total	**32**

IX. List of Practicals

S.No.	Practical	No. of Practicals
1.	Study of various hydraulic pumps	1
2.	Study of various hydraulic motors	1
3.	Study of various hydraulic valves	1
4.	Study of various hydraulic directional control valves	2
5.	Study of various hydraulic cylinder piston arrangements	1
6.	Engineering properties of hydraulic fluids	2
7.	Study of hydraulic system of tractor	1
8.	Study of power steering system	1
9.	Study of power pack, pneumatic circuits, components of pneumatic systems	2
10.	Practical examination	1
	Total	**13**

X. Suggested Reading

- Anthony E. 2003. *Fluid Power with Applications*. Pearsons Education (Singapore) Pvt. Ltd.
- Krutz G. 1984. *Design of Agricultural Machines*. John Wiley and Sons.
- Majumdar S R. 2003. *Oil Hydraulics Systems: Principles and Maintenance*. Tata McGraw Hill Co.
- Merritt HE. 1991. *Hydraulic Control System*. John Wiley and Sons Inc.

I. Course Title : Applied Instrumentation in Farm Machinery

II. Course Code : FMPE 513

III. Credit Hours : 2+1

IV. Aim of the course

To understand the operation of instruments that is used in design and evaluation of farm machinery and their application.

V. Theory

Unit I

Strain gauges, types and applications in two and three dimensional force measurement in farm machinery. Various methods of determining strain/stresses experimentally. Design, selection and analysis of strain gauges.

Unit II

Introduction to transducers (sensors). Active and passive transducers, analog and digital modes, null and deflection methods. Performance characteristics of instruments including static and dynamic characteristics.

Unit III

Load cells, torque meters, flow meters types and principles of working. Devices for measurement of temperature, relative humidity, pressure, sound, vibration, displacement (LVDT) etc. Recording devices and their types. Measuring instruments for calorific value of solid, liquid, and gaseous fuels.

Unit IV

Basic signal conditioning devices, data acquisition system. Micro computers for measurement and data acquisition. Data storage and their application including wireless communication. Application of sensors in farm machinery and power: Tractor and selected farm machinery.

VI. Practical

Calibration of load cells, torque meters, flow meters etc. Experiment on LVDT, strain gauge transducer, speed measurement using optical devices, vibration measurement, making of thermocouples etc, application of sensors in farm machinery like wheel hand hoe, etc.

VII. Learning outcome

The student will be able to select and implement suitable systems for measurement of different parameters like force, torque, speed and pressure etc, that are used in design and evaluation of Farm machinery.

VIII. Lecture schedule

S.No.	Lecture	No. of Lectures
	Unit I	
1.	Strain gauges and its types; working principle, wheatstone bridge measurement, commercial available strain gauges	2
2.	Applications of strain gauges in two and three dimensional force measurement in farm machinery	2
3.	Various methods of determining strain/stresses experimentally.	2
4.	Design, selection and analysis of strain gauges.	2

S.No.	Topic	No of Lectures
	Unit II	
5.	Introduction to transducers (sensors).	1
6.	Active and passive transducers, analog and digital modes, null and deflection methods.	2
7.	Performance characteristics of instruments including static and dynamic characteristics.	2
	Unit III	
8.	Load cells, torque meters, flow meters types and principles of working	3
9.	Devices for measurement of temperature and relative humidity	2
10.	Devices for measurement of pressure and sound	2
11.	Devices for measurement of vibration and displacement (LVDT)	2
12.	Recording devices and their types	1
13.	Measuring instruments for calorific value of solid, liquid, and gaseous fuels	2
	Unit IV	
14.	Basic signal conditioning devices and data acquisition system	1
15.	Micro computers for measurement and data acquisition; general purpose microcontrollers and microprocessors	2
16.	Data storage and their application including wireless communication	2
17.	Application of sensors in farm machinery and power: Tractor and selected farm machinery	2
	Total	**32**

IX. List of Practicals

S.No.	Topic	No of Practicals
1.	Calibration of Load Cells	2
2.	Calibration of Torque Meters	1
3.	Calibration of Flow Meters	1
4.	Experiment on LVDT.	2
5.	Experiment on Strain Gauge	1
6.	Speed measurement using optical devices	2
7.	Vibration Measurement	2
8.	Making of Thermocouples	2
9.	Application of Sensors in Farm Machinery like wheel hand hoe etc.	3
	Total	**16**

X. Suggested Reading

- Ambrosius EE. 1966. *Mechanical Measurement and Instruments*. The Ronald Press Company.
- Doeblin EO. 2004. *Measurement System- Application and Design*. Tata McGrawHill
- Nakra BC and Choudhary KK. 1985. *Instrumentation, Measurement and Analysis*.2nd Edition Tata McGraw Hill.
- Nachtigal CL (Editor). 1990. *Instrumentation and Control. Fundamentals and Application*. Wiley Series in Mechanical Engineering.
- Oliver FJ. 1971. *Practical Instrumentation Transducers*. Hayden book company Inc.

I. Course Title : Systems Simulation and Computer Aided Problem Solving in Engineering

II. Course Code : FMPE 514

III. Credit Hours : 1+1

IV. Aim of the course

To give the student orientation in simulation of continuous and discrete systems especially using computer programme and software.

V. Theory

Unit I

Mathematical modeling and engineering problem solving: Conservation laws and engineering. Computers and software: Software development, structured programming, logical representation. Modular programming. Approximation: Round off errors, truncation errors, significant figures, accuracy and precision.

Unit II

Nature of simulation: Systems models and simulation, discreet event simulation, time advance mechanisms, components of discrete event simulation model, simulation of single server queuing system. Program organization and logic, development of algorithm. Simulation of an inventory system.

Unit III

Solving roots of equation using computers. Application in: Ideal and non-ideal gas laws, open channel flows, design of an electric circuit, vibration analysis. Solving linear algebraic equation on computers: Naïve Gauss Elimination, techniques for improving solutions, LU decomposition and matrix inversion. Application in: Steady state analysis of chemical reactors, statically determinate truss, current and voltage in circuits, spring mass systems.

Unit IV

Optimization techniques. Search techniques: Golden Sections, quadratic interpolation. Application: Optimum design of tank, least cost treatment of waste water, power transfer for circuits. Solving ordinary differential equation on computers: Modeling engineering systems with ordinary differential equation, solution techniques using computers.

VI. Practical

Comparison of analytical and numerical solutions using Spread sheet. Generation of random variables. Generation of discreet and continuous random variate-coding. Implementation of single server queue on computer. Exercises with software packages for roots of equation: Solving linear algebraic equation, curve fitting and optimization. Solving simultaneous equation through Gauss elimination, solving steady state analysis of chemical reactors, statically determinate truss, current and voltage in circuits, spring mass systems on computers. Application of ordinary differential equation to solve mixed reactor problems, predator prey models and chaos.

VII. Learning outcome

Ability to analyze problems from a systems perspective and apply the principles to simulation of continuous and discrete engineering systems.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction to mathematical modeling in engineering problem solving, comparison of analytical and numerical approaches.	1
2.	Conservation laws applied to engineering, modeling simple system	1
3.	Computer modeling, computing environments software development process.	1
4.	Modular design, top down design, structured programming, – algorithm design.	1
5.	Program composition, quality control- testing and documentation software strategy.	1
6.	Approximation- round off errors- accuracy and precision – definitions, number system in the computer- truncation errors.	1
7.	Nature of simulation, systems models and simulation.	1
8.	Discreet event simulation, time advance mechanisms, components of discreet event simulation model.	1
9.	Principles of simulation of singular server queuing system.	1
10.	Programme organization and logic for single server queuing system.	1
11.	Development of algorithm, single server queuing system.	1
12.	Solving roots of equation in computers, graphical method.	1
13.	Developing algorithm for bisection method, false position method.	1
14.	Application of roots of equation to gas laws, open channel flows.	1
15.	Application of roots of equation to electric circuits, vibration analysis.	1
16.	Solving linear algebraic equation in engineering practices.	1
17.	Developing algorithm for Gaussian elimination.	1
18.	Pitfalls of elimination methods and remedies.	1
19.	Overview of LU decomposition.	1
20.	LU decomposition algorithms, calculating inverse of matrix.	1
21.	Application of linear algebraic equation to statically determinate truss.	1
22.	Application of linear algebraic equation to Circuit analysis.	1
23.	Application of linear algebraic equation to spring mass system.	1
24.	Introduction to optimization in engineering, Formulation of Problems.	1
25.	One dimensional unconstrained optimization, development of algorithm for golden sections.	1
26.	One dimensional unconstrained optimization quadratic interpolation.	1
27.	Application of optimization to design of tank.	1
28.	Application of optimization to waste water treatment problem.	1
29.	Application of optimization to power transfer circuits.	1
30.	Formulating engineering problems using ordinary differential equation.	1
31.	Solving ordinary differential equation using computers, Euler's method.	1
32.	Solving ordinary differential equation using modeling engineering systems, computers, Runge-kutta method.	1
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Exercises in developing simple programmes in C.	1
2.	Demonstration of solutions using analytical and numerical methods for simple problems.	1
3.	Development of programmes for generation of random variables.	1
4.	Writing programme for generating random variates.	1

S.No.	Topic	No of Practicals
5.	Writing programme for event advance mechanism of single server queuing system.	1
6.	Writing programme for arrival module of single server queuing system.	1
7.	Writing programme for departure module of single server queuing system and statistical performance.	1
8.	Writing programme for solution of roots of equation.	1
9.	Solving simple engineering problems using roots of equation.	1
10.	Development of algorithm for Gaussian elimination.	1
11.	Application of Gaussian elimination to mass balance problems and statically determinate truss.	1
12.	Application of Gaussian elimination to analysis of electrical circuits.	1
13.	Development of algorithm for Golden Sections and application.	1
14.	Application of optimization technique to design of tank.	1
15.	Application of optimization technique to waste water treatment.	1
16.	Predator prey models and chaos.	1
	Total	**16**

X. Suggested Reading

- Balagurusamy E. 2000. *Numerical Methods.*Tata McGraw Hill Publishing Company limited, New Delhi.
- Chapra SC and Canale RP. 1994. *Introduction to Computing for Engineers*. 2nd Edition McGraw Hill International Edition, New York.
- Dent JB and Blackie MJ. 1979. *System Simulation in Agriculture.* Applied Science Publishers Ltd., London.
- Law AM. 2015. *Simulation Modeling and Analysis*. McGraw Hill International Edition, New York.
- Schilling RJ and Harries SL. 2002. *Applied Numerical Methods for Engineers Using MATLAB and C.*Thomson Asia Pvt. Ltd. Singapore.
- Veerarajan T and Ramachnadran T. 2004. *Numerical Methods with Programmes in C and C++*. Tata McGraw Hill Publishing company limited, New Delhi.

I. Course Title : Computer Aided Design of Machinery

II. Course Code : FMPE 515

III. Credit Hours : 0+2

IV. Aim of the course

To learn the practice of designing components and assemblies based on computer aided drafting technique.

V. Practical

Learning 2D drafting: Controlling display settings, setting up units, drawing limits and dimension styles. Drawing and dimensioning simple 2D drawings, keyboard shortcuts. Working with blocks, block commands. Exercise in simple assembly in orthographic. Exercise in measuring and drawing simple farm machinery parts.
Learning 3D Drafting: Advantages of virtual prototyping-starting the 3D drafting environment, self learning tools, help and tutorials. Familiarizing with user interface, creating files and file organization, structuring and streamlining. Features of document window. Concept of coordinate system: Working coordinate system, model coordinate system, screen coordinate system, graphics exchange standards and

database management system. Working with feature manager and customizing the environment. Planning and capturing design intent. Documentation of design. Using design journal and design binder. Preliminary design review and layout.
Practice in drawing 2D sketches with sketcher and modifying sketch entries. Adding Reference geometry: Planes and axes. Adding relations and working with relations. Dimensioning a sketch. Exercises.
Parts and features: Sketched features and applied features, pattern and mirror features. Documenting design. Assembly: Creating and organizing assemblies, connecting parts and subassemblies with mates. Organizing the assembly by using layouts.
Exercise in creating drawing: Setting up and working with drawing formats, creating drawing views from the 3D model, making changes and modifying dimensions.
Case studies: Measuring and drawing assemblies of farm implements and their components.

VI. Learning outcome

The student will be able to conceptualize spatial concepts and design components and assemblies of Farm machinery and make graphic models using commercial CAD software like Solid Works, Catia and AutoCAD.

VII. List of Practicals

S.No.	Topic	No of Practicals
1.	Learning 2D drafting: Controlling display settings, setting up units, drawing limits and dimension styles.	2
2.	Drawing and dimensioning simple 2D drawings, keyboard shortcuts.	1
3.	Working with blocks, block commands. Exercise in simple assembly in orthographic.	1
4.	Exercise in measuring and drawing simple farm machinery parts.	2
5.	Learning 3D Drafting: Advantages of virtual prototyping-starting the 3D drafting environment, self learning tools, help and tutorials. Familiarizing with user interface, creating files and file organization, structuring and streamlining. Features of document window.	2
6.	Concept of coordinate system: Working coordinate system, model coordinate system, screen coordinate system, graphics exchange standards and database management system.	2
7.	Working with feature manager and customizing the environment. Planning and capturing design intent.	2
8.	Documentation of design. Using design journal and design binder. Preliminary design review and layout.	1
9.	Practice in drawing 2D sketches with sketcher and modifying sketch entries.	2
10.	Adding Reference geometry: Planes and axes. Adding relations and working with relations. Dimensioning a sketch. Exercises.	2
11.	Parts and features: Sketched features and applied features, pattern and mirror features. Documenting design.	2
12.	Assembly: Creating and organizing assemblies, connecting parts and subassemblies with mates.	2
13.	Organizing the assembly by using layouts.	1
14.	Exercise in creating drawing: Setting up and working with drawing formats, creating drawing views from the 3D model, making changes and modifying dimensions.	2
15.	Case studies: Measuring and drawing assemblies of farm implements and their components.	5
	Total	**32**

VIII. Suggested Reading

- Jankowski G and Doyle R. 2007. *SolidWorks® For Dummies®*, 2nd Edition, Published by Wiley Publishing, Inc. ISBN: 978-0-470-12978-4
- Shih R H. 2014. *AutoCAD 2014 Tutorial-First Level: 2D Fundamentals*. SDC Publications

I. Course Title : Advanced Manufacturing Technologies

II. Course Code : FMPE 516

III. Credit Hours : 2+1

IV. Aim of the course

To learn the modern manufacturing techniques and their application to manufacture of different components and assemblies.

V. Theory

Unit I

Material and their characteristics, structure and properties of materials, wood, ferrous, Non-ferrous, alloys, plastic, elastomers, ceramics and composites. Material selection and metallurgy: Equilibrium diagram, time temperature transformation curves, heat treatments, surface treatment: Roughness and finishing.

Unit II

Measurement and quality assurance: Quality control, tolerance, limits and clearance. Automated 3-D coordinate measurements. Advance casting processes and powder metallurgy. Forming process: Fundamentals of metal forming, hot and cold rolling, forging processes, extrusion and drawing.

Unit III

Workshop practices applied in prototype production, jigs and fixtures. Traditional machining processes: Cutting tools, turning, boring, drilling, milling and related processes. Non traditional machining processes fuzzy c-mean (FCM), electric discharge machining (EDM), laser beam machining (LBM), Abrasive jet machining (AJM), and Wire-electro-discharge machining (EDM).

Unit IV

Joining processes: Gas flame processes, arc processes, brazing and soldering, adhesive and bonding.

Unit V

Numerical control: Command system codes, programme, cutter position X and Y, incremental movements, linear contouring, Z movements and commands. Manufacturing systems and automation. Robotics and robot arms. 3-D printing. Integrated manufacturing production system.

Practical

Identification of material and their application. Study of heat treatment processes and their suitability with respect to materials. Tool and equipments for measurements: Tolerance limits, clearance and surface finish. Site visits for study of advanced manufacturing techniques. Case studies.

VI. Learning outcome

The students will be able to select suitable manufacturing technique to fabricate different components used in Farm machinery.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Material and their characteristics.	1
2.	Structure and properties of materials wood, ferrous, Non-ferrous, alloys, plastic, elastomers, ceramics and composites.	2
3.	Material selection and metallurgy: Equilibrium diagram, time temperature transformation curves.	1
4.	Heat treatments, surface treatment: Roughness and finishing.	2
5.	Measurement and quality assurance: Quality control, tolerance, limits and clearance.	1
6.	Automated 3-D coordinate measurements and practice.	2
7.	Advance casting processes and powder metallurgy.	1
8.	Forming process: Fundamentals of metal forming, hot and cold rolling, forging processes, extrusion and drawing.	2
9.	Forging processes, extrusion and drawing.	1
10.	Workshop practices applied in prototype production, jigs and fixtures.	1
11.	Traditional machining processes: Cutting tools, turning, boring, drilling, milling and related processes.	2
12.	Non traditional machining processes fuzzy c-mean (FCM), electric discharge machining (EDM), laser beam machining (LBM).	2
13.	Electric discharge machining (EDM), laser beam machining (LBM).	1
14.	Abrasive jet machining (AJM), and wire-electro-discharge machining (EDM).	2
15.	Joining processes: Gas flame processes, arc processes.	2
16.	Brazing and soldering processes.	1
17.	Adhesive and bonding processes.	1
18.	Numerical control: Command system codes.	1
19.	NC Programme, Robotics and robot arms.	2
20.	Cutter position X and Y, incremental movements, linear contouring, Z movements and commands.	1
21.	Manufacturing systems and automation.	1
22.	3-D printing and integrated manufacturing production system.	2
	Total	**32**

VIII. List of Practicals

S.No.	Topic	No. of Practicals
1.	Identification of material and their application.	2
2.	Study of heat treatment processes and their suitability with respect to materials.	5
3.	Tool and equipments for measurements: Tolerance limits, clearance and surface finish.	4
4.	Site visits for study of advanced manufacturing techniques.	2
5.	Case studies.	2
6.	Practical examination	1
	Total	**16**

IX. Suggested Reading

- Begeman ML, Ostwald PF and Amstead BH. 1979. *Manufacturing Processes: SI Version*. John Wiley and Sons. 7th Edition.
- Chapman PAJ. 1996. *Workshop Technology*, Part III. CBS Publisher and distributors Pvt

Ltd. 3rd Edition international Edition.
- Gupta RB. 2017. *Production Technology*, Vol I - Production Process. Satya Prakashan, New Delhi.
- Hoyos L. 2010. *Fundamentals of Tool Design*. American Society of Tool and Manufacturer Engineers. Sixth Edition.
- Jain RK. 1994. *Production Technology: A Textbook for Engineering Students*. Khanna Publishers, New Delhi.
- Polukin P, Gringerg B, Kantenik S, Zhadan V and Vasilye D. *Metal Process Engineering*, MIR Publishers Moscow.

I. Course Title : Machinery for Precision Agriculture

II. Course Code : FMPE 517

III. Credit Hours : 2+1

IV. Aim of the course

To learn the principles behind precision agriculture and the systems for implanting the same.

V. Theory

Unit I

Importance of precision agriculture. Mapping in farming for decision making. Geographical concepts of PA.Understanding and identifying variability

Unit II

Geographical Position System (GPS) Basics (Space Segment, Receiver Segment, Control Segment), Error and correction, Function and usage of GPS. Introduction to Geographic Information system (GIS), function of GIS, use of GIS for decisions. IDI devices usage in Precision Agriculture Yield monitor, variable rate applicator for fertilizers, seed, chemicals etc. Remote sensing Aerial and satellite imagery. Above ground (non-contact) sensors.

Unit III

Data analysis, concepts of data analysis, resolution, Surface analysis. Analysis application interpretive products (map, charts, application map etc).

Unit IV

Electronics and Control Systems for Variable rate applications, Precision Variable Equipment, Tractor-Implement interface technology, Environmental Implications of Precision Agriculture.

Unit V

Goals based on end results of Precision Agriculture, Recordkeeping, Spatial Analysis, Variable Rate Application, Reducing of negative environmental impact, Crop/ technology cost optimization. Economic of precision agriculture and determining equipment and software, review of Cost/Benefit of Precision Agriculture, System vs. Parcels. Making a selection.

VI. Practical

Calculation of the benefits of Data and Mapping, Determining Latitude/Longitude, UTM or State Plane Position Navigation with Waypoints, Configuring a GPS System. Defining area of field for prescriptive treatment. Making the Grid, The Grid Sampling Process, generation of yield maps, Thematic or Spatial Resolution, Yield

Map Example, Surface Analysis in Arc-View.

VII. Learning outcome

Knowledge about the principles guiding the concept of precision agriculture and Farm Machinery and equipment systems that make muse of this principle.

VIII. Lecture Schedule

S.No.	Topic	No of Lectures
1.	Introduction to precision agriculture, its importance and applications	1
2.	Mapping in farming for decision making and geographical concepts of PA.	2
3.	Understanding and identifying variability	1
4.	Introduction to Geographical Position System (GPS). Function and usage of GPS	2
5.	Basics of GPS (Space Segment, Receiver Segment, Control Segment), Error and correction	2
6.	Introduction to Geographic Information system (GIS), function of GIS, use of GIS for decisions.	2
7.	Remote sensing including aerial and satellite imagery	2
8.	IDI devices usage in Precision Agriculture Yield monitor, variable rate applicator for fertilizers, seed, chemicals etc. Above ground (non-contact) sensors	2
9.	Data analysis, concepts of data analysis	3
10.	Surface analysis. Analysis application interpretive products (map, charts, application map etc)	2
11.	Precision Variable Equipment	2
12.	Electronics and Control Systems for variable rate applications	2
13.	Tractor-Implement interface technology, Environmental Implications of Precision Agriculture	2
14.	Recordkeeping, Spatial Analysis	2
15.	Rate Application, reducing of negative environmental impact, Crop/technology cost optimization	2
16.	Economic of precision agriculture and determining equipment	2
17.	Review of Cost/Benefit of Precision Agriculture, Making a selection	2
	Total	**33**

IX. Practical Schedule

S.No.	Topic	No of Practicals
1.	Calculation of the benefits of data and mapping	1
2.	Determining Latitude/Longitude, UTM or State Plane Position Navigation with Waypoints	2
3.	Configuring a GPS System	1
4.	Defining area of field for prescriptive treatment	1
5.	Making the grid and grid sampling process	2
6.	Collection of tractor-implement interface data	1
7.	Generation of yield maps	2
8.	Example of spatial and temporal variability and resolution	1
9.	Surface Analysis using software like Arc-View	2
10.	Economic of precision agriculture and determining equipment	2
11.	Cost/Benefit of Precision Agriculture for making a optimized selection	2
	Total	**17**

X. Suggested Reading

- Clay SA, Clay DE and Bruggeman SA. 2017. *Practical Mathematics for Precision Farming* American Society of Agronomy, Crop Science Society and Soil Science Society of America, 5585 Gulford Rd, Madison, WI 53711
- Henten EJV, Goense D and Lokhorst C. 2009. *Precision Agriculture*. Wageningen Academic Publishers.
- Ram T, Lohan SK, Singh R and Singh P. 2014. *Precision Farming: A New Approach*. Astral International Pvt. Ltd., New Delhi, ISBN: ISBN 978-81-7035-827-5 (Hardbound) ISBN 978-93-5130-258-2 (International Edition).
- Shannon DK, Clay DE and Kitchen NR (editors). 2018. *Precision Agriculture Basics* American Society of Agronomy, Crop Science Society and Soil Science Society of America, 5585 Gulford Rd, Madison, WI 53711
- Singh AK and Chopra UK. 2007. Geoinformatics Applications in Agriculture. New India Publishing Agency, PritamPura, New Delhi.

I. Course Title : Machinery for Horticulture and Protected Agriculture

II. Course Code : FMPE 518

III. Credit Hours : 2+0

IV. Aim of the course

To learn about the different machinery used in cultivation of vegetable crops, orchard crops and also in protected agriculture.

V. Theory

Unit I

Vegetable cultivation, nursery machinery, tray seeders, grafting machines, vegetable trans-planters. Machinery for planting crops on raised beds, mulch laying and planting machines. Harvesting of vegetable crops: Harvesting platforms and pickers.

Unit II

Machinery for orchard crops: Pit diggers, inter-cultivators and basin forming equipment for orchards. Machinery for transplanting of trees. Harvesters for fruit crops: Shaker harvesters, types and principle of operation. Elevated platforms for orchard management and harvesting. Pruning machines.

Unit III

Machinery for orchards, vineyard machinery spraying machines, inter-cultivation machines. High clearance machines and special purpose machinery for crops on trellis. Machinery for special crops: Tea leaf harvesters, pruners and secateurs.

Unit IV

Machinery for lawn and garden: Grass cutters, special machinery for turf maintenance. Turf aerators and lime applicators.

Unit V

Protected agriculture: Principles, mechanical systems of greenhouse, ventilation systems, shading system, water fogging system, irrigation system, sensors, electrical and electronic system. Intelligent Control system for greenhouses. Machinery for processing of growth media, tray filling machines-tray sowing machines, transplanting machines. Robotic grafting machines. Weeding and thinning equipment. Crop protection and harvest under protected agriculture.

VI. Learning outcome

Knowledge about different principles of mechanizing cultivation of horticultural crops and in protected agriculture.

VII. Lecture Schedule

S.No.	Topic	No. of Lecture
1.	History of vegetable cultivation in India and scope of mechanization in Horticulture	1
2.	Methods of Nursery propagation techniques and machinery for nursery and tray seeders	1
3.	Machinery for field preparation for vegetables (Disc harrows, Disc plough, offset rotavator, sub soiler, bed makers)	1
4.	Principles of mulch laying and planting machines. Types of vegetable transplanters and their construction and working	1
5.	Working and construction of subsurface drip laying machine. Types of planters for vegetable crops and its working	1
6.	Principles of Pneumatic vegetable seeders and its working. Machinery for harvesting of vegetable crops like root crop harvester, its construction and working	1
7.	Types of vegetable extraction machine, its working and construction	1
8.	Types of pickers, their construction and working	1
9.	Construction and working of different types of post hole diggers	1
10.	Types of tractors and their uses in orchards	1
11.	Types of inter cultivators and its construction and working.	1
12.	Types of brush cutters and its working	1
13.	Types of basin forming equipment for orchards. Machinery for transplanting of trees and their construction and working	1
14.	Types of elevated platforms for orchard management. Types of Tree Pruners and principles and its working and construction	1
15.	Types of fruit pluckers and its working and construction	1
16.	Principles and working and construction of shaker harvesters	1
17.	Types of vineyard machinery and its working and construction	1
18.	Types of spraying machines and its working and construction. High clearance machines and special purpose machinery for crops on trellis.	1
19.	Types of orchard sprayers, its working and construction	1
20.	Types of Tea leaf harvesters, pruners and secateurs and its working and Construction	1
21.	Special purpose machinery for crops on trellis	1
22.	Types of lawn and garden mowers and its working.	1
23.	Studies on special machinery for turf maintenance working and construction of Turf aerators and lime applicators	1
24.	Introduction to protected agriculture. Principles of protected agriculture	1
25.	Greenhouses - Mechanical systems, ventilation systems, shading system, water fogging system and irrigation system.	2
26.	Sensors, electrical and electronic system. Intelligent Control system for greenhouses	1
27.	Machinery for processing of growth media, tray filling machines-tray sowing machines, transplanting machines	1
28.	Robotic grafting machines. Weeding and thinning equipment	1
29.	Crop protection and harvest under protected agriculture	1
	Total	**30**

VIII. Suggested Reading

- Bell B and Cousins S. 1997. *Machinery for Horticulture.* Old Pond Publishing Ltd ISBN-10: 0852363699,ISBN-13: 978-0852363690
- *Good Agricultural Practices for Greenhouse Vegetable Production in the South East European countries* FAO Rome 2017.
- Ponce P, Molina A, Cepeda P, Lugo E and MacCleery B. 2014. *Greenhouse Design and Control.* CRC Press, ISBN 9781138026292 - CAT K23481, 1st Edition.

Course Title with Credit Load
Ph.D. in Farm Machinery and Power Engineering

Major Courses (Requirement: 12 Credits)

Course Code	Course Title	Credit Hours
FMPE 601*	Advances in Farm Machinery and Power Engineering	2+1
FMPE 602	Advances in Machinery for Precision Agriculture	2+1
FMPE 603	Energy Conservation and Management in Production Agriculture	3+0
FMPE 604	Mechanics of Tillage in Relation to Soil and Crop	2+1
FMPE 611	Mechanics of Traction and its Application	2+1
FMPE 612*	Farm Machinery Management and Systems Engineering	2+1
FMPE 613	Machinery for Special Farm Operations	2+1
FMPE 614	Ergonomics in Working Environment	2+1
	Total	17+7

Minor Courses (Requirement: 06 Credits)

Course Code	Course Title	Credit Hours
REE 615	Energy Planning Management and Economics	3+0
REE 602	Thermo-Chemical Conversion of Biomass	2+1
ME-507	Fatigue Design	2+1
ME-515	Computer Aided Design	2+1
CSE 506	Digital Image Processing	2+1

Any other course (s) of other department other than course(s) from major can be taken as per recommendations of the student's advisory committee.

Supporting Courses (Requirement: 05 Credits)

Course Code	Course Title	Credit Hours
*CPE-RPE	Research and Publication Ethics	1+1
	Courses from subject matter fields (other than Major and Minor) relating to area of special interest and research problem can be taken as per recommendations of the student's advisory committee.	

*Course has been made compulsory by UGC for PhD students. Course Code and its detailed course outline to be adopted in toto as recommended by UGC.

List of Other Essential Requirements

Course Code	Course Title	Credit Hours
FMPE 691	Doctoral Seminar-I	0+1
FMPE 692	Doctoral Seminar-II	0+1
FMPE 699	Doctoral Research	0+75

Course Contents
Ph.D. in Farm Machinery and Power Engineering

I. Course Title : Advances in Farm Machinery and Power Engineering

II. Course Code : FMPE 601

III. Credit Hours : 2+1

IV. Aim of the course

To familiarize the students about modern developments in construction, design and analysis of farm machinery systems as applied in different areas of agriculture.

V. Theory

Unit I

Advances in mechanization as applicable to Indian context. Future outlook for improving agricultural productivity and reducing cost. Mechanization: Review of the applications of some of the advanced mechanization technologies and constraints in adaptability. Levels of mechanization and transition between levels.

Unit II

Sustainable mechanization management: Management of compaction of agricultural fields. Strategies to develop machinery and systems that reduce compaction. Concept of Controlled Traffic Farming (CTF) systems. Introduction of wide span mechanization to vegetable production systems to enhance productivity and sustainability.

Unit III

Optimization of production processes to minimize energy loss in agriculture. The rationale for the use of photovoltaic systems in farming. The Energy Returned on Energy Invested (EROEI) ratio as an indicator for evaluating the efficiency of renewable energy sources.

Unit IV

board sensors, computing hardware, algorithms and software. Manipulator type ag-robots: Use in food processing, dairy, horticulture, and orchard industries.

Unit V

Precision Livestock Farming (PLF): Individual identification and monitoring of animals, tractability of livestock products. Developments in livestock and building control: Radio telemetry systems to remotely monitor and record physiological parameters. Silage process and their variants. Coordination of machinery system to enhance quality of silage and forage conditioners.

VI. Practical

Case studies and presentations on: Mechanization in India-analysis of machinery data- mechanization index and relation between productivity and mechanization. Levels of mechanization in different crops. Design of traffic lanes-field geometry and generating guideline lanes for operation of machinery. Planning use of multiple machinery-sugarcane harvesting system. Measurement of soil compaction due to heavy machinery using cone penetrometer. Machine vision system design–case studies. Challenges in development of robotic machinery in agricultural operations-case studies.

VII. Learning outcome

The students will be able to design, operate and maintain surface irrigation systems, surface and sub-surface pressurized irrigation systems, and managing crop productivity with poor quality of waters without deteriorating soil conditions.

VIII. Lecture schedule

S.No.	Topic	No. of Lectures
1.	Advances in mechanization as applicable to Indian context.	2
2.	Mechanization in large scale agricultural fields	1
3.	Mechanization in small scale agricultural fields	1
4.	Future outlook for improving agricultural productivity and reducing cost.	1
5.	Requirements of energy and fuels for machinery operations	2
6.	Case studies of the applications of some of the advanced mechanization technologies and constraints in adaptability.	2
7.	Case studies of Technology transfer mechanisms in India	1
8.	Levels of mechanization and transition between levels.	1
9.	Sustainable mechanization management.	1
10.	Management of compaction of agricultural fields.	1
11.	Strategies to develop machinery and systems that reduce compaction.	1
12.	Concept of Controlled Traffic Farming (CTF) systems.	1
13.	Introduction of wide span mechanization to vegetable production systems to enhance productivity and sustainability.	2
14.	Optimization of production processes to minimize energy loss in agriculture.	2
15.	The rationale for the use of photovoltaic systems in farming.	1
16.	The Energy Returned on Energy Invested (EROEI) ratio as an indicator for evaluating the efficiency of renewable energy sources.	2
17.	Machine vision system-hardware and software technologies, and machine learning and image analysis techniques.	1
18.	Unmanned agricultural ground vehicles (UAGVs)	1
19.	UAGVs instrumented mobile platform, on board sensors, computing hardware, algorithms and software.	1
20.	Manipulator type ag-robots: Use in food processing, dairy, horticulture, and orchard industries.	2
21.	Precision Livestock Farming (PLF): Individual identification and monitoring of animals, tractability of livestock products.	1
22.	Developments in livestock and building control: Radio telemetry systems to remotely monitor and record physiological parameters.	2
23.	Silage process and their variants. Coordination of machinery system to enhance quality of silage and forage conditioners.	1
24.	Silage and forage conditioners.	1
	Total	**32**

IX. List of Practicals

S.No.	Topic	No of Practicals
1.	Case studies of Mechanization in India	1
2.	Case studies of Mechanization in SAARC countries	1
3.	To find mechanization index.	1
4.	Relation between productivity and mechanization in India and Punjab.	1
5.	Relation between productivity and mechanization in developed countries.	1
6.	Levels of mechanization in cereal crops like paddy, Wheat etc.	1
7.	Levels of mechanization in Horticulture crops	1
8.	Levels of mechanization in cotton crop and pulses and oilseed crops	1
9.	Design of traffic lanes-field geometry and generating guideline lanes for operation of machinery.	1
10.	Planning use of multiple machinery-sugarcane harvesting system.	1
11.	Measurement of soil compaction due to heavy machinery using cone penetrometer.	1
12.	Machine vision system design–case studies.	1
13.	Machine vision system design–case studies.	1
14.	Unmanned agricultural ground vehicles (UAGVs) for different applications like spraying, imaging etc.	1
15.	Challenges in development of robotic machinery in agricultural operations-case studies.	1
16.	Developments in livestock and building control: Radio telemetry systems to remotely monitor and record physiological parameters.	1
	Total	**16**

X. Suggested Reading

- Chen G. (ed). 2018. *Advances in Agricultural Machinery and Technologies*. Boca Raton: CRC Press, https://doi.org/10.1201/9781351132398.
- Edwards GTC, Hinge G, Skou-Nielsen N and Villa-Henriksen A. 2017. *Route Planning Evaluation of a Prototype Optimized in Field Route Planner for Neutral Material Flow Agricultural Operations*. *Biosystems Engineering* **153**: 149-157. https://www.sciencedirect.com/science/article/pii/S1537511016303713.
- Seyyedhasani H. 2017. *Using the Vehicle Routing Problem (VRP) to Provide Logistic Solutions in Agriculture*. Ph.D. dissertation. University of Kentucky, Kentucky, USA. https://www. researchgate.net/publication/264791116_Advances in Agricultural Machinery Management A Review.
- Srivastava A K. 2006. *Engineering Principles of Agricultural Machines*. 2nd Edition American Society of Agricultural and Biological Engineers (ISBN) 1-892769-50-6 ASAE Publication 801M0206.

I. Course Title : Advances in Machinery for Precision Agriculture
II. Course Code : FMPE 602
III. Credit Hours : 2+1

IV. Aim of the course

Detailed study of the hardware system used in precision agriculture (PA) and techniques of using them in precision agriculture.

V. Theory

Unit I

Global navigation satellite system (GNNS). Satellite ranging: Accuracy, standards, components of GIS, data layers, map component, attribute table component, function of a GIS, resolution. Data formats: Vector or raster. GIS for precision farming, data analysis, field calculator, convert to grid, interpolation, reclassification, image classification, band math, interpretation of analysis, farm management information systems, and crop intelligence.

Unit II

Yield Monitors: Components, Differential GPS Receiver, GNSS Receiver, mass flow sensors. Impact plates, measuring volume with a photoelectric sensor. Using microwave radiation, and Gamma rays to estimate volume, volumetric flow sensing and alternatives. Grain moisture sensor, fan speed sensor, elevator speed sensor, header position, yield monitor data, cotton yield monitors.

Unit III

Sources of soil variability, general soil sampling basics, systematic variability, selecting a soil sampling strategy. Parameters: Electrical conductivity, electromagnetic sensors, sensing mechanical impedance. Proximal plant sensing systems, crops canopy reflectance and fluorescence. Machine vision thermal sensors, mechanical sensors, acoustic sensors.

Unit IV

Remote sensing platforms: Aircraft or satellite. Sensors: Imaging or non imaging, active or passive. Making use of reflected energy or emitted energy. The spectral signature of vegetation, vegetation indices, application to agriculture, nutrient management, weed management, disease and insect management, water management.

VI. Practical

Simple programming for automating precision farming calculations. Mathematics of longitude and latitude. Spatial statistics, soil sampling and understanding soil testing results for precision farming, calculations. Supporting management zones, understanding soil, water and yield variability in precision farming. Developing prescriptive soil nutrient maps, essential plant nutrients, fertilizer sources, and application rates calculations. Deriving and using an equation to calculate economic optimum fertilizer and seeding rates cost of crop production.

VII. Learning outcome

Ability to understand design and operate PA systems.

VIII. Lecture schedule

S.No.	Topic	No. of Lectures
1.	Introduction about Global navigation satellite system (GNNS	1
2.	Satellite ranging including accuracy, standards etc.	1
3.	Differential GNSS Receiver, RTK etc.	1
4.	Components of GIS, data layers, map component,	1
5.	Attribute table component, function of a GIS, resolution.	1
6.	Data formats: Vector or raster.	1
7.	GIS for precision farming, data analysis, field calculator, convert to grid,	1
8.	Interpolation, reclassification, image classification, band math and interpretation of analysis.	1

S.No.	Topic	No. of Lectures
9.	Farm management information systems, and crop intelligence.	1
10.	Introduction about Yield monitors and its components	1
11.	Mass flow and impact plate sensors, measuring volume with a photoelectric sensor. Lecture 12: Microwave radiation and Gamma rays to estimate volume,	1
12.	Different types of grain moisture sens	1
13.	Fan speed sensor, elevator speed sensor, header position, yield monitor data,	1
14.	Yield monitors for non-grain crops	1
15.	Sources of soil variability, general soil sampling basics, systematic variability Lecture 17: Selecting a soil sampling strategy.	1
16.	Proximal and remote sensing based soil sensors	1
17.	Electromagnetic based sensors for soil electrical conductivity measurement	1
18.	Sensing mechanical impedance based sensors for soil compaction	1
19.	Spectroscopy for determination of soil properties	1
20.	Introduction about proximal plant sensing systems	1
21.	Remote sensing platforms: Aircraft or satellite.	1
22.	Type of plant sensors: Imaging or non imaging, active or passive.	1
23.	Use of reflected or emitted energy for vegetation detection	1
24.	The spectral signature of vegetation, vegetation indices, application to agriculture	1
25.	Sensing system for nutrient management,	1
26.	Crops canopy reflectance and fluorescence.	1
27.	Machine vision thermal sensors, mechanical sensors, acoustic sensors	1
28.	Sensors for weed detection and management	1
29.	Sensing Techniques for disease and insect management,	1
30.	Different type of sensors/devices for water management.	1
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Simple programming for automating precision farming calculations	1
2.	Mathematics of longitude and latitude	1
3.	Spatial and temporal statistics using GIS	1
4.	Soil sampling strategies, understanding and results for precision farming	1
5.	Creation of management zones	1
6.	Measurement of yield variability in the field	1
7.	Measurement of soil Compaction in the field	1
8.	Measurement of soil EC in the field	1
9.	Measurement of soil pH in the field	1
10.	Developing and understanding prescriptive soil nutrient maps	1
11.	Measurement of essential plant nutrients in the field	1
12.	Fertilizer sources, and application rates calculations	1
13.	Deriving and using an equation to calculate economic optimum fertilizer	1
14.	Calculation of optimum seeding rates for optimized returns	1
15.	Cost of crop production using precision technologies.	1
	Total	**15**

X. Suggested Reading

- Clay DE, Clay SA and Bruggeman SA. 2017. *Practical Mathematics for Precision Farming*. American Society of Agronomy, Madison, WI, USA.
- Ram T, Lohan SK, Singh R and Singh P. 2014. *Precision Farming: A New approach*. Astral International Pvt. Ltd., New Delhi, India. ISBN: ISBN 978-81-7035-827-5 (Hardbound) ISBN 978-93-5130-258-2 (International Edition).
- Shannon DK, Clay DE and Kitchen NR Newell. 2018. *Precision Agriculture Basics*. American Society of Agronomy, Inc., Madison, WI, USA.
- Singh AK and Chopra UK. 2007. *Geoinformatics Applications in Agriculture*. New India Publishing Agency, New Delhi, India.
- Van-Henten EJ, Goense D and Lokhorst C. (ed). 2009. *Precision Agriculture*. Wageningen Academic Publishers, Wageningen, Netherlands.

I. Course Title : Energy Conservation and Management in Production Agriculture

II. Course Code : FMPE 603

III. Credit Hours : 3+0

IV. Aim of the course

Detailed study of the hardware system used in precision agriculture (PA) and techniques of using them in precision agriculture.

V. Theory

Unit I

Global navigation satellite system (GNNS). Satellite ranging: Accuracy, standards, components of GIS, data layers, map component, attribute table component, function of a GIS, resolution. Data formats: Vector or raster. GIS for precision farming, data analysis, field calculator, convert to grid, interpolation, reclassification, image classification, band math, interpretation of analysis, farm management information systems, and crop intelligence.

Unit II

Yield Monitors: Components, Differential GPS Receiver, GNSS Receiver, mass flow sensors. Impact plates, measuring volume with a photoelectric sensor. Using microwave radiation, and Gamma rays to estimate volume, volumetric flow sensing and alternatives. Grain moisture sensor, fan speed sensor, elevator speed sensor, header position, yield monitor data, cotton yield monitors.

Unit III

Sources of soil variability, general soil sampling basics, systematic variability, selecting a soil sampling strategy. Parameters: Electrical conductivity, electromagnetic sensors, sensing mechanical impedance. Proximal plant sensing systems, crops canopy reflectance and fluorescence. Machine vision thermal sensors, mechanical sensors, acoustic sensors.

Unit IV

Remote sensing platforms: Aircraft or satellite. Sensors: Imaging or non imaging, active or passive. Making use of reflected energy or emitted energy. The spectral signature of vegetation, vegetation indices, application to agriculture, nutrient management, weed management, disease and insect management, water management.

VI. Practical

Simple programming for automating precision farming calculations. Mathematics of longitude and latitude. Spatial statistics, soil sampling and understanding soil testing results for precision farming, calculations. Supporting management zones, understanding soil, water and yield variability in precision farming. Developing prescriptive soil nutrient maps, essential plant nutrients, fertilizer sources, and application rates calculations. Deriving and using an equation to calculate economic optimum fertilizer and seeding rates cost of crop production.

VII. Learning outcome

Ability to understand design and operate PA systems.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction	1
2.	Classification of energy	2
3.	Energy coefficients	2
4.	Energy requirements for wheat production	2
5.	Energy requirements for paddy production	2
6.	Energy requirements for maize production	2
7.	Energy requirements for cotton production	2
8.	Energy requirements for oil seeds production	1
9.	Energy requirements for pulse production	2
10.	Energy requirements for production of other crops	2
11.	Energy requirements for vegetable production	2
12.	Energy requirements for fruit production	1
13.	Energy requirements for fish production	1
14.	Energy requirements for meat and milk production	2
15.	Limits of energy conservation	1
16.	Energy planning, management and forecasting in agriculture	3
17.	Design of integrated energy supply system	2
18.	Energy conservation and returns	2
19.	Assessment of energy conservation technology	2
20.	Case studies on application of various techniques of energy conservation and management	2
	Total	**36**

IX. Suggested Reading

- Mittal JP, Panesar BS, Singh S, Singh CP and Mannan KD. 1987. *Energy in Production Agriculture and Food Processing*. ISAE and School of Energy Studies for Agriculture, PAU Ludhiana, ISAE Publication.
- Pimental D. 1980. *Handbook of Energy Utilization in Agriculture*. CRC Press. Boca Rotan, USA.
- Singh S and Singh RS. 2014. *Energy for Production Agriculture*. DKMA, ICAR, New Delhi, India.

I. Course Title : Mechanics of Tillage in Relation to Soil and Crop

II. Course Code : FMPE 604

III. Credit Hours : 2+1

IV. Aim of the course

To have deeper understanding of the tillage process in terms of crop requirement, soil characteristics and machinery function.

V. Theory

Unit I

Soil condition and soil strength determining factors. General aspects of mechanical behavior of soil elements. Soil compaction, conditions for its occurrence. Methods of estimation of soil compaction by experimental stress distribution. Concept of soil distortion, deformation at constant volume. Expansion of soil at breaking.

Unit II

Occurrence of soil breaking fundamentals. Measures of resistance against breaking. Shear failure and Coulomb's law. Compaction v/s shear failure. Tensile failure of soil, idealized brittle failure, Griffith's Model. Loading rate and repeated loading effects. Draft calculation using mechanism of rigid soil bodies.

Unit III

Crop requirements: Root structure, Soil conditions and purpose of tillage, looseness of soil and depth of loosening. Structure of seed bed. Soil properties, properties affected by tillage and those not affected by tillage. Soil compaction, formation of clods and dust. Effect of tillage on erosion and water logging. Impact of climate factors on soil. Tillage requirement for various types of soils.

Unit IV

Tillage operations for special tasks. Preparation of soil for cropping and stubble management. Primary and secondary tillage. Ploughing and its effect on soil. Disc tillage: Appropriate conditions and effect. Requirement of seed bed and techniques of creating proper seed bed. Quality of sowing and sowing methods. Modern trends and objectives of soil tillage.

Unit V

Plough bodies: Generalized representation, intake main flow and output process. Main flow under different surface curvatures. Kinetic aspects of plough bodies with different shapes. Draft of plough bodies as affected by moisture, speed and attachments.

VI. Practical

Characterization of soil condition before and after tillage. Cone penetrometer resistance, bulk density, moisture content. Measurement of forces on tillage tools under soil bin condition/ field condition. Measurement of soil manipulation by different tillage tools: Pulverization, furrow profile, inversion and mixing. Measurement of energy required for soil breakup by different methods. Field study of crop root development in relation to soil compaction and hard pan. Measurement of moisture movement in different surface configuration: Ridges, furrows, raised bed and flat bed. Field evaluation of plant establishment in relation to planting parameters.

VII. Learning outcome

Ability to design tillage machinery based on engineering principles as applied tom tillage science.

VIII. Lecture Schedule

S.No.	Topic	Lecture No
	Unit I	
1.	Soil condition and soil strength determining factors.	**1**
2.	General aspects of mechanical behavior of soil elements.	**1**
3.	Soil compaction, conditions for its occurrence.	**2**
4.	Methods of estimation of soil compaction by experimental stress distribution.	1
5.	Concept of soil distortion, deformation at constant volume.	1
6.	Expansion of soil at breaking.	1
	Unit II	
7.	Occurrence of soil breaking fundamentals.	1
8.	Measures of resistance against breaking.	1
9.	Shear failure and Coulomb's law.	1
10.	Compaction v/s shear failure.	1
11.	Tensile failure of soil, idealized brittle failure, Griffith's Model.	1
12.	Loading rate and repeated loading effects.	1
13.	Draft calculation using mechanism of rigid soil bodies.	1
	Unit III	
14.	Crop requirements: Root structure, Soil conditions and purpose of tillage, looseness of soil and depth of loosening.	1
15.	Structure of seed bed. Soil properties, properties affected by tillage and those not affected by tillage.	2
16.	Soil compaction, formation of clods and dust.	1
17.	Effect of tillage on erosion and water logging.	1
18.	Impact of climate factors on soil.	1
19.	Tillage requirement for various types of soils.	1
	Unit IV	
20.	Tillage operations for special tasks.	1
21.	Preparation of soil for cropping and stubble management.	1
22.	Primary and secondary tillage. Ploughing and its effect on soil.	1
23.	Disc tillage: Appropriate conditions and effect.	1
24.	Requirement of seed bed and techniques of creating proper seed bed.	1
25.	Quality of sowing and sowing methods.	1
26.	Modern trends and objectives of soil tillage.	1
	Unit V	
27.	Plough bodies: Generalized representation, intake main flow and output process.	1
28.	Main flow under different surface curvatures.	1
29.	Kinetic aspects of plough bodies with different shapes.	1
30.	Draft of plough bodies as affected by moisture, speed and attachments.	1
	Total	**32**

IX. List of Practicals

S.No.	Topic	No of Practicals
1.	Characterization of soil condition before and after tillage.	2
2.	Cone penetrometer resistance, bulk density, moisture content.	1
3.	Measurement of forces on tillage tools under soil bin condition/ field condition.	2
4.	Measurement of soil manipulation by different tillage tools: Pulverization, furrow profile, inversion and mixing.	2

S.No.	Topic	No. of Practicals
5.	Measurement of energy required for soil breakup by different methods.	2
6.	Field study of crop root development in relation to soil compaction and hard pan.	2
7.	Measurement of moisture movement in different surface configuration: Ridges, furrows, raised bed and flat bed.	2
8.	Field evaluation of plant establishment in relation to planting parameters.	1
	Total	**14**

X. Suggested Reading

- Birkas M. 2014. *Book of Soil Tillage*. Szent Istvan University Press, Godollo, Hungary. ISBN-978-963-269-447-4 (Unit III & IV).
- Koolen AJ and Kuipers H. 1983. *Agricultural Soil Mechanics*. Springer-Verlag. New York, USA. ISBN 13:978-3-642-69012-9 (Unit I, II, V).

I. Course Title : Mechanics of Traction and its Application

II. Course Code : FMPE 611

III. Credit Hours : 2+1

IV. Aim of the course

Learning techniques of modelling soil traction device interaction under different states of wheel and under different soil conditions by analytical and empirical method.

V. Theory

Unit I

Tractor performance in soft soils, operational states of wheel: Wismer and Luth. Path traced by point on tyre periphery. Rolling resistance, conditions of wheel soil interaction, theoretical prediction, work on soil deformation, Bekke's model, derivation of resistance offered by flat rigid plate on soft soil. Measurement of sinkage parameters. Soft wheel on soft surface and rigid wheel on soft surface. Empirical prediction of tractive force: Bekker's model, stress deformation relation in soil, analysis of tractive performance of tracks.

Unit II

Empirical modelling of tractor performance, tractive performance modelling and mobility number. Empirical models for rolling resistance and traction by Gee-Clough. Derivation of equations for drawbar pull and drawbar power.

Unit III

Rigid wheel systems. Rigid wheel at rest: Soil bearing capacity, contact pressure and sinkage. Rigid wheel at driving state: Ground reaction on rigid wheel during driving action, force balance in soil reaction to driving wheel, determination of driving force, compaction resistance and effective driving force. Energy equilibrium under driving wheel.

Unit IV

Wheel under braking state: Slip velocity and amount of slippage under braked wheel. Soil deformation under braked wheel. Distribution of shear stresses and normal stress under driving wheel.

Unit V

Tyre wheel system-deformation of tyre and area of contact. Deformation of tyre and its measurement. Tyre deformation as function of inflation pressure. Ground reaction during pure rolling of tyre on hard surface. Trafficability in soft terrain, concept of wheel mobility number-cornering characteristic of wheel forces on a steered wheel under driving and braking conditions. Relation between cornering force and self-aligning torque.

VI. Practical

Measurement of soil parameters for modelling traction-simulation of the different traction models to obtain the tractive performance. Calculating the performance of tractor drive wheels, Braking performance of trailer wheels on road, Planter metering drive wheels, Tractor front wheel. Measurement of performance of tyres under soil bin condition/field condition for driving and braking. Measurement of variation in contact patch of tractor tyres under different inflation pressures. Design of lugged wheels for wet puddle soil condition. Field experiment with tractive performance of tractor.

VII. Learning outcome

Ability to model vehicle traction mechanics and provide insight into behavior of vehicles under different soil conditions.

VIII. Lecture Schedule

S.No.	Topic	No. of Lecture
1.	Tractor performance in soft soils, operational states of wheel: Wismer and Luth.	2
2.	Path traced by point on tyre periphery.	1
3.	Rolling resistance, conditions of wheel soil interaction, theoretical prediction, work on soil deformation, Bekke's model, derivation of resistance offered by flat rigid plate on soft soil.	4
4.	Measurement of sinkage parameters.	1
5.	Soft wheel on soft surface and rigid wheel on soft surface.	1
6.	Empirical prediction of tractive force: Bekker's model, stress deformation relation in soil, analysis of tractive performance of tracks	2
7.	Empirical modelling of tractor performance, tractive performance modelling and mobility number.	2
8.	Empirical models for rolling resistance and traction by Gee-Clough.	1
9.	Derivation of equations for drawbar pull and drawbar power.	1
10.	Rigid wheel systems. Rigid wheel at rest: Soil bearing capacity, contact pressure and sinkage.	2
11.	Rigid wheel at driving state: Ground reaction on rigid wheel during driving action.	2
12.	Force balance in soil reaction to driving wheel, determination of driving force, compaction resistance and effective driving force.	2
13.	Energy equilibrium under driving wheel.	1
14.	Wheel under braking state: Slip velocity and amount of slippage under braked wheel.	2
15.	Soil deformation under braked wheel.	1
16.	Distribution of shear stresses and normal stress under driving wheel.	1

S.No.	Topic	No of Lectures
17.	Tyre wheel system-deformation of tyre and area of contact.	1
18.	Deformation of tyre and its measurement. Tyre deformation as function of inflation pressure.	1
19.	Ground reaction during pure rolling of tyre on hard surface.	1
20.	Trafficability in soft terrain, concept of wheel mobility number-cornering characteristic of wheel forces on a steered wheel under driving and braking conditions.	2
21.	Relation between cornering force and self-aligning torque.	1
	Total	**32**

IX. List of Practicals

S.No.	Topic	No of Practicals
1.	Measurement of soil parameters for modelling traction-simulation of the different traction models to obtain the tractive performance.	3
2.	Calculating the performance of tractor drive wheels, Braking performance of trailer wheels on road, Planter metering drive wheels, Tractor front wheel.	4
3.	Measurement of performance of tyres under soil bin condition/ field condition for driving and braking.	2
4.	Measurement of variation in contact patch of tractor tyres under different inflation pressures.	1
5.	Design of lugged wheels for wet puddle soil condition.	2
6.	Field experiment with tractive performance of tractor.	2
7.	Revision	1
8.	Revision	1
	Total	**16**

X. Suggested Reading

- Muro T and O'Brien J. 2004. *Terramechanics: Land Locomotion Mechanics*. Lisse, Netherlands. ISBN 90 5809 572 X (Unit III, IV, V).
- Macmillan RH. 2010. *The Mechanics of Tractor-Implement Performance: Theory and Worked Examples: A Textbook for Students and Engineers*. Custom Book Centre, University of Melbourne, Australia. http://hdl.handle.net/11343/33718 (Unit I, II).

I. Course Title : Farm Machinery Management and Systems Engineering

II. Course Code : FMPE 612

III. Credit Hours : 2+1

IV. Aim of the course

Understanding Farm Machinery from systems approach and ability to model the Farm machinery system.

V. Theory

Unit I

Mathematical models of field machinery systems: Operational constrains, power constrains, weather constrains. Systems approach to field operations and models of: Tillage, seeding, chemical application, harvesting, storage and irrigation systems.

Unit II

Engineering economics: Concept of incremental and differential cost, economic efficiency, time value of money. Equipment investment cost: Operational cost, production cost, income cost and uncertainty cost. B.C. ratio, payback period, IRR machinery replacement policies.

Unit III

Uncertainty: Concepts of probability, probability functions, distributions, sampling. Statistics, confidence limits, significance, contingency tables, analysis of variance. Regression and correlation. Monte Carlo methods and applications to farm machinery.

Unit IV

System modeling in farm machinery: Numerical methods, analogs, models with uncertainty stochastic service system. Feasibility system design-stability. Deterministic systems and stochastic systems.

Unit V

Optimum Design: Trial and error, differential calculus, calculus of variations. Allocations: Linear programming, simplex technique. Transportation and assignment technique. Critical path scheduling, dynamic programming, game and its applications to farm machinery management.

VI. Practical

Solving problems of mathematical models of field machinery, constraints, power constraints, weather constraints. Problems relates to tillage seeding chemical application harvesting and storage and irrigation systems. Problem solving in Economics of Engineering, calculation of investment cost, operational cost, and uncertainty cost. Case studies in machine performance modelling, Economics of machine selection, Analog components, Analog modelling stochastic system modelling and critical path scheduling.

VII. Learning outcome

Ability to understand and develop model of any farm machinery system to help in selection, management and optimization.

VIII. Lecture Schedule

S.No.	Topic	No. of Lecture
1.	Understanding Farm Machinery from systems approach and ability to model the Farm machinery system.	2
2.	Mathematical models of field machinery systems: Operational constrains, power constrains, weather constrains.	2
3.	Systems approach to field operations and models of: Tillage, seeding, chemical application, harvesting, storage and irrigation systems.	3
4.	Engineering economics: Concept of incremental and differential cost, economic efficiency, time value of money	1
5.	Equipment investment cost: Operational cost, production cost, income cost and uncertainty cost. B.C. ratio, payback period, IRR machinery replacement policies.	2
6.	Uncertainty: Concepts of probability, probability functions, distributions, sampling	2

S.No.	Topic	No of Lectures
7.	Statistics, confidence limits, significance, contingency tables, analysis of variance.	1
8.	Regression and correlation. Monte Carlo methods and applications to farm machinery.	3
9.	System modeling in farm machinery: Numerical methods, analogs, models with uncertainty stochastic service system.	3
10.	Feasibility system design-stability	1
11.	Deterministic systems and stochastic systems.	2
12.	Optimum Design: Trial and error, differential calculus, calculus of variations	2
13.	Allocations: Linear programming, simplex technique Transportation and assignment technique	4
14.	Critical path scheduling, dynamic programming, game and its applications to farm machinery management.	4
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Problems solving of mathematical models of field machinery, constraints, power constraints, weather constraints	3
2.	Mathematical problems relates to tillage, seeding, chemical application harvesting and storage and irrigation systems	3
3.	Problem solving in Economics of Engineering, calculation of investment cost, operational cost, and uncertainty cost	3
4.	Case studies in machine performance modelling, Economics of machine selection	2
5.	Case studies in machine performance modelling	2
6.	Economics of Power and machine selection	2
	Total	**15**

X. Suggested Reading

- Hunt DR. 1986. *Engineering Models for Agricultural Production*. AVI Pub. Co., Westport, CT, USA.
- Hunt D and Wilson D. 2015. *Farm Power and Machinery Management*. Waveland Press, Illinois, USA.
- Singh S and Verma SR. 2009. *Farm Machinery Maintenance and Management*. DIPA, ICAR, New Delhi.

I. Course Title : Machinery for Special Farm Operations

II. Course Code : FMPE 613

III. Credit Hours : 2+0

IV. Aim of the course

To bring to focus special farm operations that are not covered under conventional operations and the machinery used for such operations.

V. Theory

Unit I

Machinery for land development. Tractor operated and self-propelled machines for laying drainage system, sub surface drip laying machines, subsoiler, trenchers, laser levelers.

Unit II

Machines for plant protection, pneumatic, thermal type sprayers, aero/drone spraying and other methods of spraying, electrostatic charging, air sleeve boom sprayer, disinfection of seed beds by micro waves and other methods. Safety aids for operator and advances in plant protection method.

Unit III

Field plot machinery and its importance. Fertilizer and manure spreader.

Unit IV

Machines for residue management. Silage and hay making machines.

Unit V

Machinery for horticultural crops. Crop specific machines for cotton, sugarcane, forage/fodder. Machines for processing and handling of agricultural products.

VI. Learning outcome

Understanding of the broad horizon of agricultural machinery used for specialized agricultural operations.

VII. Lecture Schedule

S.No.	Topic	No of Lectures
1.	Machinery for land development	1
2.	Tractor operated and self-propelled machines for laying drainage system, sub surface drip laying machines, subsoiler, trenchers	2
3.	Laser levelers	2
4.	Machines for plant protection	1
5.	Pneumatic, thermal type sprayers	2
6.	Aero/drone spraying and other methods of spraying,	2
7.	Electrostatic charging, air sleeve boom sprayer	2
8.	Disinfection of seed beds by micro waves and other methods	1
9.	Safety aids for operator and advances in plant protection method	2
10.	Field plot machinery and its importance	1
11.	Fertilizer and manure spreader	2
12.	Machines for residue management (in situ)	4
12.	Machines for residue management (ex situ)	2
14.	Silage and hay making machines	3
15.	Machinery for horticultural crops	2
16.	Crop specific machines for cotton, sugarcane, forage/fodder	2
17.	Machines for processing and handling of agricultural products	1
	Total	**32**

VIII. Suggested Reading

- Boson ES, Sultan-Shakh EG, Smirnov II and Verniaev OV. 2016. *Theory, Construction and Calculation of Agricultural Machines*. Scientific Publishers.
- Kanafozski C and Karwowiki T. 1976. *Agricultural Machines: and Construction*. Vol. I&II, Translated and published by US Dept. of Agriculture and National Science Foundation, Washington, DC, USA.
- Kepner RA, Bainer R and Barger EL. 2017. *Principles of Farm Machinery*. CBS publishers and Distributors Pvt. Ltd, New Delhi, India.

I. **Course Title** : **Ergonomics in Working Environment**
II. **Course Code** : **FMPE 614**
III. **Credit Hours** : **2+1**

IV. **Aim of the course**

To enable the student to understand the concept of designing the working environment and designing farm machinery and equipment to ensure operators comfort and safety.

V. **Theory**

Unit I

Musculoskeletal problems in sitting and standing postures-behavioral aspects of posture, body mechanics. Workspace design for standing and seated workers. Display units, controls and human-machine interaction, design of static work.

Unit II

Noise and noise control. Measurement of noise and safe limits. Protection from noise. Vibration and health. Vibrations generated by agricultural machines. Types of vibrations: Whole body vibrations and hand transmitted vibrations. Methods of measurements of vibrations, hazards of vibrations. Vibration White Fingers (VWF). Vibration reductions in agricultural machines.

Unit III

Working environment-heat and cold stress conditions. Thermal balance of human body. Measurement of thermal environment. Heat and cold stress condition. Thermoregulatory system of human body. Heat and cold acclimatization. Effect of climate on human performance. Environmental dust and its measurement: Organic and inorganic dust. Types of dust and their hazards: Respirable, thoracic and inhalable dust. Personal protection from dust.

Unit IV

Time motion study and its purpose. Application of Time motion study in agricultural and processing operations. Recent research works related to ergonomics in agriculture.

VI. **Practical**

Design of workspace for static work in standing and sitting positions. Study of body mechanics and postures in design of agricultural machinery. Human energy expenditure, calibration of subjects, Human work load and its assessment. Study of work and rest schedule. Measurement of visibility of tractors. Measurement and control of noise in tractors and self-propelled machines. Measurement of human vibrations in farm tractors and agricultural machines. Study of dust generated in agricultural operations.

VII. **Learning outcome**

Ability to design working environment of different agricultural machinery for efficient and safe operations.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Basics of body mechanics, stability and support	1
2.	Control of muscle function, fatigue and discomfort	1
3.	Musculoskeletal problems in sitting and standing posture	2
4.	Behavioural aspects of posture, risk factors for musculoskeletal disorders	1
5.	Importance of ergonomics in workspace design	1
6.	Workspace design for standing workers	1
7.	Workspace design for seated workers	1
8.	First hourly examination	1
9.	Visual display units, controls and human- machine interaction	1
10.	Design of static work	1
11.	Importance of noise control and safe limits for human	1
12.	Measurement of noise, reduction and protection	1
13.	Machine vibrations, human vibrations and health hazards	1
14.	Whole body vibrations and hand transmitted vibrations	1
15.	Methods of measurements of vibrations and health hazards	1
16.	Vibration reduction techniques for agricultural machines	1
17.	Mid-semester examination	1
18.	Working environment- heat and cold stress conditions, thermal balance of human body	1
19.	Measurement of thermal environment	1
20.	Thermo-regulatory system of human body, heat and cold acclimatization, effect of climate on human performance	2
21.	Environmental dust and its measurement, type of dust - organic and inorganic dust, dust health hazard	1
22.	Respirable, thoracic and inhalable dust, protection from dust	1
23.	Time motion study and its purpose	1
24.	Application of time motion study in agricultural and processing operations	1
25.	Recent research work related to physiological parameters of ergonomics in agriculture	1
26.	Recent research work related to tractor space layout and design of controls	1
27.	Recent research work related to noise studies on farm machines	1
28.	Recent research work related to vibrations studies on farm machines	1
29.	Recent research work related to accidents and safety studies on farm machines	1
30.	Revision and discussion	1
	Total	32

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Design of workspace for static work in standing or sitting posture	1
2.	Study of body mechanics and posture in design of agricultural machinery	2
3.	Study of displays and controls in tractors	1
4.	Calibration of subjects on ergometer and treadmill	2
5.	Human workload and its assessment	1

S.No.	Topic	No of Practicals
6.	Study of work and rest schedule	1
7.	Measurement of visibility to tractor operators	1
8.	Measurement of noise in tractors and self-propelled machines	1
9.	Measurement of machine component vibration	1
10.	Measurement of hand arm vibrations	1
11.	Measurement of whole body vibrations	1
12.	Study of dust generated in agricultural operations	1
13.	Case study of design improvement in agricultural machine/ tool through ergonomic concept	1
14.	Practical examination	1
	Total	**16**

X. Suggested Reading

- Astrand PO, Rodahl K, Dahl HA and Stromme SB. 2003. *Textbook of Work Physiology: Physiological Bases of Exercise*. Champaign IL: Human Kinetics.
- Bridger RS. 2009. *Introduction to Ergonomics*. 3rd edition CRC Press, Boca Raton, USA.
- Gite LP, Majmudar J, Mehta CR and Khadatkar A. 2009. *Anthropometric and Strength Data of Indian Agricultural Workers for Farm Equipment Design*. Central Institute of Agricultural Engineering, Bhopal, India.
- Gite LP, Agrawal KN, Mehta CR, Potdar RR and Narwariya BS. 2019. *Handbook of Ergonomical Design of Agricultural Tools, Equipment and work Places*. Jain Brothers, New Delhi.
- Kroemer KHE and Grandjean E. 1997. *Fitting the Task to the Human: A Textbook of Occupational Ergonomics*. Taylor & Francis, Philadelphia, USA.
- Pearsons K. 2003, *Human Thermal environments: The Effects of Hot, Moderate and Cold Environment on Human Health, Comfort and Performance*. Taylor and Francis, New York, USA.
- Sanders MS and McCormick EJ. 1993. *Human Factors in Engineering and Design*. McGraw Hill, New York, USA.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 4

Agricultural Engineering
– Processing and Food Engineering

Preamble

(Processing and Food Engineering)

Three major points were kept in mind while preparing course curricula related to Processing and Food Engineering (1) the syllabus and courses taught at UG level as recommended by 6th Dean committee (2) preparing students to keep pace with future requirement of the human resource in institutions and industry (3) to align the syllabus with ARS/NET examination.

Course curricula and course outlines in Processing and Food Engineering have been designed keeping in view the courses offered by the faculties from associated/ closely related disciplines, viz. Mechanical Engineering, Mathematics, Renewable Energy Engineering, Electrical, Electronics and Computer Engineering, Farm Machinery and Power Engineering, Civil Engineering etc.

It becomes more important for the post graduate students to not only learn the recent advances but have also to be trained/ hands on experience in the modern and latest techniques in their major disciplines so that they can participate and contribute in the development and advancement in their related fields. Further, the shrinking job opportunities in the National Agricultural Research System (ICAR/SAUs) have put additional pressure on our education system to prepare students in tune with the demands of the corporate sector.

All courses are designed to cover all basic topics and by taking into consideration demands of corporate sector harnessing commercial aspects, modern research tools and their applications, supplementary skills required and enhancing the global competitiveness and employability of students. To meet these objectives new courses were added which covers areas: Instrumentation and Sensors in Food Processing, Agri-Project Planning and Management, Dairy Product Processing, Design of Aquacultural Structures and Thermal Environmental Engineering for Agricultural Processing.

Further, existing courses were suitably modified and restructured by deleting topics already covered in UG, removing overlapping topics in different courses, adding topics/ courses to cover ARS/NET exam syllabus and topic important to the food industry and emerging trends in Processing and Food Engineering. The modified/revised courses cover the areas: Transport Phenomena in Food Processing, Unit Operations in Food Process Engineering, Field Crops Process Engineering, Horticultural Crops Process Engineering, Storage Engineering and Handling of Agricultural Produce, Food Package Engineering, Application of Engineering Properties in Food Processing, Food Quality and Safety, Food Processing Technologies, Food Processing Equipment and Plant Design, Seed Process Engineering, Farm Structures and Environmental Control, Processing of Meat, Poultry and Fish, Advances in Food Process Engineering, Drying and Dehydration of Food Materials, Textural and Rheological Characteristics of Food Materials, Agricultural Waste and By-Products Utilization, Mathematical Modeling in Food Processing and Bioprocess Engineering.

The course content and syllabus upgraded make it more of practical oriented and as per ARS/NET Syllabus.

The ICAR recommendations for PG courses have been taken into consideration in framing these courses. It is hoped that these will prove very useful to the future students.

Course Title with Credit Load
M.Tech. in Processing and Food Engineering

Major Courses (Requirement: 20 Credits)

Course Code	Course Title	Credit Hours
*PFE 501	Transport Phenomena in Food Processing	2+1
*PFE 502	Unit Operations in Food Process Engineering	2+1
*PFE 503	Field Crops Process Engineering	2+1
*PFE 504	Horticultural Crops Process Engineering	2+1
PFE 505	Storage Engineering and Handling of Agricultural Produce	2+1
PFE 506	Food Package Engineering	1+1
PFE 507	Instrumentation and Sensors in Food Processing	2+1
PFE 508	Application of Engineering Properties in Food Processing	2+1
PFE 509	Food Quality and Safety	2+1
PFE 510	Food Processing Technologies	2+1
PFE 511	Food Processing Equipment and Plant Design	1+1
PFE 512	Seed Process Engineering	1+1
PFE 513	Agri-Project Planning and Management	2+1
PFE 514	Farm Structures and Environmental Control	2+1
PFE 515	Dairy Product Processing	2+1
PFE 516	Processing of Meat, Poultry and Fish	2+1
PFE 517	Design of Aquacultural Structures	2+1
PFE 518	Thermal Environmental Engineering for Agricultural Processing	2+1
	Total	**33+18**

*Compulsory Courses

Minor Courses (Requirement: 08 Credits)

Course Code	Course Title	Credits
ME 501	Mechatronics and Robotics in Agriculture	2+0
ME 502	Refrigeration Systems	2+1
REE 513	Energy, Ecology and Environment	3+0
REE 518	Energy Management in Food Processing Industries	1+1
FMPE 502	Testing and Evaluation of Agricultural Equipment	1+1
FMPE 514	System Simulation and Computer Aided Problem Solving in Engineering	1+1

Course Code	Course Title	Credit Hours
FMPE 515	Computer Aided Design of Machinery	0+2
CSE 501	Big Data Analytics	2+0
CSE 502	Artificial Intelligence	2+0
MATHS 501	Finite Elements Method	1+1
MATHS 502	Numerical Methods for Engineers	2+1
CE 501	Dimensional Analysis and Similitude	1+1
	Any other course (s) of other department other than course(s) from major can be taken as per recommendations of the student's advisory committee.	

Supporting Courses (Requirement: 06 Credits)

Course Code	Course Title	Credit Hours
*STAT 501	Statistical Methods for Research Works	2+1
	Courses from subject matter fields (other than Major and Minor) relating to area of special interest and research problem can be taken as per recommendations of the student's advisory committee.	

*Compulsory Course

Common Courses (Requirement: 05 Credits)

Course Code	Course Title	Credit Hours
*PGS 501	Library and Information Services	0+1
*PGS 502	Technical Writing and Communications Skills	0+1
*PGS 503	Intellectual Property and its management in Agriculture	0+1
*PGS 504	Basic Concepts in Laboratory Techniques	0+1
*PGS 505	Agricultural Research, Research Ethics and Rural Development Programmes	0+1

*Detailed course outline to be developed by designated BSMA

List of Other Essential Requirements

Course Code	Course Title	Credit Hours
PFE 591	Seminar	0+1
PFE 599	Thesis Research	0+30

Course Contents
M.Tech. in Processing and Food Engineering

I. Course Title : Transport Phenomena in Food Processing

II. Course Code : PFE 501

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with the principles of heat, mass and momentum transfer and its applications in food processing

V. Theory

Unit I

Introduction to heat and mass transfer and their analogy. Steady and unsteady state heat transfer. Analytical and numerical solutions of unsteady state heat conduction equations. Use of Gurnie-Lurie and Heisler Charts in solving heat conduction problems: Applications in food processing including freezing and thawing of foods.

Unit II

Convective heat transfer in food processing systems involving laminar and turbulent flow. Heat transfer in boiling liquids. Heat transfer between fluids and solid foods. Functional design of heat exchangers: shell and tube, plate and scraped surface heat exchangers. Radiation heat transfer: governing laws, shape factors, applications in food processing.

Unit III

Momentum transfer.Mass flow and balance. Steady and unsteady flow.Theory and equation of continuity.Bernoulli's theorem and application. Flow through immerged bodies, Measurement of flow, pressure and other parameters. Flow driving mechanism.

Unit IV

Molecular diffusion in gases, liquids and solids.Molecular diffusion in biological solutions and suspensions.Molecular diffusion in solids. Unsteady state mass transfer and mass transfer coefficients.Molecular diffusion with convection and chemical reaction.Diffusion of gases in porous solids and capillaries. Mass transfer applications in food processing.

VI. Practical

Solving problems on steady and unsteady state conduction with or without heat generation.Numerical analysis.Problems in natural and forced convection, radiation.Design of heat exchangers. Experiments on heat conduction, convection and radiation heat transfer.

VII. Learning outcome

The course will impart requisite knowledge about transport phenomenon with respect to heat, mass and momentum transfer which is necessary to understand the food processing operations. After going through the course, students will be able to understand, analyse and solve numerically the food processing operations where heat/mass/momentum transfer is involved.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction to basic heat and mass transfer and their analogy	2
2.	Steady and unsteady state heat transfer.	2
3.	Use of Gurnie-Lurie and Heisler Charts in solving heat conduction problems	1
4.	Applications in food processing including freezing and thawing of foods.	1
5.	Convective heat transfer in food processing systems involving laminar and turbulent flow	2
6.	Heat transfer in boiling liquids, Heat transfer between fluids and solid foods.	2
7.	Functional design of heat exchangers; Shell and tube, plate and scraped surface heat exchangers.	2
8.	Radiation heat transfer: governing laws, shape factors, applications in food processing.	2
9.	Classification of Flow Phenomena, Momentum Flow and Momentum Equation for Laminar Flow, Momentum transfer. Mass flow and balance.	2
10.	Steady and unsteady flow, Fluid Element Trajectories, Stream Function and Velocity Potential	1
11.	Theory and equation of continuity. Bernoulli's theorem and application.	1
12.	Flow through immerged bodies, Measurement of flow; Measurement of flow pressure and other parameters. Flow driving mechanism.	2
13.	Mass Transfer (Diffusion),Diffusion: Phenomenological Description, Diffusion Coefficient and Fick's Law	2
14.	Driving Force for Diffusion, Microscopic Picture of Diffusion	1
15.	Molecular diffusion in biological solutions and suspensions.	1
16.	Unsteady state mass transfer and mass transfer coefficients.	2
17.	Molecular diffusion with convection and chemical reaction	1
18.	Diffusion of gases in porous solids and capillaries	1
19.	Mass transfer applications in food processing.	2
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Solving problems on steady conduction	1
2.	Solving problems on steady conductionwith or without heat generation	1
3.	Solving problems on steady and unsteady state conduction	2
4.	Steady and unsteady state conduction with or without heat generation	1
5.	Numerical analysis in heat transfer	1
6.	Problems in natural and forced convection	2
7.	Solving problems of heat transfer by radiation	2
8.	Design of heat exchangers.	2
9.	Experiments on heat conduction, convection	2
10.	Experiments on radiation heat transfer	1
	Total	**15**

X. Suggested Reading

- Bird, Stewart, Lightfoot 2002. *Transport Phenomena*, John Wiley & Sons.
- Bodh Raj 2012. *Introduction to Transport Phenomena*, PHI.
- Christie J. 1993. *Transport Process and Unit Operations*. Prentice-Hall of India Private Limited, New Delhi ISBN 0-13-045253-X.
- Coulson JM and Richardson JF. 1999. *Chemical Engineering*. Vol. II, IV.ThePergamon Press.
- Earle RL. 1985. *Unit Operations in Food Processing*. Pergamon Press.
- Holman JP 1992. Heat Transfer. McGraw Hill.
- Jorge Welti-Chanes, Jorge F and Velez-Ruiz 2002. *Transport Phenomena in Food Processing*. CRC Press ISBN: 9781566769938 Geankoplis.
- McCabe WL and Smith JC 1999. *Unit Operations of Chemical Engineering*. McGraw Hill.
- Plawsky, Joel L 2014. *Transport Phenomena Fundamentals*, CRC Press, ISBN: 978-1-4665-5535-8,1466555351.

I. Course Title : Unit Operations in Food Process Engineering

II. Course Code : PFE 502

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with different unit operations applicable in food industries.

V. Theory

Unit I

Review of basic engineering mathematics. Units and dimensions. Mass and energy balance. Principles of fluid flow. Heat transfer: Conduction, convection and radiation.Heat exchangers and their designs.

Unit II

Drying and dehydration: Psychrometry, theories of drying, EMC, equipment for drying of solid, pastes and liquid foods. Evaporation: Components, heat and mass balance in single and multiple effect evaporators, equipment and applications, steam economy. Thermal processing: Blanching, pasteurization and sterilization, death rate kinetics, process time calculations, sterilization equipment.

Unit III

Refrigeration and freezing: Principles, freezing curve, freezing time calculation, freezing equipment, cold chain.

Unit IV

Mechanical separation: Principle and equipment involved in sieving, filtration, sedimentation and centrifugation, cyclone separation. Material handling: Conveyors and elevators, components and design considerations for belt, chain, bucket and screw conveyors.

Unit V

Size reduction: Principles of size reduction, size reduction laws. Size reduction equipment: Jaw crusher, gyratory crusher, roller mill, hammer mill.

VI. Practical

Study of fluid flow properties. Study of heat exchangers, functional design of heat exchangers.Application of psychometric chart.Determination of EMC.Study of driers. Solving problems on single and multiple effect evaporator. Elevating and conveying equipments. Size reduction equipments. Cleaning and sorting equipment. Sieve analysis. Kinetics of fruits and vegetables dehydration.Calculation of refrigeration load, solving of numerical problems. Visit to related food industry.

VII. Learning outcome

The students will get knowledge on various unit operations, backbone of all food processes. Knowledge on basic principles of thermal food processes, size reduction and separation operations involved in food processing and related equipment will prepare students to solve problems related with food processing. This will help students to solve problems of post-production processes and will also enhance employability in food industries.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Calculations of material balance related to various food processes	3
2.	Study of energy balance for processing operation and related parameters	3
3.	Study of fluid statics, fluid dynamics, flow characteristics	2
4.	Introduction to heat transfer, modes of heat transfer, heat conduction	2
5.	Introduction to Psychometrics basics	2
6.	Study of Dehydration, EMC, Mechanism of drying constant rate period, Falling rate period	2
7.	Study of drying equipments	2
8.	Evaporation, types of evaporators, Flow arrangements Mass and energy balance, Steam economy	2
9.	Thermal processing: Blanching, pasteurization and sterilization, death rate kinetics, process time calculations, sterilization equipment.	3
10.	Refrigeration and freezing: Principles, freezing curve, freezing time calculation, freezing equipment, cold chain.	2
11.	Mechanical separation: Principle and equipment involved in sieving, filtration, sedimentation and centrifugation, cyclone separation.	2
12.	Material handling: Conveyors and elevators, components and design considerations for belt, chain, bucket and screw conveyors.	2
13.	Study of principles involved in the size reduction and separation. Equipment used	3
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Use of units, dimensions and basic mathematical applications	1
2.	To judge the students ability for solving mass balance problems	2
3.	To judge the students ability for solving Energy balance problems	2
4.	To assess the flow rate of fluids through pipes and channels	1
5.	To verify the Bernoulli's Equation	1
6.	To Study heat exchangers and calculation of log mean temperature difference	1
7.	To solve the heat transfer problems	2
8.	To study different dryers used in drying of biological materials	1
9.	To study single effect and multi effect evaporators	1
10.	To calculate the thermal process time using trapezoidal/ Simpson's formulae	1

S.No.	Topic	No. of Practicals
11.	To find the graphical solution for calculation of thermal process time	1
12.	To study different separation equipments	1
13.	To study the size reduction equipments	1
	Total	**16**

X. Suggested Reading

- Berk. 2018. *Food Process Engineering and Technology*, Academic Press, ISBN: 978-0-12-812018-7
- Brennan JG, Butters JR, Cowell ND and Lilly AEI. 1990. *Food Engineering Operations*. Elsevier.
- Fellows P 1988. *Food Processing Technology: Principle and Practice*. VCH Publ.
- McCabe WL and Smith JC. 1999. *Unit Operations of Chemical Engineering*. McGraw Hill.
- Sahay KM and Singh KK. 1994. *Unit Operation of Agricultural Processing*. Vikas Publ. House.
- Singh RP and Heldman DR. 1993. *Introduction to Food Engineering*. Academic Press.
- Smith. 2011. *Introduction to Food Process Engineering*, Springer.
- Toledo. 2007. *Fundamentals of Food Process Engineering*, Springer.
- Varzakas. 2015. *Food Engineering Handbook*, CRC press.

I. Course Title : Field Crops Process Engineering

II. Course Code : PFE 503

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with the post harvest technology of cereals, pulses and oilseeds with special emphasis on equipment used in the milling and processing.

V. Theory

Unit I

Production and utilization of cereals and pulses, grain structure of major cereals, pulses and oilseeds and their milling fractions. Grain quality standards and physico-chemical methods for evaluation of quality of flours.

Unit II

Pre-milling treatments and their effects on milling quality. Parboiling and drying, conventional, modern and integrated rice milling operations. Wheat roller flour milling. Processes for milling of corn, oats, barley, gram, pulses, paddy and flour milling equipment.Layout of milling plants.

Unit III

Dal mills, handling and storage of by-products and their utilization. Storage of milled products.Expeller and solvent extraction processing.Assessment of processed product quality.

Unit IV

Packaging of processed products. Design characteristics of milling equipment, selection, installation and their performance. Quality standards for various processed products. Value added products of cereals, pulses and oilseeds.

VI. Practical

Physical properties of cereals and pulses, raw and milled products quality evaluations:Parboiling and drying, terminal velocities of grains and their fractions, study of paddy, wheat, pulses and oilseeds milling equipments, planning and layout of various milling plants. Development of value added products for cereals, pulses and oilseeds, visit to related agro processing industry.

VII. Learning outcome

Student's capability to mill and process (value added products) all kinds of field crops as per requirement of food industries.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Production and utilization of cereals and pulses, grain structure of major cereals, pulses and oilseeds and their milling fractions.	2
2.	Conventional, modern and integrated rice milling process, pre-milling treatments, rice parboiling, rice milling equipment and layout of rice milling plant.	5
3.	Conventional and roller wheat flour milling process, pre-milling treatments, milling equipment and layout of wheat milling plant.	4
4.	Preparation of oilseeds and pre- treatments, conventional and modern oil extraction methods viz expeller, solvent extraction and super critical fluid extraction. Milling equipment and layout of oil milling plant.	4
5.	Processes for milling of pulses, pretreatments, milling equipment and layout of pulse milling plant.	4
6.	Processes for milling of corn, oats and barley, pretreatments and milling equipments. Layout of milling plant.	3
7.	Handling, packaging and storage of milled products, by-products and their utilization.	2
8.	Assessment of processed product quality. Quality standards for various grains, processed products. Physico-chemical methods for evaluation of quality Value added products of cereals, pulses and oilseeds.	3
9.	Design characteristics of milling equipment, selection, installation and their performance.	3
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Engineering properties of grains, raw and milled products	2
2.	Physical, milling and cooking quality of grains	2
3.	Study of paddy milling process and equipments.	1
4.	Study of wheat milling process and equipments,	1
5.	Study of oil extraction process and equipments,	1
6.	Study of pulse milling process and equipments,	1
7.	Planning and layout of various milling plants.	3
8.	Development of value added products for cereals, pulses and oilseeds	2
9.	Visit to various agro processing industry.	2
	Total	**15**

X. Suggested Reading

- Asiedu JJ. 1990. *Processing Tropical Crops*. ELBS/MacMillan.
- Chakraverty A. 1995. *Post-Harvest Technology of Cereals, Pulses and Oilseeds*. Oxford and IBH.
- Golob 2002. *Crop Post-Harvest: Science and Technology* Vol. 1, Wiley-Blackwell.
- Hodges 2004. *Crop post-harvest: science and technology* Vol. 2, Wiley-Blackwell.
- Morris Lieberman. 1983. *Post-Harvest Physiology and Crop Preservation*. Plenum Press.
- Pandey PH. 1994. *Principles of Agricultural Processing*. Kalyani.
- Pillaiyar P. 1988. *Rice - Post Production Manual*. Wiley Eastern.
- Sahay KM and Singh KK. 1994. *Unit Operations in Agricultural Processing*. Vikas Publ. House.

I. Course Title : Horticultural Crops Process Engineering

II. Course Code : PFE 504

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with processing of fruits and vegetables and the design features of the equipment used for their processing.

V. Theory

Unit I

Importance of postharvest technology of fruits and vegetables, structure, cellular components, composition and nutritive value of fruits and vegetables, fruit ripening, spoilage of fruits and vegetables.

Unit II

Harvesting and washing, pre-cooling, blanching, preservation of fruits and vegetables, commercial canning of fruits and vegetables, minimal processing of fruits and vegetables.

Unit III

Cold storage of fruits and vegetables, controlled atmosphere and modified atmosphere packaging of fruits and vegetables, quality deterioration and storage.

Unit IV

Dehydration of fruits and vegetables, methods, osmotic dehydration, foam mat drying, freeze drying, microwave heating, applications, radiation preservation of fruits and vegetables, irradiation sources.

Unit V

Intermediate moisture foods, ohmic heating principle, high pressure processing of fruits and vegetables, applications, sensory evaluation of fruit and vegetable products, packaging technology for fruits and vegetables, general principles of quality standards and control, FPO, quality attributes.

VI. Practical

Determination of size, shape, density, area-volume-mass relationship of fruits and vegetables, sugar-acid ratio of fruits, evaluation of washer, grader and packaging methods, experiments on drying of fruits and vegetables, controlled atmosphere storage and quality evaluation.

VII. Learning outcome

Student's capability to mill and process (value added products) all kinds of horticultural crops as per requirement of food industries.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Importance of postharvest technology of fruits and vegetables, structure, cellular components, composition and nutritive value of fruits and vegetables.	1
2.	Techniques for harvesting and washing of fruits and vegetables. Fruit ripening and spoilage.	2
3.	Pre-cooling of fruits and vegetables.	1
4.	Blanching: importance and objectives, blanching methods, effects on food (nutrition, colour, pigment, and texture).	1
5.	Different preservation techniques for fruits and vegetables.	1
6.	Commercial canning of fruits and vegetables.	1
7.	Minimal processing of fruits and vegetables.	1
8.	Modified and CA storage of fruits and vegetables, Cold storage, heat load calculations and design.	5
9.	Quality deterioration in fruits and vegetables.	1
10.	Different storage techniques for fruits and vegetables.	1
11.	Dehydration techniques of fruits and vegetables: osmotic dehydration, foam mat drying, freeze drying, microwave heating, applications, radiation preservation of fruits and vegetables, irradiation sources.	4
12.	Intermediate moisture foods.	1
13.	Ohmic heating and high pressure processing principle for fruits and vegetables.	2
14.	Applications of different processing techniques for fruits and vegetables.	1
15.	Sensory evaluation of fruit and vegetable products.	1
16.	Packaging technology for fruits and vegetables.	2
17.	General principles of quality standards and control.	2
18.	FPO, quality attributes for fruits and vegetables.	2
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Determination of size of fruits and vegetables	1
2.	Determination of shape of fruits and vegetables	1
3.	Determination of bulk density and true density of fruits and vegetables	1
4.	Determination of area-volume-mass relationship of fruits and vegetables	1
5.	Determination of sugar-acid ratio of fruits	1
6.	Evaluation of different types of washers for fruits and vegetables	1
7.	Evaluation of different types of graders for fruits and vegetables	1
8.	Different types of packaging methods for fruits and vegetables	1
9.	Determination of the water vapor permeability of packaging materials	1
10.	Different types of drying methods for fruits and vegetables	1
11.	Comparative evaluation of different dryers for fruits and vegetables	1

S.No.	Topic	No. of Practicals
12.	Determination of solid gain and moisture loss during osmotic dehydration in fruits	1
13.	Study of components and design of controlled atmosphere storage	1
14.	Study of quality evaluation of fruits and vegetables	2
	Total	**15**

X. Suggested Reading

- Bhatti S and Varma U. 1995. *Fruit and Vegetable Processing*. CBS.
- Cruesss WV. 2000. *Commercial Fruit and Vegetable Products*. Agrobios Publisher.
- Danthy ME. 1997. *Fruit and Vegetable Processing*. International Book Publisher.
- Simson. 2016. *Post-Harvest Technology of Horticultural crops*. AAP.
- Singh. 2018. *Advances in Post-Harvest Technologies of Vegetable Crops*. AAP.
- Srivastava RP and Kumar S. 1994. *Fruit and Vegetable Preservation*. Principles and Practices. International Book Distr.
- Thompson AK. 1996. *Post Harvest Technology of Fruits and Vegetables*. Blackwell.
- Verma LR and Joshi VK. 2000. *Post Harvest Technology of Fruits and Vegetables*. Vols. I-II. Indus Publisher.

I. Course Title : Storage Engineering and Handling of Agricultural Produce

II. Course Code : PFE 505

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with the safe storage of food materials, design of storage structures and the design of different material handling equipment used in the industries.

V. Theory

Unit I

Storage of grains, biochemical changes during storage, production, distribution and storage capacity estimate models, storage capacity models, ecology, storage factors affecting losses, storage requirements.

Unit II

Bag and bulk storage, godowns, bins and silos, rat proof godowns and rodent control, method of stacking, preventive method, bio-engineering properties of stored products, function, structural and thermal design of structures, aeration system.

Unit III

Grain markets, cold storage, controlled and modified atmosphere storage, effects of nitrogen, oxygen, and carbon dioxide on storage of durable and perishable commodities, irradiation, storage of dehydrated products, food spoilage and preservation, BIS standards.

Unit IV

Physical factors influencing flow characteristics, mechanics of bulk solids, flow through hoppers, openings and ducts; design of belt, chain, screw, roller, pneumatic conveyors and bucket elevators,principles of fluidization, recent advances in handling of food materials.

VI. Practical

Physical factors influencing flow characteristics, mechanics of bulk solids, flow through hoppers, openings and ducts, design of belt, chain, screw, roller, pneumatic conveyors and bucket elevators; principles of fluidization; recent advances in handling of food materials.

VII. Learning outcome

Student's capability to understand and undertake mechanical handling of food as per requirement of food industries as well as storage devices and systems for safe storage of food for longer period of time.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Importance of storage, Types of losses, Principle of storage, Aeration of grains, Factors causing deterioration of grains, Sources of infestation	3
2.	Biochemical changes during storage, Grain storage capacity estimation models	2
3.	Factors affecting losses, Storage requirements	2
4.	Bag and bulk storage, godowns, bins and silos, Selection of storage type, Deep and shallow bins	3
5.	Rat proof godowns and rodent control, method of stacking, preventive method, bio-engineering properties of stored products	2
6.	Functional, structural and thermal design of structures, aeration system.	2
7.	Grain markets- Recent reforms, Continued constraints to grain market integration, Rice and wheat marketing channels in India, Import, export and food policy, Food grains management system	2
8.	Cold storage,Controlled and modified atmosphere storage, Effects of nitrogen, oxygen, and carbon dioxide on storage of durable and perishable commodities.	3
9.	Food irradiation, Storage of dehydrated products, Food spoilage and preservation, BIS standards.	2
10.	Physical factors influencing flow characteristics, Rolling resistance, Mechanics of bulk solids - Shear apparatus for determination of flow properties, Yield locus, Time yield locus and effective yield locus.	3
11.	Flow through hoppers, openings and ducts – Types of flow along bins or hopper wall, Flow function and Critical flow factor, Critical dimensions of hopper openings;	2
12.	Material handling equipment, Design of belt, chain, screw, roller, pneumatic conveyors and bucket elevators.	4
13.	Principles of fluidization, recent advances in handling of food materials.	2
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Determination of angle of repose	1
2.	Determination of coefficient of internal friction	1
3.	Determination of coefficient of external friction	1
4.	Physical factors influencing flow characteristics	1

S. No	Topic	No. of Practicals
5.	Determination of flow properties using Shear apparatus	1
6.	Determination of Yield locus, Time yield locus and effective yield locus from Mohr's circle	1
7.	Flow through hoppers, openings and ducts	1
8.	Design of belt conveyors	1
9.	Design of chain conveyors	1
10.	Design of screw conveyors	1
11.	Design of bucket elevators	1
12.	Design of roller conveyors	1
13.	Design of pneumatic conveyors	1
14.	Principles of fluidization	1
15.	Recent advances in handling of food materials	2
	Total	16

X. Suggested Reading

- Boumans. 1985. *Grain Handling and Storage*. Elsevier.
- FAO. 1984. *Design and Operation of Cold Stores in Developing Countries*. FAO.
- Golob. 2002. *Crop Post-Harvest: Science and Technology*. Vol 1 Wiley-blackwell.
- Hall CW. 1970. *Handling and Storage of Food Grains in Tropical and Sub-Tropical Areas*. FAO Publisher Oxford & IBH.
- Henderson S and Perry SM. 1976. *Agricultural Process Engineering*. 5th Ed. AVI Publisher.
- Hodges 2004. *Crop Post-Harvest: Science and Technology*. Vol 2, Wiley-blackwell.
- Ripp BE. 1984. *Controlled Atmosphere and Fumigation in Grain Storage*. Elsevier.
- Shefelt RL and Prussi SE. 1992. *Post Harvest Handling – A System Approach*. Academic Press.
- Vijayaraghavan S 1993. *Grain Storage Engineering and Technology*. Batra Book Service.

I. Course Title : Food Package Engineering

II. Course Code : PFE 506

III. Credit Hours : 1+1

IV. Aim of the course

To acquaint and equip the students with packaging methods, packaging materials, packaging machineries, modern packaging techniques etc.

V. Theory

Unit I

Introduction of packaging: Package, functions and design. Principle in the development of protective packaging. Deteriorative changes in foodstuff and packaging methods of prevention.

Unit II

Food containers: Rigid containers, glass, wooden boxes, crates, plywood and wire bound boxes, corrugated and fibre board boxes, textile and paper sacks, corrosion of containers (tin plate).Flexible packaging materials and their properties.Aluminum as packaging material.Evaluation of packaging material and package performance.

Unit III

Packaging equipment: Food packages, bags, types of pouches, wrappers, carton and other traditional package.Retortable pouches: Shelf life of packaged foodstuff.

Unit IV

Methods to extend shelf life.Packaging of perishables and processed foods. Special problems in packaging of food stuff.

Unit V

Package standards and regulation: Shrink packaging, aseptic packaging, CA and MAP. Biodegradable packaging: Recent advances in packaging, active packaging, smart packaging, antioxidant and antimicrobial packaging, edible films and biodegradable packaging, microencapsulation and nano encapsulation.

VI. Practical

Thickness, substance weight, water absorption capability of flexible packaging materials,strength properties of packaging materials,water vapour and gas transmission rate of flexible packaging materials,identification and chemical resistance of plastic films. Packaging of fruits/vegetables: Estimation of shelf-life of packaged food stuff, familiarization of types of packaging material.

VII. Learning outcome

Student's capability to develop packages for all kinds of food products as per requirement of food industries and thereby adding value to the food products.

VIII. Lectures Schedule

S.No.	Topic	No. of Lectures
1.	Introduction to food packaging, Definition, importance, package, functions of packaging, design.	1
2.	Principle in the development of protective packaging	1
3.	Deteriorative changes in foodstuff, Factors affecting shelf life of foods during storage, interactions of spoilage agents with environmental factors (water, oxygen, light and pH), packaging methods of prevention	1
4.	Food containers: Rigid containers, glass, wooden boxes, crates, plywood and wire bound boxes, corrugated and fibre board boxes, textile and paper sacks, corrosion of containers (tin plate).	1
5.	Flexible packaging materials and their properties. Aluminum as packaging material.	1
6.	Evaluation of packaging material and package performance: Testing methods for flexible, rigid and semi rigid materials. Paper and paper board:thickness, bursting strength, breaking length, stiffness, tear resistance, folding endurance, ply bond and surface oil absorption, Plastic film and laminates: thickness, tensile strength, gloss, haze and burning test to identify polymer, aluminium foil: thickness and pin holes, Glass containers: visual defects, colour, dimensions and impact strength and metal containers: pressure test and product compatibility	3
7.	Packaging equipment for food packages, bags, types of pouches, wrappers, carton and other traditional packages	1
8.	Retortable pouches: Shelf life of packaged foodstuff.	1
9.	Methods to extend shelf life. Packaging of perishables and processed foods	1
10.	Special problems in packaging of food stuff	1
11.	Package standards and regulation: Shrink packaging, aseptic packaging, CA and MAP	2

S.No.	Topic	No. of Lectures
12.	Recent advances in packaging, active packaging, smart packaging, antioxidant and antimicrobial packaging, edible films and biodegradable packaging, microencapsulation and nano encapsulation	2
	Total	**16**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Familiarization of types of packaging material	1
2.	Determination of thickness of different types of packaging materials	1
3.	To determinewater absorption capability of flexible packaging materials	1
4.	Determination of tensile strength of packaging material	1
5.	Determination of compressive strength of packaging material	1
6.	Determination of water vapour transmission rate of packaging material	1
7.	Determination of gas transmission rate of packaging material	1
8.	Identification of different types of plastic films	1
9.	Testing of chemical and grease resistance of packaging materials	1
10.	Determination of bursting strength of packages	1
11.	Drop test for food package strength	1
12.	Vacuum packaging of various food products	1
13.	Nitrogen packaging of food products	1
14.	To study the effect of shrink wrapping onshelf life of fruits and vegetables	1
15.	To study the effect of active modified atmosphere packaging onshelf life of fruits and vegetables	1
16.	Visit to relevant industries	1
	Total	**16**

X. Suggested Reading

- Crosby NT. 1981. *Food Packaging Materials*. Applied Science Publisher.
- Frank A. 1992. *A Handbook of Food Packaging*. Springer.
- Mahadeviah M and Gowramma RV. 1996. *Food Packaging Materials*. Tata McGraw
- Hill.Palling SJ. 1980. *Developments in Food Packaging*. Applied Science Publisher.
- Robertson GL. 2013. *Food Packaging - Principles and Practice*. 3rd Ed Taylor & Francis.
- Sacharow S and Grittin RC. 1980. *Principles of Food Packaging*. AVI Publisher.

I. Course Title : Instrumentation and Sensors in Food Processing

II. Course Code : PFE 507

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with instrumentation and use of sensors in food processing operations.

V. Theory

Unit I

Basic instrumentation systems and transducer principles. Displacement transducers, Potential meters, LDVT, Piezoelectric and capacitive transducers, Digital transducers, velocity transducers.

Unit II

Acceleration and absolute motion measurement, Force transducer, Strain gauge, Hydraulic load cell, Cantilever type and probing ring. Method of separation of force: Torque, power and energy measuring technique.

Unit III

Temperature measurement using bi-metals, thermisters, thermocouples, humidity measurement, manometers. Flow transducer, positive displacement, venturimeter, Rotameter, Drag force, hot wire anemometer.

Unit IV

Theory and classifications of chemical sensors, biosensors, fibre optic sensors, gas sensors etc. Biosensor: Concepts, types of biosensors, methods of immobilizing biosensors, application. Imaging methods: X-ray imaging, Computed tomography, MRI, Ultrasound, Hyperspectral imaging. Spectroscopy and chemometrics: UV and visual spectroscopy, NIR spectroscopy, FTIR spectroscopy.

VI. Practical

Identification of components of generalized measuring system: Calibration of instruments, experiment on LVDT, strain gauge transducer, force, torque, power and pressure, fluid flow rates, temperature, calorific value, vibration measurement.Use of data loggers and data storage devices, spectroscopy, imaging systems.

VII. Learning outcome

Student's capability to control the process operations through precise instrumentation and knowledge of sensors for precision analysis of food quality in food industries.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Basic instrumentation systems	1
2.	Transducer principles	1
3.	Displacement transducers, Potential meters, LDVT, Piezoelectric and capacitive transducers, Digital transducers, velocity transducers.	3
4.	Acceleration and absolute motion measurement, Force transducer, Strain gauge, Hydraulic load cell, Cantilever type and probing ring.	3
5.	Different methods of separation of force: Torque, power and energy measuring technique	3
6.	Temperature measurement using bi-metals, thermistors, thermocouples, humidity measurement, manometers.	3
7.	Flow transducer, positive displacement, venturi meter, Rotameter, Drag force, hot wire anemometer.	2
8.	Theory and classification of chemical sensors, biosensors, fibre optic sensors, gas sensors etc.	4
9.	Biosensor: Concepts, types of biosensors, methods of immobilizing biosensors, application.	3
10.	Imaging methods for foods, Principles, equipment, food applications- X-ray imaging, Computed tomography, MRI, Ultrasound, Hyperspectral imaging.	4
11.	Various methods of spectroscopy and chemometrics, principles, equipment, food applications- UV and visual spectroscopy, NIR spectroscopy, FTIR spectroscopy.	3
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Identification of components of generalized measuring system for temperature, pressure, relative humidity, moisture etc.	1
2.	Calibration of moisture measuring equipment	1
3.	Calibration of temperature control and measuring devices	1
4.	To study the working of Bourdon Pressure Gauge and to check the calibration of the gauge in a deadweight pressure gauge calibration set up.	1
5.	To study various temperature measuring instruments e.g. Mercury-in-glass thermometer, Thermocouple, Electrical resistance thermometer, laser thermometer and to estimate their response times	1
6.	To determine the calorific value of different food products using a bomb calorimeter having temperature sensing device	1
7.	To study a Linear Variable Differential Transformer (LVDT) and use it in a simple experimental set up to measure a small displacement	1
8.	To measure torque of a rotating shaft using torsion meter/strain gauge torque transducer	1
9.	To measure the speed of a motor shaft with the help of non-contact type pick-ups (magnetic or photoelectric)	1
10.	To measure static/dynamic pressure of fluid in pipe/tube using pressure transducer/pressure cell	1
11.	To determine the hardness/firmness of food samples using a texture analyzer	1
12.	To study the effect of vibrations during transportation on the quality of food (damage/ bruising/ texture etc) using a simulated vibration test	1
13.	To study and use the data logging and data storage devices	1
14.	To study and understand the working principle of UV and visual spectroscopy for measurement of food properties	1
15.	To study and understand the working principle of NIR and FTIR spectroscopy for measurement of food properties	1
16.	To study the working principle of X-ray imaging, Computed tomography, MRI, Ultrasound and Hyperspectral imaging for measurement of food quality	1
	Total	**16**

X. Suggested Reading

- Doebelin EO. 1990. *Measurement Systems Applications and Design*. Tata McGraw Hill.
- Erika KR and Brimelow JB. 2001. *Instrumentation and Sensors for the Food Industry*. CRC Woodhead.
- Nakra BC and Chaudhary KK. 2004. *Instrumentation Measurement and Analysis*. Tata McGraw Hill.
- Mukhopadhyay. 2014. *Novel Sensors for Food Inspection: Modelling, Fabrication and Experimentation*. Springer.
- Mukhopadhyay SC. 2017. *Sensors for Everyday Life*. Springer.
- Paré JRJ and Bélanger JMR. 1997. *Instrumental Methods in Food Analysis*. Elsevier Academic Press.

I. Course Title : Application of Engineering Properties in Food Processing

II. Course Code : PFE 508

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint the students with different techniques of measurement of engineering properties and their application in the design of processing equipment.

V. Theory

Unit I

Physical characteristics of different food grains, fruits and vegetables: Shape and size, description of shape and size, volume and density, porosity, surface area. Rheology: ASTM standard, terms, physical states of materials, classical ideal material, rheological models and equations, viscoelasticity, creep-stress relaxation, non-Newtonian fluid and viscometry, rheological properties, force, deformation, stress, strain, elastic, plastic behaviour.

Unit II

Contact stresses between bodies, Hertz problems, firmness and hardness, mechanical damage, dead load and impact damage, vibration damage, friction, effect of load, sliding velocity, temperature, water film and surface roughness. Friction in agricultural materials, rolling resistance, angle of internal friction, angle of repose, flow of bulk granular materials, aero dynamics of agricultural products, drag coefficients, terminal velocity.

Unit III

Thermal properties: Specific heat, thermal conductivity, thermal diffusivity, methods of determination, steady state and transient heat flow. Electrical properties: Dielectric loss factor, loss tangent, A.C. conductivity and dielectric constant, method of determination, energy absorption from high frequency electric field.

Unit IV

Application of engineering properties in design and operation of agricultural equipment and structures.

VI. Practical

Experiments for the determination of physical properties like length, breadth, thickness, surface area, bulk density, porosity, true density, coefficient of friction, angle of repose and colour for various food grains, fruits, vegetables, spices and processed foods, aerodynamic properties like terminal velocity, lift and drag force for food grains, thermal properties like thermal conductivity, thermal diffusivity and specific heat. Rheological properties: firmness and hardness of grain, fruits and stalk, electrical properties like dielectric constant, dielectric loss factor, loss tangent and A.C. conductivity of various food materials.

VII. Learning outcome

Student's capability to apply properties of food for design of equipment and structures.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Physical characteristics of different food grains, fruits and vegetables: Shape and size, description of shape and size.	3
2.	Volume and density, porosity, surface area.	1
3.	Rheology: ASTM standard, terms, physical states of materials, classical ideal material.	2
4.	Rheological models and equations, visco elasticity.	2
5.	Creep-stress relaxation, non-Newtonian fluid and viscometry.	1
6.	Rheological properties, force, deformation, stress, strain, elastic, plastic behavior.	1
7.	Contact stresses between bodies, Hertz problems, firmness and hardness	1
8.	Mechanical damage, dead load and impact damage.	2
9.	Vibration damage, friction, effect of load, sliding velocity.	1
10.	Temperature, water film and surface roughness.	1
11.	Friction in agricultural materials, rolling resistance, angle of internal friction, angle of repose.	2
12.	Flow of bulk granular materials.	1
13.	Aero dynamics of agricultural products, drag coefficients, terminal velocity.	3
14.	Thermal properties: Specific heat, thermal conductivity, thermal diffusivity.	1
15.	Methods of determination, steady state and transient heat flow	1
16.	Electrical properties: Dielectric loss factor, loss tangent.	1
17.	A.C. conductivity and dielectric constant, method of determination.	2
18.	Energy absorption from high frequency electric field.	1
19.	Application of engineering properties in design and operation of agricultural equipment and structures.	3
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	To determine the size of grains, pulses, oil seeds, spices, fruits and vegetables.	1
2.	To determine the shape of various food grains and fruits and vegetables.	1
3.	To determine the bulk density of food grains and fruits and vegetables.	1
4.	To determine the particle density/true density and porosity of solid grains.	1
5.	To study the comparison pycnometer for finding the particle density of food grains.	1
6.	To determine the angle of repose of grains, oilseeds etc.	1
7.	To find the coefficient of external friction for different food grains.	1
8.	To determine the coefficient of internal friction of different food grains.	1
9.	To plot the normal stress vs. sheet stress curves for different food grains.	1
10.	To study the separating behaviour of a grain sample in a vertical wind tunnel (Aspirator column).	1
11.	To study the thermal properties (thermal conductivity, thermal diffusivity and specific heat) of food grains.	2

S.No.	Topic	No. of Practicals
12.	To determine the Rheological properties: firmness and hardness of grain, fruits, stalk and vegetables.	1
13.	To study the electrical properties (dielectric constant, dielectric loss factor) of various food materials.	1
14.	To study the electrical properties (loss tangent and A.C. conductivity) of various food materials.	1
	Total	**15**

X. Suggested Reading

- Ludger F and Teixeira AA. 2007. *Food Physics Physical Properties - Measurement and Application*. Springer.
- Mohesenin NN. 1980. *Thermal Properties of Foods and Agricultural Materials*. Gordon and Breach Science Publisher.
- Mohesenin NN. 1980. *Physical Properties of Plant and Animal Materials*. Gordon & Breach Science Publisher.
- Peleg M and Bagelay EB. 1983. *Physical Properties of Foods*. AVI Publisher.
- Peter B. 2007. *The Chemical Physics of Food*. Wiley-Blackwell.
- Rao MA and Rizvi SSH. 1986. *Engineering Properties of Foods*. Marcel Dekker.
- Singhal OP and Samuel DVK. 2003. *Engineering Properties of Biological Materials*. Saroj Prakasan.
- Sitkei. 1986. *Mechanics of Agricultural Materials*. Elsevier.

I. Course Title : Food Quality and Safety

II. Course Code : PFE 509

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with the latest standards to maintain food quality and safety.

V. Theory

Unit I

Food safety:Need for quality control and safety, strategy and criteria, microbiological criteria for safety and quality, scope of food toxicology, toxic potential and food toxicants, biological and chemical contaminants.

Unit II

Food additives and derived substances, factors affecting toxicity, designing safety in products and processes, intrinsic factors, establishing a safe raw material supply, safe and achievable shelf life.

Unit III

Process equipment and machinery auditing, consideration of risk, environmental consideration, mechanical quality control.

Unit IV

Personnel hygienic standards, preventative pest control, cleaning and disinfesting system, biological factors underlying food safety.

Unit V

Preservation and stability, contaminants of processed foods, adulteration, prevention and control, FSSAI, ISO, Codex, GMP, BIS and HACCP.Practices, principles, standards, specifications, application establishment and implementation, HACCP and quality management system.Food Safety Management Systems (FSMS), Traceability.

VI. Practical

Microbiological examination of food, hazard analysis, premises design, HACCP project plan, CCP, CCP Decision tree, HACCP control chart. HACCP case studies: Survey, BIS, FPO, Codex standards and specifications. Visits to food industries to study the various quality and safety aspects adopted.

VII. Learning outcome:

Student's capability to measure food quality as well as ensure food safety in food supply chain.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Food safety: Need for quality control and safety, strategy and criteria.	2
2.	Microbiological criteria for safety and quality.	1
3.	Scope of food toxicology, toxic potential and food toxicants.	2
4.	Biological and chemical contaminants.	1
5.	Food additives and derived substances, factors affecting toxicity.	2
6.	Designing safety in products and processes, intrinsic factors.	2
7.	Establishing a safe raw material supply, safe and achievable shelf life.	2
8.	Process equipment and machinery auditing.	1
9.	Consideration of risk, environmental consideration. Biological factors underlying food safety.	2
10.	Personnel hygienic standards, preventative pest control. Cleaning and disinfesting system.	2
11.	Preservation and stability, contaminants of processed foods, adulteration, prevention and control	3
12.	FSSAI-Practices, principles, standards, specifications, application establishment and implementation	2
13.	ISO-Practices, principles, standards, specifications, application establishment and implementation.	2
14.	Codex, GMP and BIS - Practices, principles, standards, specifications, application establishment and implementation.	3
15.	HACCP and quality management system.	1
16.	Food Safety Management Systems (FSMS), Traceability.	2
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	To test microbiological contamination of food.	1
2.	To conduct hazard analysis.	2
3.	To study the premises design for food safety and quality.	2
4.	To study the HACCP project plan.	1
5.	To prepare CCP and CCP Decision tree.	2

S.No.	Topic	No. of Lectures
6.	To prepare HACCP control chart.	2
7.	To conduct the Survey and study BIS- standards and specifications.	2
8.	To study the FPO standards and specifications.	1
9.	To study the codex standards and specifications.	1
10.	Visits to food industries to study the various quality and safety aspects adopted.	2
	Total	**15**

X. Suggested Reading

- Herschdoerfer, SM. 1984. *Quality Control in the Food Industry*. Vol. 1 Academic Press.
- Herschdoerfer SM. 2012. *Quality Control in the Food Industry*. Vol. 2 Elsevier Science.
- Hubbard MR. 2003. *Statistical Quality Control for the Food Iindustry*. Springer.
- Mahadeviah M and Gowramma R V. 1996. *Food Packaging Materials*. Tata McGraw Hill.
- Mehmet M. 2011. *Biosensors in Food Processing, Safety, and Quality Control.* CRC Press.
- Palling SJ. 1980. *Developments in Food Packaging*. Applied Science Publisher.
- Sacharow S and Grittin RC. 1980. *Principles of Food Packaging*. AVI Publisher.
- Yanbo H, Whittaker AD and Lacey RE. 2001. *Automation for Food Engineering*. Food Quality Quantization and Process Control-CRC Press.

I. Course Title : Food Processing Technologies

II. Course Code : PFE 510

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with different unit operations to be performed in food industries and related equipment.

V. Theory

Unit I

Mixing and homogenization; Principles of solid and liquid mixing, types of mixers for solids, liquid and pastes homogenization. Emulsification: Principles and equipments.

Unit II

Novel dehydration technologies; Osmotic dehydration, foam mat drying, puff drying, freeze drying, microwave drying, dehumidified air drying. Extrusion: Theory, equipment, applications.

Unit III

Non-thermal processing; Principles and equipment involved in ohmic heating, pulsed electric field preservation, hydrostatic pressure technique (vacuum processing, high pressure processing of Foods), ultrasonic technology, irradiation, quality changes and effects on microorganisms, nanotechnology in food processing.

Unit IV

Distillation, leaching and extraction: Principles and equipment for distillation, crystallization, phase equilibria, multistage calculations, leaching principles and equipment, solvent extraction, super-critical fluid extraction, near critical fluid extraction: Equipment and experimental techniques used in NCF extraction and industrial application, advanced methods for extraction of food components and aroma recovery.

Unit V

Food plant hygiene; Cleaning, sterilizing, waste disposal methods, Food processing plant utilities, steam requirements in food processing, HACCP in food processing industries.

VI. Practical

Conducting experiments and solving problems on mixing and mixing indices, homogenization, distillation, crystallisation, extraction, leaching, membrane separation, reverse osmosis and ultrafiltration, design of plate and packed tower, visit to related food industry.

VII. Learning outcome

Student's capability to develop food products using recent techniques as per requirement of food industries.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Mixing and homogenization: Principles of solid and liquid mixing.	1
2.	Types of mixers for solids, liquid and pastes homogenization.	2
3.	Emulsification: Principles and equipments.	1
4.	Novel dehydration technologies: Osmotic dehydration, foam mat drying, puff drying.	2
5.	Freeze drying, microwave drying, and dehumidified air drying.	2
6.	Extrusion: Theory, equipment, applications.	2
7.	Non-thermal processing: Principles and equipment involved in ohmic heating, pulsed electric field preservation.	2
8.	Hydrostatic pressure technique (vacuum processing, high pressure processing of Foods), ultrasonic technology.	2
9.	Irradiation, quality changes and effects on microorganisms, nanotechnology in food processing.	2
10.	Distillation; Principles and equipment for distillation.	2
11.	Leaching; Principles and equipment.	2
12.	Extraction; Solvent extraction, crystallization, phase equilibria, multistage calculations.	3
13.	Super-critical fluid extraction, near critical fluid extraction: Equipment and experimental techniques used in NCF extraction and industrial application.	3
14.	Advanced methods for extraction of food components and aroma recovery.	1
15.	Food plant hygiene; Cleaning, sterilizing, waste disposal methods. Food processing plant utilities, steam requirements in food processing.	2
16.	HACCP in food processing industries.	1
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Conducting experiments and solving problems on mixing and mixing indices.	2
2.	To conduct the experiment on homogenization.	2
3.	To study the process of crystallization.	1
4.	To conduct the experiment on extraction.	2
5.	Experimentation on leaching process.	1
6.	To study the membrane separation process.	1
7.	To conduct the experiment on reverse osmosis technique.	1
8.	To conduct the experiment on ultrafilteraion process.	1
9.	Design of plate and packed tower.	2
10.	Visit to related food industry.	2
	Total	**15**

X. Suggested Reading

- Brennan JG, Butters JR, Cowell ND and Lilly AEI 1990. *Food Engineering Operations*. Elsevier.
- Earle RL. 1985. *Unit Operations in Food Processing*. Pergamon Press.
- Fellows P. 1988. *Food Processing Technology: Principle and Practice*. VCH Publisher.
- Geankoplis JC. 1999. *Transport Process and Unit Operations*. Allyn & Bacon.
- Gould GW. 1996. *New Methods of Food Preservation*. Blackie Academic & Professional.
- Heldman DR and Lund BD. 1992. *Hand Book of Food Engineering*. Marcel Dekker.
- McCabe WL and Smith JC. 1999. *Unit Operations of Chemical Engineering*. McGraw Hill.
- Sahay KM and Singh KK. 1994. *Unit Operation of Agricultural Processing*. Vikas Publ. House.
- Singh RP 1991. *Fundamentals of Food Process Engineering*. AVI Publisher.
- Singh RP and Heldman DR 1993. *Introduction to Food Engineering*. Academic Press.

I. Course Title : Food Processing Equipment and Plant Design

II. Course Code : PFE 511

III. Credit Hours : 1+1

IV. Aim of the course

To acquaint and equip the students with the design features of different food processing equipment being used in the industries along with the layout, planning of different food processing plants.

V. Theory

Unit I

Design considerations of processing agricultural and food products.

Unit II

Design of machinery for drying, milling, separation, grinding, mixing, evaporation, condensation, membrane separation.

Unit III

Human factors in design, selection of materials of construction and standard component, design standards and testing standards. Plant design concepts and general design considerations: Plant location, location factors and their interaction with plant location, location theory models, and computer aided selection of the location.

Unit IV

Feasibility analysis and preparation of feasibility report; Plant size, factors affecting plant size and their interactions, estimation of break-even and economic plant size. Product and process design, process selection, process flow charts, computer aided development of flow charts.

Unit V

Hygienic design aspects and worker's safety, functional design of plant building and selection of building materials, estimation of capital investment, analysis of plant costs and profitability's, management techniques in plant design including applications of network analysis, preparation of project report and its appraisal.

VI. Practical

Detailed design and drawing of mechanical dryers, milling equipment, separators, evaporators, mixers and separators. Each individual student will be asked to select a food processing plant system and develop a plant design report which shall include product identification and selection, site selection, estimation of plant size, process and equipment selection, process flow-sheeting, plant layout, and its evaluation and profitability analysis.

VII. Learning outcome

Student's capability to deal with food processing equipment and plant, techno-economic feasibility analysis of the project as needed in food industries.

VIII. Lecture Schedule

S.No.	Toic	No. of Lectures
1.	Design considerations of processing agricultural and food products. Plant design concepts - situations giving rise to plant design problems.	2
2.	General design considerations, Food Processing Unit Operations, Design of machinery for drying, milling and grinding	2
3.	Design principles of separation, mixing machines	1
4.	Design of evaporation, condensation, membrane separation machines	2
5.	Human factors in design, selection of materials of construction and standard component	1
6.	Design standards and testing standards	1
7.	Plant location, location factors and their interaction with plant location, location theory models, and computer aided selection of the location.	2
8.	Pre Selection/ Pre feasibility stage, Analysis Stage: Market Analysis, Situational analysis related to market	1
9.	Technical analysis, Financial Analysis, Sensitivity and risk analysis, Feasibility cost estimates	1
10.	Break Even Analysis: Introduction, Break-Even Chart, Fixed Costs, Variable costs, Breakeven point calculation	1
11.	Product and process design, process selection, process flow charts, computer aided development of flow charts.	1
12.	Hygienic design aspects and worker's safety, functional design of plant building and selection of building materials	1
13.	Estimation of capital investment, analysis of plant costs and profitability's. Management techniques in plant design including applications of network analysis. Project report and its appraisal.	2
	Total	**18**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Detailed design and drawing of mechanical dryers	2
2.	Detailed design and drawing of milling equipment	2
3.	Design of separators	2
4.	Design of evaporators	2
5.	Design of mixers and separators	2
6.	Project report preparation by students. (Individual student will select a processing plant, develop design report include product identification, site selection, estimation of plant size, process and equipment, process flow-sheeting, plant layout, its evaluation and profitability analysis	5
	Total	**15**

X. Suggested Reading

- Antonio LG and Gustavo VBC. 2005. *Food Plant Design*. CRC Press.
- Couper. 2012. *Chemical Process Equipment*. Selection and Design Elsevier.
- George S and Athanasios EK. 2015. *Handbook of Food Processing Equipment*. Springer.
- Lloyd EB and Edwin HY. 1959. *Process Equipment Design*. Wiley-Interscience.
- Michael MC. 2013. *Food Plant Sanitation: Design, Maintenance, and Good Manufacturing Practices*. CRC Press.

I. Course Title : Seed Process Engineering

II. Course Code : PFE 512

III. Credit Hours : 1+1

IV. Aim of the course

To acquaint and equip the students with seed processing along with the design features of the equipment used in their processing.

V. Theory

Unit I

Processing of different seeds and their engineering properties, principles and importance of seed processing.

Unit II

Performance characteristics of different unit operations such as precleaning, grading, conveying, elevating, drying, treating, blending, packaging and storage, seed processing machines like scalper, debreader, huller, velvet separator, spiral separator, cleaner-cum-grader, specific gravity separator, indent cylinder, disc separator, and colour sorter, seed treater, weighing and bagging machines, their operation and maintenance, installation and determination of their capacity, seed quality maintenance during processing, plant design and layout, economy and safety consideration in plant design.

Unit III

Seed drying principles and methods, theory of seed drying, introduction to different types of heated air dryers, significance of moisture equilibrium, method of maintaining safe seed moisture, thumb rule and its relevance.

Unit IV

Importance of scientific seed storage, types of storage structures to reduce temperature and humidity, management and operation/cleanliness of seed stores, packaging-principles, practices, materials and hermetic packaging, seed treatment methods and machines used, method of stacking and their impact, design features of medium and long term seed storage building.

VI. Practical

Study of various seed processing equipments such as pre-cleaners, scalpers, air screen cleaners, graders, spiral and pneumatic separators, seed treating equipment, bag closures, scale etc. and their performance evaluation, design and layout of seed processing plant and its economics, analysis of cost of operation and unit cost of processed product, effect of drying temperature and duration of seed germination and storability.

VII. Learning outcome

Student's capability to understand processing and storage requirement of seed maintaining its vigor and viability, suitable equipment for seed processing as per requirement of seed industries.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Processing of different seeds and their engineering properties.	1
2.	Principles and importance of seed processing.	1
3.	Performance characteristics of different unit operations such as pre-cleaning, grading, conveying, elevating, drying.	1
4.	Treating, blending, packaging and storage, seed processing machines like scalper, de-breeder, huller.	1
5.	Velvet separator, spiral separator, cleaner-cum-grader, specific gravity separator, indent cylinder, disc separator, and colour sorter.	1
6.	Seed treater, weighing and bagging machines, their operation and maintenance, installation and determination of their capacity.	1
7.	Seed quality maintenance during processing.	1
8.	Plant design and layout, economy and safety consideration in plant design.	2
9.	Seed drying principles and methods, theory of seed drying.	1
10.	Introduction to different types of heated air dryers.	1
11.	Significance of moisture equilibrium, method of maintaining safe seed moisture, thumb rule and its relevance.	1
12.	Importance of scientific seed storage, types of storage structures to reduce temperature and humidity.	1
13.	Management and operation/cleanliness of seed stores, packaging-principles, practices, materials and hermetic packaging.	1
14.	Seed treatment methods and machines used, method of stacking and their impact.	1
15.	Design features of medium and long term seed storage building.	1
	Total	**16**

IX. List of Practical

S.No.	Topic	No. of Practicals
1.	To study seed processing equipment such as pre-cleaners, scalpers and their performance evaluation.	2
2.	To study graders and their performance evaluation.	2
3.	To study air screen cleaners and their performance evaluation.	1
4.	To study spiral and pneumatic separators and their performance evaluation.	2
5.	To study seed treating equipment, bag closures, scale and their performance evaluation.	2
6.	To study design and layout of seed processing plant and its economics.	2
7.	To analyze the cost of operation and unit cost of processed product.	2
8.	To study the effect of drying temperature and duration of seed germination and storability.	2
	Total	**15**

X. Suggested Reading

- Babasaheb. 2004. *Seeds Handbook: Processing and Storage.* CRC.
- Gregg *et al.* 1970. *Seed Processing*. NSC.
- Guar. 2012. *A Handbook of Seed Processing and Marketing* Agrobios.
- Henderson S and Perry S M. 1976. *Agricultural Process Engineering*. 5th Ed. AVI Publisher.
- Mathad. 2017. *Seed Processing: A Practical Approach.* NIPA.
- Sahay KM and Singh KK. 1994. *Unit Operation of Agricultural Processing*. Vikas Publisher House.
- Vaugha. 1968. *Seed Processing and Handling*.https://www.mcia.msstate.edu/pdf/seed-processing-and-handling_1.pdf.

I. Course Title : Agri-Project Planning and Management

II. Course Code : PFE 513

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with the techniques of project development and evaluation along with different standards.

V. Theory

Unit I

Project development, market survey and time motion analysis.

Unit II

Selection of equipment, technology option, techno-economic feasibility and processing in production catchment.

Unit III

Product and process design, PERT, CPM, transport model, simplex, linear and dynamic programming, operation log book. Material balance and efficiency analysis, performance testing, performance indices, energy requirement and consumption. Marketing of agricultural products, market positioning.

Unit IV

BIS/FSSAI/ISO standards/ guidelines on best practices, equipment and their design and operation for handling, processing and storage of food/feed.

VI. Practical

Preparation of project and feasibility report. Salient features, design and layout of different food processing units; MSME, large processing unit. Record keeping related to production, finance and marketing. Techno-economic feasibility and SWOT analysis for Start-ups.

VII. Learning outcome

Student's capability to plan, scheduling of activities and manage a food related project as per requirement of food industries.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Project development.	2
2.	Market survey and time motion analysis.	2
3.	Selection of equipment for agro project planning.	2
4.	Technology option.	2
5.	Techno-economic feasibility and processing in production catchment.	2
6.	Product and process design.	2
7.	PERT, CPM.	2
8.	Transport model, simplex, linear and dynamic programming, operation log book.	3
9.	Material balance and efficiency analysis.	3
10.	Performance testing, performance indices, energy requirement and consumption.	3
11.	Marketing of agricultural products, market positioning.	2
12.	BIS/FSSAI/ISO standards/ guidelines on best practices.	2
13.	Equipment and their design and operation for handling, processing and storage of food/feed.	3
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	To study the preparation of project and feasibility report.	2
2.	To design salient features, design and layout of MSME.	2
3.	Design and layout of different food processing units: MSME, large processing unit.	2
4.	To study record keeping related to production.	2
5.	To study record keeping related to finance and marketing.	2
6.	To conduct experiment on agro project management and design techno-economic feasibility.	2
7.	To conduct SWOT analysis for different Start-ups.	3
	Total	**15**

X. Suggested Reading

- Ahmed T. 1997. *Dairy Plant Engineering and Management*. 4th Ed. Kitab Mahal.
- Albert L. 2017. *Project Management, Planning and Control*.
- Anandajayasekeram P. 2004. *Agricultural Project Planning and Analysis.*

I. Course Title : Farm Structures and Environmental Control

II. Course Code : PFE 514

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with the different types of farm structures and techniques, to control atmospheric parameters and to create favourable environment in the agricultural structures.

V. Theory

Unit I

Farmstead planning, survey and data collection for information bank. Analysis of data, Lay outs. Cost estimation and appraisal. Project development; Time, motion and input analysis, flow charts and drawings andcase studies.

Unit II

Farm structures (farmstead, livestock, poultry, storage godowns, farm machinery storage, biogas, green house, net house etc), their design, constructional details and design of low cost structures. Heating, ventilating and exhaust systems, air distribution and air cleaning, combustion of fuels and equipment.

Unit III

Drying and dehumidification system, air-water contact operations and evaporation, process and product air conditioning, energy efficient environmental control practices. Rural electrification, households electric wiring, rural water supply and sanitation.

Unit IV

Instruments and measurements:Codes and standards.

VI. Practical

Calculation of heating and cooling load,design calculation of moisture condensation in agricultural buildings, study of moisture migration behaviour in storage bins, design aspect of green house, net house, septic tank, grain storage structures, cold storage.

VII. Learning outcome

Student's capability to design new farm structures and create suitable atmosphere within it.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Farmstead Planning, types and objectives. Planning principles and layout, design and construction of farmstead.	2
2.	Survey and data collection for information bank. Analysis of data, Lay outs. Cost estimation and appraisal.	2
3.	Project development: Time, motion and input analysis, flow charts and drawings and case studies.	2
4.	Farm structure, layout and structural design of shelters for dairy animals (cow, buffaloes, calves, bulls etc).	3
5.	Layout and structure design of modern poultry houses (cage type) along with other associated structures.	2

S.No.	Topic	No. of Lectures
6.	Familiarization with various rural grain storage structures. Layout, design and constructional detail of grain and feed storage structures like bins and silos.	3
7.	Layout and structural design of storage structures for farm inputs like farm machinery, seeds, weedicides, insecticides and fertilizers.	1
8.	Ventilation utility in farm buildings; principles of natural ventilation; psychometric processes; heat and mass balance equation for ventilation; ventilation rates for temperature moisture and odour control.	3
9.	Rural electrification, households electric wiring, rural water supply and sanitation.	2
10.	General design considerations, operational and maintenance of biogas plant.	2
11.	Drying and dehumidification system, air-water contact operations and evaporation, process and product air conditioning, energy efficient environmental control practices.	3
12.	Environmental indices like THI; wet bulb depression, daily range, degree days, effective temperature, black globe temperature; mean radiant temperature, etc. Basic solar-earth angles and sol-air temperature.	3
13.	Instruments and measurements; Codes and standards.	2
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Planning and layout of a farmstead.	1
2.	Instruments for measurements of environmental parameters.	1
3.	Design of a farm fencing system.	1
4.	Study of moisture migration behaviour in storage bins.	1
5.	Design aspect of Septic tank.	1
6.	Design aspect of Net house.	1
7.	Design aspect of Grain storage structures.	1
8.	Design aspect of Green house.	1
9.	Design aspect of Cold storage.	1
10.	Design of a feed/fodder storage structures.	1
11.	Design of a biogas plant.	1
12.	Calculation of heating and cooling load.	1
13.	Design calculation of moisture condensation in agricultural buildings.	1
14.	Design of ventilation system for dairy and poultry house.	1
15.	Visit to Green/ Net house and cold storage.	2
	Total	**16**

X. Suggested Reading

- Albright LD. 1990. *Environmental Control for Animals and Plants*. ASAE Textbooks.
- Esmay ML and Dixon JE. 1986. *Environmental Control for Agricultural Buildings*. The AVI Corp.
- Gaudy AF and Gaudy ET. 1988. *Elements of Bioenvironmental Engineering*. Engineering Press.
- Moore FF. 1994. *Environmental Control Systems: Heating, Cooling, Lighting*. Chapman and Hall.
- Threlkeld JL. 1970. *Thermal Environmental Engineering*. Prentice Hall.

I. Course Title : Dairy Product Processing

II. Course Code : PFE 515

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with the various dairy products, processing methods and related equipment.

V. Theory

Unit I

Procurement, transportation and processing of market milk, cleaning and sanitization of dairy equipment. Special milks such as flavoured, sterilized, recombined and reconstituted toned and double toned.

Unit II

Condensed milk: Methods of manufacture and related equipment, evaluation of condensed and evaporated milk. Dried milk: Definition, methods of manufacture of skim and whole milk powder, instantiation, physiochemical properties, evaluation, defects in dried milk powder. Cream: Cream separation, neutralization, sterilization, pasteurization and cooling of cream, defects in cream, Butter: methods of manufacture, defects in butter.

Unit III

Ice cream: Methods of manufacture and related equipment, defects in ice cream, technology of softy manufacture. Cheese: Methods of manufacture, cheddar, Gouda, cottage and processed cheese, defects in cheese.

Unit IV

Indigenous milk products: Method of manufacture of *yoghurt, dahi, khoa, burfi, kalakand, gulabjamun, rosogolla, srikhand, chhana, paneer, ghee, lassi*etc.Probiotic milk product.

VI. Practical

Estimation and fat and SNF in milk.Operation of LTLT and HTST Pasteurization. Preparation of special milks.Cream separation and standardization of milk. Preparation and evaluation of table butter, ice-cream, cheese and indigenous milk product such as *khoa, chhana, paneer, ghee, rosogolla, gulabjamun, shrikhand, lassi, burfi,* etc. Visit to dairy plants.

VII. Learning outcome

Student's capability to mechanize processing operations in dairy industries for manufacturing of dairy products.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Collection and transportation of milk; Practices for collection of milk, preservation at farm, refrigeration, natural microbial inhibitors, lactoperoxidase system.	**1**
2.	Reception and treatment of milk: Reception, chilling, clarification and storage. General practices. Homogenization: pretreatments, theories, synchronization of homogenizer with operation of pasteurizer (HTST),	

S.No.	Topic	No. of Practicals
	effect of homogenization on physical properties of milk. Bactofugation: Theory and microbiology.	**3**
3.	Principles of thermal processing; kinetics of microbial destruction, thermal death curve, arrhenius equation, D value, Z value, F0 value, Q10 value. Factors affecting thermal destruction of micro organisms. Definition and description of processes; Pasteurization, thermisation, sterilization, UHT Processing.	**2**
4.	Cleaning and sanitization of dairy equipment	**1**
5.	Manufacture of special milks: flavoured, sterilized milk, recombined and reconstituted toned and doubled toned.	**2**
6.	Condensed milk, sweetened condensed milk and evaporated milk. Manufacture of evaporated milk, sweetened condensed milk and Recombined sweetened condensed milk and related equipment	**2**
7.	Physico chemical changes taking place during manufacture of condensed milk, Heat stability of milk and condensed milk, Physico chemical properties of condensed milk, Chemical defects in condensed milk, their causes and prevention.	**2**
8.	Dried Milks; Definition, grading and quality of raw milk for dried milks, Manufacture of skim milk powder (SMP), whole milk powders and heat classified powders,	**2**
9.	Physico chemical changes taking place during manufacture of dried milks, Physical properties of dried milks, Defects in dried milk during manufacture and storage, their causes and prevention.	**2**
10.	Cream: Definition, Efficiency of cream separation and factors affecting it; Neutralization, standardization, pasteurization and cooling of cream; Defects in cream	**2**
11.	Butter; Definition, Introduction to the butter making process; theory of churning, Technology of Butter manufacture, Batch and continuous methods, Defects in butter.	**2**
12.	History of ice cream industry, composition of ice cream, stabilizers and emulsifiers, properties and role in quality of ice cream Ice cream:	**1**
13.	Manufacturing, Ice cream plant components, Types of freezers, refrigeration control/ instrumentation, Technology of softy manufacture.	**2**
14.	Defects in ice cream, their causes and prevention	**1**
15.	Cheese; Manufacture of different varieties of cheese; Cheddar, Gouda, Cottage and processed cheese. Microbiological defects in cheese; their causes and prevention.	**3**
17.	Indigenous milk products: Product description, methods of manufacture of *yoghurt, dahi, khoa, burfi, kalakand, gulabjamun, rosogolla, srikhand, chhana, paneer, ghee, lassi*etc. Probiotic milk product.	**2**
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Estimation of fat and SNF in milk.	1
2.	Operation of LTLT and HTST Pasteurizer.	1
3.	Standardization of milk.	1
4.	Preparation of special milks.	1
5.	Cream separation: parts of separator and the process.	1
6.	Preparation of table butter using the power driven churn.	1
7.	Preparation of plain and fruit flavoured ice cream.	1

S.No.	Topic	No. of Practicals
8.	Preparation and analysis of *khoa* from cow and buffalo milk.	1
9.	Preparation and analysis of *chhana* from cow and buffalo milk.	1
10.	Preparation and analysis of *paneer* from cow and buffalo milk.	1
11.	Preparation and analysis of*lassi*from cow and buffalo milk.	1
12.	Preparation of *ghee* from cream and butter.	1
13.	Preparation of *rosogolla* and *gulabjamun*.	1
14.	Preparation of srikhand and burfi.	1
15.	Visit to dairy plant.	1
	Total	**15**

X. Suggested Reading

- Adnan T. 2009. *Dairy Powders and Concentrated Products* (*Society of Dairy Technology*). Wiley-Blackwell.
- Adnan T. 2006. *Probiotic Dairy Products* (*Society of Dairy Technology series*). Wiley-Blackwell.
- Britz. 2008. *Advanced Dairy Science and Technology*. Blackwell Publisher: Blackwell Publisher Professional.
- De. 2001. *Outlines of Diary Technology*. Oxford.
- Hui YH. 1992. *Dairy Science and Technology Handbook*. Vol. I, II and III Wiley.
- Spreer E. 2017. *Milk and Dairy Product Technology*. Taylor and Francis.
- Walstra P, Jan TM, Wouters and Geurts TJ. 2006. *Dairy Science and Technology*. CRC, Taylor and Francis.

I. Course Title : Processing of Meat, Poultry and Fish

II. Course Code : PFE 516

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with processing of meat, fish and poultry and the design features of the equipment used for their processing.

V. Theory

Unit I

Meat: Genetic engineering of farm animals for better meat quality, automation for the modern slaughterhouse, hot-boning of meat, new spectroscopic techniques for online monitoring of meat quality, real-time PCR for the detection of pathogens in meat, new developments in decontaminating raw meat, automated meat processing, developments in chilling and freezing of meat, high pressure processing of meat, approaches for the development of functional meat products, new techniques for analyzing raw meat, modified atmosphere packaging, perspectives for the active packaging of meat products.

Unit II

Poultry: Breeding and quality of poultry, stunning and slaughter of poultry, processing and packaging of poultry, new techniques of preservation of poultry, production of turkeys, geese, ducks and game birds, microbial hazards in poultry production and processing, latest trends in measuring quality of poultry and poultry products, treatment and disposal of poultry processing waste.

Unit III

Fish and seafood: Fresh fish handling and chill storage, modified atmospheric packaging of seafoods, fish odours and flavours, assessment of freshness of fish and seafoods, traditional dried and salted fish products, proteolysed fish products, minced fish technology, retort pouch processing technology, irradiation and microwave in fish handling and processing, advanced freezing technology for fish storage, high pressure processing of seafoods, value addition of freshwater and aqua cultured fish products, application of enzymes in fish processing and quality control, toxins, pollutants and contaminants in fish and seafoods.

Unit IV

Milk: Physical, chemical and nutritional properties of milk components, improvements in the pasteurization and sterilization of milk. Flavour generation in dairy products, controlling texture of fermented dairy products, functional dairy products, on-line measurement of product quality in dairy processing, high pressure processing of milk products, novel separation technologies to produce dairy ingredients, new technologies to increase shelf-life of dairy products, genetic engineering of milk proteins, production and utilization of functional milk proteins, methods of improving nutritional quality of milk, significance of milk fat in dairy products, chromatographic, spectrometric, ultrasound and other techniques for analysis of milk lipids.

VI. Practical

Analysis of fresh and processed meat, fish, poultry and milk products, preservation of fresh meat and fish, processing and production of different products from fresh meat, fish and milk, shelflife studies on different meat, fish and milk products. Visit to processing plants.

VII. Learning outcome

Student's capability to process meat, fish and poultry and manufacture value added products as per requirement of food industries.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Genetic engineering of farm animals for better meat quality.	1
2.	Developments in automation of the modern slaughterhouse, hot-boning process of meat, benefits of hot boning.	1
3.	New spectroscopic techniques for online monitoring of meat quality, Real-time PCR for the detection of pathogens in meat.	2
4.	Automated meat processing, developments in chilling and freezing of meat, High pressure processing of meat, approaches for the development of functional meat products.	3
5.	New techniques for analyzing raw meat, modified atmosphere and active packaging of meat products.	2
6.	Breeding and quality of poultry, Stunning and slaughter of poultry, Processing and packaging and new techniques of preservation of poultry.	2
7.	Production of turkeys, geese, ducks and game birds.	1
8.	Microbial hazards in poultry production and processing, treatment and disposal of poultry processing waste, Latest trends in measuring quality of poultry and poultry products. Treatment and disposal of poultry processing waste.	3

S No	Topic	No. of Lectures
9.	Fish and seafood: Fresh fish handling and chill storage, modified atmospheric packaging, Assessment of freshness of fish and seafoods, different traditional and proteolysed fish products, minced fish technology.	3
10.	Retort pouch processing technology, irradiation and microwave in fish processing, Advanced freezing technology for fish storage, Value addition of freshwater and aqua cultured fish products, application of enzymes in fish processing.	3
11.	Quality control: toxins, pollutants and contaminants in fish and sea foods.	1
12.	Physical, chemical and nutritional properties of milk components, improvements in the pasteurization and sterilization of milk.	2
13.	Flavour generation in dairy products, controlling of texture in fermented dairy products.	1
14.	Functional dairy products, on-line measurement of product quality, high pressure processing, Novel separation technologies to produce dairy ingredients, new technologies to increase shelf-life of dairy products.	2
15.	Genetic engineering of milk proteins, production and utilization of functional milk proteins.	1
16.	Methods of improving nutritional quality of milk, significance of milk fat in dairy products and different techniques for analysis of milk lipids.	2
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Analysis of fresh and processed meat products	1
2.	Analysis of fresh and processed fish products	1
3.	Analysis of fresh and processed poultry products	1
4.	Analysis of fresh and processed milk products	1
5.	Preservation of fresh meat and fish	1
6.	Processing and production of different products from fresh meat	2
7.	Processing and production of different products from fresh fish	2
8.	Processing and production of different products from fresh poultry	2
9.	Processing and production of different products from fresh milk	1
10.	Shelf life studies on different meat, fish and milk products	2
11.	Visit to processing plants	1
	Total	**15**

X. Suggested Reading

- Chooksey MK. 2003. *Fish Processing and Product Development*. CIFE, Kochi.
- Chooksey MK and Basu S. 2003. *Practical Manual on Fish Processing and Quality Control*. CIFE, Kochi.
- Hall GM. 1997. *Fish Processing Technology*. Blabie Academic and Professional.
- Lawrie RS. 1985. *Developments in Meat Sciences*. Vol III Applied Science Publishers.
- Mead GC. 1989. *Processing of Poultry*. Elsevier.
- Pearson AM and Tauber FW. 1984. *Processed Meats*. AVI Publishers.
- Stadelman WJ and Cotterill OJ. 1980. *Egg Science and Technology*. AVI Publishers.

I. Course Title : Design of Aquacultural Structures

II. Course Code : PFE 517

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with aquaculture structures and their design features.

V. Theory

Unit I

Inland fish farming and associated considerations.

Unit II

Fish physiology and micro-climatic considerations.Site selection for aquaculture structures.

Unit III

Design of dykes, sluice, channels etc. Aeration and feeding systems: Design of fish rearing structures, hatcheries, containers for live fish, fingerlings, fish seeds.

Unit IV

Aquaculture in recirculatory systems, oxygen and aeration, sterilization and disinfection. Recirculation of water:Reuse systems, water exchange, design of re-use systems, Inlet and outlet structures and water treatment plants.

VI. Practical

Aeration and feeding systems of fish ponds, fish farming structures, water treatment plants, containers for live fish.Design of re-use systems.Inlet and outlet structures.

VII. Learning outcome

Student's capability to design suitable aquaculture structures.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Inland fish farming.	1
2.	Considerations in site selection for designing inland fish farms.	2
3.	Preparatory work for designing inland fish farms: technological requirements, general technical, hydrological and meteorological data.	3
4.	Fish physiology.	2
5.	Micro-climatic considerations for fish farms.	1
6.	Design of dykes, sluice, channels etc.	3
7.	Aeration and feeding systems.	1
8.	Design of fish rearing structures.	1
9.	Hatcheries.	2
10.	Containers for live fish, fingerlings, fish seeds.	1
11.	Fish pond arrangements: Barrage Ponds, Contour Ponds, Paddy Ponds.	2
12.	Earth structures in fish farms: Dams and Dikes, Feeder Canals, Drainage canals, Drain Ditch, Internal Pond Drains, Borrow Pits and Internal Harvesting Pits.	3
13.	Aquaculture in recirculatory systems.	2
14.	Oxygen and aeration in fish farms. Sterilization and disinfection in fish farms.	2

S.No.	Topic	No. of Lectures
15.	Recirculation of water; Reuse systems, water exchange, design of re-use systems, Inlet and outlet structures.	3
16.	Water treatment plants in fish farms.	1
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Study of aeration systems of fish ponds.	1
2.	Study of feeding systems of fish ponds.	1
3.	Design of dykes in fish farming structures.	1
4.	Design of feeder canals in fish farming structures.	2
5.	Design of drainage canals in fish farming structures.	1
6.	Design of drain ditch in fish farming structures.	1
7.	Design of internal pond drains in fish farming structures.	1
8.	Design of borrow pits in fish farming structures.	1
9.	Design of internal harvesting pits in fish farming structures.	1
10.	Study of waste water management through aquaculture.	1
11.	Design of recirculatory ponds for waste water treatment in fish farms.	1
12.	Different types of containers for live fish.	1
13.	Design of re-use systems in fish farms.	1
14.	Different types of inlet and outlet structures in fish farms.	1
	Total	**15**

X. Suggested Reading

- FAO. 1983. *Inland Aquaculture Engineering*. ISBN 92-5-102168-6.

I. Course Title : Thermal Environmental Engineering for Agricultural Processing

II. Course Code : PFE 518

III. Credit Hours : 3+0

IV. Aim of the course

To acquaint and equip the students with the concept of thermodynamic properties of air and its application in food processing.

V. Theory

Unit I

Requirements of temperature and moisture in food preservation, processing, storage, animal and plant production systems, human comfort etc.

Unit II

Thermodynamic properties of moist air, psychrometric chart, psychrometric processes and applications. Mass transfer and evaporation of water from free surfaces, theory of psychrometer, direct contact transfer processes between moist air and water-air washer, cooling tower, heating and cooling of moist air by extended surface coils, dehumidification using moisture absorbing materials. Solar irradiations on structures, calculation of heating and cooling loads in buildings/ storage structures.

Unit III

Design of air conditioning systems, air distribution and duct design, air flow pattern and control, equipment, components and controls.Instruments for measurement and control of temperature and moisture.

Unit IV

Thermal insulation materials for environmental control systems, applications of environmental control in green house, dairy industry, potato storage etc.

VI. Learning outcome

Student's capability to design environmental control systems related to different unit operation in food processing industry.

VII. Schedule of Lectures

S.No.	Topic	No. of Lectures
1.	Requirements of temperature and moisture in food preservation, processing, storage, animal and plant production systems, human comfort etc. Various thermal indices.	5
2.	To study the different temperature, moisture and relative humidity measuring instruments.	3
3.	Thermodynamic properties of moist air.	3
4.	Psychrometric chart, psychrometric processes and applications. Mass transfer and evaporation of water from free surfaces, theory of psychrometer.	5
5.	Direct contact transfer processes between moist air and water-air washer, cooling tower, heating and cooling of moist air by extended surface coils, dehumidification using moisture absorbing materials.	4
6.	Solar irradiations on structures, calculation of heating and cooling loads in buildings/ storage structures.	5
7.	Introduction to air conditioning systems and design considerations.	4
8.	air distribution and duct design, air flow pattern and control, equipment, components and controls. Instruments for measurement and control of temperature and moisture.	4
9.	Thermal insulation materials for environmental control systems. Comparative performance of these materials.	4
10.	Applications of environmental control in farm buildings, farmstead, green house, dairy industry, poultry shed, potato storage etc.	5
	Total	**42**

VIII. Suggested Reading

- *Perry's Chemical Engineers' Handbook*, Section 12. (2007).
- Threlkald JL. *Thermal Environmental Engineering*, Pearson.

Course Title with Credit Load
Ph.D. in Processing and Food Engineering

Major Courses

Course Code	Course Title	Credit Hours
*PFE 601	Advances in Food Process Engineering	2+1
*PFE 602	Drying and Dehydration of Food Materials	2+1
PFE 603	Textural and Rheological Characteristics of Food Materials	2+1
PFE 604	Agricultural Waste and By-Products Utilization	2+1
PFE 605	Mathematical Modeling in Food Processing	3+0
PFE 606	Bioprocess Engineering	2+1
	Total	**13+5**

Minor Courses (Requirement: 06 Credits)

Course Code	Course Title	Credit Hours
CSE 506	Digital Image Processing	2+1
CSE 507	Process Control System	2+1
REE 616	Renewable Energy for Industrial Application	2+1
ME 501	Mechatronics and Robotics in Agriculture	2+0
CE 501	Dimensional Analysis and Similitude	1+1
	Any other course (s) of other department other than course(s) from major can be taken as per recommendations of the student's advisory committee.	

Supporting Courses (Requirement: 05 Credits)

Course Code	Course Title	Credit Hours
*CPE-RPE	Research and Publication Ethics	1+1
STAT 502	Theory of Designs and Analysis of Experiments	1+1
	Courses from subject matter fields (other than Major and Minor) relating to area of special interest and research problem can be taken as per recommendations of the student's advisory committee.	

*Course has been made compulsory by UGC for PhD students. Course code and its detailed course outline to be adopted in toto as recommended by UGC.

List of Other Essential Requirements

Course Code	Course Title	Credits
PFE 691	Seminar-I	0+1
PFE 692	Seminar-II	0+1
PFE 699	Thesis Research	0+75

Course Contents
Ph.D. in Processing and Food Engineering

I. **Course Title** : **Advances in Food Process Engineering**
II. **Course Code** : **PFE 601**
III. **Credit Hours** : **2+1**

IV. **Aim of the course**

To acquaint and equip the students with the modern andlatest techniques offood engineering.

V. **Theory**

Unit I

Preservation of foods: Physical and chemical methods, microbiological aspects, thermo bacteriology, process calculation and selection. Thermal processing of canned foods: Introduction, commercial sterilization systems, thermal inactivation, kinetics of bacterial spores, heat transfer in canned foods, process calculations, numerical computer simulation of heat transfer, aseptic processing.

Unit II

Low temperature preservation; Cooling and cold storage. Hurdle technology: Principles and applications. Food irradiation: Advantages and applications, beneficial chemical and biological effects on foods, mechanisms of food irradiation, sources of food irradiation, criteria for judging the efficacy, dosimetry, radiation tolerance of foods, upper irradiation dose for foods, safety of irradiated foods. Microwave processing: Interaction with food materials, microwave equipment. Hydrostatic pressure treatment of food: Equipment, processing and effect on microorganisms. High pressure processing: Introduction, equipment and operation principles. Chemical and thermodynamic principles.Applications of HP to foods.Commercial high pressure equipment and applications. Membrane concentration of liquid foods: Principles, thermodynamics and osmotic pressure, mechanisms of membrane transport, membrane transport models.

Unit III

Application of heat energy and ultrasound; Effects of different environmental factors on microbial ultrasonic resistance, effects of treatment parameters on lethal effect of ultrasound, mechanism of action of inactivation of microorganisms and enzymes, cavitation. Electrical resistance heating of food: Heat generation. Ohmic heating and moderate electric field: Introduction, microbial death kinetics, electrolytic effects, applications, ohmic heater, heating models. Pulsed electric field preservation: Principles and application, microbial inactivation mechanism, determinant factors in PFE technology, influence on food ingredients, pulsed electric field treatment unit, modeling PFE microbial inactivation, alternative applications of PFE technology, decontamination of microorganisms by surface treatment.

Unit IV

Extrusion cooking: Rheology of extrudates, newtonian models of single-screw extruder performance, non-newtonian models of single-screw extruder performance, single-screw extruder leakage flows, extruder die and its interaction with extruder behaviour, screw power demand, non-isothermal screw operation, feed zone, behavior of more complex single-screw designs, multiple-screw extruders, partially filled screws, analysis of complex screws, heat transfer in extruders, extruder residence-time distributions, recent developments, methods, equipment, design criteria of extruders.

VI. Practical

Thermal processing of foods, sterilization, irradiation, membrane concentration, ultrasound, ohmic heating, pulsed electric field preservation, extrusion cooking, product quality determination. Visit of related food industries.

VII. Learning outcome

Student's capability to process and preserve food products using advance techniques as per requirement of food industries.

VIII. Lecture Schedule

S.No.	Toic	No. of Lectures
1.	Preservation of foods; Physical and chemical methods, microbiological aspects, thermo bacteriology, process calculation and selection.	3
2.	Thermal processing of canned foods: Introduction, commercial sterilization systems, thermal inactivation, kinetics of bacterial spores, heat transfer in canned foods, process calculations, Numerical computer simulation of heat transfer, aseptic processing.	4
3.	Low temperature preservation: Cooling, cold storage and CA storage.	3
4.	Hurdle technology; Principles and applications.	2
5.	Food irradiation: Advantages and applications, beneficial chemical and biological effects on foods, mechanisms of food irradiation, sources of food irradiation, criteria for judging the efficacy, dosimetry, radiation tolerance of foods, upper irradiation dose for foods, safety of irradiated foods.	2
6.	Microwave processing; Interaction with food materials, microwave equipment.	2
7.	Hydrostatic pressure treatment of food; Equipment, processing and effect on microorganisms. High pressure processing: Introduction, equipment and operation principles. Chemical and thermodynamic principles. Applications of HP to foods. Commercial high pressure equipment and applications.	2
8.	Membrane concentration of liquid foods; Principles, thermodynamics and osmotic pressure, mechanisms of membrane transport, membrane transport models.	2
9.	Application of heat energy and ultrasound; Effects of different environmental factors on microbial ultrasonic resistance, effects of treatment parameters on lethal effect of ultrasound, mechanism of action of inactivation of microorganisms and enzymes, cavitation	2
10.	Electrical resistance heating of food: Heat generation. Ohmic heating and moderate electric field: Introduction, microbial death kinetics, electrolytic effects, applications, ohmic heater, heating models.	2

S.No.	Topic	No. of Lectures
11.	Pulsed electric field preservation; Principles and application, microbial inactivation mechanism, determinant factors in PFE technology, influence on food ingredients, pulsed electric field treatment unit, modeling PFE microbial inactivation, alternative applications of PEF technology, decontamination of microorganisms by surface treatment.	2
12.	Extrusion cooking; Rheology of extrudates, Newtonian and non-Newtonian models of single-screw extruder performance, extruder leakage flows, extruder die and its interaction with extruder behaviour, screw power demand, non-isothermal screw operation, single-screw designs, multiple-screw extruders, partially filled screws, analysis of complex screws, heat transfer in extruders, extruder residence-time distributions, recent developments, design criteria of extruders.	4
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Study of thermal processing of foods and equipment, viz. pasteurization and sterilization and tutorials.	2
2.	Study of different irradiation processes and equipments.	1
3.	Study of different membrane separation processes and equipments.	1
4.	Study of different ultrasound processes and equipments	1
5.	Study of different ohmic heating method and equipments.	1
6.	Study of different pulsed electric field preservation processes and equipments.	1
7.	Study of different extrusion cooking method and equipments.	2
8.	Product quality determination	2
9.	Visit of various food industries.	3
10.	Development of experimental setup by students	1
	Total	**15**

X. Suggested Reading

- Brennan JG, Butters JR, Cowell ND and Lilly AEI. 1990. *Food Engineering Operations*. Elsevier Publications.
- Fellows P. 1988. *Food Processing Technology: Principle and Practice*. VCH Publications.
- Geankoplis J Christie. 1999. *Transport Process and Unit Operations*. Allyn & Bacon.
- Henderson S and Perry SM. 1976. *Agricultural Process Engineering*. 5th Ed. AVI Publishing Company.
- McCabe WL and Smith JC. 1999. *Unit Operations of Chemical Engineering*. McGraw Hill.
- Sahay KM and Singh KK. 1994. *Unit Operation of Agricultural Processing*. VikasPublishing House Pvt Ltd.
- Singh RP and Heldman DR. 1993. *Introduction to Food Engineering*. Academic Press.
- Singh RP. 1991. *Fundamentals of Food Process Engineering*. AVI Publishing Company.

I. Course Title : Drying and Dehydration of Food Materials

II. Course Code : PFE 602

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with the latest technologies of dehydration of food products and the design features of different dryers.

V. Theory

Unit I

Importance of drying, principles of drying, moisture determination, equilibrium moisture content, determination of EMC, methods and isotherm models. Psychrometry; Psychrometric terms, construction and use of psychrometric charts.

Unit II

Air flow and resistance, principles and equipment for air movement and heating, drying methods and theory of drying, dryers, classification and other allied equipment, thin layer drying of cereal grains, deep bed and continuous flow drying, drying models.

Unit III

Heat requirements and thermal efficiency of drying system, aeration, tempering and dehydration, operation of dryers and their controls, selection of dryers, performance testing of grain dryers, drying characteristics of cereals, pulses and oilseeds, microwave drying, radio frequency drying and tunnel drying, principles and equipment.

Unit IV

Drying of liquid foods, spray drying, drum drying, freeze drying, foam mat drying, heat pump drying, refractance window drying, infrared drying osmotic dehydration. Principles, methods, construction and adjustments,selection of dryers, heat utilization factor and thermal efficiency.

VI. Practical

Experiments on batch type thin layer dryer, fluidized bed dryer, continuous flow mixing type dryer, continuous flow non mixing type dryer, sand medium dryer (conduction type drying), agricultural waste fired furnace dryer, spray dryer, drum dryer, foam mat drying and osmotic dehydration to evaluate the thermal efficiency and heat utilization factor.

VII. Learning outcome

Student's capability to develop dehydrated food products with higher retention of nutrients using different drying techniques and equipments.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Importance of drying, principles of drying, moisture content determination, equilibrium moisture content, determination of EMC.	2
2.	Basic concepts associated with drying – Intermolecular forces, Water activity, Molecular mobility, Glass transition temperature, Isotherm models – Langmuir, BET Isotherm	3
3.	Psychrometry; Psychrometric terms, construction and use of psychrometric charts.	3
4.	Air flow and resistance, principles and equipment for air movement and heating	3
5.	Theory of drying, Dryers, Classification and other allied equipment,	2
6.	Thin layer drying of cereal grains, deep bed and continuous flow drying, drying models.	3
7.	Heat requirements and thermal efficiency of drying system, aeration, tempering and dehydration.	3

S.No.	Topic	No. of Lectures
8.	Operation of dryers and their controls, selection of dryers, performance testing of grain dryers Drying characteristics of cereals, pulses and oilseeds,	3
9.	Microwave drying, radio frequency drying and tunnel drying, principles and equipment.	2
10.	Drying of liquid foods, spray drying, drum drying. Principles, methods, construction and adjustments.	2
11.	Freeze drying, foam mat drying, heat pump drying, refractance window drying, infrared drying, and osmotic dehydration. Principles, methods, construction and adjustments.	3
12.	Selection of dryers, heat utilization factor and thermal efficiency.	1
	Total	30

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Determination of moisture content with Oven method.	1
2.	Determination of moisture content (w.b.) with Universal/Digital moisture meter.	1
3.	Determination of moisture content (w b) with Infrared moisture meter.	1
4.	Determination of Equilibrium moisture content of grains.	1
5.	Drying of grains in a batch type thin layer dryer to evaluate the thermal efficiency and heat utilization factor.	1
6.	To evaluate the performance of fluidized bed dryer in terms of thermal efficiency and heat utilization factor.	1
7.	To draw a drying rate curve for wet grains in Satake test dryer i.e. Compartment type dryer.	1
8.	Drying of food materials in a solar assisted mechanical tray drying system.	1
9.	To dry grains in continuous flow mixing type dryer.	1
10.	To evaluate the performance of conduction type dryer.	1
11.	To determine the drying efficiency of agricultural waste fired furnace dryer.	1
12.	Drying of liquid food material in a spray dryer and evaluate its thermal efficiency and heat utilization factor.	1
13.	To evaluate the performance of a drum dryer.	1
14.	Experimentation on foam mat drying process.	1
15.	Experiment on osmotic dehydration of grapes.	1
	Total	**15**

X. Suggested Reading

- Bala BK. 1998. *Drying and Storage of Cereal Grains*. Oxford and IBH.
- Brooker DB, Bakker Arkema FW and Hall CW. 1974. *Drying Cereal Grains*. The AVI Publishing Company.
- Chakraverty A and De DS. 1999. *Post-Harvest Technology of Cereals, Pulses and Oilseeds*. Oxford & IBH.
- Hall CW. 1970. *DryingFarm Crops*. Lyall Book Depot.
- Kudra and Mujumdar. 2009. *Advanced Drying Technologies*. CRC press.

I. Course Title : Textural and Rheological Characteristics of Food Materials

II. Course Code : PFE 603

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with advances in measurement of textural and rheological characteristics affecting the food quality.

V. Theory

Unit I

Rheological properties of foods; Food rheology, physical states of materials, classical ideal material, rheological models, elements in the models, electrical equivalence, maxwell model, Kelvin model and four element burger's model, stress-strain behavior. Elastic–plastic behavior, visco-elastic behavior, creep behavior, dynamic visco-elastic behavior, flow behavior of fluids, creep, stress relaxation.

Unit II

Viscometry; Capillary viscometry, casson model, flow rate equation, friction losses in pumping, turbulent flow, newtonian fluid, power law fluid, cone and plate viscometry, parallel plate viscometry, mixer viscometry. Flow through a converging die, cogswell's equations, gibson's equations, empirical method. Applications of stress and strain, shear modulus and shear loss modulus, storage compliance and loss compliance, comparison of moduli and compliances.

Unit III

Objective and subjective measurements of texture; Texture classification, relation of food texture with structure and rheology, principles and practices of objective or instrumental texture measurements, fundamental rheological tests, physiological aspects, mechanical aspects and viscosity measurements and relationship between fundamental tests and sensory evaluation. Imitative and empirical measurements of texture; Tenderometer, brabenderfarinograph, firmness meter, texture profile method, dynamic methods for evaluation of food texture, dimensional analysis of food texture, firmness and hardness measurement.

Unit IV

Mathematical models and their application along with pipe line design and pump selection for non-newtonian fluids. Recent advances in textural, rheological and viscoelastic characteristics of foods and their associated mathematical models.

VI. Practical

Determination of viscosity of liquid foods, gumminess, chewiness, springiness and hardness of various fruits, vegetables and processed foods using texture profile analysis.Determination of force-distance relationship.Sensory evaluation/ subjective measurement and correlation between subjective and objective measurements of foods.

VII. Learning outcome

Student's capability to determine textural and rheological properties of food materials and their application in control of food processing operations.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Objective and subjective measurements of texture: Texture classification, relation of food texture with structure and rheology.	3
2.	Principles of Objective Texture Measurement.	2
3.	Practices of objective or instrumental texture measurements.	2
4.	Fundamental rheological tests, physiological aspects, mechanical aspects and viscosity measurements and relationship between fundamental tests and sensory evaluation.	2
5.	Imitative and empirical measurements of texture: Tenderometer, brabender farinograph, firmness meter, texture profile method, dynamic methods for evaluation of food texture, dimensional analysis of food texture, firmness and hardness measurement.	2
6.	Rheological properties of foods: Food rheology, physical states of materials, classical ideal material.	2
7.	Elastic–plastic behavior, visco-elastic behavior, creep behavior, dynamic visco-elastic behavior, flow behavior of fluids, creep, stress relaxation.	2
8.	Rheological models, elements in the models, electrical equivalence, maxwell model, Kelvin model and four element burger's model, stress-strain behavior.	2
9.	Viscometry; Capillary viscometry, casson model, flow rate equation, friction losses in pumping, turbulent flow, newtonian fluid, power law fluid, cone and plate viscometry, parallel plate viscometry, mixer viscometry.	2
10.	Flow through a converging die, cogswell's equations, gibson's equations, and empirical method.	2
11.	Applications of stress and strain, shear modulus and shear loss modulus, storage compliance and loss compliance, comparison of moduli and compliances.	2
12.	Correlation between physical measurements and sensory assessments of texture and viscosity.	2
13.	Mathematical models and their application along with pipe line design and pump selection for non-newtonian fluids.	2
14.	Recent advances in textural, rheological and viscoelastic characteristics of foods and their associated mathematical models.	2
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Introduction to Texture analyzer	1
2.	Study of different attachments of texture analyzer used in texture analysis of various agricultural commodities.	1
3.	To study the texture profile curve for food material	1
4.	To study the textural profile kinetics of various fruits	2
5.	To study the textural profile kinetics of various vegetables	2
6.	To study the textural profile kinetics of various processed foods	2
7.	To study the textural properties of liquid food	1
8.	To study the Compression, puncture, elongation and bending tests for food materials	3
9.	Introduction to Rapid Visco analyser	2
10.	Subjective measurement and correlation between subjective and objective measurements of foods.	1
	Total	**16**

X. Suggested Reading

- Bourne MC. 2002. *Food Texture and Viscosity: Concept and Measurement*. Academic Press.
- Deman JM. 1976. *Rheology and Texture in Food Quality*. AVI Publications.
- Mohsanin NN. 1989. *Physical Properties of Plant and Animal Material.* Vol. I, II. Gordon and Breach Science Publications.
- Steffe JF. 1992. *Rheology and Texture in Food Quality*. AVI Publications.

I. Course Title : Agricultural Waste and By-Products Utilization

II. Course Code : PFE 604

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with the techniques of utilization of agricultural waste and by-products and also about development of value added products from wastes.

V. Theory

Unit I

Conversion processes: Thermo-chemical conversions, densification, combustion and gasification, extraction, biological conversions, anaerobic digestion, biochemical digestion process, digestion systems, energy from anaerobic digestion, cellulose degradation, fermentation process. Agricultural wastes as paper, boards and fuel.

Unit II

Briquetting: Briquetted fuel from husk, hull and other wastes selection, design of briquetting machines. Utilization of shell, stem and stalk:Production of activated carbon. By-products of agro-industries:Rice mill, oil mill, cattle feed mill, valuable constituents and composition. Utilization of rice husk: Production of silica and cement from rice husk.Stabilization and storage of rice bran, extraction of rice bran oil.

Unit III

By-products of oil refining: Fatty acids/soap stock, wax and gum, characteristics and utilization. Rice germ and broken rice. Production of starch and infant food, industrial uses of starch. By-products of oil milling:Oil cake and defatted oil cake, cattle feed and industrial uses. Utilization of starch and other industrial wastes: Microcrystalline cellulose, production of ethanol, wastes of tapioca starch industries,thippi-utilization as fuel, extraction of starch by hydrolysis, utilization of starch for food, adhesives and feed purposes.

Unit IV

By-products of sugar industry: Sugarcane tops, bagasse, molasses and pressmud, utilization as animal feed. By-products of fruits and vegetables based agro-industries: Mango seed kernel and pineapple waste.

VI. Practical

Exercises on stepped grate and fixed grate rice husk furnaces, waste fired furnace, briquette machine, production of alcohol from waste materials, production and testing of paperboards and particleboards from agricultural wastes.

VII. Learning outcome

Student's capability to develop processes for effective utilization of wastes generated through milling and processing of food materials.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction to by-products and waste generation in agricultural production and processing system. Generation of agricultural and agro industrial by-products/ wastes, their properties, on site handling, storage and processing.	2
2.	Thermo-chemical conversions, biological conversions, anaerobic digestion, biochemical digestion process, digestion systems, energy from anaerobic digestion, cellulose degradation, fermentation process.	3
3.	Combustion and its types, theory, basic requirements for combustion, extraction.	2
4.	Gasification process, gasifiers- types and their functioning, factors affecting gasification process.	2
5.	Densification process, methods to densify mateials, factors to be considered.	1
6.	Utilization of wastes for paper production, production of particle board.	1
7.	Briquetting process, methods, design of machinery used for briquette formation, basic requirements, factors affecting briquetting from husk, hull and other wastes selection.	2
8.	Utilization of rice husk: Production of silica and cement from rice husk, Stabilization and storage of rice bran, extraction of rice bran oil.	2
9.	Utilization of shell, stem and stalk: Production of activated carbon.	1
10.	By-products from rice milling operations, rice husk, rice bran, utilization in different materials.	3
11.	Waste from oil mill, cattle feed mill, their valuable constituents and composition, utilization.	2
12.	By-products of oil refining: Fatty acids/soap stock, wax and gum, characteristics and utilization.	1
13.	Rice germ and broken rice. Production of starch and infant food, industrial uses of starch.	1
14.	By-products of oil milling: Oil cake and defatted oil cake, cattle feed and industrial uses.	1
15.	Utilization of starch and other industrial wastes: Microcrystalline cellulose, production of ethanol, wastes of tapioca starch industries.	2
16.	Thippi-utilization as fuel, extraction of starch by hydrolysis, utilization of starch for food, adhesives and feed purposes.	2
17.	By-products of sugar industry: Sugarcane tops, bagasse, molasses and press mud, utilization as animal feed.	2
18.	By-products of fruits and vegetables based agro-industries: Mango seed kernel and pineapple waste.	2
	Total	32

IX. List of Practicals

S.No.	Experiment	No. of Practicals
1.	To Determine of moisture content of biomass.	1
2.	To Determine of ash content of biomass.	1
3.	To determine Proximate analysis of biomass/waste/residue.	2
4.	Exercises on stepped grate and fixed grate rice husk furnaces.	2
5.	Exercises on waste fired furnaces.	1
6.	Exercises on combustion calculation.	1
7.	To study the briquetting machine.	1

S.No.	Topic	No. of Lectures
8.	To study the various quality parameters of briquettes.	1
9.	To study the production of alcohol from waste materials.	1
10.	To study the production of paper boards and particle boards from agricultural wastes.	2
11.	To determine the properties of paper boards and particle boards from agricultural wastes.	2
	Total	**15**

X. Suggested Reading

- ASAE Standards. 1984. *Manure Production and Characteristics.*
- Bor SL. (Ed.). 1980. *Rice: Production and Utilization*. AVI Publ.
- Chahal DS. 1991. *Food, Feed and Fuel from Biomass*. Oxford & IBH.
- Chakraverty A. 1989. *Biotechnology and other Alternative Technologies for Utilisation of Biomass/Agricultural Wastes*. Oxford & IBH.
- Donald LK and Emert HG. 1981. *Fuels from Biomass and Wastes*. Ann. Arbor. Science Publ.
- Srivastava PK, Maheswari RC and Ohja TP. 1995. *Biomass Briquetting and Utilization*. Jain Bros.
- USDA. 1992. *Agricultural Waste Management Field Handbook*. USDA.

I. Course Title : Mathematical Modeling in Food Processing

II. Course Code : PFE 605

III. Credit Hours : 3+0

IV. Aim of the course

To acquaint and equip the students with the mathematical modeling techniques and their applications in food processing

V. Theory

Unit I

An overview of the modeling process.Introduction to mathematical, correlative and explanatory models.Formulation, idealization and simplification of the problems.

Unit II

Probability models, series and linear mathematical approximation, dynamic and interacting dynamic processes.

Unit III

Applications of mathematical modelling techniques to food processing operations like parboiling, convective drying, pasteurization, dehydration, shelf-life prediction, fermentaiton, aseptic processing, moisture diffusion, deep fat drying, microwave processing, infrared heating and ohmic heating.

Unit IV

Stochastic finite element analysis of thermal food processes. Neural networks approach to modelling food processing operations.

VI. Learning outcome

Student's capability to develop models for food processing operations for prediction and control of operations.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	An overview of the modeling process.	2
2.	Introduction to mathematical, correlative and explanatory models. Formulation, idealization and simplification of the problems.	3
3.	Probability models, series and linear mathematical approximation	3
4.	Dynamic Mathematical Model, Analysis of Dynamic Mathematical Models, dynamic and interacting dynamic processes.	3
5.	Basic Concepts of Systems Analysis and Simulation.	2
6.	Common Heat and Mass Transfer Models Dimensional Analysis.	3
7.	Model-based techniques in food processing.	2
8.	Applications of mathematical modelling techniques to parboiling of rice, convective drying/ dehydration, deep fat drying etc.	4
9.	Applications of mathematical modelling techniques to pasteurization of milk and juices.	4
10.	Applications of mathematical modelling techniques to fermentation, aseptic processing, moisture diffusion.	4
11.	Applications of mathematical modelling techniques in shelf-life prediction of agricultural commodities.	3
12.	Applications of mathematical modelling techniques to microwave heating, infrared heating and ohmic heating.	3
13.	Stochastic finite element analysis of thermal food processes.	3
14.	Probability models, series and linear mathematical approximation	3
15.	Neural networks approach to modelling food processing operations.	3
	Total	**45**

VIII. Suggested Reading

- Fischer M, Scholten HJ and Unwin D. 1996. *Spatial Analytical Perspectives on GIS*. Taylor & Francis.
- Fish NM and Fox RI. 1989. *Computer Application in Fermentation Technology: Modelling and Control of Biotechnological Processes*. Elsevier.
- Gold HJ. 1977. *Mathematical Modelling of Biological Systems - An Introductory Guidebook*. John Wiley & Sons.
- Hunt DR. 1986. *Engineering Models for Agricultural Production*. The AVI Publ.
- Koeing HE, Tokad Y, Kesacan HK and Hedgers HG. 1967. *Analysis of Discrete Physical Systems*. McGraw Hill.
- Meyer JW. 2004. *Concepts of Mathematical Modeling*. McGraw Hill.
- Peart RM and Curry RB. 1998. *Agricultural Systems, Modelling and Simulation*. Marcel Dekker.
- Tijms HC. 1984. *Modelling and Analysis. A Congrtational Approach*. Wiley Publ.

I. Course Title : Bioprocess Engineering

II. Course Code : PFE 606

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with the basic principles of biochemical process engineering.

V. Theory

Unit I

Applications of engineering principles: Mass and energy balance, fluid flow principles, Unit operations of process engineering.

Unit II

Fundamentals of growth kinetics, maintenance energy and yield concepts, principles of media sterilization, media formulations of industrial fermentation.

Unit III

Aerobic and agitated rheology of fermentative fluids, design and scale-up of bioreactors, enzyme reactors.

Unit IV

Principles of recovery of fermented products in bio-processing, instrumentation, transport phenomenon.

VI. Practical

Kinetics of one substitute reactions, kinetics of growth in batch cultures, design consideration for bioreactors, media preparation and sterilization, microprocessor based monitoring of bioprocess parameters.

VII. Learning outcome

Student's capability to calculate the mass and energy balances in ant process operations, understanding growth kinetics and design bioreactors as per requirement of food industries.

VIII. Lectures Schedule

S.No.	Topic	No. of Lectures
1.	Basic engineering principles and their applications. Use of units and dimensions.	3
2.	Mass balance: steady and unsteady. Problem solving involving blending, separation, drying, growth, recycling etc.	3
3.	Energy balance in food processing operations. Use of steam tables in calculation of heat requirements etc.	3
4.	Fluid flow principles: Static and dynamic. Concept of viscosity. Types of flow. Flow through pipes. Mass and energy balance in fluid flow. Calculation of pressure drop in pipes.	4
5.	Fundamentals of growth kinetics, maintenance energy and yield concepts.	3
6.	Principles of media sterilization, media formulations of industrial fermentation.	3
7.	Aerobic and agitated rheology of fermentative fluids.	3
8.	Design and scale-up of bioreactors, enzyme reactors.	3
9.	Principles of recovery of fermented products in bio-processing, instrumentation, transport phenomenon.	5
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	To study the instruments used for measurement of temperature, relative humidity, flow rate, pressure, wind velocity, solar radiation etc.	1
2.	Use of units, dimensions and basic mathematical applications.	1
3.	To judge the students ability for solving mass balance problems.	2
4.	To judge the students ability for solving Energy balance problems.	2
5.	To study the kinetics of one substitute reactions.	1

S.No.	Topic	No. of Practicals
6.	To assess the kinetics of growth in batch cultures.	1
7.	To study the order of reactions involving single/multiple reactants/products.	1
8.	To study the various thermal and structural parameters affecting the design of bioreactors.	1
9.	To assess the student's ability for design of bioreactors by solving related numerical problems.	2
10.	To prepare various media cultures and assess their effectiveness with time.	1
11.	To study the mechanism of sterilization of cultures.	1
12.	To study the various electronic gadgets for continuous monitoring of bioprocess parameters.	1
	Total	**15**

X. Suggested Reading

- Brennan JG, Butters JR, Cavell ND and Lilly AEI. 1990. *Food Engineering Operations*. Elsevier.
- Coulson JM and Richadson JF. 1999. *Chemical Engineering*. Vols. II, IV. The Pergamon Press.
- Greanoplis JC. 1999. *Transport Process and Unit Operation*. Allyn & Bacon
- Treybal RE. 1981. *Mass Transfer Operations*. 3rd Ed. Harper & Row.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 4

Agricultural Engineering
– Irrigation and Drainage Engineering

Preamble
(Irrigation and Drainage Engineering)

Course curricula and course outlines in Irrigation and Drainage Engineering are designed in view of the fact that courses are offered by students from disciplines of faculties of Soil Science, Agronomy and Agricultural Meteorology.

At the post graduate level it becomes more important where they have not only to learn the recent advances in their subjects but have also to be trained in the modern and latest techniques in their disciplines so that they can participate and contribute in the development and advancement in their related fields. Further, the shrinking job opportunities in the National Agricultural Research System (ICAR/SAUs) have put additional pressure on our education system to prepare students in tune with the demands of the private sector.

All courses are designed to cover all basic topics and have been designed by taking into consideration demands of private sector harnessing commercial aspects, modern research tools and their applications, supplementary skills required, and enhancing the global competitiveness and employability of students. The emphasis has been given on precision irrigation and modeling management and accordingly new courses “Water and nutrient management under protected cultivation, Waste water management and utilization in agriculture, Sensing and automation in irrigation systems, Climate change and water resources, Multi criteria decision making system” are framed in view of the recent developments in the subject.

The courses have been revised, updated and restructured in view of current developments and emerging trends in Irrigation and Drainage Engineering. The revised courses cover the areas: Design of farm drainage systems, Command area management, Design of surface irrigation systems, Design of drip and sprinkler irrigation systems, Ground water engineering, Remote sensing and GIS for land and water resource management, Water conveyance and distribution, Minor irrigation, Design of pumps for irrigation and drainage, Water resources systems engineering, Irrigation economics, Planning and management, Watershed management and modeling, Flow through porous media, Dryland water management technologies, Recent developments in irrigation engineering, Advances in drainage engineering, Hydro-Mechanics and ground water modeling, Soil-Water-Plant-Atmospheric modeling, Plant growth modeling and simulation, Applied watershed hydrology, Reservoir operation and river basin modeling and Modeling soil erosion processes and sedimentation.

The course content and syllabus upgraded with more of practical orientation and as per ARS Syllabus.

The ICAR recommendations for PG courses have been taken into consideration in framing these courses. It is hoped that these will prove very useful to the future students.

Course Title with Credit Load
M.Tech. in Irrigation and Drainage Engineering

Major Courses (Requirement: 20 Credits)

Course Code	Course Title	Credits
IDE 501	Design of Surface Irrigation Systems	1+1
*IDE 502	Design of Farm Drainage Systems	2+1
IDE 503	Command Area Management	2+1
IDE 504	Water and Nutrient Management Under Protected Cultivation	2+1
*IDE 505	Design of Drip and Sprinkler Irrigation Systems	2+1
*IDE 506	Ground Water Engineering	2+1
SWCE 507/IDE 507	Remote Sensing and GIS for Land and Water Resource Management	2+1
IDE 508	Waste Water Management and Utilization in Agriculture	2+1
IDE 509	Water Conveyance and Distribution	2+1
IDE 510	Minor Irrigation	2+1
IDE 511	Design of Pumps for Irrigation and Drainage	2+0
IDE 512	Crop Environmental Engineering	2+0
IDE 513	Water Resources Systems Engineering	2+1
IDE 514	Irrigation Economics, Planning and Management	2+0
IDE 515	Sensing and Automation in Irrigation Systems	3+0
	Total	30+11

*Compulsory course

Minor Courses (Requirement: 08 Credits)

Course Code	Course Title	Credits
SWCE 505	Watershed Management and Modeling	2+1
SWCE 506	Flow Through Porous Media	2+0
SWCE 508	Climate Change and Water Resources	3+0
SWCE 510	Dryland Water Management Technologies	2+0
FMPE 517	Machinery for Precision Agriculture	2+1
REE 513	Energy, Ecology and Environment	3+0
CE 501	Dimensional Analysis and Similitude	2+0
CSE 501	Big Data Analytics	2+0
CSE 502	Artificial Intelligence	2+0
CSE 504	Soft Computing Techniques in Engineering	2+1

Course Code	Course Title	Credits
MATH 501	Finite Element Methods	2+0
MATH 502	Numerical Methods for Engineers	2+0
ME 501	Mechatronics and Robotics in Agriculture	2+0
	Any other course(s) of other department can be taken as per recommendationsof the student's advisory committee.	

Supporting Courses (Requirement: 06 Credits)

Course Code	Course Title	Credits
*STAT 501	Statistical Methods for Research Works	2+1
	Courses from subject matter fields (other than Major and Minor) relating to area of special interest and research problem can be taken as per recommendations of the student's advisory committee.	

*Compulsory Course

Common Courses (Requirement: 05 Credits)

Course Code	Course Title	Credits
*PGS 501	Library and Information Services	1+0
*PGS 502	Technical Writing and Communication Skills	1+0
*PGS 503	Intellectual Property and its management in Agriculture	1+0
*PGS 504	Basic Concepts in Laboratory Techniques	1+0
*PGS 505	Agricultural Research, Research Ethics and Rural Development Programmes	1+0

*Detailed course outline to be developed by designated BSMA

List of Other Essential Requirements

Course Code	Course Title	Credits
IDE 591	Seminar	0+1
IDE 599	Thesis Research	0+30

Course Contents
M.Tech. in Irrigation and Drainage Engineering

I. Course Title : Design of Surface Irrigation Systems

II. Course Code : IDE 501

III. Credit Hours : 1+1

IV. Aim of the course

To acquaint students for design and evaluation of various surface irrigation methods, design optimum layout, conveyance network for efficient use of water in surface irrigation system.

V. Theory

Unit I

Climate and irrigation water requirement. Irrigation principles, losses, conveyance, distribution, application and water budgeting. Estimation techniques of effective rainfall. Irrigation softwares: CROPWAT, AQUACROP.

Unit II

Farm irrigation systems. Irrigation efficiencies. Economic feasibility. Irrigation water quality and salinity management techniques. Design of water conveyance, control and distribution systems.

Unit III

Hydraulics: Design and operation of border, check basin, furrow, sprinkler and trickle irrigation systems. Flow dynamics, drop size distribution and spray losses in sprinklers. Cablegation, surge and bubbler irrigation. Automation of irrigation system.

Unit IV

Basic water management concepts and objectives. Alternative irrigation scheduling techniques. Integrated approach to irrigation water management.

VI. Practical

Design and evaluation of border, furrow, check basin, sprinkler and micro-irrigation. Computation of frictional losses. Design of underground water conveyance systems. Economics of irrigation methods. Visit to mechanized farms.

VII. Learning outcome

The students will be able to plan and design various surface irrigation systems and irrigation scheduling techniques for efficient use of water. They will also be exposed to irrigation softwares used for design purpose.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Climate and irrigation water requirement	1
2.	Irrigation principles, losses, conveyance, distribution, application and water budgeting	2

S.No.	Topic	No. of Lectures
3.	Estimation techniques of effective rainfall	2
4.	Irrigation softwares; CROPWAT, AQUACROP	2
5.	Farm irrigation systems. Irrigation efficiencies, Economic feasibility	2
6.	Irrigation water quality and salinity management techniques	2
7.	Design of water conveyance, control and distribution systems	2
8.	Hydraulics; Design and operation of border, check basin and furrow irrigation systems.	5
9.	Hydraulics: Design and operation of sprinkler and trickle irrigation systems	4
10.	Flow dynamics, drop size distribution and spray losses in sprinklers	2
11.	Cablegation, surge and bubbler irrigation	3
12.	Automation of irrigation system	2
13.	Basic water management concepts and objectives	2
14.	Alternative irrigation scheduling techniques	1
15.	Integrated approach to irrigation water management	2
	Total	**34**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Estimation of different techniques of effective rainfall	1
2.	Design of irrigation methods using irrigation software's: CROPWAT, AQUACROP	3
3.	Design of water conveyance, control and distribution systems.	1
4.	Design and evaluation of border irrigation method	1
5.	Design and evaluation of furrow irrigation method	1
6.	Design and evaluation of check basin method	1
7.	Design and evaluation of sprinkler irrigation method	1
8.	Design and evaluation of trickle irrigation method	1
9.	Study of automation of irrigation system	1
10.	Design of underground water conveyance systems	1
11.	Study of economics of irrigation methods	2
12.	Visit to mechanized farms	1
	Total	**15**

X. Suggested Reading

- Finkel HJ. 1983. *Handbook of Irrigation Technology*. Vols. I-II, CRC Press.
- James LG. 1988. *Principles of Farm Irrigation System Design*. John Wiley and Sons, New York, USA.
- Karmeli D, Peri G and Todes M. 1985. *Irrigation Systems: Design and Operation*. Oxford University Press.
- Michael AM. 2008. *Irrigation Theory and Practices*. Vikas Publishing House Pvt. Ltd, New Delhi.
- Pillsbury AF. 1972. *Sprinkler Irrigation*. FAO Agricultural Development Paper No. 88, FAO.
- Rydzewski. 1987. *Irrigation Development Planning*. John Wiley and Sons.
- Sivanappan RK 1987. *Sprinkler Irrigation*. Oxford and IBH.
- Sivanappan RK, Padmakumari O and Kumar V. 1987. *Drip Irrigation*. Keerthy Publ, House.

I. Course Title : Design of Farm Drainage Systems

II. Course Code : IDE 502

III. Credit Hours : 2+1

IV. Aim of the course

To provide in depth knowledge of water logging and salt affected areas, surface and sub-surface drainage systems, design and reclamation of salt affected waterlogged areas.

V. Theory

Unit I

Salt affected waterlogged areas in India. Water quality criteria and brackish water use for agriculture. Drainage requirements and crop growth under salt affected waterlogged soil.

Unit II

Concept of critical water table depth for waterlogged soil and crop growth. Drainage investigations and drainage characteristics of various soils. Methods of drainage system and drainage coefficient.

Unit III

Theories and applications of surface and subsurface drainage. Planning, design and installation of surface and subsurface drainage systems for waterlogged and saline soils. Theories and design of vertical drainage, horizontal subsurface drainage and multiple well point system. Drainage materials.

Unit IV

Steady and unsteady state drainage equations for layered and non-layered soils. Principle and applications of Hooghoudt, Kirkham, Earnst, Glover Dumm, Kraijenhoff-van-de-leur equations. Drainage for salinity control.

Unit V

Salt balance, leaching requirement and management practices under drained conditions. Disposal of drainage effluents. Case study for reclamation of salt affected waterlogged areas.

VI. Practical

Measurement of in-situ hydraulic conductivity. Estimation of drainage coefficient and leaching requirements. Delineation of waterlogged areas through isobar, isobath and topographic maps. Design of surface and subsurface drainage systems. Design of filter and envelop materials.

VII. Learning outcome

The students will able to develop surface as well as subsurface drainage network in the agriculture field, install and laying of the drainage pipe with fitting of all accessories at their place and derive equation for different flow in drainage system and their approaches.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Waterlogging, causes of waterlogging, salt built up in waterlogged soil, solute transport in salt affected soil. Recent salt affected areas in different states and country as whole	2

S.No.	Topic	No. of Lectures
2.	Technology and approach for reclamation of salt affect waterlogged areas	2
3.	Drainage requirement and crop growth under salt affected waterlogged soil. Drainage water/ brackish water quality and it's criteria for use in agriculture	2
4.	Concept of critical water table depth for waterlogged soil and crop growth	1
5.	Drainage investigations and drainage characteristics of various soils.	2
6.	Methods of drainage system: surface, sub surface, well drainage and bio-drainage and drainage coefficient	1
7.	Theories and applications of surface and sub surface drainage	3
8.	Planning, design and installation of surface and subsurface drainage systems for waterlogged and saline soils	3
9.	Theories of vertical and horizontal subsurface drainage systems	2
10.	Theory, design and application of multiple well point system	1
11.	Drainage materials. Design of filter and envelop for drainage system with different materials	2
12.	Steady state drainage equations for layered and non layer soils	2
13.	Unsteady state drainage equations for layered and non layer soils	3
14.	Principle and application, Hooghoudt and Khirkham equation	3
15.	Principles and application of Ernst, Glover Dumm, Karigenth off–van-de-law eaquation	2
16.	Drainage for salinity control, salt balance equation, leaching requirement and management practices under drained conditions, Disposal of drainage effluents	3
17.	Case study: Integrated planning, design and installation of drainage system for reclamation of salt affected waterlogged areas	2
	Total	**36**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Delineation of waterlogged areas through isobar, isobath and topographic maps	3
2.	Measurement of in-situ hydraulic conductivity	1
3.	Estimation of drainage coefficient from rainfall data	2
4.	Determination of leaching requirements for reclamation of salt affected land	2
5.	Design of surface drainage systems	2
6.	Design of subsurface drainage systems	2
7.	Design of filter and envelop materials	2
8.	Visit to drainage installation site/Institute	2
	Total	**16**

X. Suggested Reading

- Bhattacharaya AK and Michael AM. 2003. *Land Drainage*. Vikas Publ.
- Clande Ayres and Daniel Scoates AE. 1989. *Level Drainage and Reclamation*. Mc.Graw Hill.
- Luthin JN. 1978. *Drainage Engineering*. Wiley Eastern.
- Ritzema HP (Ed.) 1994. *Drainage Principles and Applications*. ILRI
- Roe CE. 1966. *Engineering for Agricultural Drainage*. McGraw Hill.
- Schilfgaarde Jan Van (Editor). 1974. *Drainage for Agriculture*. Monograph No. 17. American Society of Agronomy Madison, Wisconsin, USA.

I. **Course Title : Command Area Management**

II. **Course Code : IDE 503**

III. **Credit Hours : 2+1**

IV. **Aim of the course**

To acquaint students about the concept of command area management, assessment and appraisal of water availability in command areas, water management problems in command areas and their possible remedies including socio-economic aspects of irrigation command.

V. **Theory**

Unit I

Concept of command area development as an integrated approach. Command area project formulation, major, medium and minor projects. Command areas in India, command area activities and their prioritization. Source of budget for CAD works. Structure of command area development, organization, role and responsibilities of CADA.

Unit II

Laser based land grading survey and levelling in command areas. Design of lined and unlined canals. Diversion head works and canal head regulators, cross drainage works, canal falls, canal breaches. Design of On Farm Water Distribution Network, operation and maintenance of canal.

Unit III

Assessment and appraisal of water availability in command areas. Water management problems in command areas and their possible remedies. Duty of water, its determination and factors affecting it. Methods of improving duty of canal water. Feasibility of drip irrigation in irrigated command areas.

Unit IV

Single and multi-objective command area planning for the better management and allocation of irrigation water. Conjunctive use of canal water and groundwater. Real time canal irrigation scheduling.

Unit IV

Canal performance indices. Diagnostic analysis and perform appraisal of command area projects. Water user's association–functions, problems encountered during formation of WUA and strategy and overcome the problems. Participatory irrigation management efforts and strategy for preparing PIM. Socio economic aspects of irrigation management in command areas.

VI. **Practical**

Study of canal, tank and tube well in a command area. Study of design and operational parameters of a command area. Study of water balance in a command. Study the impact of command area project on crop yield and environment. Conflict resolution through PRA exercise. Diagnostic analysis of the problems of command area through PRA and field observations. Analysis of equity in water distribution. Considerations for preparation of roistering schedules. Study of the functioning of irrigation cooperatives/water user's associations. Preparation of command area development plan.

VII. Learning outcome

The students will be able to understand the concept of command area and its management, to analyze problem diagnostics and remedies of command area and able to understand the performance evaluation procedure of command area.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Concept of command area development as an integrated approach	1
2.	Command area project formulation, major, medium and minor projects	2
3.	Command areas in India	1
4.	Command area activities and their prioritization	1
5.	Source of budget for CAD works	1
6.	Structure of command area development	1
7.	Organization, role and responsibilities of CADA	1
8.	Laser based land grading survey and levelling in command areas	1
9.	Design of lined and unlined canals	2
10.	Diversion head works and canal head regulators, cross drainage works, canal falls, canal breaches	2
11.	Design of On Farm Water Distribution	1
12.	Network, operation and maintenance of canal	1
13.	Assessment and appraisal of water availability in command areas	1
14.	Water management problems in command areas and their possible remedies	2
15.	Duty of water, its determination and factors affecting it. Methods of improving duty of canal water	2
16.	Feasibility of drip irrigation in irrigated command areas	1
17.	Single and multi-objective command area planning for the better management and allocation of irrigation water	1
18.	Conjunctive use of canal water and groundwater	1
19.	Real time canal irrigation scheduling	1
20.	Canal performance indices	1
21.	Diagnostic analysis and perform appraisal of command area projects	1
22.	Water user's association–functions, problems encountered during formation of WUA and strategy and overcome the problems	2
23.	Participatory irrigation management efforts and strategy for preparing PIM	2
24.	Socio economic aspects of irrigation management in command areas	2
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Study of canal, tank and tube well in a command area	1
2.	Study of design and operational parameters of a command area	2
3.	Study of water balance in a command	1
4.	Study the impact of command area project on crop yield and environment	2
5.	Study about conflict resolution through PRA exercise	2
6.	Diagnostic analysis of the problems of command area through PRA and field observations	2
7.	Analysis of equity in water distribution	1

S.No.	Topic	No. of Lectures
8.	Considerations for preparation of roistering schedules	1
9.	Study of the functioning of irrigation cooperatives/water user's associations	2
10.	Preparation of command area development plan	2
	Total	**16**

X. Suggested Reading

- Jos´eLiria Montanes. 2006. *Design, Construction, Regulation and Maintenance*. Taylor and Francis Publication.
- Modi PN. *Irrigation Water Resources and Water Power Engineering*. Standard Publishers.
- Singh VP. 2014. *Entropy Theory in Hydraulic Engineering: An Introduction*. ASCE Press.
- Sharma SK. *Irrigation Water Resources and Water Power Engineering*. Standard Publishers.
- Swamee PK and Chahar BR. *Design of Canals*. Springer Publications.

I. Course Title : Water and Nutrient Management under Protected Cultivation

II. Course Code : IDE 504

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint students about the concept of soilless culture in agriculture, water and nutrient management, water potential in soilless media and automation for climate control under protected cultivation.

V. Theory

Unit I

Significance of soilless culture in agriculture. Functions of the root system. Response of root growth to local nutrient concentrations. Interactions between environmental conditions and form of N nutrition.

Unit II

Roots as source and sink for organic compounds and plant hormones. Physical and chemical properties of soilless media.

Unit III

Water content and water potential in soilless media. Water movement in soilless media. Uptake of water by plants in soilless media and water availability.

Unit IV

Production technology for vegetables under protected conditions in soil and soilless media. Automation for climate control in protected structures. Thermal modeling of greenhouse environment for protected cultivation.

VI. Practical

Filter types and its selection criteria. Design and installation of drip irrigation system for vegetables and orchards. Irrigation and fertigation scheduling for vegetables and horticultural. Study of different types of sensors, relay and control mechanism for controlled irrigation and fertigation. Design of automated system for irrigation and fertigation. Design and installation of different protected structures as per the guidelines of NHM. Design and fabrication of soilless medium for crop/flower production. Economical evaluation of automated irrigation system and soilless medium for crop/flower production.

VII. Learning outcome

The students will able to understand the concept of soilless farming including nutrient management, water content and water potential in soilless media along with automation for climate control under protected cultivation.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Significance of soilless culture in agriculture	1
2.	Functions of the root systems	1
3.	Response of root growth to local nutrient concentrations	2
4.	Interactions between environmental conditions and form of N nutrition	2
5.	Roots as source and sink for organic compounds and plant hormones	2
6.	Physical and chemical properties of soilless media	2
7.	Water content and water potential in soilless media	2
8.	Water movement in soilless media: water retained, drainage, plant use, etc	2
9.	Uptake of water by plants in soilless media and water availability	3
10.	Production technology for vegetables under protected conditions in soil and soilless media	4
11.	Automation for climate control in protected structures	3
12.	Thermal modeling of greenhouse environment using multiple regressions	2
13.	Thermal modeling of greenhouse environment using energy and mass balance approaches	4
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	To study the filter types and their selection criteria	1
2.	Design and installation of drip irrigation system for vegetables	1
3.	Design and installation of drip irrigation system for orchards	1
4.	Irrigation and fertigation scheduling for vegetables and horticultural crops	1
5.	Study of different types of sensors, relay and control mechanism for controlled irrigation and fertigation	1
6.	Design of automated system for irrigation and fertigation	1
7.	Design and installation of different protected structures as per guidelines of NHM	6
8.	Design and fabrication of soilless medium for vegetable crops	1
9.	Design and fabrication of soilless medium for flower production	1
10.	Economical evaluation of automated irrigation system and soilless medium for crop/flower production	1
	Total	**15**

X. Suggested Reading

- Howard M Resh. *Hydroponic Food Production*. CRC Press, New York.
- Michael Raviv and Heinrich J Lieth 2014. *Soilless Culture*. CRC Press.
- Meier Schwarz. *Soilless Culture Management*. Springer publications, New York.

I. Course Title : Design of Drip and Sprinkler Irrigation Systems

II. Course Code : IDE 505

III. Credit Hours : 2+1

IV. Aim of the course

To provide exposure of new cutting-edge technologies to the students in design of drip and sprinkler irrigation systems including selection of pipe and fertigation techniques.

V. Theory

Unit I

Suitability of sprinkler and drip irrigation systems under Indian conditions. Basic hydraulics of sprinkler and micro irrigation system.

Unit II

Pipe flow analysis. Friction losses and pressure variation. Flow in nozzles and emitters.

Unit III

Design and evaluation of sprinkler and micro irrigation systems in relation to source, soil, climate and topographical conditions.

Unit IV

Selection of pipe size, pumps and power units. Layout, distribution, efficiency and economics.

Unit V

Fertigation through sprinkler and micro irrigation systems. Fertigation techniques involved in drip and sprinkler irrigation system.

VI. Practical

Design of drip and sprinkler irrigation system. Calculation of total head. Determination of uniformity of sprinkler discharge at field. Numerical on hydraulics of dripper. Calculation of different types of efficiencies of installed drip system. Calculation of cost benefits of drip and sprinkler irrigation system.

VII. Learning outcome

Students will understand design aspects of various drip and sprinkler irrigation systems including friction losses and flow variations. They may also expose to various fertigation techniques involved in the system.

VIII. Lecture Schedule

S.No.	Topic	No. of lectures
1	Plant-soil-atmosphere relationships	3
2	Evapotranspiration, methods for estimation of evapotranspiration, Irrigation water requirements, Irrigation principles, Numerical Problems	2
3	Drip irrigation, adaptability, limitations, components and classification of systems	2
4	Pipe flow analysis, types of friction losses in main, sub-main and lateral, pressure variation in drip irrigation system and their calculations	2

S.No.	Topic	No. of Lectures
5	Design of drip irrigation system based on source of irrigation, soil, climate and topographical conditions and hydraulics of drip components with numerical problems	3
6	Selection of pipe, pump and power unit	2
7	Fertigation: advantages, limitations, methods, fertilizers solubility and their compatibility, precautions, frequency, duration and injection rate, Emitter clogging and prevention	2
8	Performance evaluation of drip irrigation system	1
9	Sprinkler irrigation, adaptability, limitations, components and classification of systems	2
10	Pipe flow analysis, types of friction losses, pressure variation in sprinkler irrigation system and their calculations	2
11	Flow in nozzles, drop size distribution, spray evaporation	1
12	Hydraulic and engineering design of sprinkler irrigation system on source of irrigation, soil, climate and topographical conditions, numerical problems	3
13	Fertigation techniques in sprinkler irrigation	1
14	Selection of pipe, pump and power unit	2
15	Performance evaluation of sprinkler irrigation system	1
16	Irrigation scheduling techniques and automation in drip and sprinkler irrigation system	2
17	Benefit cost ratio of drip and sprinkler irrigation system	1
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Study of different components of drip and sprinkler irrigation system	1
2.	Determination of physical properties of soil	1
3.	Design of drip irrigation system for orchards	1
4.	Design of micro-irrigation system for row crops	1
5.	Design of sprinkler irrigation system for vegetable crops	1
6.	Design of sprinkler irrigation system for field crops	1
7.	Estimation of total head in drip and sprinkler irrigation system	1
8.	Determination of filtration efficiency of different filters	1
9.	Evaluation of drip irrigation system	1
10.	Determination of uniformity of sprinkler discharge at field	1
11.	Study of hydraulics of drippers	1
12.	Estimation of fertigation rate in drip irrigation system	1
13.	Calculation of different types of efficiencies of installed drip system	1
14.	Study of Automation in micro-irrigation system	1
15.	Calculation of cost benefits of drip irrigation system	1
16.	Calculation of cost benefits of sprinkler irrigation system	1
	Total	**16**

X. Suggested Reading

- Jensen ME. (Editor). 1983. *Design and Operation of Farm Irrigation Systems*. ASAE, Monograph No. 3. USA.
- James LG. 1988. *Principles of Farm Irrigation System Design*. John Wiley and Sons, New York, USA.

- Michael AM. 2006. *Irrigation Theory and Practice*. Vikas Publ. New Delhi.
- Withers Bruce and Vipond Stanley. 1974. *Irrigation: Design and Practice.* B.T. Batsford Ltd, London.
- Sivanappan RK. 1987. *Sprinkler Irrigation*. Oxford and IBH Publishing Co. New Delhi.

I. Course Title : Ground Water Engineering

II. Course Code : IDE 506

III. Credit Hours : 2+1

IV. Aim of the course

To provide comprehensive knowledge to the students in aquifers, groundwater flow, artificial groundwater recharge techniques, well hydraulics and groundwater models.

V. Theory

Unit I

Water resources of India. Occurrence, storage and movement of groundwater in alluvial and hard rock formations. Principles of groundwater flow. Interaction between surface water and groundwater.

Unit II

Natural and artificial groundwater recharge. Conjunctive use of surface and groundwater. Groundwater balance. Fluctuation of water table beneath a recharge site. Delineation of groundwater potential zones using RS and GIS, MODFLOW equation.

Unit III

Derivation of hydraulics of fully and partially penetrating wells in confined, leaky and unconfined aquifers. Flow net analysis.

Unit IV

Analysis of multi aquifers. Flow analysis in interfering wells. Pumping tests for estimation of aquifer parameters. Wells near recharge and impermeable boundaries. Skimming well technology.

Unit V

Design of well field. Salt water intrusion in inland and coastal aquifers. Application of groundwater models for groundwater management. Calibration and validation of models.

VI. Practical

Water table contour maps and determination of groundwater flow. Estimation of aquifer characteristics. Problems on non-leaky and leaky aquifers. Analysis of pumping test data. Computation of interference of wells. Groundwater computer simulation models.

VII. Learning outcome

The student will be able to analyze storage, movement and flow characteristics of different aquifers and also model ground water and plan for ground water recharge including delineation of potential groundwater recharge zones.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Water Resources of India. Occurrence, movement of groundwater and storage of groundwater in geological formation	2
2.	Study of hydro geological formation in India	1
3.	Principal of Groundwater flow. Interaction between surface water and groundwater.	
4.	Natural and artificial groundwater recharge. Conjunctive use of surface and groundwater	1
5.	Groundwater balance and fluctuation of water table beneath recharge sites	2
6.	Delineation of groundwater potential zones using RS and GIS	2
7.	Study of MODFLOW and its application	2
8.	Hydraulics of wells	1
9.	Steady state flow to fully penetrating well in unconfined, confined and leaky aquifer	2
10.	Unsteady state flow to fully penetrating wells in unconfined, confined and leaky aquifer	3
11.	Steady state flow to partially penetrating well in unconfined, confined and leaky aquifer	2
12.	Unsteady state flow to partially penetrating wells in unconfined, confined and leaky aquifer	3
13.	Flow net analysis for groundwater flow	1
14.	Steady and Unsteady flow in Multi aquifers	2
15.	Flow analysis in interfering multiple wells	2
16.	Pumping tests for estimation of aquifer parameters	1
17.	Flow to wells near recharge and impermeable boundaries	2
18.	Design of well field and skimming well technology (multiple well point system)	2
19.	Salt water intrusion in inland and coastal aquifers	2
20.	Groundwater modelling approaches	1
21.	Study of various groundwater models	2
22.	Application of groundwater models for groundwater management	2
23.	Calibration and validation of models	2
	Total	**40**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Delineation of water table contour maps.	2
2.	Determination of groundwater flow using contour maps	1
3.	Estimation of aquifer characteristics by Theis and Cooper-Jacob method	2
4.	Estimation of aquifer characteristics by Chow's and Theis recovery method	2
5.	Hand on exercise for analysis groundwater flow through well in leaky aquifers.	2
6.	Hand on exercise for analysis groundwater flow through well in non-leaky aquifers.	2
7.	Analysis of pumping test data for estimation of aquifer parameters.	1
8.	Computation of drawdown and discharge under interference of wells.	2
9.	Simulation of groundwater flow using various computer models (MODFLOW, etc)	2
	Total	**16**

X. Suggested Reading

- Boonstra J and de Ridder NA. 1981. *Numerical Modeling of Groundwater Basins*. ILRI.
- Demenico PA. 1972. *Concept and Models in Groundwater Hydrology*. McGraw Hill.
- Huisman L 1972. *Ground Water Recovery*. Mac Millan.
- Jat ML and SR Bhakar 2008. *Ground Water Hydrology*. Agro-tech Publishing Academy. Udaipur.
- Polubarinova Kochina P Ya. 1962. *Theory of Ground Water Movement*. Princeton Univ. Press.
- Raghunath HM 1992. *Ground Water*. Wiley Eastern.
- Todd DK 1997. *Ground Water Hydrology*. Wiley Eastern.

I. Course Title : GIS and Remote Sensing for Land and Water Resource Management

II. Course Code : IDE 507/SWCE 507

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint students with recent technology of RS and GIS including satellite data analysis, digital image processing and thematic mapping of land use, surface and ground water.

V. Theory

Unit I

Physics of remote sensing. Electromagnetic radiation (EMR), interaction of EMR with atmosphere, earth surface, soil, water and vegetation. Remote sensing platforms: Monitoring atmosphere, land and water resources: LANDSAT, SPOT, ERS, IKONOS and others. Indian Space Programme.

Unit II

Satellite data analysis. Visual interpretation. Digital image processing. Image pre-processing. Image enhancement. Image classification. Data merging.

Unit III

Basic components of GIS. Map projections and co-ordinate system. Spatial data structure: Raster, vector. Spatial relationship. Topology. Geodatabase models: Hierarchical, network, relational, object-oriented models. Integrated GIS database. Common sources of error. Data quality: Macro, micro and Usage level components, Meta data. Spatial data transfer standards.

Unit IV

Thematic mapping. Measurement in GIS: Length, perimeter and areas. Query analysis. Reclassification, Buffering and Neighbourhood functions. Map overlay: Vector and raster overlay. Interpolation and network analysis. Digital elevation modelling. Analytical Hierarchy Process. Object oriented GIS, AM/FM/GIS and Web Based GIS.

Unit V

Spatial data sources. 4M GIS approach water resources system. Thematic maps. Rainfall runoff modelling, groundwater modelling and water quality modelling. Flood inundation mapping and modelling. Drought monitoring. Cropping pattern change analysis. Performance evaluation of irrigation commands. Site selection for artificial recharge. Reservoir sedimentation.

VI. Practical

Familiarization with the remote sensing instruments and satellite imagery. Aerial Photograph and scale determination with stereoscope. Interpretation of satellite imagery and aerial photograph. Determination of Parallaxes in images. Introduction to digital image processing software and GIS software and their working principles. Generation of digital elevation model (DEM) for land and water resource management. Case studies on mapping, monitoring and management of natural resources using remote sensing and GIS.

VII. Learning outcome

The student will be able to use satellite remote sensing to perform image analysis and classification for developing thematic maps and also able to integrate satellite data with GIS to undertake recourse mapping and lanning studies.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction and brief history of RS and GIS, applications of RS and GIS	1
2.	Physics of remote sensing. Electromagnetic radiation (EMR), interaction of EMR with atmosphere, earth surface, soil, water and vegetation.	1
3.	Remote sensing platforms: Monitoring atmosphere, land and water resources: LANDSAT, SPOT, ERS, IKONOS and others. Indian Space Programme	2
4.	Satellite data analysis. Visual interpretation.	1
5.	Digital image processing- Image pre-processing, Image enhancement, Image classification, data merging.	3
6.	Basic components of GIS- Map projections and co-ordinate system.	2
7.	Spatial data sources,Thematic maps.	1
7.	Spatial data structure: Raster, vector data, Spatial relationship-Topology	1
8.	Geodatabase models: Hierarchical, network, relational, object-oriented models. Integrated GIS database	3
9.	Data quality, Common sources of error, Macro, micro and Usage level components, Meta data and Spatial data transfer standards	2
10.	Measurement in GIS- Length, perimeter and areas.	1
10.	Query analysis. Reclassification, Buffering and Neighbourhood functions.	1
11.	Map overlay: Vector and raster overlay	1
12.	Interpolation and network analysis	1
13.	Digital elevation modelling. Analytical Hierarchy Process. Object oriented GIS, AM/FM/GIS and Web Based GIS.	3
14.	GIS approach to Rainfall runoff modelling, Flood inundation mapping and modelling.	2
15.	GIS approach to Groundwater modelling and water quality modelling,	2
16.	Site selection for artificial recharge. Reservoir sedimentation	1
17.	Drought monitoring	1
18.	Performance evaluation of irrigation commands	1
19.	Cropping pattern change analysis	1
	Total	**32**

7 IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Familiarization with the remote sensing instruments and satellite imagery	1

S.No.	Topic	No. of Practicals
2.	Methods of establishing ground truth survey and Comparison between ground truth and remotely sensed data	2
3.	Aerial Photograph and scale determination with stereoscope	1
4.	Interpretation of satellite imagery and aerial photograph	1
5.	Determination of Parallaxes in images	1
6.	Demonstration on GPS; Provision of Ground Control by GPS in different mode	1
7.	Introduction to digital image processing software	1
8.	Introduction to GIS software	1
9.	Data input; Data editing and Topology creation -Digitization of point, line and polygon features	
10.	SRTM and CARTO DEM download from web and Georeferencing of an image	1
11.	Delineation of Watershed, DEM generation: slope, Aspect, flow direction, Flow accumulation, Drainage, network and morphometric analysis	2
12.	LULC by supervised classification and LULC by unsupervised classification	1
13.	Application of Remote Sensing data and GIS for water quality parameters	
14.	Temporal satellite data analysis for vegetation condition, crop water requirement calculation	1
15.	Erosion mapping using aerial and satellite Data	1
	Total	**17**

X. Suggested Reading

- Charles Elach and Jakob van Zyl. 2006. *Introduction to the Physics and Techniques of Remote Sensing*. John Wiley & Sons publications.
- Ian Heywood Sarah, Cornelius and Steve Carver. 2002. *An Introduction to Geographical Information Systems*. Pearson Education. New Delhi.
- James B Campbell and Randolph H Wynne. 2011. *Introduction to Remote Sensing*. The Guilford Press.
- Lillesand TM and Kiefer RW. 2008. *Remote Sensing and Image Interpretation*. John Wiely and Sons.
- Paul Curran PJ. 1985. *Principles of Remote Sensing*. ELBS Publications.
- Rees WG. 2001. *Physical Principles of Remote Sensing*. Cambridge University Press.
- Thanappan Subash. 2011. *Geographical Information System*. Lambert Academic Publishing.

I. Course Title : Waste Water Management and Utilization in Agriculture

II. Course Code : IDE 508

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint students about status of waste water and water quality requirements, standards both for domestic and irrigation purposes and also to provide in depth knowledge of waste water treatment methods and utilization in agriculture.

V. Theory

Unit I

Status of wastewater in India. Sources of contamination and characterization of urban and rural wastewater for irrigation. Water quality: Physical, chemical and biological parameters of wastewater.

Unit II

Water quality requirement: Potable water standards, wastewater effluent standards, water quality indices. Irrigation water quality standards and guidelines for their restricted and unrestricted uses. Selection of appropriate forestry trees, fruits, vegetables, oilseeds and food grain crop for wastewater utilization.

Unit III

Control measures for preventing soil and other surface/groundwater source contamination. Different types of wastewater, pollutants and contaminants. Impact of wastewater on ecosystem, eutrophication, biomagnification, water borne diseases.

Unit IV

Wastewater treatment methods: Physical, chemical and biological. General water treatments: Wastewater recycling, constructed wetlands, reed bed system. Carbon foot prints of wastewater reuse. Environmental standards.

Unit V

Regulation and environmental impact assessment (EIA): Environmental standards-CPCB Norms for discharging industrial effluents to public sewers. Stages of EIA-Monitoring and Auditing. Environmental clearance procedure in India.

VI. Practical

Measurement of water quality indices in the lab. Field demonstration of impact of waste water on eco-system and human health. Waste water treatment methods and effect of waste water in contamination of ground water. Visit of waste water treatment plant near by area.

VII. Learning outcome

The students will be able to understand sources and treatment methods of waste water quality with standard norms of water quality for domestic and irrigation purposes and also be exposed to waste water recycling and environmental standards.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Status of wastewater in India, Sources of contamination and characterization of urban and rural wastewater for irrigation	2
2.	Water quality: Physical, chemical and biological parameters of wastewater	2
3.	Wastewater quality requirement: Potable water standards, wastewater effluent standards, water quality indices. Irrigation water quality standards both national and global and guidelines for their restricted and unrestricted uses.	2
4.	Different types of wastewater, pollutants and contaminants.	1
5.	Impact of wastewater on ecosystem, eutrophication, biomagnification, water borne diseases.	2
6.	Key drivers of wastewater use in agriculture and existing approaches for regulating wastewater reuse in agriculture	2
7.	Selection of appropriate forestry trees, fruits, vegetables, oilseeds and food grain crop for wastewater utilization and practices used for irrigation	3
8.	Health Risks Associated with the Use of Wastewater for Irrigation	1
9.	Wastewater treatment methods: Physical, chemical and biological.	3

S.No.	Topic	No. of Lectures
10.	Choice of (Cost-Effective) Wastewater Treatment Systems for Irrigation	2
11.	General water treatments: Wastewater recycling, constructed wetlands, reed bed system.	2
12.	Carbon foot prints of wastewater reuse. Environmental standards.	2
13.	Management of health and environmental risks of wastewater irrigation	1
14.	Regulation and environmental impact assessment (EIA): Environmental standards-CPCB Norms for discharging industrial effluents to public sewers. Valuation of environmental impacts.	3
15.	Impact on groundwater resources and soil health, EIA process, Stages of EIA-monitoring and auditing. Environmental clearance procedure in India	3
16.	Economics of wastewater irrigation	1
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Study on physical, chemical and biological parameters of wastewater	1
2.	Determination of EC and pH of wastewater	1
3.	Determination of BOD of wastewater	1
4.	Determination of COD of wastewater	1
5.	Determination of TSS and TDS of wastewater	1
6.	Determination RSC of wastewater	1
7.	Determination of e-coli in the wastewater	1
8.	On field demonstration of wastewater use for the irrigation	1
9.	Determination of nutrient (N, P and K) concentration in wastewater	2
10.	Field demonstration of impact of waste water on eco-system and human health.	1
11.	Study on various wastewater treatment methods	2
12.	Study on effect of wastewater on contamination of ground water	1
13.	Visit of village pond treatment nearby area	1
14.	Visit of sewerage treatment plant nearby area	1
	Total	**16**

X. Suggested Reading

- Charis Michel Galanakis. *Sustainable Water and Wastewater Processing*. Elsevier Publication, Amsterdam.
- Sean X Liu. 2014. *Food and Agricultural Wastewater Utilization and Treatment*. Wileu Blackwell New York.
- Shirish H, Sonawane Y, Pydi Setty T, Bala Narsaiah and S Srinu Naik. 2017. *Innovative Technologies for the Treatment of Industrial Wastewater: A Sustainable Approach*. CRC Press.
- Stuetz Richard. *Principles of Water and Wastewater Treatment Processes* (*Water and Wastewater Process Technologies*). IWA Publishing.
- Syed R Qasim and Guang Zhu. 2018. *Wastewater Treatment and Reuse: Theory and Design Examples*. CRC Press.

I. **Course Title : Water Conveyance and Distribution**

II. **Course Code : IDE 509**

III. **Credit Hours : 2+1**

IV. **Aim of the course**

To develop the common understanding of different conveyance structure in irrigation network and provide knowledge of various flow and their computations including sediment transport in channels.

V. **Theory**

Unit I

Channel characteristics. Prismatic and non-prismatic channel. Steady, unsteady, uniform and non-uniform flow. Open channel and their properties. Energy and momentum, critical flow computation and application. Basic Concepts of free surface flow, classification of flow, velocity and pressure distribution.

Unit II

Uniform flow, conservation laws and specific energy. Application of momentum and energy equation. Channel transition. Study of critical flow, uniform flow, gradually varied flow, rapid varied flow, spatially varied flow and unsteady flow and their computations.

Unit III

Energy dissipation. Flow control structures and flow measurement. Theories and methods of open channel design.

Unit IV

Sediment transport in channels. Regime flow theories. Tractive force theory. Design of stable channels.

Unit V

Basic principles of pipe flow, pipe flow problems and equivalent pipe. Principles of network synthesis. Pipe network analysis. Water transmission lines. Cost considerations: Single-Input source. Branched systems: Single-Input source. Looped Systems: Multi-Input source. Branched systems: Multi-Input source, Looped systems. Decomposition of a large water system and optimal zone size.

VI. **Practical**

Computation and use of geometrical and hydraulic elements of open channel. Use of flow measuring devices and methods and their limitations. Examination of velocity distribution and calculation of energy and momentum coefficients. Solution of channel design problems. Appraisal of flow control and distribution structures. Analysis and computation of flow profiles.

VII. **Learning outcome**

The student will be able to infuse the knowledge about different types of channel flow and their behavior and also able to gain the knowledge of appraisal of flow control and distribution structures including design of stable channel.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Channel characteristics. Prismatic and non-prismatic channel	1
2.	Steady, unsteady, uniform and non-uniform flow	1
3.	Open channel and their properties	2
4.	Energy and momentum, critical flow computation and application	2
5.	Basic Concepts of free surface flow, classification of flow, velocity and pressure distribution	2
6.	Uniform flow, conservation laws and specific energy	2
7.	Application of momentum and energy equation	1
8.	Channel transition	1
9.	Study of critical flow, uniform flow, gradually varied flow, rapid varied flow	2
10.	Spatially varied flow and unsteady flow and their computations	2
11.	Energy dissipation	1
12.	Flow control structures and flow measurement	1
13.	Theories and methods of open channel design	2
14.	Sediment transport in channels	1
15.	Regime flow theories	1
16.	Tractive force theory	1
17.	Design of stable channels	1
18.	Basic principles of pipe flow, pipe flow problems and equivalent pipe	1
19.	Principles of network synthesis. Pipe network analysis	1
20.	Water transmission lines. Cost considerations: Single-Input source. Branched systems: Single-Input source	2
21.	Looped Systems: Multi-Input source. Branched systems: Multi-Input source, Looped systems	2
22.	Analysis and computation of flow profiles	2
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Computation and use of geometrical and hydraulic elements of open channel	2
2.	Study of Flow measuring devices,methods and their limitations	2
3.	Examination of velocity distribution	2
4.	Calculation of energy and momentum coefficients	2
5.	Channel design: problems and its solution	3
6.	Appraisal of flow control and distribution structures	2
7.	Analysis and computation of flow profiles	3
	Total	**16**

X. Suggested Reading

- Chaudhry MH. 1993. *Open Channel Flow*. Prentice-Hall, NJ.
- Chow VT. 1979. *Open Channel Hydraulics*. McGraw Hill Inc. N York.
- French RH. 1986. *Open Channel Hydraulics*. McGraw Hill Pub Co., N York
- Henderson FM. 1966. *Open Channel Flow*. Macmillan Co. New York.
- Prabhata K Swamee and Ashok K Sharma. *Design of Water Supply Pipe Networks*. John Wiley New York.
- Subramanya K. 2008. *Flow in Open Channels*. Tata McGraw Hill Pub.
- Terry Sturm. 2011. *Open Channel Hydraulics*. Tata McGraw Hill Pub.

I. Course Title : Minor Irrigation

II. Course Code : IDE 510

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint students about the need and scope of minor irrigation in India. To provide in-depth knowledge in design and operation of surface and groundwater-based irrigation practices.

Unit I

Definition, scope, historical background and progress in minor irrigation works in India, Assessment of surface water resource. Design and operation of surface water storage structures.

Unit II

Evaporation and seepage control. Groundwater development methods and their scope. Groundwater extraction devices and methods. Aquifer characteristic and their evaluation. Wells in alluvial and rocky aquifers.

Unit III

Well interference, spacing and multiple well point system for controlled groundwater pumping. Safe yield from wells. Augmentation of well yield through pumping and recovery time management.

Unit IV

Well design, drilling and construction. Tube well strainers, gravel packing and resistance to flow. Pumps and prime movers for groundwater lifting. Diagnosis of sick and failed wells and their remediation.

Unit V

Conjunctive use of surface and groundwater. Legislation for groundwater development and management. Groundwater recharge and its use.

V. Practical

Measurement of seepage loss from reservoirs. Estimation of inflow to surface reservoir. Measurement of evaporation loss from surface reservoirs. Pumping test and determination of aquifer parameters. Establishment of draw down-discharge characteristic. Well log analysis and deciding on length and placement of strainers. Computation of well interference and deciding on well spacing. Estimation of irrigation for given discharge from well. Estimating pumping cost for irrigation. Analysis of ground water quality. Problems on well design.

VI. Learning outcome

The students will be able to understand minor irrigation practices and their importance in Indian agriculture. They will also expose to conjunctive use of surface and groundwater and able to perform groundwater development legislation, recharge and utilization practices.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Definition and scope of minor irrigation works in India	1
2.	Historical background and progress in minor irrigation works in India	2

S.No.	Topic	No. of Lectures
3.	Assessment of surface water resource	1
4.	Design and operation of surface water storage structures	2
5.	Evaporation and seepage control	1
6.	Groundwater development methods and their scope	2
7.	Groundwater extraction devices and methods	1
8.	Aquifer characteristic and their evaluation	2
9.	Wells in alluvial and rocky aquifers	1
10.	Well interference	2
11.	Spacing and multiple well point system for controlled groundwater pumping	2
12.	Safe yield from wells	1
13.	Augmentation of well yield through pumping and recovery time management	2
14.	Well design, drilling and construction	2
15.	Tube well strainers	1
16.	Gravel packing and resistance to flow	2
17.	Pumps and prime movers for groundwater lifting	2
18.	Diagnosis of sick and failed wells and their remediation	1
19.	Conjunctive use of surface and groundwater	1
20.	Legislation for groundwater development and management	1
21.	Groundwater recharge and its use	2
	Total	**32**

VIII. List of Practicals

S.No.	Topic	No. of Practicals
1.	Measurement of seepage loss from reservoirs	1
2.	Estimation of inflow to surface reservoir	2
3.	Measurement of evaporation loss from surface reservoirs	1
4.	Pumping test and determination of aquifer parameters	2
5.	Establishment of draw down-discharge characteristic	2
6.	Well log analysis and deciding on length and placement of strainers	2
7.	Computation of well interference and deciding on well spacing	2
8.	Estimation of irrigation for given discharge from well	1
9.	Estimating pumping cost for irrigation	1
10.	Analysis of ground water quality	1
11.	Problems on well design	1
	Total	**16**

IX. Suggested Reading

- Garg SK. 1987. *Irrigation Engineering and Hydraulic Structures*. Khanna Publisher, Delhi.
- Garg SK. 1987. *Hydrology and Water Resource Engineering*. Khanna Publishers, Delhi.
- Michael AM. 2006. *Irrigation Theory and Practice*. Vikas Publications, New Delhi.
- Sharma RK. 1987. *Hydrology and Water Resources Engineering*. Dhanpat Rai and Sons, New Delhi.
- Subramanian K. 1993. *Engineering Hydrology*. Tata Mc-Graw-Hill Co. New Delhi.

I. Course Title : Design of Pumps for Irrigation and Drainage

II. Course Code : IDE 511

III. Credit Hours : 2+0

IV. Aim of the course

To acquaint students about basic hydraulic design of various pumps, energy requirement in pumping, solar photovoltaic system and solar pump including design of pumping station.

V. Theory

Unit I

Basic hydraulic design of centrifugal pump. Net positive suction head and cavitation, vapour pressure, water hammering problem in centrifugal pump.

Unit II

Principles and design of pumping systems for agricultural drainage. Selection and performance of characteristics of vertical turbine pump, submersible pump and axial flow pump.

Unit III

Multiple well point system and their design. Energy requirement in groundwater pumping.

Unit IV

Non-conventional energy sources for pumping, wind mills, micro turbines, solar pumps. Hydraulic ram: Selection and design criteria. Solar photovoltaic system.

Unit V

Design of pumping station. Techno-economic evaluation. Efficient pumping system operation, flow control strategies and conservation measures for pumping systems.

VI. Learning outcome

The students will be able to select the pump for desired discharge to be pumped from particular water source by developing pump characteristics curve, able to analyze the flow in different types of pump and also able to design the pumping station for managing the irrigation and drainage system.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Different types of pumps used under different conditions	1
2.	Principal and working of centrifugal pump	1
3.	Basic hydraulic design of centrifugal pump	1
4.	Net positive suction head and cavitation, vapour pressure, water hammering problem in centrifugal pump	3
5.	Use of pumpsets for agricultural drainage under different conditions.	1
6.	Principles and design of pumping systems for agricultural drainage.	2
7.	Selection and performance of characteristics of vertical turbine pump	2
8.	Flow pattern in turbine pumps	1
9.	Selection and performance of characteristics of vertical submersible pump	2
10.	Flow pattern in submersible pumps	1
11.	Visit to Pumping Industry	5
12.	Use of Multiple well point/skimming well point system under different conditions and its design	1
13.	Energy requirement and efficiency for Multiple well point/skimming well point system	1
14.	Introduction and use of Non-conventional energy sources for pumping	1
15.	Selection and design criteria for Solar photovoltaic system	2
16.	Selection and design criteria for wind mills, micro turbines, solar pumps. Hydraulic ram	3

S.No.	Topic	No. of Lectures
17.	Introduction to pumping station and its components & design	1
18.	Techno-economic design evaluation in pumping sets	1
19.	Energy conservation measures under different pumping units under different flow conditions	2
	Total	**32**

VIII. Suggested Reading

- Bansal RK. 1990. *A Text Book of Fluid Mechanics and Hydraulic Machines*. Laxmi Publications, New Delhi.
- Church AH and Jagdish Lal. 1973. *Centrifugal Pumps and Blowers*. Metropolitan Book Co. Pvt. Ltd. Delhi.
- Luthin JN. 1966. *Drainage Engineering*. Wiley and Sons. New York, USA.
- Michael AM and Khepar SD. 1989. *Water Wells and Pump Engineering*. Tata McGraw Hill Publishing Co., New Delhi.

I. Course Title : Crop Environmental Engineering

II. Course Code : IDE 512

III. Credit Hours : 2+0

IV. Aim of the course

To develop the common understanding aerial and edaphic environments for plant growth, energy and mass transfer which help to maximizing the crop yield. To understand the basic interface of soil and root and its characteristics.

V. Theory

Unit I

Principles of heat, mass and momentum transport. Transport of radiant energy, radiation environment, micro climatology of radiation. Micrometeorology: Turbulent transfer profiles and fluxes. Interpretation of flux measurement. Laws of electromagnetic radiation, its measurement and estimation.

Unit II

Profile balance of heat, mass and momentum in and above crop communities. Climatic changes and plant response to environmental stresses. Measurement and estimation of potential evapotranspiration on point and regional scale.

Unit III

Root anatomy, water flow in roots and root density models (microscopic and macroscopic). Stem anatomy and pressure volume curves. Methods of measuring water status in plants. Estimating ET using three temperature model and MODIS algorithm. Soil–Plant–Atmosphere system: Basic properties. Dynamics of water movement. ET-yield relations.

Unit IV

Principles of optimal scheduling of irrigation and seasonal allocation of limiting water supplies using LP and DP. Seasonal and dated production functions. Crop yield modelling and condition assessment. Instrumentation and techniques for monitoring plant environments.

Unit V

Design and operation of controlled environment facilities and their instrumentation. Climatic changes and plant response to environmental stresses. Evapotranspiration models.

VI. Learning outcome

The students will be able to identify climatic changes on plant and how plant responds to environmental stresses and evapotranspiration. The students will be exposed for design and operation of controlled environment facilities and crop yield modeling.

VII. Lecture Schedule

S.No.	Topic	No. of lectures
1.	Principles of heat, mass and momentum transport	2
2.	Transport of radiant energyradiation environment, micro climatology of radiation	2
3.	Micrometeorology: Turbulent transfer profiles and fluxes. Interpretation of flux measurement	1
4.	Laws of electromagnetic radiation, its measurement and estimation	1
5.	Profile balance of heat, mass and momentum in and above crop communities	1
6.	Climatic changes and plant response to environmental stresses	1
7.	Measurement and estimation of potential evapotranspiration on point and regional scale	1
8.	Root anatomy, water flow in roots and root density models (microscopic and macroscopic)	1
9.	Stem anatomy and pressure volume curves	1
10.	Methods of measuring water status in plants	1
11.	Estimating ET using three temperature model and MODIS algorithm	2
12.	Soil–Plant–Atmosphere system: Basic properties	1
13.	Dynamics of water movement	1
14.	ET-yield relations	2
15.	Principles of optimal scheduling of irrigation	1
16.	Seasonal allocation of limiting water supplies using LP and DP	2
17.	Seasonal and dated production functions	2
18.	Crop yield modelling and condition assessment	2
19.	Instrumentation and techniques for monitoring plant environments	2
20.	Design and operation of controlled environment facilities and their instrumentation	2
21.	Climatic changes and plant response to environmental stresses	1
22.	Evapotranspiration models	2
	Total	**32**

VIII. Suggested Reading

- Abtew W and Melese A. 2017. *Evaporation and Evapotranspiration: Measurements and Estimations*. Springer Publications.
- Campbell GS and Norman JM. *An Introduction to Environmental Biophysics*. Springer Publication New York.
- Ghildyal BP and Tripathy RP. 1987. *Fundamental of Soil Physics.* Wiley Eastern.
- Monteith JL and Unsworth MH. *Principles of Environmental Physics*. Elsevier, Amsterdam.
- Slatyor O P 1967. *Plant Water Relationship*. Academic Press.
- Yang Y. *Evapotranspiration over Heterogeneous surfaces: Models and Applications*. Springer Publications.

I. Course Title : Water Resources Systems Engineering

II. Course Code : IDE 513

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint students about the concept of optimization and its application in water resources management, mathematical programming techniques and multi objective water resources planning.

V. Theory

Unit I

Concepts and significance of optimization in water resources management. Model development in water management. Objective functions, deterministic and stochastic inputs.

Unit II

Soil plant atmosphere system. Problem formulation. Mathematical programming techniques: Linear programming, simplex method.

Unit III

Non-linear programming, quadratic programming, integer programming. Transportation problem and solution procedure. Geometric programming and dynamic programming.

Unit IV

Application of optimization techniques for water resources planning. Conjunctive use of water resources. Crop production functions and irrigation optimization.

Unit V

Multi objective water resources planning. Critical path method. Programme evaluation and review technique. Economic models. Project evaluation and discounting methods.

VI. Practical

Assessment of water resources. Problems related to water allocation in agriculture under single and multiple cropping system. Use of computer software for linear and dynamic programming. Introduction to the use of other programming methods. Sensitivity analysis of different alternatives of water resources development and allocation. Analysis of water demand and supply. Analysis of Competitive demands for water by various sectors of development. Benefits and cost of water resources development.

VII. Learning outcome

The students will be able to identify objective function and components in water resource planning problems and also able to formulate and solve various mathematical programming models of water resource system as well as to develop conjunctive use and crop production function optimization models.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Concepts and significance of optimization in water resources management	1
2.	Model development in water management	1

S.No.	Topic	No. of Lectures
3.	Objective functions, deterministic and stochastic input	1
4.	Soil plant atmosphere system. Problem formulation. Mathematical programming techniques	1
5.	Linear programming, simplex method	5
6.	Non-linear programming, quadratic programming, integer programming	5
7.	Transportation problem and solution procedure	3
8.	Geometric programming	3
9.	Dynamic programming	4
10.	Application of optimization techniques for water resources planning	2
11.	Conjunctive use of water resources	1
12.	Crop production functions and irrigation optimization	2
13.	Multi objective water resources planning. Critical path method	2
14.	Programme evaluation and review technique	1
15.	Economic models	2
16.	Project evaluation and discounting methods	1
	Total	**35**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Assessment of water resources of the region	1
2.	Problems on water allocation in agriculture under single and multiple cropping system	2
3.	Familiarization with computer software for linear programming	3
4.	Hands on exercise for non-linear programming on computer	3
5.	Hands on exercise for dynamic programming on computer	3
6.	Sensitivity analysis of different alternatives of water resources development and allocation	2
7.	Analysis of water demand and supply	2
8.	Benefits and cost of water resources development	1
	Total	**17**

X. Suggested Reading

- Larry WM. 1996. *Water Resources Handbook*. Mc-Graw-Hill.
- Loucks DP *et al*. 1981. *Water Resources System Planning and Analysis*. Prentice Hall.
- Rao SS. 1978. *Optimization Theory and Application*. Wiley Eastern.
- Wallander WW and Bos M. 1990. *Water Resource System Planning and Management*.

I. Course Title : Irrigation Economics Planning and Management

II. Course Code : IDE 514

III. Credit Hours : 2+0

IV. Aim of the course

To impart knowledge of various public and government policy on regulation and allocation of irrigation water, cost and benefit analysis including project evaluation, decision making process and risk analysis.

V. Theory

Unit I

Economic analysis. Problems in project selection. Methods and approaches to water pricing. Criteria for investment and pricing in irrigation projects. Social benefits, problems and causes of under-utilization. Mathematics of economic analysis. Cost allocation, separable and non-separable costs. Discounting factors and techniques. Determination of benefits, cost and benefit analysis. Project evaluation. Limitations of benefit-cost analysis. Dynamics of project analysis.

Unit II

Role of financial analysis. Distinctions from economic analysis. Financial feasibility and analysis. Impact of public policies on regulation and allocation of irrigation water. Relative economic efficiency of alternative irrigation water management models. Irrigation system improvement by simulation and optimization to enhance irrigation water use efficiency.

Unit III

Indian agriculture, main problems, population, government policies, systems, organizing agriculture production. Farm Management: Definition, importance, scope, relation with other sciences and its characteristics.

Unit IV

Socio-economic survey. Importance of such survey in planning, implementation and evaluation of project performance. Planning of socio-economic survey, types of data sets to be collected, preparing the questionnaires form, schedules sampling, editing and scrutinizing of secondary data, classification and analysis of data.

Unit V

Role of farm management principles in decision making for irrigated agriculture. Decision making process, assessing risk and uncertainty in planning.

VI. Learning outcome

The students will be able to estimate the cost benefit analysis, pricing and investment criteria on irrigation project evaluation and finding their problems. The students will also expose to conduct socio-economic survey and analyse secondary data.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Economic analysis, problems in project selection	1
2.	Methods and approaches to water pricing	1
3.	Criteria for investment and pricing in irrigation projects	1
4.	Social benefits, problems and causes of under-utilization	1
5.	Mathematics of economic analysis	1
6.	Cost allocation, separable and non-separable costs	1
7.	Discounting factors and techniques	1
8.	Determination of benefits and limitations of cost-benefit analysis	1
9.	Project evaluation	1
10.	Dynamics of project analysis	1
11.	Role of financial analysis	1
12.	Distinctions from economic analysis	1
13.	Financial feasibility and analysis	1
14.	Impact of public policies on regulation and allocation of irrigation water	1
15.	Relative economic efficiency of alternative irrigation water management models	2

S.No.	Topic	No. of Lectures
16.	Irrigation system improvement by simulation and optimization to enhance irrigation water use efficiency	2
17.	Indian agriculture, main problems, population, government policies, systems, organizing agriculture production	2
18.	Farm Management: Definition, importance, scope, relation with other sciences and its characteristics	2
19.	Socio-economic survey: Importance of survey in planning, implementation and evaluation of project performance	2
20.	Planning of socio-economic survey, types of data sets to be collected, preparing the questionnaires form, schedules sampling, editing and scrutinizing of secondary data	2.
21.	Classification and analysis of data	1
22.	Role of farm management principles in decision making for irrigated agriculture	2
23.	Decision making process	1
24.	Assessing risk and uncertainty in planning	2
	Total	**32**

VIII. Suggested Reading

- Heady, Early Orel, Hexem R and Roger W. 1978. *Water Production Functions for Irrigated Agriculture*.
- James Douglas and Lee Rober R. 1995. *Economics of Water Resource Planning*. Tata Mcgraw-Hill Publication Company Ltd, Bombay, New Delhi.
- Joshi SS and TR Kapoor. 2001. *Fundamentals of Farm Business Management*. Kalyani Publishers, Ludhiana.
- *Management of Water Project-Decision Making and Investment Appraisal*. Oxford Publication Co.
- Sharma VK. 1985. *Water Resource Planning and Management*. Himalaya Publication House, New Delhi.

I. Course Title : Sensing and Automation in Irrigation Systems

II. Course Code : IDE 515

III. Credit Hours : 3+0

IV. Aim of the course

To acquaint students about the concept of sensing and automation in irrigation system, wireless sensor network and digital signal processor. To provide knowledge of surface irrigation automation.

V. Theory

Unit I

Sensing and sensors. Sensor classifications. Wireless sensor networks. History of wireless sensor networks (WSN). Communication in a WSN. Important design constraints of a WSN like Energy, self management, wireless networking, decentralized management, design constraints, security etc.

Unit II

Node architecture. Sensing subsystem. Analog-to-Digital converter. The processor subsystem, architectural overview, microcontroller, digital signal processor, application-specific integrated circuit, field programmable gate array (FPGA).

Unit III

Communication interfaces, serial peripheral interface, inter-integrated circuit, the IMote node architecture, The XYZ node architecture, the Hogthrob node architecture.

Unit -IV

Applications in surface irrigation automation, automation based on volume, time, fertigation scheduling, water logging, salinity, oxygen diffusion systems, etc.

VI. Learning outcome

The students will be able to understand concept of automation in irrigation system which is quite important to enhance water use efficiency and also able to understand Node architecture and other routing protocols.

VII. Lecture Schedule

S.No.	Topics	No. of Lectures
1.	Sensing and sensors	2
2.	Sensor classifications	2
3.	History of wireless sensor networks (WSN) and Wireless sensor networks	3
4.	Communication in a WSN	1
5.	Important design constraints of a WSN like Energy, self-management, wireless networking, decentralized management, design constraints, security etc	3
6.	Node architecture	1
7.	Sensing subsystem	1
8.	Analog-to-Digital converter	2
9.	The processor subsystem	1
10.	Architectural overview	1
11.	Microcontroller	2
12.	Digital signal processor	2
13.	Application-specific integrated circuit	2
14.	Fieldprogrammable gate array (FPGA)	2
15.	Communication interfaces	2
16.	Serial peripheral interface	3
17.	Inter-integrated circuit	2
18.	The IMote node architecture	2
19.	The XYZ node architecture	2
20.	The Hogthrob node architecture	2
21.	Applications in surface irrigation automation	3
22.	Automation based on volume, time, fertigation scheduling, water logging, salinity, oxygen diffusion systems, etc	4
	Total	**45**

VIII. Suggested Reading

- Cauligi S Raghavendra, Krishna M Sivalingam and Taieb Znati. *Wireless Sensor Networks*. Springer.
- Edgar H, Callaway Jr. and Edgar H Callaway. *Wireless Sensor Networks: Architectures and Protocols*.
- Holger Karl and Andreas Willig. *Protocols and Architectures for Wireless Sensor Networks*. John Wiley & Sons.
- Waltenegus Dargie and Christian Poellabauer. *Fundamentals of Wireless Sensor Networks:* Theory and Practice. A John Wiley and Sons, Ltd, Publication.

Course Title with Credit Load
Ph.D. in Irrigation and Drainage Engineering

Major Courses (Requirement: 12 Credits)

Course Code	Course Title	Credit Hours
IDE 601*	Recent Developments in Irrigation Engineering	2+1
IDE 602*	Advances in Drainage Engineering	2+1
IDE 603	Hydro-Mechanics and Ground Water Modeling	3+0
IDE 604	Soil-Water-Plant-Atmospheric Modeling	2+1
IDE 605	Plant Growth Modeling and Simulation	2+0
IDE 606	Multi Criteria Decision Making System	2+0
	Total	**13+3**

Minor Courses (Requirement: 06 Credits)

Course Code	Course Title	Credit Hours
SWCE 502	Applied Watershed Hydrology	2+1
SWCE 603	Reservoir Operation and River Basin Modeling	2+1
SWCE 604	Modeling Soil Erosion Processes and Sedimentation	2+1
CSE 503	Neuro-Fuzzy Application in Engineering	2+1
CSE 506	Digital Image Processing	2+1
FMPE 602	Advances in Machinery for Precision Agriculture	2+1
REE 615	Energy Planning, Management and Economics	3+0
	Any other course(s) of other department can be taken as per recommendations of the student's advisory committee.	

Supporting Courses (Requirement: 05 Credits)

Course Code	Course Title	Credit Hours
CPE-RPE*	Research and Publication Ethics	1+1
	Courses from subject matter fields (other than Major and Minor) relating to area of special interest and research problem can be taken as per recommendations of the student's advisory committee.	

***Course has been made compulsory by UGC for PhD students. Course code and its detailed course outline to be adopted in toto as recommended by UGC.**

List of other Essential Requirements

Course Code	Course Title	Credit Hours
IDE 691	Seminar-I	0+1
IDE 692	Seminar-II	0+1
IDE 699	Thesis Research	0+75

Course Contents
Ph.D. in Irrigation and Drainage Engineering

I. Course Title : Recent Developments in Irrigation Engineering

II. Course Code : IDE 601

III. Credit Hours : 2+1

IV. Aim of the course

To focus the students for the recent designs progressed in surface irrigation systems, surface and subsurface drip irrigation systems and for utilizing good and poor-quality waters for sustaining crop productivity.

V. Theory

Unit I

Geospatial analysis of hydraulic properties of the soil. Surge flow irrigation systems. One dimensional and two-dimensional zero inertia modelling of border irrigation, surge irrigation and furrow irrigation. Integral equation solutions to surface irrigation. Design of irrigation runoff recovery systems. Cablegation: Automated supply for surface irrigation. Analyzing wind distortion in sprinkler irrigation systems uniformity.

Unit II

Design of sub-surface drip irrigation systems. Modeling soil water regimes and solute distribution emanating from surface and sub-surface drip irrigation systems. Recent developments in designs of surface and sub-surface drip irrigation systems. Effects of emitter variability and plant and soil variability on soil moisture distribution uniformity. Irrigation scheduling through partial root zone irrigation. Low energy drip irrigation systems.

Unit III

Drip irrigation for poor quality water. Drip automation for time and volume. Drip irrigation system modification for waste water utilization. Modeling deficit irrigation and crop yield in response to hydraulic variation of the system and distribution uniformity of the soil-crop water fertilizer response function. Crop water salinity response function.

Unit IV

Drip irrigation in command area development. Mulching and its effect on crop productivity. Analyzing moisture and temperature profiles with time and depth. Effect of shading and mulching on crop productivity, vapour phase movement.

VI. Practical

Designing border irrigation using zero inertia model, volume balance approaches, evaluating surge flow irrigation systems, operation of segmented border irrigation systems for enhancing water use efficiency, geospatial analysis of soil properties, design and planning of surface drip irrigation systems using various designs, design of subsurface drip irrigation, analyzing three dimensional moisture movement under subsurface drip irrigation using simple empirical models, design and planning of surface and subsurface drainage systems, developing the irrigation schedules using partial root zone irrigation, seasonal and dated production functions for forecasting crop yield

VII. Learning outcome

The students will be able to design, operate and maintain surface irrigation systems, surface and sub-surface pressurized irrigation systems and managing crop productivity with poor quality of waters without deteriorating soil conditions.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Geospatial analysis of hydraulic properties of soil: Geospatial analysis, Spatial interpolation, Data quality assessment, Vegetation analysis, Correlation analysis	3
2.	Surge flow: Effect of surging on infiltration and surface flow hydraulics, surge flow systems	2
3.	Zero inertia modeling of border irrigation	2
4.	Integral equation solutions to surface irrigation: Border and furrow irrigation method	2
5.	Design of irrigation runoff recovery systems: Border and furrow irrigation method	3
6.	Cablegation: Automated supply for surface irrigation	2
7.	Wind effects on sprinkler irrigation performance: Analyzing wind distortion in sprinkler irrigation system uniformity	2
8.	Design of sub-surface drip irrigation systems, Modeling soil water regimes and solute distribution emanating from sub-surface drip irrigation systems	3
9.	Effects of emitter variability and plant and soil variability on soil moisture distribution uniformity	2
10.	Irrigation scheduling through partial root zone irrigation.	2
11.	Low energy drip irrigation systems	2
12.	Drip irrigation for poor quality water, Drip automation for time and volume, Drip irrigation system modification for waste water utilization	2
13.	Modeling deficit irrigation and crop yield in response to hydraulic variation of the system and distribution uniformity of the soil-crop water fertilizer response function, Crop water salinity response function	3
14.	Drip irrigation in command area development	2
15.	Mulching and its effect on crop productivity, Analyzing moisture and temperature profiles with time and depth, Effect of shading and mulching on crop productivity, vapour phase movement	3
	Total	**35**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Study of geospatial analysis of soil properties	
2.	Design of border irrigation using zero inertia model	1
3.	Design of border irrigation using volume balance approach	1
4.	Design and evaluation of surge flow irrigation system	1
5.	Design of irrigation runoff recovery system for border irrigation method	1

S.No.	Topic	No. of Practicals
6.	Design of irrigation runoff recovery system for furrow irrigation method	1
7.	Design and planning of cablegation system	1
8.	Analysis of wind distortion in sprinkler irrigation system uniformity	1
9.	Design and planning of subsurface drip irrigation system	1
10.	Analysis of three dimensional moisture movement under subsurface drip irrigation using simple empirical models	2
11.	Development of irrigation schedules using partial root zone irrigation	1
12.	Modeling deficit irrigation and crop yield in response to hydraulic variation of the system and distribution uniformity of the soil-crop water fertilizer response function	1
13.	Analysis of moisture and temperature profiles with time and depth	1
14.	Development of seasonal and dated production functions for forecasting crop yield	
	Total	**15**

X. Suggested Reading

- Cuenca RH. 1989. *Irrigation System Design: An Engineering Approach*. Prentice Hall, New York.
- Hoffman GJ, Evans RG, Jensen ME, Martin DL and Elliot RL. (ed). 2007. *Design and Operation of Farm Irrigation Systems*. American Society of Agricultural Engineers St. Joseph Michigan.
- James LG. 1988. *Principles of Farm Irrigation System Design*. John Wiley and Sons, New York, USA.
- Nakayama FS and Bucks DA. 1986. *Trickle Irrigation for Crop Production: Design, Operation and Management*. Elsevier Publications, Amsterdam.
- Skogerboe GV and Walkar WR. 2008. *Surface Irrigation Theory and Practice*. Prentice Hall, New York.

I. Course Title : Advances in Drainage Engineering

II. Course Code : IDE 602

III. Credit Hours : 2+1

IV. Aim of the course

To provide comprehensive knowledge of advances in land drainage, synthetic materials for drainage systems, linear flow laws and environmental issues related to drainage.

V. Theory

Unit I

Physics of land drainage. Forces, surface tension and energy effects water. Energy of soil water. Capillary potential.

Unit II

Devices to measure capillary potential. Hystersis, Darcy's law. Synthetic materials for drainage systems. Environmental issues related to drainage. Socio-economic impacts of drainage systems.

Unit III

Laplace equation its derivation and solution in various forms. Boundary value problems, Liner flow laws.

Unit IV

Drainage criteria saturated flow theory, steady flow and non steady flow. Controlled drainage for reducing agricultural non-point pollution. Application of simulation models for drainage systems.

Unit V

Flow equations in general and the approach. Flow problem and physical boundary conditions.

VI. Practical

Steady state and non steady state flow problems. Measurement of capillary potential. Use of various synthetic materials under the field condition. Use of simulated models for drainage system.

VII. Learning outcome

The student will be familiar about energy of soil water, capillary potential, drainage material and various sources of agricultural pollution and also able to develop and apply simulation model for management of drainage system for particular area.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Physics of land drainage: Forces acting on movement of water through soil profile, surface tension, capillary forces and energy effects movement of water, Energy of soil water	5
2.	Capillary potential: Effect of capillary potential on movement of water through porous media, devices to measure capillary potential. Hystersis effect in drainage of soil, Darcy's law	3
3.	Synthetic materials for drainage systems: Design of filter and envelop for drainage system with synthetic materials	2
4.	Environmental issues related to drainage. Socio-economic impacts of drainage systems	2
5.	Drainage Flow Equation: Laplace equation its derivation and solution in various forms, Liner flow laws	4
6.	Boundary value problems: Initial and boundary condition and its solution	3
7.	Drainage criteria: Drainage criteria for different type of soils and crops, guidelines for design and installation of drainage system	2
8.	Saturated flow theory: steady flow and non steady saturated flow	3
9.	Controlled drainage for raising crop and reducing agricultural non-point pollution	2
10.	Application of simulation models for drainage systems (DRAINMOD, SALTMOD, etc)	4
11.	Flow equations: general drainage flow equations and the approach, drainage flow problems and solutions with physical boundary conditions	3
	Total	**34**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Steady state drainage flow problems	3
2.	Unsteady state drainage flow problems	3
3.	Measurement of capillary potential	2

S.No.	Topic	No. of Practicals
4.	Use of various synthetic materials for drainage filter under the field condition	2
5.	Design of filter and envelop with synthetic materials	2
6.	Use of simulated models for drainage system	4
	Total	**16**

X. Suggested Reading

- Chauhan HS. 1999. *Mathematical Modeling of Agricultural Drainage, Ground Water and Seepage*. ICAR Publication New Delhi.
- Kirkham DL and Powers WL. 1972. *Advanced Soil Physics*. Inter Science, New York.
- Lambert K Smedema, Willem FV, Lotman and David Rycroft. 2004. *Modern Land Drainage: Planning, Design and Management of Agricultural Drainage Systems.* CRC Press.
- Ritzema HP. (Ed.). 1994. *Drainage Principles and Applications*. ILRI.
- Skaggs RW and Schilfgaarde Jan Van. 1999. *Agriculture Drainage*. Monograph No. 17. American Society of Agronomy Madison, Wisconsin, USA.

I. Course Title : Hydro-Mechanics and Groundwater Modeling

II. Course Code : IDE 603

III. Credit Hours : 3+0

IV. Aim of the course

To acquaint students about the concept of soil aquifer system, unsaturated flow models, numerical modeling of groundwater flow, theory of krigging and movement of groundwater in fractured and swelling porous media.

V. Theory

Unit I

Concept of soil aquifer system, flow of water in partially saturated soils. Partial differential equation of flow, pressure under curved water films, moisture characteristic functions.

Unit II

Physical models, Analog models, Mathematical modelling, Unsaturated flow models, Numerical modelling of groundwater flow, Finite difference equations and solutions. Successive over relaxation. Alternating direction implicit procedure. Crank Nicolson equation. Iterative methods. Direct methods. Inverse problem. Finite element method.

Unit III

Determination of unsaturated hydraulic conductivity and model for its estimation. Diffusivity and its measurement. Infiltration and exfiltration from soils in absence and presence of water table.

Unit IV

Fence diagram and aquifer mapping. Movement of groundwater in fractured and swelling porous media. Spatial variability, theory of krigging.

Unit V

Data requirements. Conceptual model design: Conceptualization of aquifer system. Parameters, Input-output stresses, Initial and Boundary conditions. Model design and execution: Grid design, Setting boundaries, Time discretization and transient simulation. Model calibration: Steady state and unsteady state. Sensitivity analysis. Model validation and prediction. Uncertainty in the model prediction.

VI. Learning outcome

The students will be able to understand complex mechanics movement of water in soil systems and also able to estimate the statistical parameters for better understanding of soil aquifer system, model validation and prediction.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Concept of soil aquifer system	1
2.	Flow of water in partially saturated soils	1
3.	Partial differential equation of flow	1
4.	pressure under curved water films, moisture characteristic functions	1
5.	Different types of Models used in hydrology and Groundwater	1
6.	Unsaturated flow models	1
7.	Numerical modelling of groundwater flow	1
8.	Finite difference equations and solutions, Finite difference equations and solutions, Alternating direction implicit procedure	4
9.	Crank Nicolson equation. Iterative methods	2
10.	Inverse problem. Finite element method	1
11.	Determination of unsaturated hydraulic conductivity and model for its estimation	2
12.	Diffusivity and its measurement	1
13.	Infiltration and exfiltration from soils in absence and presence of water table	2
14.	Fence diagram and aquifer mapping	2
15.	Movement of groundwater in fractured and swelling porous media, Spatial variability, theory of krigging	4
16.	Data requirements. Conceptual model design: Conceptualization of aquifer system. Parameters, Input-output stresses, Initial and Boundary conditions	4
17.	Model design and execution: Grid design, Setting boundaries, Time discretization and transient simulation	4
18.	Model calibration: Steady state and unsteady state. Sensitivity analysis. Model validation and prediction. Uncertainty in the model prediction	6
19.	Course Seminar	4
	Total	**43**

VIII. Suggested Reading

- Anderson MP and Woessner WW. 1992. *Applied Groundwater Modelling: Simulation of Flow and Advective Transport*. Academic Press, Inc.
- Elango L and Jayakumar R. 2001. *Modelling in Hydrology*. Allied Publishers Ltd.
- Fetter CW. 1999. *Contaminant Hydrogeology*. Prentice Hall.
- Kirkham and Powers. 1972. *Advanced Soil Physics*. John Wiley & Sons.
- Muskat M. 1937. *The Flow of Homogeneous Fluid through Porous Media*. McGraw Hill.
- Rushton KR. 2003.*Groundwater Hydrology: Conceptual and Computational Models. Wiley,*

I. Course Title : Soil-Water-Plant-Atmospheric Modeling

II. Course Code : IDE 604

III. Credit Hours : 2+1

IV. Aim of the course

To impart the knowledge of measurement of radiation within plant cover, thermodynamics of flow through plant cells, heat transfer and radiation exchange under plant cover.

V. Theory

Unit I

Radiation balance of earth's surface. Turbulent transport of heat and momentum. Radiation exchange and heat transfer in a low plant cover.

Unit II

Measurement of radiation, leaf and air temperature, humidity and wind profiles within plant cover. Predicting potential evapotranspiration.

Unit III

Thermodynamics of flow through plant cells. Dynamics of water movement through soil plant atmosphere system. Stomatal aperture, photosynthesis and actual evapotranspiration relationship.

Unit IV

Production functions of evapotranspiration. Evapo-transpiration in mathematical modelling and optimization of design and regulation of irrigation systems and for utilization of limited water resources in agriculture.

Unit V

Crop water requirement under protected cultivation and remote sensing-based modeling.

VI. Practical

Estimation of potential evapotranspiration. Measurement of ET parameters under open and protected cultivation and development of stochastic and deterministic models of ET. Use of software for estimation of crop water requirement and ET.

VII. Learning outcome

The students will be able to understand the measurement of radiation, photosynthesis and actual evapotranspiration relationship along with modeling of evapotranspiration.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Radiation balance of earth's surface	1
2.	Turbulent transport of heat and momentum	2
3.	Radiation exchange and heat transfer in a low plant cover	2
4.	Measurement of radiation, leaf and air temperature, humidity and wind profiles within plant cover	2
5.	Predicting potential evapotranspiration	2
6.	Thermodynamics of flow through plant cells	2
7.	Dynamics of water movement through soil plant atmosphere system	2

S.No.	Topic	No. of Lectures
8.	Stomatal aperture, photosynthesis and actual evapotranspiration relationship	1
9.	Production functions of evapotranspiration	3
10.	Evapo-transpiration in mathematical modelling and optimization of design and regulation of irrigation systems and for utilization of limited water resources in agriculture	4
11.	Crop water requirement under protected cultivation and remote sensing-based modeling	4
	Total	**29**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Estimation of potential evapotranspiration using FAO 56 Penman Monteith equation	1
2.	Estimation of potential evapotranspiration using FAO Cropwat model	1
3.	Estimation of potential evapotranspiration using FAO ETo calculator	2
4.	Measurement of ET parameters under open condition	1
5.	Measurement of ET parameters under protected cultivation	1
6.	Development of stochastic models of ET	3
7.	Development of deterministic models of ET	3
8.	Use of software for estimation of crop water requirement and ET	2
	Total	**14**

X. Suggested Reading

- Amarjit Basra. 1994. *Mechanisms of Plant Growth and Improved Productivity*. CRC Press New York.
- Daniel Hillel. *Advances in Irrigation*. All Volumes.
- Nieder AR and Benbi D. 2003. *Handbook of Processes and Modeling in the Soil-Plant System*. CRC Press New York.
- Peter J Gregory. *Plant Roots, their Growth Activity and Interaction with Soils*. Wiley Blackwell New York.

I. Course Title : Plant Growth Modeling and Simulation

II. Course Code : IDE 605

III. Credit Hours : 2+0

IV. Aim of the course

To impart the in-depth knowledge of plant growth modeling, type of modeling approach, quantitative analysis of photosynthesis and remote sensing-based modeling.

V. Theory

Unit I

Introduction to plant growth modeling. Simulation and simulation language. Types of models and modeling approaches.

Unit II

Relational diagram of principle process. Structure of a generalized agricultural simulator. Input environment and techniques for monitoring plant environment.

Unit III

Process and aspects of growth and development. Input yield models. Quantitative analysis of photosynthesis, respiration, growth, water and nutrient uptake. Yield functions.

Unit IV

Remote sensing-based modeling and field variability of growth influencing factors.

VI. Learning outcome

The students will be able to know various plant growth models and their application based on input environmental parameters. Student will be acquainted with generalized agricultural simulator.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction to plant growth modelling	4
2.	Simulation and simulation language	4
3.	Types of models and modeling approaches	4
4.	Relational diagram of principle process	2
5.	Structure of a generalized agricultural simulator	2
6.	Input environment and techniques for monitoring plant environment	4
7.	Process and aspects of growth and development. Input yield models	4
8.	Quantitative analysis of photosynthesis, respiration, growth, water and nutrient uptake. Yield functions	3
9.	Remote sensing-based modelling	3
10.	Field variability of growth influencing factors	2
	Total	**32**

IX. Suggested Reading

- Charls-Edwards DA. 1981. *The Mathematics of Photosynthesis and Productivity*. Academic Press, London.
- Evans LT. 1963. *Environmental Control of Plant Growth*. Academic Press, New York, USA.
- Goudriaan J and Van Laar HH. 1994. *Modelling Potential Crop Growth Process*. Kluweer Academic Publisher, Dordrecht, The Netherlands.
- Jones JW and Ritchie JT. 1990. *Crop Growth Models*. In: ASAE Monograph on Management of Farm Irrigation.
- Thorwey JHM and Johnson IR. 1990. *Plant and Crop Modelling: A Mathematical Approach to Plant and Crop Physiology*. Clarendon Press, Oxford.

I. Course Title : Multi Criteria Decision Making Systems

II. Course Code : IDE 606

III. Credit Hours : 2+0

IV. Aim of the course

To acquaint students about multi criteria decision making system which include multi-attribute decision making and multi-objective decision making.

V. Theory

Unit I

Introduction: MCDM overview, basic foundations and Pareto optimality elementary decision analysis. Decision trees and influence diagrams.

Unit II

Multi–attribute decision making (MADM): Deterministic utility theory, value decomposition, additive value decomposition, Multi–facility location analysis, expected utility theory, single attribute utility functions, multi–attribute overview, two–attribute utility models, multi–attribute computer programs, multi–attribute assessment.

Unit III

Multi-objective decision making (MODM): Vector optimization theory, weighting methods, weighting example. Linear vector optimization (LVOP), parametric decomposition, LVOP algorithm, LVOP example.

Unit IV

Non interactive and interactive methods: Geoffrion's Bi-criterion method, linear goal programming, nonlinear and integer goal programming.

Unit V

Interactive trade-off methods: Zionts–Wallenius, Surrogate worth, Group decision making methods.

VI. Learning outcome

The students will be able to understand and learn to apply various techniques for the best solutions of real-life command area and other hydrological problems.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	MCDM overview	1
2.	Basic foundations and Pareto optimality elementary decision analysis	2
3.	Decision trees and influence diagrams	1
4.	Multi-attribute decision making (MADM): Deterministic utility theory, value decomposition, additive value decomposition	2
5.	Multi-facility location analysis	1
6.	Expected utility theory	1
7.	Single attribute utility functions	1
8.	Multi-attribute overview	1
9.	Two-attribute utility models	1
10.	Multi-attribute computer programs and multi–attribute assessment	2
11.	Multi-objective decision making (MODM)	1
12.	Vector optimization theory	1
13.	Weighting methods and examples related with weighting	2
14.	Linear vector optimization (LVOP)	1
15.	Parametric decomposition	2
16.	LVOP algorithm and LVOP example	2
17.	Non interactive and interactive methods	2
18.	Geoffrion's Bi-criterion method	1
19.	linear goal programming, nonlinear and integer goal programming	2
20.	Interactive trade-off methods	1
21.	Zionts-Wallenius and Surrogate worth	2
22.	Group decision making methods	2
	Total	**32**

VIII. Suggested Reading

- Cohon JL. 2004. *Multiobjective Programming and Planning*. Dover Publications.
- Doumpos M and Grigoroudis E. 2013. *Multicriteria Decision Aid and Artificial Intelligence: Links, Theory and Applications*. Wiley-Blackwell.
- Figueira J, Greco S and Ehrgott M 2007. *Multiple Criteria Decision Analysis: State of the Art Surveys*. Springer.
- Tzeng GH and Huang JJ. 2011. *Multiple Attribute Decision Making: Methods and Applications*. Chapman and Hall/CRC.
- Tzeng GH and Huang JJ. 2013. *Fuzzy Multiple Objective Decision Making*. Chapman and Hall/CRC.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 4

Agricultural Engineering
– Renewable Energy Engineering

Preamble
(Renewable Energy Engineering)

Course curricula and course outlines in Renewable EnergyEngineering are designed in view of the fact that courses are offered by students from disciplines of faculties of Farm Machinery and Power Engineering, Irrigation and Drainage Engineering, Process and Food Engineering.

At the post graduate level it becomes more important where they have not only to learn the recent advances in their subjects but have also to be trained in the modern and latest techniques in their disciplines so that they can participate and contribute in the development and advancement in their related fields.Further, the shrinking job opportunities in the National Agricultural Research System (ICAR/SAUs) have put additional pressure on our education system to prepare students in tune with the demands of the private sector.

All courses are designed to cover all basic topics andhave been designed by taking into consideration demands of private sector harnessing commercial aspects, modern research tools and their applications, supplementary skills required, and enhancing the global competitiveness and employability of students.The emphasis has been given on precision irrigation and modeling management and accordingly new courses "Wind energy, solid waste management, new alternate energy system, advances in renewable energy systemsand Energy generation from agricultural waste and byproducts"are framed in view of the recent developments in the subject.

The courses have been revised, updated and restructured in view of current developments and emerging trends in Renewable Energy Engineering.The revised courses cover the areas:Energy auditing, conversion and management, Solar photovoltaic system design and analysis, Renewable energy policy, planning and economics, Advances in renewable energy systems, New alternate energy systems, Fuel and combustion, Advances in biogas technology, Solid waste and waste water management, Advanced photovoltaic power generation, Renewable energy for industrial application, Bio-fuel technologies and application and Energy modeling and simulation.

The course content and syllabus upgraded with more of practical orientation and as per ARS Syllabus.

The ICAR recommendations for PG courses have been taken into consideration in framing these courses. It is hoped that these will prove very useful to the future students.

Course Title with Credit Load M.Tech. in Renewable Energy Engineering

Major Courses (Requirement: 20 Credits)

Course Code	Course Title	Credit Hours
REE 501*	Renewable Energy Technologies	2+1
REE 502*	Solar Thermal Energy Conversion Technologies	2+1
REE 503*	Biomass Energy Conversion Technologies	2+1
REE 504	Energy Auditing, Conservation and Management	2+1
REE 505	Wind Energy Conversion and Utilization	2+1
REE 506	Solar Photovoltaic System Design and Analysis	1+1
REE 507	Renewable Energy Policy, Planning and Economics	3+0
REE 508	Alternate Fuels and Applications	2+1
REE 509	Biogas Technology and Mechanism	1+1
REE 510	Energy, Ecology and Environment	3+0
REE 511	Design and Analysis of Renewable Energy Conversion Systems	2+1
REE 512	Energy Generation from Agricultural Waste and Byproducts	2+1
REE 513	Agro Energy Audit and Management	2+1
REE 514	Green House Energetic and Passive Architecture	1+1
REE 515	Energy Management in Food Processing Industries	1+1
	Total	**28+13**

*Compulsory Course

Minor Courses (Requirement: 08 Credits)

Course Code	Course Title	Credit Hours
FMPE 517	Machinery for Precision Agriculture	2+1
FMPE 518	Machinery for Horticulture and Protected Agriculture	2+0
PFE 511	Application of Engineering Properties in Food Processing	2+1
PFE 519	Bioprocess Engineering	2+1
IDE 511	Design of Pumps for Irrigation and Drainage	2+0
CE 501	Dimensional Analysis and Similitude	2+0
FMPE 515	Computer Aided System Design	0+2
CSE 501	Big Data Analytics	2+1
CSE 502	Artificial Intelligence	2+1
CSE 504	Soft Computing Techniques in Engineering	2+1
MATH 501	Finite Element Methods	1+1

Course Code	Course Title	Credits
MATH 502	Numerical Methods for Engineers	2+1
ME 501	Mechatronics and Robotics in Agriculture	2+0
	Any other course(s) of other department other than courses from major can be taken as per recommendations of the student's advisory committee.	

Supporting Courses (Requirement: 06 Credits)

Course Code	Course Title	Credits
*STAT 501	Statistical Methods for Research Works	2+1
	Courses from subject matter fields (other than Major and Minor) relating to area of special interest and research problem can be taken as per recommendations of the student's advisory committee.	

*Compulsory Course

Common Courses (Requirement: 05 Credits)

Course Code	Course Title	Credits
*PGS 501	Library and Information Services	1+0
*PGS 502	Technical Writing and Communication Skills	1+0
*PGS 503	Intellectual Property and its management in Agriculture	1+0
*PGS 504	Basic Concepts in Laboratory Techniques	1+0
*PGS 505	Agricultural Research, Research Ethics and Rural Development Programmes	1+0

*Detailed course outline to be developed by designated BSMA

List of Other Essential Requirements

Course Code	Course Title	Credits
IDE 591	Seminar	0+1
IDE 599	Thesis Research	0+30

Course Contents
M.Tech. in Renewable Energy Engineering

I. Course Title : Renewable Energy Technologies

II. Course Code : REE 501

III. Credit Hours : 2+1

IV. Aim of the course

To provide knowledge, understanding and application oriented skills on renewable energy sources and relevant technologies towards their effective utilization for meeting energy demand.

V. Theory

Unit I

Solar Energy: Heat transfer, estimation and physical conversion, Instruments for measurement. Energy collection and analysis: FPC, ETC, concentrating collectors. Solar energy application: Direct and indirect. Solar photovoltaic technology: Conversion, Systems components, integrations and applications.

Unit II

Energy from biomass and wastes: Production, distribution, characterization, treatments, recycling. Biomass conversion technologies: Thermo-chemical, bio-chemical and agro-chemical technology. Raw materials, process parameters, end products and utilization.

Unit III

Wind energy: Resource estimation, technologies, performance curves, power and torque characteristics. Airfoils and rotors: Wind mill parameters, wind farms design and considerations.

Unit IV

Alternate Energy Technologies: Ocean Thermal Energy Conversion, Geothermal, Tidal, Hydro. Energy conversion systems: Resources, systems integrations and analysis, applications. Energy storage: Types, materials, characteristics and application.

VI. Practical

Analysis of solar collectors.Solar Photovoltaic cell characteristics, analysis of SPV systems.Characterization of biomass. Design and benefit analysis of energy systems. Design and efficiency testing of wind energy conversion devices.

VII. Learning outcome

The students is acquainted the skill to understand technical aspects and principles of renewable energy characteristics of the resource base (solar radiation, wind energy, bio energy, etc.) In a further steps an economic analysis of supply technologies.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Solar energy: introduction. Solar radiations measuring Instruments	1
2.	Passive Flat plate solar collectors, types. Passive solar water heaters. Performance of solar water heater. Effect of various parameters on performance	2
3.	Solar passive concentrators: Brief introduction to main types of solar concentrators, solar cookers	1
4.	Solar passive crop dryers: Description of various types of solar crop dryers, Applications of solar crop dryers	2
5.	Solar photovoltaic technology: Conversion, Systems components, integrations and applications	2
6.	Biomass Production, distribution, characterization, treatments, recycling.	1
7.	Review of gasifiers basics; Selection criteria for type and capacity of gasifier; Performance parameters for gasifiers e.g. SGR, turn down ratio etc;	1
8.	Basic design of small scale Imbert type downdraft gasifier (without use of Tables) and Basic features of throatless and inverted downdraft gasifiers (No designing)	1
9.	Baling for densification of biomass and briquetting machines for densification of biomass	1
10.	Bio-chemical and agro-chemical technologies for biomass conversion	2
11.	Raw materials, process parameters, end products and utilization for bio-chemical and agro-chemical technologies	2
12.	Resource estimation of wind energy, technologies and performance curves	2
13.	Power and torque characteristics	2
14.	Wind mill parameters	2
15.	Wind farms design and considerations	2
16.	Ocean Thermal Energy Conversion	2
17.	Geothermal, Tidal and Hydro Energy conversion systems	2
18.	Energy storage: Types, materials, characteristics and application	4
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Analysis of solar collectors	3
2.	Solar Photovoltaic cell characteristics, analysis of SPV systems	3
3.	Characterization of biomass	4
4.	Design and benefit analysis of energy systems	3
5.	Design and efficiency testing of wind energy conversion devices	3
	Total	**16**

X. Suggested Reading

- Culp AW. 1991. *Principles of Energy Conversion*. McGraw-Hill Pub. Co Inc., New York.
- Duffie JA and Beckman WA. 1991. *Solar Engineering of Thermal Processes*. John Wiley, New York.
- Garg HP and Prakash J. 1976. *Solar Energy, Fundamentals and Applications*. Tata McGraw-Hill Pub. Co. Inc., New Delhi.
- Odum HT and Odum EC. 1976. *Energy Basis for Man and Nature*. McGraw-Hill Pub. Co. Inc., New York.

- Rai GD. 2001. *Non Conventional Energy Sources*. Khanna Publishers, Delhi.
- Sukhatme SP. 1997. *Solar Energy, Principles of Thermal Collection and Storage*. Tata McGraw-Hill. Pub. Co. Ltd, New Delhi.
- Twidell JW and Weir AD. 1986. *Renewable Energy Sources*. E & FN Spon Ltd., London.

I. Course Title : Solar Thermal Energy Conversion Technologies

II. Course Code : REE 502

III. Credit Hours : 2+1

IV. Aim of the course

To provide in-depth knowledge, understanding and application oriented skills on solar thermal conversion technologies and their effective utilization for meeting energy demand.

V. Theory

Unit I

Characteristics of solar radiation: Attenuation, absorption, scattering and air mass. Solar earth geometry.

Unit II

Solar flux and weather data. Solar radiation data and estimation: Radiation estimation models and applications. Heat and mass transfer in solar energy utilization: Gray surface, sky radiation, radiation heat transfer coefficient, reflectivity, transitivity, transmittance absorption product. Selective surfaces and materials.

Unit III

Solar thermal energy collectors (track and untrack): Heat capacity effect, time constant measurement, design and efficiency calculations, F chart method utility.

Unit IV

Techno-economic feasibility of solar thermal energy applications: Cooking, air heating for drying, steam generation, space heating and cooling, refrigeration, architecture, absorption cooling, thermal power generation.

VI. Practical

Solar radiation measurement, estimation model applications, design of collectors, study of materials used in solar system. Energy balance and efficiency calculation of collectors.

VII. Learning outcome

The student is able to understand the detail knowledge about working and design of various solar thermal devices able to design different solar thermal devices.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction to characteristics of solar radiation and Solar earth geometry	2
2.	Solar flux and weather data measurement and interpretation	2
3.	Estimation of Solar radiation data using models and estimation	3
4.	Heat and mass transfer in solar energy utilization	2

S.No.	Topic	No. of Lectures
5.	Gray surface, sky radiation, radiation heat transfer coefficient	2
6.	Reflectivity, Transitivity, Transmittance Absorption	2
7.	Selective surfaces and materials as solar energy collectors	2
8.	Heat capacity effect, time constant measurement of solar energy	2
9.	Design and efficiency calculations of Solar thermal energy collectors	4
10.	F chart method utility for Designing Solar Thermal Water Heating Systems	2
11.	Techno-economic feasibility of solar thermal energy in cooking, drying of food products, space heating and cooling.	4
12.	Economic feasibility of solar thermal energy in refrigeration, architecture, absorption cooling, thermal power generation.	4
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Measurement of Solar radiation	1
2.	Estimation of solar energy by model applications	2
3.	Design of solar energy collectors	2
4.	Study of materials used in solar system	1
5.	Energy balance in solar energy collectors	2
6.	Efficiency calculation of collectors	2
	Total	**10**

X. Suggested Reading

- Bansal NK, Kleeman MK and Meliss M. 1990. *Renewable Energy Sources and Conversion Technologies*.Tata McGraw-Hill Pub. Co. Ltd, Delhi.
- Duffie JA and Beckman WA. 2006. *Solar Thermal Engineering Process*. John Wiley & Sons, New Jersey.
- Hsien JS. 2014. *Solar Energy*. Prentice Hall Inc., New Jersey.
- Garg HP. 1990. *Advances in Solar Energy Technology*. Springer Publishing Company, Dordrecht, Netherland.
- Kalogirou SA. 2013. *Solar Energy Engineering*. Academic Press, Cambridge, Massachusetts.
- Kishore VVN. 2008. *Renewable Energy Engineering and Technology–A Knowledge Compendium*. TERI Press, New Delhi, India.
- Pai BR and Ramaprasad MS. 1991. *Power Generation through Renewable Sources of Energy*. Tata McGraw-Hill Pub. Co., New Delhi.
- Sukhatme SP and Nayak J. 2008. S*olar Energy: Principles of Thermal Collection and Storage*. Tata McGraw-Hill Publishing Company Limited, New Delhi, India.

I. Course Title : Biomass Energy Conversion Technologies

II. Course Code : REE 503

III. Credit Hours : 2+1

IV. Aim of the course

To understand the bio-conversion technologies and fuels system, types of biomass derived fuels and energy, thermo-chemical conversion of biomass to heat and power, value adding of agro-residues.

V. Theory

Unit I

Biomass characterization: Types and resources, sustainability issues, assessment tools and methodologies, biomass fuel characterization, Biomass supply chain concept. Direct use of biomass: Size reduction, baling, pelletization, briquetting technologies.

Unit II

Biochemical conversion of biomass: Feedstock, process design, operation, optimized process parameters and utilization for biogas and bioethanol production.

Unit III

Biomass combustion: Stoichiometric air requirement, chemistry of combustion, design of combustion system, combustion zones, flame structure, stability, emissions. Co-firing of biomass.

Unit IV

Thermo-chemical conversion of biomass: Feedstock, chemistry, reactor design, operation, optimized process parameters and utilization for gasification, carbonization, torrefaction and pyrolysis.

Unit V

Cogeneration technologies: Cycles, topping, bottoming, selection, problems, applications. Waste heat recovery: Estimation, systems, design and application.

VI. Practical

Biomass characterization.Design of bioreactors.Study of techno-economical feasibility of bio-chemical conversion process.Performance evaluation of combustion gadgets, gasifiers and pyrolytic converters.Design of waste heat recovery system.

VII. Learning outcome

The students is enable to extract the energy from biomass and acquainted the skill to know how to choose the suitable biomass fuels for different industrial applications with design and economics of the system.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Biomass characterization: Types and resources, sustainability issues, assessment tools and methodologies, biomass fuel characterization, Biomass supply chain concept.	3
2.	Direct use of biomass	1
3.	Size reduction, baling, pelletization, briquetting technologies.	2
4.	Biochemical conversion of biomass	1
5.	Feedstock, process design, operation, optimized process parameters.	2
6.	Utilization for biogas and bioethanol production.	1
7.	Biomass combustion	1
8.	Stoichiometric air requirement, chemistry of combustion.	3
9.	Design of combustion system.	2
10.	Combustion zones, flame structure, stability, emissions.	2
11.	Co-firing of biomass.	1
12.	Thermo-chemical conversion of biomass: Feedstock, chemistry.	2
13.	Reactor design.	1

S.No.	Topic	No. of Lectures
14.	Operation, optimized process parameters and utilization for gasification, carbonization, torrefaction and pyrolysis.	2
15.	Cogeneration technologies: Cycles, topping, bottoming, selection.	2
16.	Cogeneration Problems and applications.	2
17.	Waste heat recovery	2
18.	Estimation, systems, design and application.	2
	Total	**32**

IX. List of Practicals

S.No.	Topics	No. of Practicals
1.	Characterization of biomass	2
2.	Design of bio-reactors	1
3.	Determination of techno-economical feasibility of bio-chemical conversion process.	2
4.	Performance evaluation of combustion gadgets	1
5.	Performance evaluation of gasifiers	1
6.	Performance evaluation of pyrolytic converters	1
7.	Design of waste heat recovery system	2
	Total	**10**

X. Suggested Reading

- Chakravorty A. 1985. *Biogas Technology & other Alternative Technologies*. Oxford & IBH Publication Ltd, Delhi.
- Chaturvedi P. 1995. *Bio-Energy Resources: Planning, Production and Utilization*. Concept Pub. Co., New Delhi.
- Goswami DY. 1986. *Alternative Energy in Agriculture*.Vol. II (Ed), CRC, Press Inc., Florida, USA.
- Stout BA. 1984. *Biomass Energy Profiles*. FAO Agril. Services Bulletin No.54., Elsevier Science Publishers Ltd, England.
- Twidell JW and Weir AD. 2006. *Renewable Energy Sources*. E & F N Spon Ltd, New York.
- Vimal OP. 1984. *Energy from Biomass*.Agrcole Publishing Academy, New Delhi.

I. Course Title : Energy Auditing, Conservation and Management

II. Course Code : REE 504

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip about the sources of energy, conservation of energy and its management. Study of energy efficiency, energy planning, forecasting and energy economics.

V. Theory

Unit I

Energy conservation: Concepts, energy classification, equivalents, scenario, energy pricing, importance. Energy conservation act.

Unit II

Energy auditing and economics: Energy management, energy audit strategy, types. Energy performance: Bench marking, fuel substitutions, energy audit instruments, material and energy balance. Energy conversion: Energy index, cost index. Financial management.

Unit III

Thermal energy audit: Performance evaluation, energy conservation opportunities in boilers, steam system and furnaces, insulation, refractory's and other thermal utilities.

Unit IV

Electrical Energy audit: Electrical systems, electricity billing, load management, power factor. Performance evaluation and energy conservation opportunities in motors, compressed air system, HVAC and refrigeration system, fans and blowers, pumps and lighting system.

Unit V

Energy auditing and reporting in industries, Replacement of renewable energy technology option, case study in agro-industries.

VI. Practical

Problems on energy index, cost index. Problems on material balance and energy balance. Financial management.Energy audit and conservation opportunities in thermal and electrical utilities. Case studies on energy audit and conservation.

VII. Learning outcome

Able to understand the concept of energy auditing, conservation and management. The in-depth knowledge about the quantification, conservation opportunity and retrofitting of energy efficient system integration is expected from the course.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Energy conservation: Introduction, Concepts, Scenario	2
2.	Classification of Energy	1
3.	Energy equivalents, energy pricing, importance.	2
4.	Energy conservation act.	2
5.	Introduction to energy management, energy audit strategy and types.	2
6.	Energy performance: Bench marking, fuel substitutions.	1
7.	Energy audit instruments, material and energy balance.	2
8.	Energy conversion: Energy index, cost index. Financial management.	2
9.	Performance evaluation and energy conservation opportunities in boilers.	1
10.	Insulation, refractory's and other thermal utilities.	2
11.	Performance evaluation and energy conservation opportunities in steam system and furnaces.	2
12.	Electrical Energy audit: Electrical systems, electricity billing, load management, power factor.	2
13.	Performance evaluation and energy conservation opportunities in motors, compressed air system.	2
14.	Performance evaluation and energy conservation opportunities in HVAC and refrigeration system.	2
15.	Performance evaluation and energy conservation opportunities in fans and blowers, pumps and lighting system.	2
16.	Energy auditing and reporting in industries.	1
17.	Replacement of renewable energy technology option.	2
18.	Case study in agro-industries.	2
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Problems on energy index.	2
2.	Problems on cost index.	2
3.	Problems on material balance.	2
4.	Problems on energy balance.	2
5.	Financial management.	2
6.	Energy audit and conservation opportunities in thermal utilities.	2
7.	Energy audit and conservation opportunities in electrical utilities.	2
8.	Case studies on energy audit and conservation.	2
	Total	**16**

X. Suggested Reading

- *Energy Management*, *Bi-monthly Journal* National Productivity Council, New Delhi.
- Guide Books for *National Certification Examination for Energy Managers and Energy Auditors,* Book 1–4, 2005 Bureau Energy Efficiency, New Delhi.
- Murgai MP and Chandra R. 1990. *Progress in Energy Auditing and Conservation, Boiler Operations*. Wiley Eastern Ltd, New Delhi.
- Murphy WR and McKay G. 1982. *Energy Management*. Butterworth & Co., Publishers Ltd., London.
- Porter R and Roberts T. 1985. *Energy Saving by Waste recycling*. Elsevier applied science publishers, New York, USA.
- Smith CB. 1981. *Energy Management Principles, Applications, Benefits and Savings*. Pergamon Press Inc., Oxford, England.
- Victor B. 1983. *Ottaviano, Energy Management*. An OTIS Publication, Ottaviano Technical Service Inc., Melville, New York.

I. Course Title : Wind Energy Conversion and Utilization

II. Course Code : REE 505

III. Credit Hours : 2+1

IV. Aim of the course

To acquire the in-depth knowledge of wind energy conversion systems, wind potential mapping, estimation and analysis of wind data.

V. Theory

Unit I

Wind mapping and assessment: Wind energy potential, nature of wind, Weibull and Rayleigh analysis, instruments, history and taxonomy of wind mills, wind power laws.

Unit II

Wind turbine aerodynamics: Momentum theories, basic aerodynamics, airfoils and their characteristics. Horizontal Axis Wind Turbine (HAWT): Blade element theory, wake analysis. Vertical Axis Wind Turbine (VAWT): Aerodynamics, rotor design, power regulation, yaw system.

Unit III

Selection of site.Mechanical and electrical applications. Wind farms: Interfacing, maintenance. Management of power generated by wind mill: Instruments and controls. Stand alone and grid connected systems. Wind energy storage. Wheeling and banking. Cost economics. Testing and certification procedures.

Unit IV

Wind turbine loads: Aerodynamic loads in steady operation, wind turbulence, static. Wind energy control system (WECS). Synchronous and asynchronous generators. Annual Energy Output (AEO). Testing of WECS.

VI. Practical

Visit to meteorological observatory. Wind velocity mapping and curve analysis. Wind energy instruments and resource assessment. Design of wind mills, water pumping wind mills.Performance evaluation of wind aero-generator. Wind turbine loads. Economics of wind energy systems.

VII. Learning outcome

The students will acquire knowledge regarding mechanism of wind energy and different types of wind machines available to harness wind power and also able to design wind turbine for irrigation as well as for power generation.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Mapping of Wind energy and its assessment, nature of wind, Wind energy potential	2
2.	Weibull and Rayleigh analysis	2
3.	Instruments, history and taxonomy of wind mills, wind power laws	2
4.	Aerodynamics of Wind turbine, Momentum theories, airfoils and their characteristics	3
5.	Elemental theory of Horizontal and Vertical Axis Wind Turbine (HAWT)	2
6.	Aerodynamics of wind turbines, rotor design, power regulation, yaw system	2
7.	Selection of site for wind mill installation, Mechanical and electrical applications of wind mills	2
8.	Wind farms: Interfacing and maintenance, Instruments and controls for management of power generated by wind mill	3
9.	Stand alone and grid connected systems, Wind energy storage, Wheeling and banking.	2
10.	Economics of wind mills	2
11.	Testing and certification procedures for wind mills	3
12.	Wind turbine Aerodynamic loads in steady operation, wind turbulence, static.	2
13.	Wind energy control system (WECS), Synchronous and asynchronous generators	2
14.	Annual Energy Output (AEO), Testing of Wind energy control system	3
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Visit to meteorological observatory	1
2.	Wind velocity mapping and curve analysis	2
3.	Wind energy instruments and resource assessment	1
4.	Design of wind mills	1

S.No.	Topic	No. of Practicals
5.	Water pumping wind mills	1
6.	Performance evaluation of wind aero-generator	2
7.	Study of Wind turbine loads	2
8.	Economics of wind energy systems.	2
	Total	**12**

X. Suggested Reading

- Cheremision NP. 1978. *Fundamental of Wind Energy*: Ann Arbor Science, Pub. Inc., Michigan.
- Eldridge FR. 1980. *Wind Machines*. Van Nostr and Reinhold Co., New York.
- More HG and Maheshwari RC. *Wind Energy Utilization in India,* Technical Bulletin No. CIAE/82/38, CIAE, Bhopal.
- Lipman NH, Muggrove PJ and Pontin GW. 1982. *Wind Energy for the Eighties*. Peter Peregrinus Ltd. Stenvenage, New York.
- Lysen EH. 1983. *Introduction to Wind Energy*. Consultancy Services Wind Energy Developing Countries, Netherlands.
- Manwell JF, McGswan JG and Rogers AL. 2012. *Wind Energy Explained–Theory Design and Application*. John Wiley and Sons, New Jersey.
- Powar AG and Mohod AG. 2010. *Wind Energy Technologies*. Jain Publication, New Delhi.

I. Course Title : Solar Photovoltaic System Design and Analysis

II. Course Code : REE 506

III. Credit Hours : 1+1

IV. Aim of the course

To provide detail knowledge about working and design of various solar photovoltaic systems for power generation.

V. Theory

Unit I

Physics of solar cells: Crystal structure, band theory, semiconductor, p-n junctions, absorption of radiation, generation, recombination and carrier separation. Standard solar cell structure: I,V characteristics, conversion efficiency, losses in solar cell, impact of radiation and temperature.

Unit II

Solar PV module technologies, First generation: Silicon wafer based technology, Second generation: Thin film technologies, Third generation/emerging PV technologies: Organic PV, Dye sensitized PV, Quantum-dot, Hot-carrier, up conversion and down conversion. Latest benchmark efficiencies: Laboratory and manufacturing. Fabrication technologies.

Unit III

Solar PV systems: Balance of System (BoS), SPV system design guideline and methodologies, introduction to PVSyst, designing of standalone/grid connected PV systems for domestic/commercial use. Rooftop business models: CAPEX and RESCO, canal top, floating PV system design.

Unit IV

Materials and devices for energy storage: Batteries, Carbon Nano-Tubes (CNT), fabrication of CNTs, CNT-polymer composites, ultra-capacitors etc.

VI. Practical

Solar cell efficiency testing.SPV fabrication technologies.System integration and BoS matching studies.PV software's operation and utilization.Design and estimation of SPV systems components for agrobased industrial applications.Batteries performance testing.

VII. Learning outcome

Student is able to design different solar photovoltaic system for power generation with system integration and economic analysis.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Physics of solar cells: Crystal structure, band theory, semiconductor, p-n junctions	1
2.	Absorption of radiation, generation, recombination and carrier separation.	2
3.	Standard solar cell structure: I,V characteristics, conversion efficiency, losses in solar cell, impact of radiation and temperature.	2
4.	Solar PV module technologies, First generation: Silicon wafer based technology, Second generation: Thin film technologies.	1
5.	Third generation/emerging PV technologies: Organic PV, Dye sensitized PV, Quantum-dot, Hot-carrier, up conversion and down conversion.	1
6.	Latest benchmark efficiencies: Laboratory and manufacturing. Fabrication technologies.	2
7.	Solar PV systems: Balance of System (BoS), SPV system design guideline and methodologies,	1
8.	Introduction to PVSyst, designing of standalone/grid connected PV systems for domestic/commercial use.	2
9.	Rooftop business models: CAPEX and RESCO, canal top, floating PV system design.	2
10.	Materials and devices for energy storage: Batteries, Carbon Nano-Tubes (CNT), Fabrication of CNTs, CNT-polymer composites, ultra-capacitors etc.	2
	Total	**16**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	To demonstrate the I-V and P-V characteristics of PV module with varying radiation and temperature level and efficiency determination.	1
2.	To demonstrate the I-V and P-V characteristics of series combination of PV modules and efficiency determination.	1
3.	To demonstrate the I-V and P-V characteristics of parallel combination of PV modules and efficiency determination.	1
4.	To show the effect of variation in tilt angle on PV module power.	1
5.	To demonstrate the effect of shading on module output power and efficiency determination.	1
6.	Study on SPV fabrication technologies.	1
7.	Study on system integration and BoS matching.	1

S.No.	Topic	No. of Practicals
8.	PV software's operation and utilization.	1
9.	Design and estimation of SPV systems components for agrobased industrial applications.	1
10.	Battery performance testing.	1
	Total	**10**

X. Suggested Reading

- Garg HP. 1990. *Advances in Solar Energy Technology*. D. Publishing Company, Tokyo.
- Duffle JA and Beckman WA. 1991. *Solar Engineering of Thermal Processes*. John Wiley, New Jersey.
- Green MA. 1981. *Solar Cells Operating Principles, Technology, and System Applications*. Prentice Hall, Upper Saddle River, New Jersey.
- Kreith F and Kreider JF. 1978. *Principles of Solar Engineering*. McGraw-Hill, New York.
- Luque A and Hegedus S. 2011. *Handbook of Photovoltaic Science and Engineering Education*. John Wiley & Sons, New Jersey.
- Solanki CS. 2011. *Solar Photovoltaic: Fundamentals, Technologies and Applications*. PHI Learning Private Ltd, Delhi.
- Sze SM and Kwok K Ng. 2007. *Physics of Semiconductor Devices*. 3rd Edn. John Wiley & Sons, New Jersey.
- Veziroglu TN. 1977. *Alternative Energy Sources*. Vol.5. McGraw-Hill, New York.

I. Course Title : Renewable Energy Policy, Planning and Economics

II. Course Code : REE 507

III. Credit Hours : 3+0

IV. Aim of the course

To provide the in-depth knowledge about the current energy policy and planning, environmental economics, policy and ecology.

V. Theory

Unit I

Introduction to policy parameters, regulatory bodies.Introduction to overall policy environment on energy sector, policy formulation parameters. Entities: Consumers and their tariffs, generator, DISCOM, Regulators: CERC and SERC, Statutory bodies. Typical issues of Indian power sector.

Unit II

Indian energy Policy: Introduction, Electricity Act, National Policy on Tariff, Climate Change, RE, Solar Missions, Wind Power and Regulatory Commissions. Concept of Grid Code, Green Corridor, Solar and Hybrid Parks. Electricity Trading: Open Access, RPO Distributed Generation Regional Grid Region. International Energy Policies and Treaties.

Unit III

Policy and planning: Energy, environment interaction, clean development mechanism, financing of energy systems, software for energy planning, socio-economical approach. Project management in energy: Cost economics-sensitivity and risk analysis.

Unit IV

Energy economics: economic evaluation of renewable energy systems, life cycle costing, components of energy investment and risk and uncertainties in energy investment.

VI. Learning outcome

A student is be able to develop an interdisciplinary knowledge base that will enable them to understand and solve contemporary energy policy, planning and environmental problems.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction to policy parameters and regulatory bodies in Energy	2
2.	Introduction to overall policy environment on energy sector, policy formulation parameters	3
3.	Entities: Consumers and their tariffs	2
4.	Generator, DISCOM, Regulators: CERC and SERC, Statutory bodies.	3
5.	Typical issues of Indian power sector.	2
6.	Introduction to Indian energy Policy and Electricity Act	3
7.	National Policy on Tariff	2
8.	Climate Change, RE, Solar Missions, Wind Power and Regulatory Commissions	3
9.	Concept of Grid Code, Green Corridor, Solar and Hybrid Parks.	3
10.	Clean development mechanism, financing of energy systems	3
11.	Policy and planning in Energy, environment interaction	2
12.	Electricity Trading: Open Access, RPO Distributed Generation Regional Grid Region. International Energy Policies and Treaties.	4
13.	Software for energy planning, socio-economical approach.	3
14.	Project management in energy: Cost economics-sensitivity and risk analysis.	4
15.	Energy economics: economic evaluation of renewable energy systems	3
16.	Life cycle costing, components of energy investment	3
17.	Risk and uncertainties in energy investment	3
	Total	**48**

VIII. Suggested Reading

- BEE Reference book: no.1/2/3/4.
- Bhattacharyya SC. 2011. *Energy Economics*. Springer, New York City, USA.
- Brown CE. 2002. *World Energy Resources*. Springer, New York City, USA.
- Conti J. 2016. *International Energy Outlook*. US Energy Information Administration (*EIA*), Washington.
- Culp AW. 1991. *Principles of Energy Conversion*. McGraw-Hill Int. edition, New York.
- Krithika PR and Mahajan S. 2014. *Governance of Renewable Energy in India: Issues and Challenges*. TERI, New Delhi.
- Parikh JK. 1981. *Modeling Approach to Long Term Demand and Energy Policy Implication for India*. IIASA, Laxenburg, Austria.
- Reddy AKN, Williams RH, Goldenberg J and Johansson TB. 1987. *Energy for a Sustainable World*. Wiley-Eastern Ltd, New Delhi, India.
- TEDDY Year Book Published by Tata Energy Research Institute (TERI).

I. Course Title : Alternate Fuels and Applications

II. Course Code : REE 508

III. Credit Hours : 2+1

IV. Aim of the course

To get acquainted with various alternate fuels, their applications and also to learn safety factors of alternate fuel, efficiency, economics and commercial considerations.

V. Theory

Unit I

Introduction to alternate fuels: Methanol, ethanol, biogas, producer gas, hydrogen and fuel cell. Production composition and properties, combustion characteristics, comparison with conventional fuels, potential, possibilities and problems.

Unit II

Fuel cell: Principle, classification, system efficiency. Life cycle assessment of fuel cell systems.

Unit III

Hydrogen fuel: Production, gas cleanup, challenges and opportunities. Hydrogen storage and energy economy.

Unit IV

Utilization: Thermal and mechanical applications. Environmental impact and safety factors of alternate fuel, efficiency, economics and commercial considerations.

VI. Practical

Performance of I.C. engines on alternate fuels, measurement of flue gas parameters, thermal applications of alternate fuels. Hydrogen production. Biomass based fuel cell. Integrated biomass based gasifier for power generation.

VII. Learning outcome

Students will understand various properties of alternate fuels like methanol, ethanol, fuel cells, hydrogen fuel for energy efficient utilization.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction to alternate fuels: methanol, ethanol, biogas, producer gas, and hydrogen fuel cell.	3
2.	Alternate fuels: potential, possibilities and problems.	2
3.	Production, composition and properties of methanol.	2
4.	Production, composition and properties of ethanol.	2
5.	Production, composition and properties of biogas.	2
6.	Production, composition and properties of producer gas.	2
7.	Production and properties of hydrogen fuel cell.	2
8.	Combustion characteristics of alternate fuels, comparison of with conventional fuels.	3
9.	Fuel cell: Principle, classification, system efficiency.	2
10.	Life cycle assessment of fuel cell systems.	2
11.	Hydrogen fuel: gas cleanup.	2
12.	Hydrogen fuel: challenges and opportunities	2

S.No.	Topic	No. of Lectures
13.	Hydrogen storage and energy economy.	1
14.	Thermal and mechanical applications alternate fuel.	2
15.	Environmental impact and safety factors of alternate fuels, efficiency, economics and commercial considerations.	3
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Performance of I.C. engines on alternate fuels (biogas, producer gas and bio diesel)	3
2.	Measurement of flue gas parameters.	1
3.	Thermal applications of alternate fuels (biogas, producer gas and bio diesel)	3
4.	Hydrogen production.	1
5.	Biomass based fuel cell.	1
6.	Integrated biomass-based gasifier for power generation.	1
	Total	**10**

X. Suggested Reading

- Babu MKG and Subramanian KA. 2013. *Alternative Transportation Fuels: Utilization in Combustion Engines*. CRC Press, Florida.
- Bungay HR. 1981. *Energy, the Biomass Options*. John Willey & Sons, New York.
- Dahiya A. 2014. *Bioenergy: Biomass to Biofuels. Engines*. Springer, New York City, New York.
- Demirbas A. 2010. *Biodiesel: A Realistic Fuel Alternative for Diesel Chemicals*. Academic Press, Cambridge, England.
- Klass DL. 1998. *Biomass for Renewable Energy, Fuels, and Chemicals*. Academic Press, Cambridge, England.
- Mukunda HS. 2011. *Understanding Clean Energy and Fuels from Biomass*. Wiley India.
- San PA. 1980. *Biochemical and Photosynthetic: Aspects of Energy Production*. Academic Press. London.
- Speight JG and Loyalka SK. 2007. *Handbook of Alternative Fuel Technologies*. CRC Press. Florida.
- Twidell JW and Weir AD. 1986. *Renewable Energy Sources*. E & FN Spon Ltd, New York.

I. Course Title : Biogas Technology and Mechanism

II. Course Code : REE 509

III. Credit Hours : 1+1

IV. Aim of the course

To provide the in-depth knowledge about biogas technology and its mechanism in detail to use the biogas as domestic as well as commercial fuel.

V. Theory

Unit I

Biogas Technology: Potential and status, chemistry, physical conditions and utilization of alternate feedstock materials.

Unit II

Types of reactors: Single phase, two phase processes. High rate biomethanation process, selection of model and size, construction technique, material requirement. Design concept of night soil, kitchen waste, solid state cold condition biogas plants.

Unit III

Biogas distribution and utilization: Properties and uses of biogas, design of gas distribution system. Biogas utilization devices: Biogas scrubbing and compressing, dual fuel engines and its limitations, generation of power. Testing of biogas appliances.

Unit IV

Effluent: Handling of effluent biogas plant, effluent treatment and management, BDS applications and enrichment. Cost and financial viability of biogas plants.Repair and maintenance of biogas plants.

VI. Practical

Design of biogas plant for solid and liquid wastes, cost estimation, analysis of biogas, purification of biogas.Performance evaluation of biogas appliances.Testing of biogas burner for heat transfer, thermal and cooking efficiency. Bio digested slurry analysis, use of biogas spent slurry. Carbon credits.

VII. Learning outcome

Students are able to design, select, estimate and analyzed the biogas technology, chemical and physical conditions and get acquainted with various biogas appliances.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Biogas Technology potential and status	1
2.	Chemistry, physical conditions and utilization of alternate feedstock materials	1
3.	Types of reactors: Single phase, two phase processes.	1
4.	High rate bio-methanation process, selection of model and size, construction technique, material requirement	2
5.	Design concept of night soil, kitchen waste, solid state cold condition biogas plants	1
6.	Properties and uses of biogas, design of gas distribution system	1
7.	Biogas scrubbing and compressing, dual fuel engines and its limitations, generation of power	2
8.	Testing of biogas appliances	2
9.	Handling of biogas plant effluents, effluent treatment and management	1
10.	Bio digested Slurry applications and enrichment	2
11.	Cost and financial viability of biogas plants	1
12.	Repair and maintenance of biogas plants	1
	Total	**16**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Design of biogas plant for solid and liquid wastes	1
2.	Cost estimation of different biogas plants: KVIC, Janta, Deenbandhu, type	2

S.No.	Topic	No. of Lectures
3.	Analysis of biogas	1
4.	Experiment on purification of biogas	1
5.	Performance evaluation of biogas appliances	1
6.	Testing of biogas burner for heat transfer, thermal and cooking efficiency	2
7.	Analysis of Bio-digested slurry	2
8.	Study on use of biogas spent slurry	1
9.	Study and analysis of Carbon credits.	1
	Total	**12**

IX. Suggested Reading

- Abbasi SA and Nipaney PC. 1993. *Modeling and Simulation of Biogas System Economies*. Ashish Pub. House, New Delhi.
- Chawala OP. 1986. *Advances in Biogas Technology*. ICAR, New Delhi.
- Khandelwal KC and Mahdi SS. 1986. *Biogas Technology*. A Practical Hand Book, Vol.I, Tata McGraw-Hill Pub. Co. Ltd, New Delhi.
- Mittal KM. 1996. *Biogas Systems: Principles and Applications*. New Age international (P) Ltd, New Delhi.
- Rohlich GA, Walbot V, Connar LJ, Golueke CG, Hinesly TD, Jones PH, Lapp HM, Loehr RC, LueiHing C, Pfeffer JT, Prakasam TBS and Brown NL. 1977. *Methane Generation from Human Animals and Agril Wastes*. National Academy of Sciences, Washington.
- Tasneem A, Tauseef SM and Abbasi SA. 2012. *Biogas Energy*. Springer Publications, Springer Science and Business Media, New York, USA.
- Van BA. 1981. *Chinese Biogas Manual*. Intermediate Technology Publications, London.

I. Course Title : Energy, Ecology and Environment

II. Course Code : REE 510

III. Credit Hours : 3+0

IV. Aim of the course

To provide detail knowledge of carbon cycle, ecosystem, climate change and global environmental change and inter linkages of renewable energy sources.

V. Theory

Unit I

Global carbon cycle.Carbon reservoirs flow and human interventions. Global warming and climate change. Energy efficient technology: Efficiency hierarchy, energy dependent activities, energy policies, linkage between energy use and economic growth and environment.

Unit II

Ecosystem: Kinds, transfection, components of ecosystem, ecosystem development of evaluation, major ecosystem of the world, physical environment and metrology.

Unit III

Climate change: Impact and models. Energy for sustainable development: Development indices, pillars, subsystems, principles and dimensions. Low carbon technologies: Energy efficiency projects, carbon trading.

Unit IV

Environment, Environmental degradation: Thermal and chemical pollution, primary and secondary pollutant, air pollution, water pollution, unclear energy hazard, radioactive hazards, mining hazards, land use, oil spills and gas leaks.

Unit V

Global environmental changes: United Nations Framework Convention on Climate Change (UNFCC), Kyoto protocol and clean development mechanism: Overview, administration, participation, institutions, procedures, project design and formulation.

VI. Learning outcome

Students will able to understand the relationship between carbon cycle, energy policies, energy use and economic growth and factors affecting environment.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Global carbon cycle.	1
2.	Carbon reservoirs flow and human interventions.	2
3.	Global warming and climate change.	2
	Energy efficient technology: Efficiency hierarchy, energy dependent activities, energy policies, linkage between energy use and economic growth and environment.	4
4.	Ecosystem: Kinds, transfection, components of ecosystem,	3
5.	Ecosystem development of evaluation, major ecosystem of the world, physical environment and metrology.	3
6.	Climate change: Impact and models.	3
	Energy for sustainable development: Development indices, pillars, subsystems, principles and dimensions.	2
7.	Low carbon technologies: Energy efficiency projects, carbon trading.	3
8.	Environment, Environmental degradation	1
9.	Thermal and chemical pollution, primary and secondary pollutant, air pollution,	3
10.	Water pollution	1
11.	unclear energy hazard	1
12.	Radioactive hazards, mining hazards, land use, oil spills and gas leaks.	3
13.	Global environmental changes: United Nations Framework Convention on Climate Change (UNFCC)	4
14.	Kyoto protocol and clean development mechanism: Overview, administration, participation, institutions, procedures, project design and formulation.	4
	Total	**40**

VIII. Suggested Reading

- Canter LC. 1979. *Environmental Impact Assessment*. McGraw Hill Pub. Co., New York.
- Coley D. 2008. *Energy and Climate Change*. John Wiley & Sons, Ltd., New Jersey.
- Dessler A. 2011. *Introduction to Modern Climate Change*. Cambridge University Press, Cambridge, England.
- Essam E and Hinnami EI. 1991. *Environmental Impact of Production and Use of Energy*. Tycooly Press Ltd, Dublin.
- Fowler JM. 1984. *Energy and the Environment, Second Edition*. McGraw-Hill, New York.
- Kaushika ND and Kaushik K. 2004. *Energy, Ecology and Environment: A Technological Approach*. Capital Publishing, New Delhi.
- Mathur AN, Rathore NS and Vijay VK. 1995. *Environmental Awareness*, Himanshu Pub., Udaipur.

- Puppy HG. *Energy and Environment, Mankind and Energy Needs*. Elsevier Pub. Co., New York.
- Rathore NS and Kurchania AK. 2001. *Climatic Changes and their Remedial Measures*. Shubhi Publications, Gurgaon.
- Thomdike EH. 1978. *Energy and Environment: A Premier for Scientists and Engineers*. Adson, Wesley Pub. Co., Boston, US.
- Wilson R and Jones WJ. 1974. *Energy, Ecology and the Environment*. Academic Press Inc., Cambridge, Massachusetts, US.

I. Course Title : Design and Analysis of Renewable Energy Conversion Systems

II. Course Code : REE 511

III. Credit Hours : 2+1

IV. Aim of the course

To design and analyze renewable energy conversion systems, thermodynamics involved in it and performance of renewable energy systems.

V. Theory

Unit I

Energy cycle of the earth. Estimation and assessment of renewable energy sources: Water flow and storage, ocean currents and tides, biomass energy, solar energy, wind energy and other renewable energy sources.

Unit II

Thermodynamics of renewable energy conversion: Energy and exergy analysis of renewable energy power systems. Optimum design of hybrid renewable energy systems: Concept, considerations and methodologies.

Unit III

Design of renewable energy systems: Design concept, operational parameters, consideration and rational values for agro industrial applications.

Unit IV

Performance analysis of renewable energy systems: Standards and test codes, optimum performance records, evaluation and maintenance aspects, uses of HOMER (Hybrid Optimization Model for Electric Renewable) software.

VI. Practical

Estimation and assessment of renewable energy sources in India.Thermodynamic principles of energy conversion.Design and operational parameters of renewable energy systems. Study on standards and test codes of renewable energy systems.

VII. Learning outcome

Students will able to design of various energy conversion systems, standards and test codes of renewable energy systems and their performance analysis.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Energy cycle of the earth	1
2.	Estimation and assessment of renewable energy sources: Water flow and storage, ocean currents and tides	2

S.No.	Topic	No. of Lectures
3.	Estimation and assessment of renewable energy sources: biomass energy, solar energy, wind energy	3
4.	Estimation and assessment of renewable energy sources: other renewable energy sources.	2
5.	Thermodynamics of renewable energy conversion: Energy and energy analysis of renewable energy power systems.	4
6.	Optimum design of hybrid renewable energy systems: Concept, considerations and methodologies.	4
7.	Design of renewable energy systems: Design concept, operational parameters,	4
8.	Design of renewable energy systems: Consideration and rational values for agro industrial applications.	4
9.	Performance analysis of renewable energy systems: Standards and test codes, optimum performance records	3
10.	Performance analysis of renewable energy systems: Evaluation and maintenance aspects	3
11.	Uses of HOMER (Hybrid Optimization Model for Electric Renewable) software.	2
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Estimation and assessment of renewable energy sources in India	1
2.	Thermodynamic principles of energy conversion	2
3.	Design and operational parameters of biogas plant	2
4.	Design of a updraft gasifier using solid biomass	2
5.	Design of solar photovoltaic plant for a hostel/building	2
6.	Life cycle assessment and financial assessment of a photovoltaic plant for a hostel/building	1
7.	Study on standards of renewable energy systems	1
8.	Study on test codes of renewable energy systems	2
	Total	**13**

X. Suggested Reading

- Boyle G. 1996. *Renewable Energy: Power for Sustainable Future*. Oxford Univ. Press, England.
- Culp AW. 1991. *Principles of Energy Conservation*. Tata McGraw-Hill, New Delhi.
- Duffle JA and Beckman WA. 1991. *Solar Engineering of Thermal Processes*. John Wiley, Hoboken, North America.
- Garg HP and Prakash J. 1997. *Solar Energy: Fundamental and Application*. Tata McGraw-Hill, New Delhi.
- Grewal NS, Ahluwalia S, Singh S and Singh G. 1997. *Hand Book of Biogas Technology*. TMH New Delhi.
- Lambert T and Lilienthal P 2004. *Homer: The Micro-Power Optimization Model*. National Renewable Energy Lab., Philippines.
- Manwell JF, McGowan JG and Rogers AL. 2003. *Wind Energy Explained*. John Wiley, Hoboken, North America.
- Mittal KM. 1985. *Biomass Systems: Principles and Applications*. New Age International, New Delhi.
- Patel MK. 1999. *Wind and Solar Power Systems*. CRC Press, Florida.

I. Course Title : Energy Generation from Agricultural Waste and Byproducts

II. Course Code : REE 512

III. Credit Hours : 2+1

IV. Aim of the course

To focus on agricultural wastes and by products for its utilization for energy generation.

V. Theory

Unit I

By Products: Generation, estimation and utilization. Agricultural and agro industrial by-products/wastes: Properties, characterization, on site handling, storage and processing. Concept, scope and maintenance of waste management and effluent treatment

Unit II

Waste as fuel: Utilization pattern, pretreatments, secondary treatments, mechanism, construction, efficiency and suitability.

Unit III

Utilization of agro based industrial wastes for paper production, production of particle board, fertilizer through vermi-composting and fuel.

Unit IV

Thermo-chemical and biochemical conversion of agricultural waste and byproducts: Densification, combustion, gasification, extraction, pyrolysis, carbonization, torrefaction, liquefaction, anaerobic digestion and fermentation process.

VI. Practical

Estimation and characterization of agricultural waste and byproducts, production of fuel from agricultural wastes and by products, techno-economic feasibility of waste to fuel systems.

VII. Learning outcome

Student will be able to understand the estimation, characterization, storage and handling of agricultural wastes and by products to generate the energy.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction to Agricultural and agro industrial by-products/wastes:.	1
2.	Generation, estimation and utilization of Agricultural and agro-industrial by-products/wastes	2
3.	Properties, characterization, of Agricultural and agro industrial by-products/wastes	1
4.	On site handling, storage and processing Agricultural and agro industrial by-products/wastes	2
5.	Concept, scope and maintenance of waste management and effluent treatment	2
6.	Introduction to Waste as fuel:.	1
7.	Utilization pattern of waste as Fuel in India and world	1

S.No.	Topic	No. of Lectures
8.	Pretreatments and secondary treatments for waste for conversion to Fuel	2
9.	Mechanism, construction, efficiency and suitability of treatments	2
10.	Utilization of agro based industrial wastes for paper production	2
11.	Production of particle board,	1
12.	Fertilizer through vermi-composting and fuel	1
13.	Introduction to Thermo-chemical of agricultural waste and by-products	1
14.	Introduction to biochemical conversion of agricultural waste and by-products	1
15.	Densification	1
16.	Combustion	1
17.	Gasification	1
18.	Extraction	1
19.	Pyrolysis	1
20.	Carbonization	1
21.	Torrefaction	1
22.	Liquefaction	1
23.	Anaerobic digestion	2
24.	Fermentation process	2
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Estimation of agricultural waste by remote sensing and field Method	2
2.	Characterization of agricultural waste and by products	1
3.	Determination of moisture content of biomass	1
4.	Determination of Volatile solids	1
5.	Determination of Fixed carbon content of biomass	1
6.	Determination of ash content of biomass	1
7.	Estimation of calorific value of biomass	1
8.	Estimation of calorific value of biogas	1
9.	Estimation of calorific value of producer gas	1
10.	Determination of Lignin Cellulose Hemicellose in Biomass	1
11.	Production of fuel from agricultural wastes and by products,	1
12.	Production of Biogas, Producer gas and Biodiesel from Agricultural waste	2
13.	Techno-economic feasibility of waste to fuel systems	2
	Total	**16**

X. Suggested Reading

- Anonymous. 1984. *Manure Production and Characteristics*. ASAE Standards, America.
- Chahal DS. 1991. *Food, Feed and Fuel from Biomass*. Oxford & IBH, New Delhi.
- David C Wilson. 1981. *Waste Management, Planning, Evaluation, Technologies*. Clarendon Press, Oxford, England, UK.
- Klass DL and George EH. 1981. *Fuels from Biomass and Wastes*. Ann. Arbor. Science Publ., New York.
- Luh BS. 1991. *Rice: Production and Utilization*. AVI Publ. Company Inc., Westport, Connecticut.
- Srivastava PK, Maheswari RC and Ohja TP. 1995. *Biomass Briquetting and Utilization*. Jain Bros. Publications, New Delhi.

I. Course Title : Agro Energy Audit and Management

II. Course Code : REE 513

III. Credit Hours : 2+1

IV. Aim of the course

To emphasize the energy audit and its management in agriculture production system and agro based industries.

V. Theory

Unit I

Energy resources on the farm: Conventional and non-conventional forms of energy and their use. Heat equivalents and energy coefficients for different agricultural inputs and products.Pattern of energy consumption and their constraints in production of agriculture.

Unit II

Direct and indirect energy, energy audit of production agriculture, rural living and scope of conservation.

Unit III

Energy requirement in different agro-based industries: Energy analysis, energy ratio and specific energy value. Identification of energy efficient machinery systems: energy losses and their management.

Unit IV

Energy analysis techniques and methods: Energy balance, output and input ratio, resource utilization, conservation of energy sources. Energy conservation planning and practices.

VI. Practical

Study of energy audit techniques, energy use pattern and management strategies in various agro-industries, assessment of overall energy consumption, production and its cost in selected agro- industries. Estimation of energy requirement in different agriculture production system, study of energy input/output ratio of different agriculture production system.

VII. Learning outcome

Students will learn detail energy audit, energy balance techniques, energy management strategies, energy conservation planning and practices in agriculture production system.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Energy resources on the farm.	2
2.	Conventional and non-conventional forms of energy and their use.	2
3.	Heat equivalents and energy coefficients for different agricultural inputs and products.	3
4.	Pattern of energy consumption and their constraints in production of agriculture.	3
5.	Direct and indirect energy	2
6.	Energy audit of production agriculture, rural living and scope of conservation.	3

S.No.	Topic	No. of Lectures
7.	Energy requirement in different agro-based industries.	2
8.	Energy analysis, energy ratio and specific energy value.	2
9.	Identification of energy efficient machinery systems.	2
10.	Energy losses and their management.	2
11.	Energy analysis techniques and methods.	2
12.	Energy conservation planning and practices.	2
13.	Energy balance, output and input ratio, resource utilization.	3
14.	Conservation of energy sources.	2
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Study of energy audit techniques.	2
2.	Energy use pattern and management strategies in various agro-industries.	2
3.	Assessment of overall energy consumption, production and its cost in selected agro-industries.	2
4.	Estimation of energy requirement in different agriculture production system.	2
5.	Study of energy input/output ratio of different agriculture production system.	2
	Total	**10**

X. Suggested Reading

- Fluck RC and Baird CD. 1984. *Agricultural Energetics*. AVI Publ. Company, Inc., Westport, Connecticut.
- Kennedy WJ Jr and Turner WC. 1984. *Energy Management*. Prentice Hall, Upper Saddle River, New Jersey.
- Pimental D. 1980. *Handbook of Energy Utilization in Agriculture*. CRC Press, Florida.
- Rai GD. 1998. *Nonconventional Sources of Energy*. Khanna Publ., New Delhi.
- Singh CP. 1978. *Energy Requirement of Important Farm Operations for Existing Cropping System in Punjab*. PAU, Ludhiana.
- Twindal JW and Wier AD. 1986. *Renewable Energy Sources*. E & F.N. Spon Ltd, New York.
- Verma SR, Mittal JP and Singh S. 1994. *Energy Management and Conservation in Agricultural Production and Food Processing*.USG Publ. & Distr, Ludhiana.

I. Course Title : Green house Energetic and Passive Architecture

II. Course Code : REE 514

III. Credit Hours : 1+1

IV. Aim of the course

To provide the in-depth knowledge about greenhouse design, energetics, production technique, passive heating concept and evaporative cooling etc.

V. Theory

Unit I

Green House: Environmental requirement, analysis of thermal energy flows, analysis of a greenhouse as solar collector. Instrumentation and control in green house.

Unit II

Passive concepts and components: Passive heating concepts, direct gain, indirect grain, isolated gains and sunspace passive cooling concepts,

Unit III

Evaporative cooling: Evaporative air and water coolers, application of wind, water and earth for cooling, use of isolation, shading, paint sand cavity walls for cooling.

Unit IV

Passive heating and cooling: Concepts, roof pond/sky therm, roof radiation trap, vary thermo wall, earth sheltered or earth based structures and earth air tunnels, ventilation, components, windows and thermal storage.

VI. Practical

Design of passive structures for animals, rural housing, study of evaporative cooling, air and light flows in house, survey of green houses, green house energetic.

VII. Learning outcome

Students get knowledge of thermal energy flows, analysis of green house, instrumentation and control in green house.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Green House: Environmental requirement, analysis of thermal energy flows, analysis of a greenhouse as solar collector.	3
2.	Instrumentation and control in green house.	2
3.	Passive concepts and components	1
4.	Passive heating concepts	1
5.	Direct gain, indirect grain, isolated gains and sunspace passive cooling concepts	3
6.	Evaporative cooling: Evaporative air and water coolers, application of wind, water and earth for cooling	2
7.	Use of isolation, shading, paint sand cavity walls for cooling.	1
8.	Passive heating and cooling	1
9.	Concepts, roof pond/sky theorem, roof radiation trap, vary thermo wall, earth sheltered or earth based structures and earth air tunnels, ventilation, components, windows and thermal storage.	2
	Total	**16**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Design of passive structures for animals.	2
2.	Design of passive structures for rural housing	2
3.	Study of evaporative cooling	1
4.	Study of air and light flows in house	1
5.	Survey of green houses	8
6.	Green house energetic	2
	Total	**16**

X. Suggested Reading

- Parkar BE. 1991. *Solar Energy in Agriculture*. Elsevier, Amsterdam.
- Pattern AR. 1975. *Solar Energy for Heating and Cooling of Building*. Noyal Date Corporation (NDC), Park Ridge, New Jersey, USA.
- Paul JK. 1975. *Passive Solar Energy Design and Materials*. Noyel Data Corporation, Park Ridge, New Jersey, USA.
- Radhamanohar K and Igathinathane C. 2000. *Green House Technology and Management*. B.S. Publication. 4309 Sultan Basar, Hyderabad.
- Sodha MS, Bansal NK, Kumar PKA and Malik MAS. 1986. *Solar Passive: Building Science and Design*. Pergamon Press, New York.

I. Course Title : Energy Management in Food Processing Industries

II. Course Code : REE 515

III. Credit Hours : 1+1

IV. Aim of the course

To acquaint and equip the students with different energy management techniques including energy auditing of food industries.

V. Theory

Unit I

Energy forms and units, energy perspective, norms and scenario, energy auditing, data collection and analysis for energy conservation in food processing industries.

Unit II

Sources of energy, its audit and management in various operational units of the agro-processing units, passive heating, passive cooling, sun drying and use of solar energy, biomass energy and other non-conventional energy sources in agro-processing industries.

Unit III

Reuse and calculation of used steam, hot water, chimney gases and cascading of energy sources. Energy accounting methods, measurement of energy, design of computer-based energy management systems, economics of energy use.

VI. Practical

Study of energy use pattern in various processing units i.e., rice mills, sugar mills, dal mills, oil mills, cotton-ginning units, milk plants, food industries etc. Energy audit study and management strategies in food processing plants.Identification of energy efficient processing machines.Assessment of overall energy consumption, production and its cost in food processing plants, visit to related food processing industry.

VII. Learning outcome

Student's capability to understand energy sources, analyze energy requirement in food processing operations and to economize it in food industries.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Energy forms and units, energy perspective, norms and scenario	2
2.	Energy auditing: definition, types of energy audit, planning	2
3.	Data collection and analysis for energy conservation in food processing industries.	2
4.	Sources of energy, its audit and management in various operational units of the agro-processing units	2
5.	Passive heating, passive cooling, sun drying and use of solar energy in agro-processing industries.	1
6.	Use of biomass energy and other non-conventional energy sources in agro-processing industries.	2
7.	Reuse and calculation of used steam, hot water, chimney gases and cascading of energy sources.	2
8.	Energy accounting methods, measurement of energy	1
9.	Design of computer-based energy management systems, economics of energy use.	2
	Total	**16**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Study of energy use pattern in rice mill	1
2.	Study of energy use pattern in sugar mill	1
3.	Study of energy use pattern in dal mill	1
4.	Study of energy use pattern in oil mill	1
5.	Study of energy use pattern in cotton-ginning unit	1
6.	Study of energy use pattern in milk plant	1
7.	Energy management strategies in rice mill	1
8.	Energy management strategies in sugar mill	1
9.	Energy management strategies in oil mill	1
10.	Energy management strategies in milk plant	1
11.	Identification of energy efficient processing machines	2
12.	Assessment of overall energy consumption, production and its cost in food processing plants	2
13.	Visit to related food processing industry	1
	Total	**15**

X. Suggested Reading

- Pimental D. 1980. *Handbook of Energy Utilization in Agriculture*. CRC Press.
- Rai GD. 1998. *Non-conventional Sources of Energy*. Khanna Publisher.
- Twindal JW and Wier AD. 1986. *Renewable Energy Sources*. E & F. N. Spon Ltd.
- Verma SR, Mittal JP and Singh S. 1994. *Energy Management and Conservation in Agricultural Production and Food Processing*. USG Publisher and Distributors, Ludhiana.

Course Title with Credit Load
Ph.D. in Renewable Energy Engineering

Major Courses (Requirement: 12 Credits)

Course Code	Course Title	Credit Hours
*REE 601	Biochemical Conversion of Biomass	2+1
*REE 602	Thermo-Chemical Conversion of Biomass	2+1
*REE 603	Advances in Renewable Energy Systems	2+1
REE 604	New Alternate Energy Systems	2+1
*REE 605	Fuels and Combustion	2+1
REE 606	Advances in Biogas Technology	2+1
REE 607	Solid Waste and Waste Water Management	2+1
REE 608	Advanced Photovoltaic Power Generation	1+1
REE 609	Energy Planning, Management and Economics	3+0
REE 610	Renewable Energy for Industrial Application	2+1
REE 611	Biofuel Technologies and Applications	1+1
REE 612	Energy Modelling and Simulation	1+1
	Total	**22+11**

*****Course has been made compulsory by UGC for PhD students. Course code and its detailed course outline to be adopted in toto as recommended by UGC.

Minor Courses (Requirement: 06 Credits)

Course Code	Course Title	Credit Hours
FMPE 612	Farm Machinery Management and System Engineering	2+1
ME 501	Mechatronics and Robotics in Agriculture	2+0
PFE 614	Agri- Project Planning and Management	1+1
	Any other course(s) of other department other than course(s) from major can be taken as per recommendations of the student's advisory committee.	

Supporting Courses (Requirement: 05 Credits)

Course Code	Course Title	Credit Hours
*CPE-RPE	Research and Publication Ethics	1+1
	Courses from subject matter fields (other than Major and Minor) relating to area of special interest and research problem can be taken as per recommendations of the student's advisory committee.	

***Course has been made compulsory by UGC for PhD students. Course code and its detailed course outline to be adopted in toto as recommended by UGC.**

List of other Essential Requirements

Course Code	Course Title	Credit Hours
IDE 691	Doctoral Seminar-I	0+1
IDE 692	Doctoral Seminar-II	0+1
IDE 699	Doctoral Research	0+75

Course Contents
Ph.D. in Renewable Energy Engineering

I. Course Title : Biochemical Conversion of Biomass

II. Course Code : REE 601

III. Credit Hours : 2+1

IV. Aim of the course

To impart the advanced knowledge about biochemical conversion technologies of biomass, engineering design and kinetic of bio-energy systems.

V. Theory

Unit I

Biomass formation: Energy recovery and recycling. Biochemical conversion of organic wastes: Methane production, vertical through digesters, high solid digestion, sludge treatment.

Unit II

Lagoons: Composting, contact and filter digestion, reactors, physical and chemical removal of dissolved materials. Activated sludge and other suspended culture process parameters. Waste waters, biological film flow processes, sanitation land fill, pre-digestion of waste.

Unit III

Engineering design of biogas units: Biogas boosters, structural behaviour, alternate construction materials, multi-criteria optimization, immobilization, modular biogas for tropical areas, kinetic models.

Unit IV

Bioconversion of biomass to alcohol: Types and pre-treatment of biomass, production process. Fermenter design and process parameters.Economics of bio-alcohol production, reaction kinetics, gasohol.Bio-hydrogen from algae/biomass.

VI. Practical

Lagoons and compositing. Biogas plant: Analysis of biogas system. Determination of methane production rate and parameters, biogas storage, purification, utilization and kinetic equations.Alcohol production, optimization of process parameters, fermenter designing and evaluation.Economic calculations of biogas and alcohol.

VII. Learning outcome

The student will able to design, analyze and evaluate the various biomass conversion technologies and parameters related to biomass for utilization of it for fuel extraction.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Biomass formation.	1
2.	Energy recovery and recycling.	1

S.No.	Topic	No. of Lectures
3.	Biochemical conversion of organic wastes.	1
4.	Methane production, vertical through digesters, high solid digestion.	2
5.	Sludge treatment.	1
6.	Lagoons: Composting, contact and filter digestion, reactors.	2
7.	Physical and chemical removal of dissolved materials.	2
8.	Activated sludge and other suspended culture process parameters.	2
9.	Waste waters	1
10.	Biological film flow processes, sanitation land fill, pre-digestion of waste.	2
11.	Engineering design of biogas units	2
12.	Biogas boosters, structural behaviour.	1
13.	Alternate construction materials.	1
14.	Multi-criteria optimization, immobilization.	2
15.	Modular biogas for tropical areas. Kinetic models	2
16.	Bioconversion of biomass to alcohol	1
17.	Types and pre-treatment of biomass production process.	2
18.	Fermenter design and process parameters.	2
19.	Economics of bio-alcohol production.	1
20.	Reaction kinetics, Gasohol.	1
21.	Bio-hydrogen from algae/biomass.	2
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Lagoons and compositing.	1
2.	Analysis of biogas systems.	2
3.	Determination of methane production rate and parameters.	1
4.	Biogas storage, purification.	1
5.	Biogas storage utilization and kinetic equations.	1
6.	Alcohol production, optimization of process parameters.	1
7.	Fermenter designing and evaluation.	1
8.	Economic calculations of biogas and alcohol.	2
	Total	**10**

X. Suggested Reading

- Culp AW. 1979. *Principles of Energy Conversion*. McGraw Hill Book Company, New York, USA.
- Kiang YH. 1981. *Waste Energy Utilization Technology*. Marcel Dekkar, New York, USA.
- Klan E. 1985. *Energy from Biomass and Wastes*. Institute of Gas Technology, Chicago.
- Wilson DG and Reinhold VN. 1977. *Hand Book of Solid Waste Management*. McGraw Hill Book Company, New York, USA.

I. Course Title : Thermo-Chemical Conversion of Biomass

II. Course Code : REE 602

III. Credit Hours : 2+1

IV. Aim of the course

To help students to understand in depth knowledge of thermo-chemical conversion of organic waste, combustion chemistry and different heat based conversion technologies for fuel and power generation.

V. Theory

Unit I

Biomass: Characterization, resources and energy recovery. Thermo-chemical conversion of organic wastes.Chemical thermodynamics, stoichiometry and thermodynamics.

Unit -II

Combustion of fuels: Solid fuels, stoker, types, fluidised bed. Liquid fuels: Atomization, vapour concentration, combustion phenomena. Gaseous fuel: Flame characteristics, inflammability limits, submerged combustion, combustion with explosion flame, pulsating combustion.

Unit III

Biomass Gasification: Gasifier configurations, classification, entrained flow, fluidized bed, moving bed, plasma gasification. Coal gasification technologies.Syngas characteristics.Tar and particulates in gasification.Integrated coal gasification.Gas turbine technologies.

Unit IV

Pyrolysis: Models, regimes, kinetics and effect of process parameters. Radiant heat flux, heterogeneous reactions, wall heat transfer.Fluidised bed reactors: Heat transfer circulating beds, moving bed reactor.

Unit V

Torrefaction and charcoal production: Carbonization parameters, temperature zone, input output, energy density ratios and characterization of finished products.

VI. Practical

Combustion thermodynamics and phenomenon in solid, liquid and gaseous fuels.TGA studies. Liquid and gaseous burners, flame studies, flue gas, heat budgeting. Kinetic study on gasifiers. Producer gas based power generation systems. Kinetic and model studies for torrefaction, char coal and bio oil production.

VII. Learning outcome

Students will enable to critical analysis of combustion of fuel and system design for thermos chemical conversion technologies for domestic and industrial applications.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Biomass: Characterization, resources and energy recovery.	2
2.	Thermo-chemical conversion of organic wastes.	1
3.	Chemical thermodynamics and stoichiometry.	3
4.	Combustion of solid fuels: stoker, types, fluidized bed.	2
5.	Combustion of liquid fuels: Atomization, vapour concentration, combustion phenomena.	2
6.	Combustion of gaseous fuel: Flame characteristics, inflammability limits, submerged combustion, combustion with explosion flame, pulsating combustion.	2
7.	Biomass Gasification: Gasifier configurations, classification, entrained flow, fluidized bed, moving bed, plasma gasification.	3
8.	Coal gasification technologies, Integrated coal gasification.	2

S.No.	Topic	No. of Lectures
9.	Syngas characteristics, Tar and particulates in gasification.	2
10.	Gas turbine technologies.	2
11.	Pyrolysis: Models, regimes, kinetics and effect of process parameters.	2
12.	Radiant heat flux, heterogeneous reactions, wall heat transfer.	2
13.	Fluidized bed reactors: Heat transfer circulating beds, moving bed reactor.	2
14.	Torrefaction and charcoal production: Carbonization parameters, temperature zone, input output	2
15.	Energy density ratios and characterization of finished products.	2
	Total	**31**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Combustion thermodynamics and phenomenon in solid, liquid and gaseous fuels	2
2.	Determination of efficiency of improved chulha through water boiling test procedure.	1
3.	Thermo-gravimetric analysis of biomass sample	1
4.	Study of liquid burners	1
5.	Study of gaseous burners	1
6.	Flame studies and flue gases	1
7.	Study on heat budgeting	1
8.	Study on kinetics of fluidized bed gasifier	1
9.	Producer gas based power generation systems	1
10.	Kinetic and model studies for Torrefaction	2
11.	Kinetic and model studies for charcoal production.	2
12.	Kinetic and model studies for bio oil production.	2
	Total	16

X. Suggested Reading

- Culp AW. 1979. *Principles of Energy Conversion*. McGraw Hill Book Company, New York, USA.
- Glassman I. 1987. *Combustion*. Academic Press Inc. Orlando, Florida, USA.
- Klan E. 1985. *Energy from Biomass and Wastes*. Institute of Gas Technology, Chicago.
- Kiang YH. 1981. *Waste Energy Utilization Technology*. Marcel Dekkar, New York, USA.
- Rezaiyan J and Cheeremisinoff NP. 2005. *Gasification Technologies–A Primer for Engineers and Scientists*. CRC Press, Taylor and Francis group, New York, USA.
- Tchobanoglous G and Elliassen HTR. 1978. *Solid Wastes*. McGraw Hill Book Company, New York, USA.
- Wilson DG and Reinhold VN. 1977. *Hand Book of Solid Waste Management*. Van Nostrand Reinhold Company, New York.

I. Course Title : Advances in Renewable Energy Systems

II. Course Code : REE 603

III. Credit Hours : 2+1

IV. Aim of the course

To provide in depth knowledge, understanding and application oriented skills on advanced renewable energy systems and relevant technologies towards their effective utilization for meeting energy demand.

V. Theory

Unit I

Solar thermal energy systems: Kinetics and heat transfer analysis, modelling studies. Design and performance of solar thermal systems, mathematical models, power plants, design and performance.

Unit II

Photovoltaics: Thermodynamic limitations of photocells. Semiconductors: P-n and n-p junctions, module design, sizing, power control and storage, space charge control, low pressure diode, cesium converter. Photo electro chemical cells, photo electrolysis cell.

Unit III

Wind power: Rotor design procedure, betz limit, ideal horizontal axis wind turbine, wake rotation, momentum theory and blade element theory, blade shape for ideal rotor without wake rotation, performance prediction wind turbine rotor dynamics and dynamic models.

Unit IV

Designing of water pumping wind mills: Electric power, power transformers, electrical machines, ancillary electrical equipment, wind power to consumer/grid. Wind turbine: Sitting, installation and operation issues, offshore wind farms, operation in severe climates.

VI. Practical

Design parameters of air collectors. Thermal analysis and heat loss, regularity models of heliostatic fields, power plant design. Photovoltaic cells characteristic curves. Water pumping.Power control system, grid control devices.Design of wind mills, rotor design procedure, momentum theory and blade element theory. Wind mill installation and operation issues.

VII. Learning outcome

The student is able to design and analyzed the renewable energy systems and relevant technologies critically with economic feasibility.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Solar thermal energy systems.	1
2.	Kinetics and heat transfer analysis, modelling studies.	3
3.	Design and performance of solar thermal systems	2
4.	Mathematical models, power plants, design and performance.	2
5.	Solar thermal energy systems: Kinetics and heat transfer analysis, modelling studies.	2
6.	Design and performance of solar thermal systems, mathematical models, power plants, design and performance.	3
7.	Photo-voltaic	1
8.	Thermodynamic limitations of photocells.	2
9.	Semiconductors: P-n and n-p junctions, module design, sizing, power control and storage, space charge control, low pressure diode, cesium converter.	2
10.	Photo electro chemical cells, photo electrolysis cell	1

S.No.	Topic	No. of Lectures
11.	Wind power	1
12.	Design procedure of rotor, betz limit, ideal horizontal axis wind turbine, wake rotation, momentum theory and blade element theory, blade shape for ideal rotor without wake rotation,	3
13.	Performance prediction wind turbine rotor dynamics and dynamic models.	1
14.	Designing of water pumping wind mills.	1
15.	Electric power, power transformers.	1
16.	Electrical machines, ancillary electrical equipment, wind power to consumer/grid.	2
17.	Wind turbine: Sitting, installation and operation issues,	2
18.	Offshore wind farms, operation in severe climates	2
	Total	**32**

IX. Practical

S.No.	Topic	No. of Practicals
1.	Design parameters of air collectors.	1
2.	Thermal analysis and heat loss,	1
3.	Regularity models of heliostatic fields	1
4.	Design of power plant.	2
5.	Photovoltaic cells characteristic curves.	1
6.	Analysis of water pumping with photovoltaic cells.	1
7.	Power control systems.	1
8.	Grid control devices.	1
9.	Design of wind mills.	2
10.	Rotor design procedure	1
11.	Momentum theory and blade element theory	2
12.	Installation of wind mill.	1
13.	Wind mill operation issues.	1
	Total	16

X. Suggested Reading

- Anderson EE. 1983. *Fundamentals of Solar Energy Conversion*. Addision Wesley publication Company, Boston, United State.
- Kishore VVN. 2008. *Renewable Energy Engineering and Technology–A Knowledge Compendium*. TERI Press, New Delhi, India.
- More HG and Maheshwari RC. *Wind Energy Utilization in India*. Technical Bulletin No.CIAE/82/38,CIAE, Bhopal.
- Powar AG and Mohod AG. 2010. *Wind Energy Technology*. Jain Publication, New Delhi, India.
- Rai GD. 1994. *Nonconventional Sources of Energy*. Khanna Publishers, New Delhi, India.
- Rao S and Parulekar BB. 1994. *Energy Technology Nonconventional, Renewable and Conventional*. Khanna Publishers, New Delhi, India.
- Sitharthan R and Geethanjali M. 2014. *Wind Energy Utilization in India: A Review*. Middle-East Journal of Scientific Research, Pakistan.
- Solanki CS. 2011. *Solar Photovoltaics: Fundamentals, Technologies and Applications*. PHI Learning Private Limited, New Delhi, India.
- Sukhatme SP and Nayak J. 2008. *Solar Energy: Principles of Thermal Collection and Storage.* Tata McGraw Hill Publishing Company Limited, New Delhi, India.

I. Course Title : New Alternate Energy Systems

II. Course Code : REE 604

III. Credit Hours : 2+1

IV. Aim of the course

To get acquainted with various recent and emerging alternate fuels and their various applications for power generation.

V. Theory

Unit I

Hydrogen production: Water splitting, electrolytic meth-ods, chemical cycle, photo splitting, photo galvanic, photo chemical. Hydrogen storage and utilization. Fuel cells: Reactions, types, design, applications, conversion and problems. Thermoelectric convertor and thermionic convertors.Magneto hydra dynamic system (MHD). Electro gas dynamics (EGD): Principles, types.

Unit II

Tidal energy: Operating mode, energy content. Estimation of wave power, tidal power sites and ocean thermal energy cycle (OTEC): Baseline design, heat design, power cycle design, plant working.

Unit III

Geo-thermal energy system: Classification, binary cycle conversion, waterfed heat pumps, electric generation, steam generation, steam field. Heat mining, Darcy's law, volcano related heat resources, sedimentary basins, hot dry rocks.

Unit IV

Power generation through alternative sources. Environmental pollution: Measurements and control methods, instrumentation, pollution standards, social cost estimates, CO_2 reduction potential, CO_2 sequestration.

VI. Practical

Testing of electrolysis plant, photo electric plant, photo plant, design criteria of fuel cell. Design considerations for alternative energy systems.

VII. Learning outcome

Students are able to understand the various recent and emerging alternate energy sources and their utilization for meeting the increasing energy demand.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Hydrogen production: Water splitting, electrolytic meth-ods, chemical cycle, photo splitting, photo galvanic, photo chemical.	2
2.	Hydrogen storage and utilization.	1
3.	Fuel cells: Reactions, types, design, applications, conversion and problems.	2
4.	Thermoelectric convertor and thermionic convertors.	2
5.	Magneto hydra dynamic system (MHD). Electro gas dynamics (EGD): Principles, types.	2
6.	Tidal energy: Operating mode, energy content.	1
7.	Estimation of wave power, tidal power sites and ocean thermal energy	

S.No.	Topic	No. of Lectures
	cycle (OTEC)	2
8.	Baseline design, heat design, power cycle design, plant working.	3
9.	Geo-thermal energy system	1
10.	Classification, binary cycle conversion, waterfed heat pumps, electric generation, steam generation, steam field.	4
11.	Heat mining, Darcy's law, volcano related heat resources, sedimentary basins, hot dry rocks.	3
12.	Power generation through alternative sources.	1
13.	Environmental pollution	1
14.	Measurements and control methods for environmental pollution.	1
15.	Instrumentation, pollution standards,	2
16.	Social cost estimates.	1
17.	CO_2 reduction potential, CO_2 sequestration.	2
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Design parameters of air collectors.	1
2.	Thermal analysis and heat loss,	1
3.	Regularity models of heliostatic fields	1
4.	Testing of electrolysis plant	2
5.	Testing of photo electric plant	2
6.	Testing of photo plant.	2
7.	Design criteria of fuel cell	2
8.	Design considerations for alternative energy systems	2
	Total	**10**

X. Suggested Reading

- Culp JA. 1979. *Principles of Energy Conversion*. McGraw-Hill Book Company, London.
- Appleby A C 1987. *Fuel Cells: Trends in Research and Application*. Hemisphere, Washington.
- Blomen LJMJ and Mugerwa MN. 1993. *Fuel Cell System*. Plenum Press, New York, USA.
- Thielhein KD. 1977. *Alternate Energy Sources*. International compendium, Hemi sphere publishing company, London.

I. Course Title : Fuel and Combustion
II. Course Code : REE 605
III. Credit Hours : 2+1

IV. Aim of the course

To get acquainted with in depth knowledge about solid, liquid and gaseous fuels and their combustion kinematics. Understand of different combustion technologies.

V. Theory

Unit I

Solid and liquid fuels: Type and availability, oxidation, hydrogenation of solid fuel and processing of solid fuels. Liquid Fuels: Processing, properties testing of liquid fuels and refining. Liquid fuels from other sources: Preparation and storage. Production technologies for solid and liquid fuel.

Unit II

Gaseous Fuels: Types, processing and testing of gaseous fuels, gases from biomass refinery gases, LPG, oil gasification, cleaning and purification of gaseous fuels. Gaseous fuel production technologies.

Unit III

Combustion Stoichiometry: Thermodynamics and kinetics, solid, liquid and gaseous fuels. Combustion of solid fuels. Biomass combustion, stages of wood combustion, industrial biomass combustion concepts, types of combustion system.

Unit IV

Combustion of liquid fuels: Atomization, vapor concentration, droplet and ignition. Liquid fuel burners: Atomizing air burners, pressure jet atomizing burners, thin fluid burners, rotary atomizing burners.

Unit V

Combustion of gaseous fuel: Character, shape and size of the flame. Flame stabilization of bluff bodies.Effect of equivalence on reaction rate and extinction velocity, submerged combustion, combustion with explosion flame, pulsating combustion.

VI. Practical

Determination of fuel properties of solid, liquid and gaseous fuels.Determination of efficiency of combustion system using solid, liquid and gaseous fuel.Standard testing of burners for thermal efficiency for solid, liquid and gaseous fuel.

VII. Learning outcome

Students will able to design, estimate and critical analysis of various combustion techniques for efficient utilization of fuels.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Type and availability of solid and liquid fuels.	1
2.	Oxidation and hydrogenation of solid fuel.	1
3.	Processing of solid fuels.	1
4.	Processing of liquid fuel, properties and testing of liquid fuels.	2
5.	Refining of liquid fuel.	1
6.	Liquid fuels from other sources: Preparation and storage.	1
7.	Production technologies for solid and liquid fuel.	2
8.	Gaseous fuel production technologies.	1
9.	Gases from biomass, refinery gases and LPG.	2
10.	Oil gasification.	1
11.	Types, processing and testing of gaseous fuels.	2
12.	Cleaning and purification of gaseous fuels.	1
13.	Combustion Stoichiometry: thermodynamics and kinetics.	1
14.	Solid, liquid and gaseous fuels.	2
15.	Combustion of solid fuels, biomass combustion, stages of wood combustion.	2
16.	Industrial biomass combustion concepts.	1
17.	Types of combustion systems.	1
18.	Combustion of liquid fuels: Atomization, vapor concentration, droplet and ignition.	2

S.No.	Topic	No. of Lectures
19.	Liquid fuel burners: Atomizing air burners, pressure jet atomizing burners, thin fluid burners, rotary atomizing burners.	2
20.	Combustion of gaseous fuel: Character, shape and size of the flame.	2
21.	Flame stabilization of bluff bodies.	1
22.	Effect of equivalence on reaction rate and extinction velocity.	1
23.	Submerged combustion, Combustion with explosion flame, Pulsating combustion.	1
	Total	**32**

IX. Practical

S.No	Topic	No. of Practicals
1.	Determination of fuel properties of solid fuels.	1
2.	Determination of fuel properties of liquid fuels.	1
3.	Determination of fuel properties of gaseous fuels.	1
4.	Determination of efficiency of combustion system using solid fuels.	1
5.	Determination of efficiency of combustion system using liquid fuels.	1
6.	Determination of efficiency of combustion system using gaseous fuels.	1
7.	Standard testing of burners for thermal efficiency for solid.	1
8.	Standard testing of burners for thermal efficiency for liquid fuel.	1
9.	Standard testing of burners for thermal efficiency for gaseous fuel.	1
	Total	**09**

X. Suggested Reading

- Babu MKG and Subramanian KA. 2013. *Alternative Transportation Fuels: Utilization in Combustion Engines*. CRC Press, Boca Raton, Florida.
- Glassman I. 1987. *Combustion*. Academic Press Inc. Orlando, Florida, USA.
- Mukunda HS. 2011. *Understanding Clean Energy and Fuels from Biomass*. Wiley India Publication, New Delhi, India.
- Sarkar S. 1990. *Fuels and Combustion*. Orient Longmans, Bombay.
- Speight JG and Loyalka SK. 2007. *Handbook of Alternative Fuel Technologies*. CRC Press, Boca Raton, Florida.

I. Course Title : Advances in Biogas Technology

II. Course Code : REE 606

III. Credit Hours : 2+1

IV. Aim of the course

The students will understand advances in biogas technology and its mechanism in detail. To analyze the case studies for understanding success and failures. To facilitate the students in developing skills in the decision making process.

V. Theory

Unit I

Worldwide review of anaerobic digesters, realistic potential- of biogas, analysis of biogas system and proposed means for their prospects.Engineering design of biogas units for biogas production from solid and liquid wastes.

Unit II

Design parameters: Affecting and failure of biogas systems, structural behaviour and conditions of fixed dome digesters, alternate construction- materials, gas holders for gas production in colder regions, heating, stirring etc.

Unit III

Multi-criteria optimization design of fermentation systems, immobilization, modular biogas for tropical rural areas.Toxicity effect of pesticides herbicides on the anaerobic digestion process. Kinetic models, design equa-tions, contact and anaerobic filter digesters, high rate digesters.

Unit IV

Scrubbing, purification and compression of biogas. Scaling-up and standardization of biogas plant for power generation and heating. Advanced biofuels: Bio-CNG/ renewable natural gas (RNG) as vehicle fuel.Liquefaction of biogas.

VI. Practical

Engineering design and analysis of biogas system.Development of kinetic equations.Biogas purification, compression and liquefaction.Industrial applications of biogas.

VII. Learning outcome

The student is able to analyse the various aspects of biogas energy management systems, Carry out techno-economic feasibility for biogas plant, to apply the knowledge in planning and operations of biogas energy system.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Review of anaerobic digesters	1
2.	Realistic potential- of biogas	1
3.	Analysis of biogas system	2
4.	Proposed means for prospects of biogas systems	1
5.	Engineering design of biogas units for biogas production from solid and liquid wastes	3
6.	Design parameters: Affecting and failure of biogas systems	2
7.	Structural behavior and conditions of fixed dome digesters	2
8.	Alternate construction- materials for biogas plants	1
9.	Design of biogas plants for colder regions	1
10.	Heating and stirring systems for biogas plants	2
11.	Multi-criteria optimization design of fermentation systemscontact and anaerobic filter digesters, high rate digesters	2
12.	Immobilization, modular biogas for tropical rural areas	2
13.	Toxicity effect of pesticides herbicides on the anaerobic digestion process	1
14.	Chemical kinetics and mathematical modeling of bio-methanation process	2
15.	Contact and anaerobic filter digesters, high rate digesters	1
16.	Scrubbing, purification and compression of biogas.	2
17.	Scaling-up and standardization of biogas plant for power generation and heating	2
18.	Bio-CNG/renewable natural gas (RNG) as vehicle fuel	2
19.	Liquefaction of biogas	2
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Engineering design and analysis of biogas system	3
2.	Development of kinetic equations	3
3.	Biogas purification, compression and liquefaction	3
4.	Industrial applications of biogas	3
5.	Preparation of Detailed Project Reports for commercial biogas projects	4
	Total	**16**

X. Suggested Reading

- Abbasi SA and Nipaney PC. 1993. *Modeling and Simulation of Biogas System Economies*. Ashish Publication House, New Delhi.
- Abbasi T, Tauseef SM and Abbasi SA. 2012. *Biogas Energy*. Springer publications, New York, USA.
- Chawala OP. 1986. *Advances in Biogas Technology*. ICAR, New Delhi.
- Mittal KM. 1996. *Biogas Systems: Principles and Applications*. New Age international Publication Limited, New Delhi.
- Rohlich GA, Walbot V, Connar LJ, Golueke CG, Hinesly TD, Jones PH, Lapp HM, Loehr RC, LueiHing C, Pfeffer JT, Prakasam TBS and Brown NL. 1977. *Methane Generation from Human Animals and Agril Wastes*. National Academy of Sciences, Washington.

I. Course Title : Solid Waste and Waste Water Management

II. Course Code : REE 607

III. Credit Hours : 2+1

IV. Aim of the course

To provide in depth knowledge, understanding and application oriented skills on sources, quality, classification and characteristics of solid waste along with municipal and compost treatment and remote sensing technologies for waste management.

V. Theory

Unit I

Solid waste: Sources, quality, classification and characteristics, collection and reduction at source, handling, storage, transportation and disposal methods.

Unit II

Reactor for anaerobic digestion: Contact and filter digestion, homogenous and non-homogeneous reactors. Energetic and kinetics of anaerobic treatment.

Unit III

Gas transfer, mass models, bubble aeration, film flow oxygen transfer, stripping, solids removal. Activated sludge and other suspended culture processes parameters. Biosorption of contact stabilization.

Unit IV

Sanitation land fill, munici-pal and compost treatment. Predigestion of waste.Sensors, ICT and remote sensing technologies for waste management.

VI. Practical

Design principles in waste treatment, equipment specifica-tion and instrumentation.

Mathematical modelling of BOD and COD reduction rate, recovery by batch distillation.

VII. Learning outcome

The student is able to estimate, characterize and design of solid waste conversion system and also able to understand the energetic and kinetics of anaerobic treatment, sanitation land fill, pre-digestion of waste etc.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction to Solid waste	1
2.	Sources, classification and characteristic and quality	2
3.	Collection and handling and Transportation	2
4.	Disposal methods, reduction at source	3
5.	Reactor for anaerobic digestion	2
6.	Contact and filter digestion	2
7.	homogenous and non-homogeneous reactors	2
8.	Energetic and kinetics of anaerobic treatment.	2
9.	Gas transfer, mass models,	3
10.	Bubble aeration, film flow oxygen transfer, stripping, solids removal.	2
11.	Activated sludge and other suspended culture processes parameters.	2
12.	Biosorption of contact stabilization	1
13.	Sanitation land fill,	2
14.	Municipal and compost treatment	2
15.	Predigestion of waste.	1
16.	Sensors, ICT and remote sensing technologies for waste management	3
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Design principles in waste treatment	3
2.	Specifica-tion of equipment for waste treatment	2
3.	Instrumentation for waste treatment	2
4.	Mathematical modelling of BOD and COD reduction rate	3
5.	Development of computer code for Mathematical modelling of BOD and COD reduction rate	3
6.	Recovery by batch distillation.	3
	Total	**16**

X. Suggested Reading

- Bridgwater AV and Mum-ford CJ. 1979. *Waste Recycling and Pollution Control Handbook*. Van Nostrand Reinhold Company, New York.
- Kreith F and Tchobanoglous G. 2002. *Handbook of Solid Waste Management*. McGraw Hill Book Company, New York.
- Ramachandra TV. 2006. *Management of Municipal Solid Waste*. Capital Publication Company, New Delhi.
- Tchobanoglous G, Theisenand H and Elliassen R. 1978. *Solid Wastes*. McGraw Hill Book Company, New York.

I. Course Title : Advanced Photovoltaic Power Generation

II. Course Code : REE 608

III. Credit Hours : 1+1

IV. Aim of the course

To develop a comprehensive technological understanding in solar PV system components. To provide in depth understanding of design parameters to help design and simulate the performance of a solar PV power plant. To pertain knowledge about planning, project implementation and operation of solar PV power generation.

V. Theory

Unit I

Semiconductors: Transport properties, junctions, dark and illumination characteristics. Single junction and multi junction films. Solar PV concentrator cells and systems. Thin film solar cells: Nano, micro, and polycrystalline solar cells.

Unit II

Systems for remote applications and large solar PV power plants: System integrations, roof top system, sizing methodology, power control, storage, tracking and control. PCID simulation of industrial solar cell structure, software's in solar cell simulation.

Unit III

Space charge control, low pressure diode, MMPT, cesium converter, system considerations. Photo electro chemical cells and materials.Photogalvanic cells: Recent development.

Unit IV

Conjunctive use of photo conversion systems: Photo-agriculture system, components, integration and economics. Software's for PV system integration and designing. PV system for ground mounted and rooftop plants with shadow analysis.

VI. Practical

PV systems for typical applications, water pumping, solar PV tracking and mechanical clock tracking. Testing of power control system for output regulation, charging and discharging characteristics of storage by PV panels.

VII. Learning outcome

Student will able to design different solar photovoltaic system for power generation. Design and simulate a PV power plant using software tool, Plan, project implementation, operation and maintenance. Carry out techno-economic-environmental performance evaluation of a solar PV power plant.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Semiconductors: Transport properties, junctions, dark and illumination characteristics.	1
2.	Single junction and multi junction films, Solar PV concentrator cells and systems.	1
3.	Thin film solar cells: Nano, micro, and polycrystalline solar cells.	1
4.	Systems for remote applications, Large solar Photovoltaic power plants: System integrations, roof top system and sizing methodology	2

S.No.	Topic	No. of Lectures
5.	Power control, storage, tracking and control in Photovoltaic power plants.	1
6.	PCID simulation of industrial solar cell structure, software's in solar cell simulation	2
7.	System considerations for Space charge control, low pressure diode, MMPT and cesium converter	2
8.	Photo electro chemical cells and materials	1
9.	Recent development in Photogalvanic cells	1
10.	Conjunctive use of photo conversion systems: Photo-agriculture system, components, integration and economics	1
11.	Softwares for PV system integration and designing.	2
12.	PV system for ground mounted and rooftop plants with shadow analysis	1
	Total	16

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Typical applications of Photovoltaic (PV) systems	1
2.	Applications of Photovoltaic systems in water pumping	2
3.	Study of Solar PV tracking and mechanical clock tracking	2
4.	Testing of power control system for output regulation	3
5.	Charging and discharging characteristics of storage by PV panels.	2
	Total	**10**

X. Suggested Reading

- Duffle JA and Beckman WA. 1991. *Solar Engineering of Thermal Processes*. John Wiley, New Jersey.
- Fonash SJ. 1982. *Solar Cell Device Physics*. Academic Press, Cambridge, England.
- Garg HP. 1990. *Advances in Solar Energy Technology*. Springer Publishing Company, Dordrecht, Netherland.
- Green MA. 1981. *Solar Cells Operating Principles, Technology, and System Applications*. Prentice Hall, New Jersey.
- Kreith F and Kreider JF. 1978. *Principles of Solar Engineering*. McGraw Hill, New York.
- Luque A and Hegedus S. 2011. *Handbook of Photovoltaic Science and Engineering Education*. John Wiley and Sons, New Jersey.
- Solanki CS. 2011. *Solar Photovoltaic: Fundamentals, Technologies and Applications*. PHI Learning Private Limited, Delhi.
- Sze SM and Kwok KN. 2007. *Physics of Semiconductor Devices*. John Wiley & Sons, New Jersey.
- Veziroglu TN. 1977. *Alternative Energy Sources*. McGraw Hill, New York.

I. Course Title : Energy Planning, Management and Economics

II. Course Code : REE 609

III. Credit Hours : 3+0

IV. Aim of the course

To acquaint and equip with energy planning, management and economical evaluation for agricultural production system.

V. Theory

Unit I

Energy resources on the farm: Conventional and non-conventional forms of energy and their use. Heat equivalents and energy coefficients for different agricultural inputs and products.Pattern of energy consumption and their constraints in production of agriculture.Direct and indirect energy.

Unit II

Energy audit of production agriculture and rural living and scope of conservation. Identification of energy efficient machinery systems, energy losses and their management.

Unit III

Energy analysis techniques and methods: Energy balance, output and input ratio, resource utilization, conservation of energy sources. Energy conservation planning and practices.

Unit IV

Energy forecasting, energy economics, energy pricing and incentives for energy conservation, factors effecting energy economics. Techno-economic evaluation of RET's, computation of programme for efficient energy management.

VI. Learning outcome

The student will be able to quantify, analyze and forecast the demand and supply of different energy for agriculture production system.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Energy resources on the farm: Conventional and non-conventional forms of energy and their use.	3
2.	Heat equivalents and energy coefficients for different agricultural inputs and products.	3
3.	Pattern of energy consumption and their constraints in production agriculture. Direct and indirect energy.	3
4.	Energy audit of production agriculture and rural living and scope of conservation.	4
5.	Identification of energy efficient machinery systems	3
6.	Energy losses and their management.	4
7.	Energy analysis techniques and methods: Energy balance, output and input ratio, resource utilization, conservation of energy sources.	4
8.	Energy conservation planning and practices.	4
9.	Energy forecasting	3
10.	Energy pricing and incentives for energy conservation,	3
11.	Energy economicsand factors affecting energy economics	4
12.	Techno-economic evaluation of RET's	4
13.	Computation of programme for efficient energy management.	3
	Total	45

VIII. Suggested Reading

- Fluck RC and Baird CD. 1984. *Agricultural Energetics*. AVI Publication, United State.
- Kennedy WJ and Turner WC. 1984. *Energy Management*. Prentice Hall, New Jersey.
- Pimental D. 1980. *Handbook of Energy Utilization in Agriculture*. CRC Press, Florida.

- Rai GD. 1998. *Nonconventional Sources of Energy*.Khanna Publication, New Delhi.
- Twindal JW and Wier AD. 1986. *RenewableEnergy Sources*. E & F N Spon, New York.
- Verma SR, Mittal JP and Singh S. 1994. *Energy Management and Conservation in Agricultural Production and Food Processing*. USG Publication, Chicago.

I. Course Title : Renewable Energy for Industrial Application

II. Course Code : REE 610

III. Credit Hours : 2+1

IV. Aim of the course

To provide the knowledge regarding the energy consumption pattern in agro based industries, quantification techniques and identification of opportunities for renewable energy sources.

V. Theory

Unit I

Elucidation of unit operations in industry.Energy quantification techniques, system boundary, estimation of productivity, plant capacity utilization, energy density ratio and energy consumption pattern.Energy flow diagram conservation opportunities identification.

Unit II

Solar energy for industrial application: Solar water heating, steam solar cooking system, industrial solar dryer and solar process heat, solar cooling system (refrigeration, air conditioning and solar architecture technology), solar furnace and solar green house technology for high-tech cultivation. Solar photovoltaic technology for industrial power.

Unit III

Bio energy for industrial application: Quantification of industrial bio-waste, characterization, power generation through bio-methanation, gasification and dendro thermal power plant.

Unit IV

Wind energy: Aero generator of new era and national and international state of art in wind power generation. Other renewable energy sources: Magneto hydro dynamics, fuel cells technology and micro-hydro energy technology.

VI. Practical

Elucidation and energy consumption for unit operations in industry. Study of energy quantification and identification of opportunities for RET's. Design of solar dryers.Design of solar photovoltaic system.Design of gasifiers for thermal energy and power generation. Design of combuster (gasifier stove). Study of solar greenhouse.Study of biogas engine generator set.Case study of agro-industrial energy estimation and visit to RSE power generation site.

VII. Learning outcome

Students will be acquainted with energy quantification techniques, design of system, economic evaluation and utilization of renewable energy sources for agro-industrial applications.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Elucidation of unit operations in industry.	1
2.	Energy quantification techniques, system boundary,	2
3.	Estimation of productivity, plant capacity utilization,	2
4.	Energy density ratio and energy consumption pattern.	2
5.	Energy flow diagram conservation opportunities identification.	1
6.	Solar energy for industrial application.	1
7.	Solar water heating.	1
8.	Steam solar cooking system.	1
9.	Industrial solar dryer and solar process heat.	2
10.	Solar cooling system (refrigeration, air conditioning and solar architecture technology).	2
11.	Solar furnace.	1
12.	Solar greenhouse technology for high-tech cultivation.	2
13.	Solar photovoltaic technology for industrial power.	1
14.	Bio energy for industrial application	1
15.	Quantification of industrial bio-waste, its characterization	2
16.	Power generation through bio-methanation,	2
17.	Gasification and dendro thermal power plant.	2
18.	Wind energy: Aero generator of new era.	1
19.	National and international state of art in wind power generation.	2
20.	Other renewable energy sources: Magneto hydro dynamics, fuel cells technology and micro-hydro energy technology.	3
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Elucidation and energy consumption for unit operations in industry.	1
2.	Study of energy quantification and identification of opportunities for RET's	1
3.	Design of solar dryers.	2
4.	Design of solar photovoltaic system.	2
5.	Design of gasifiers for thermal energy and power generation.	2
6.	Design of combuster (gasifier stove).	2
7.	Study of solar greenhouse.	1
8.	Study of biogas engine generator set.	1
9.	Case study of agro-industrial energy estimation	2
10.	Visit to RSE power generation site.	1
	Total	**15**

X. Suggested Reading

- Duffie JA and Beakman WA. 2006. *Solar Energy Thermal Process*. John Wiley and Sons, New York.
- Kumar S. 2011. *Energy Conservation Building User Code Guide*. Bureau of Energy Efficiency, New Delhi.
- Rathore NS, Kurchania AK and Panwar NL. 2007. *Non Conventional Energy Sources*. Himanshu Publications, Udaipur, Rajasthan.
- Sayigh AAM. 2012. *Solar Energy Engineering*. Academic Press, New York.
- Singh P, Kurchania AK, Rathore NS and Mathur AN. 2005. *Sustainable Development through Renewable Energy Sources*. Yash Publications, Bikaner, Rajasthan.

I. Course Title : Biofuel Technologies and Applications

II. Course Code : REE 611

III. Credit Hours : 1+1

IV. Aim of the course

To get acquainted with recent biofuel production technologies and their applications.To perform financial estimations of the biofuel projects.To get insight of the various biofuel technologies.

V. Theory

Unit I

Liquid biofuels: Non-edible oilseeds, oil extraction, pre-processing, characterization. World scenario: Liquid fuel challenges and some solutions. Liquid bio-fuel applications.

Unit II

Bioethanol: First and second generation ethanol production technologies. Production of syngas from biomass, production of methanol from syngas, production of ethanol from lingo-cellulosic biomass. Syngas and poly-generation, chemical conversion of syngas to methanol and ethanol and some advanced fuels like bio butanol, bio-propanol.

Unit III

BioCNG: Biogas to green vehicle fuel, anaerobic digestion. Bio gas opportunities: Landfill gas, agricultural and industrial wastewater and additional sources of methane.

Unit IV

Biodiesel: Feedstock for biodiesel, manufacturing processes for biodiesel, value addition by utilization of by-products, environmental impacts of biodiesel, biodiesel from algae, biodiesel engines.

Unit V

Pyrolysis oil: Fast pyrolysis technologies, composition and issues of bio oil. Bio oil upgradation technologies.

VI. Practical

Evaluation of liquid fuel system for heat and power generation and characterization of liquid fuel, transesterification process.Engine performance on biodiesel.Biogas-engine system for transport vehicle.Bio oil production by pyrolysis.

VII. Learning outcome

Student will able to understand the bio-fuel production technologies with financial viability and applications of bio-fuel in different sector of development.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Liquid biofuels: Non-edible oilseeds, oil extraction, pre-processing, characterization.	1
2.	World scenario: Liquid fuel challenges and some solutions. Liquid bio-fuel applications.	1
3.	Bioethanol: First- and second-generation ethanol production technologies.	1
4.	Production of syngas from biomass.	1

S.No.	Topic	No. of Lectures
5.	Production of methanol from syngas.	1
6.	Production of ethanol from lingo-cellulosic biomass.	1
7.	Syngas and poly-generation.	1
8.	Chemical conversion of syngas to methanol and ethanol, some advanced fuels like bio butanol, bio-propanol.	1
9.	Bio CNG: Biogas to green vehicle fuel, anaerobic digestion.	1
10.	Bio gas opportunities: Landfill gas, agricultural and industrial wastewater and additional sources of methane.	1
11.	Biodiesel: Feedstock for biodiesel, manufacturing processes for biodiesel, value addition by utilization of by-products, environmental impacts of biodiesel.	2
12.	Biodiesel from algae, biodiesel engines.	1
13.	Pyrolysis oil: Fast pyrolysis technologies.	1
14.	Composition and issues of bio oil	1
15.	Bio oil up-gradation technologies.	1
	Total	**16**

IX. List of Practicals

S. No.	Topic	No. of Practicals
1.	Evaluation of liquid fuel system for heat and power generation.	2
2.	Characterization of liquid fuel.	1
3.	Transesterification process.	2
4.	Engine performance on biodiesel.	1
5.	Biogas-engine system for transport vehicle.	1
6.	Bio oil production by pyrolysis.	1
	Total	**08**

X. Suggested Reading

- Boyle G. 2008. *Renewable Energy*. Atlantic Publishing Company, New Delhi.
- Gonsalves JB. 2006. *An Assessment of the Biofuels Industry in* John *India.* Wiley & Sons, New Delhi.
- Kishore VVN. 2008. *Renewable Energy Engineering and Technology–A Knowledge Compendium. Education.* TERI Press, Delhi.
- Klass D. 1998. *Biomass for Renewable Energy, Fuels, and Chemicals.* Entech International, Barrington, Illinois, USA.
- Mitzlaff KV. 1988. *Engines for Biogas–Theory, Modification, Economic Operation.* Deutsches Zentrum für Entwicklungstechnologien–GATE, Germany.

I. Course Title : Energy Modelling and Simulation

II. Course Code : REE 612

III. Credit Hours : 1+1

IV. Aim of the course

The objective of this course is to provide in depth knowledge about various mathematical models, interdependence of energy, ecology and environment, energy modelling in the context of climate change.

V. Theory

Unit I

Model: Basics, system, boundary, interaction, types of models, physical, analogy models and applications. Mathematical models: Concepts, input, output model, stochastic, deterministic, empirical models, linear, non-linear models, interdependence of energy, economy, environment, modelling concept and application.

Unit II

Energy Modelling: Review of various energy sector models, energy demand analysis and forecasting, energy supply assessment and evaluation, energy demand, supply balancing, energy modelling in the context of climate change.

Unit III

Model studies in gasification, pyrolysis, biogas, fermentation, biodiesel, solar, wind technologies and heat transfer applications. Moving boundary models.

Unit -IV

Energy economics of energy sources: Investment and cost management in various energy technologies. Economics of energy generation, energy conservation economics, financial analysis, sensitivity and risk analysis.

VI. Practical

Formulating dimensionless numbers, applications, types of models, mathematical model formulation and types, Software's and model evaluation. Development of models in thermo-chemical and biochemical conversion processes. Studies on model development in solar and wind technologies, economics of energy generation and conservation, financial analysis.

VII. Learning outcome

Students will get thorough knowledge about energy modelling of gasification, pyrolysis, biogas system, fermentation, biodiesel production system, solar and wind technologies etc.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction to Model	1
2.	Basics, system, boundary, interaction, types of models, physical, analogy models.	2
3.	Model applications.	1
4.	Mathematical models: Concepts, input, output model, stochastic, deterministic, empirical models, linear, non-linear models, interdependence of energy, economy, environment.	3
5.	Modelling concept and application.	1
6.	Energy Modelling	1
7.	Review of various energy sector models.	1
8.	Energy demand analysis and forecasting.	1
9.	Energy supply assessment and evaluation	1
10.	Energy demand, supply balancing.	2
11.	Energy modelling in the context of climate change.	2
12.	Model studies in gasification, pyrolysis.	2
13.	Model studies in biogas, fermentation.	1
14.	Model studies in biodiesel.	1
15.	Model studies in solar.	1
16.	Model studies in wind technologies.	1
17.	Heat transfer applications.	1
18.	Moving boundary models.	1

S.No.	Topic	No. of Lectures
19.	Energy economics of energy sources	1
20.	Investment and cost management in various energy technologies.	2
21.	Economics of energy generation.	1
22.	Energy conservation economics, financial analysis.	2
23.	Energy conservation sensitivity and risk analysis	2
	Total	32

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Formulating dimensionless numbers.	1
2.	Applications of dimensionless numbers.	1
3.	Types of models for dimensionless numbers.	1
4.	Mathematical model formulation and types.	2
5.	Software's and model evaluation.	2
6.	Development of models in thermo-chemical	1
7.	Development of models in biochemical conversion processes.	1
8.	Studies on model development in solar technologies.	1
9.	Studies on model development in wind technologies	1
10.	Economics of energy generation and conservation	2
11.	Financial analysis.	1
	Total	**14**

X. Suggested Reading

- Desai A V 1990. *Energy Planning and Economics*. New Age International Publication Limited, New Delhi.
- Munasinghe M and Meier P 1993. *Energy Policy Analysis and Modelling* (*Cambridge Energy and Environment Series*). Cambridge University Press, England.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 4

Agricultural Engineering
– Soil and Water Conservation Engineering

Preamble

(Soil and Water Conservation Engineering)

Course curricula and course outlines in Soil and Water Conservation Engineering are designed in view of the fact that courses are offered by students from disciplines of faculties of Soil Science, Agronomy and Agricultural Meteorology.

At the post graduate level it becomes more important where they have not only to learn the recent advances in their subjects but have also to be trained in the modern and latest techniques in their disciplines so that they can participate and contribute in the development and advancement in their related fields. Further, the shrinking job opportunities in the National Agricultural Research System (ICAR/SAUs) have put additional pressure on our education system to prepare students in tune with the demands of the private sector.

All courses are designed to cover all basic topics and have been designed by taking into consideration demands of private sector harnessing commercial aspects, modern research tools and their applications, supplementary skills required, and enhancing the global competitiveness and employability of students. The emphasis has been given on advanced watershed hydrology and modeling management and accordingly new courses "Stochastic hydrology, Climate change and water resources, Waste water treatment and utilization, Multi criteria decision making system" are framed in view of the recent developments in the subject.

The courses have been revised, updated and restructured in view of current developments and emerging trends in Soil and Water Conservation Engineering. The revised courses cover the areas: Advanced Soil and Water Conservation Engineering, Applied Watershed Hydrology, Soil and Water Conservation Structures, Watershed Management and Modeling, Flow Through Porous Media, Remote sensing and GIS for land and water resource management, Dryland Water Management Technologies, Minor irrigation, Design of Drip and Sprinkler Irrigation Systems, Groundwater engineering, Water Resources Systems Engineering, Advances in Hydrology, Soil and Water Systems Simulation and Modeling, Reservoir Operation and River Basin Modeling, Modeling Soil Erosion Processes and Sedimentation.

The course content and syllabus upgraded with more of practical orientation and as per ARS Syllabus.

The ICAR recommendations for PG courses have been taken into consideration in framing these courses. It is hoped that these will prove very useful to the future students.

Course Title with Credit Load
M.Tech. in Soil and Water Conservation Engineering

Major Courses (Requirement: 20 Credits)

Course Code	Course Title	Credit Hours
*SWCE 501	Advanced Soil and Water Conservation Engineering	2+1
*SWCE 502	Applied Watershed Hydrology	2+1
SWCE 503	Soil and Water Conservation Structures	2+1
SWCE 504	Stochastic Hydrology	2+1
*SWCE 505	Watershed Management and Modeling	2+1
SWCE 506	Flow Through Porous Media	2+0
SWCE 507/IDE 507	Remote Sensing and GIS for Land and Water Resource Management	2+1
SWCE 508	Climate Change and Water Resources	3+0
SWCE 509	Numerical Methods in Hydrology	2+0
SWCE 510	Dryland Water Management Technologies	2+0
	Total	**19+6**

*Compulsory course

Minor Courses (Requirement: 08 Credits)

Course Code	Course Title	Credit Hours
IDE 505	Design of Drip and Sprinkler Irrigation Systems	2+1
IDE 506	Groundwater Engineering	2+1
IDE 510	Minor Irrigation	2+1
IDE 513	Water Resources Systems Engineering	2+1
CE 501	Dimensional Analysis and Similitude	2+0
CE 502	Water Quality and Pollution Control	2+1
FMPE 517	Machinery for Precision Agriculture	2+1
REE 513	Energy, Ecology and Environment	3+0
CSE 501	Big Data Analytics	2+0
CSE 502	Artificial Intelligence	2+0
CSE 504	Soft Computing Techniques in Engineering	2+1
MATH 501	Finite Element Methods	2+0
MATH 502	Numerical Methods for Engineers	2+0
ME 501	Mechatronics and Robotics in Agriculture	2+0
	Any other course(s) of other department can be taken as per recommendations of the student's advisory committee.	

Supporting Courses (Requirement: 06 Credits)

Course Code	Course Title	Credit Hours
*STAT 501	Statistical Methods for Research Works	2+1
	Courses from subject matter fields (other than Major and Minor) relating to area of special interest and research problem can be taken as per recommendations of the student's advisory committee.	

*Compulsory Course

Common Courses (Requirement: 05 Credits)

Course Code	Course Title	Credit Hours
*PGS 501	Library and Information Services	1+0
*PGS 502	Technical Writing and Communication Skills	1+0
*PGS 503	Intellectual Property and its management in Agriculture	1+0
*PGS 504	Basic Concepts in Laboratory Techniques	1+0
*PGS 505	Agricultural Research, Research Ethics and Rural Development Programmes	1+0

*Detailed course outline to be developed by designated BSMA

List of other Essential Requirements

Course Code	Course Title	Credit Hours
SWCE 591	Seminar	0+1
SWCE 599	Thesis Research	0+30

Course Contents
M.Tech. in Soil and Water Conservation Engineering

I. Course Title : Advanced Soil and Water Conservation Engineering
II. Course Code : SWCE 501
III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip students with the advances in soil and water conservation measures, use of RS and GIS and Software's for design of soil and water conservation structures.

V. Theory

Unit I

Concept of probability in design of soil and water conservation structures. Probability and continuous frequency distribution. Fitting empirical distributions.

Unit II

Relevance of soil and water conservation in agriculture and in the river valley projects. Layout and planning of soil and water conservation measures. Software's for design of conservation structures.

Unit III

Productivity loss due to soil erosion. Water stress and water excess. Types and mechanics of soil erosion. Software's for soil loss estimation, WEAP, EPIC

Unit IV

Theories of sediment transport. Control of runoff and sediment loss. Sediment deposition process. Estimation of sediment load.

Unit V

Design of soil and water conservation structures: Check dams, gully plugs, gabion structures, earth dams, silt detention dams, farm ponds, etc., and the alternate use of the stored water for agriculture. Application of Remote Sensing and GIS in Soil and Water Conservation.

VI. Practical

Assessment of erosive status of a watershed through field measurement or analysis of morphometric properties. Estimation of erosivity index of rainfall. Determination of soil physical properties: Texture, grain size distribution, Atterberg's limits, various moisture percentages. Locating best possible sites of soil and water conservation structures on the basis of map features and erosivity status. Estimation of costs of soil and water conservation measures.

VII. Learning outcome

The students will able to plan and design soil and water conservation measures in particular watershed using RS and GIS techniques. They can estimate the sedimentation and capacity losses, design of gully control structures and earthen dams usingsoftware's.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Concept of probability in design of soil and water conservation structures	2
2.	Probability and continuous frequency distribution	2
	Fitting empirical distributions	2
3.	Relevance of soil and water conservation in agriculture and in the river valley projects	2
4.	Layout and planning of soil and water conservation measures	2
5.	Software's for design of conservation structures	1
6.	Productivity loss due to soil erosion	1
7.	Water stress and water excess	1
8.	Types and mechanics of soil erosion	1
9.	Software's for soil loss estimation, WEAP, EPIC	3
10.	Theories of sediment transport	2
11.	Control of runoff and sediment loss	1
12.	Sediment deposition process and estimation of sediment load	2
13.	Design of soil and water conservation structures: Check dams, gully plugs, gabion structures, earth dams, silt detention dams, farm ponds, etc., and the alternate use of the stored water for agriculture	6
14.	Application of Remote Sensing and GIS in Soil and Water Conservation	3
	Total	**31**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Assessment of erosive status of a watershed through field measurement	2
2.	Morphometric analysis of a watershed	2
3.	Estimation of erosivity index of rainfall	1
4.	Determination of soil texture	1
5.	Determination of soil grain size distribution	1
6.	Determination of Atterberg's limits of soil	1
7.	Determination of various soilmoisture percentages	1
8.	Locating best possible sites of soil and water conservation structures on the basis of map features and erosivity status	2
9.	Design of Check dams, gully plugs, gabion structures, earth dams, silt detention dams and farm ponds	4
10.	Estimation of costs of soil and water conservation measures	2
	Total	**17**

X. Suggested Reading

- Garg SK. 1987. *Irrigation Engineering and Hydraulic Structures*. Khanna Publishers, New Delhi.
- Kirkby MJ and Morgan PPC (eds). 1980. *Soil Erosion*. John Wiley and Sons. New York, USA.
- Suresh R. 2016. *Soil and Water Conservation Engineering*. Standard Publishers and Distributors, Delhi.

I. Course Title : Applied Watershed Hydrology

II. Course Code : SWCE 502

III. Credit Hours : 2+1

IV. Aim of the course

To provide in depth knowledge of surface and sub-surface hydrology of watershed including stream flow measurement and computer simulation of hydrological processes in small watersheds.

V. Theory

Unit I

Hydrology in water resources planning, rainfall, surface runoff and sub-surface runoff as components of hydrologic cycle. Runoff phenomena, relationship between precipitation and runoff. Stream flow measurement and analysis of data in detail.

Unit II

Synthetic unit hydrograph. Recent advances in analysis of hydrologic data and flow from small watersheds. Methods of runoff estimation from small watersheds. Use of IUH and various methods of estimation. Runoff estimation models: SCS, CN software.

Unit III

Micro climate, estimation methods of evaporation. Advances and improvements in rational approach. SCS approach criticism and improvements.

Unit IV

Hydrological hazard functions. Methods of estimation of hydrologic parameters. Data transformation.

Unit V

Calibration and evaluation of hydrologic models. Computer simulation of hydrological process in small watersheds.

VI. Practical

Delineation of watershed and study of watershed characteristics. Measurement of rainfall and runoff in a watershed and data analysis. Estimation of infiltration and runoff from a watershed. Analysis and derivation of various types of hydrographs. Flood routing. Reservoir sedimentation. Watershed model components. Visit to a watershed.

VII. Learning outcome

The students will be able to understand and analyze the process and the effect of various climatic parameters on rainfall-runoff relationship. They can also be able to develop the competency for calibration and evaluation of hydrologic models and computer simulation.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Hydrology in water resources planning, rainfall, surface runoff and sub-surface runoff as components of hydrologic cycle	2
2.	Basics of watershed hydrology and processes, global and watershed perspectives	2

S.No.	Topic	No. of Lectures
3.	Runoff phenomena, relationship between precipitation and runoff	1
4.	Synthetic unit hydrograph, Unit hydrograph and its derivation including for complex storm,	3
5.	S-hydrograph and derivation, Use of IUH and various methods of estimation.	3
6.	Runoff estimation models: SCS, CN software	3
7.	Flood routing principles	2
8.	Recent advances in analysis of hydrologic data and flow from small watersheds. Methods of runoff estimation from small watersheds.	3
9.	Micro climate, estimation methods of evaporation. Advances and improvements in rational approach. SCS approach criticism and improvements	3
10.	Process of sedimentation of reservoirs	2
11.	Hydrological hazard functions, Methods of estimation of hydrologic parameters, Data transformation,	3
12.	Hydrologic modeling approaches, component conceptualization, types of watershed hydrologic models and choice of model.	3
13.	Calibration and evaluation of hydrologic models. Computer simulation of hydrological process in small watersheds	2
	Total	**32**

VIII. List of Practicals

S.No.	Topic	No. of Practicals
1.	Delineation of watershed and study of watershed characteristics	1
2.	Measurement of rainfall and runoff in a watershed	1
3.	Analysis of hydrologic data and flow from small watersheds	1
4.	Estimation of infiltration and runoff from a watershed	1
5.	Measurement and analysis of stream flow data	1
6.	Analysis of synthetic unit hydrograph for complex storm	1
7.	Analysis of S-hydrograph for complex storm	1
8.	Use of runoff estimation models: SCS, CN software	2
9.	Study of different types of flood routing methods	2
10.	Computer simulation of hydrological process in small watersheds	1
11.	Study of reservoir sedimentation	1
12.	Study of watershed model components	1
13.	Visit to a watershed	1
	Total	**16**

IX. Suggested Reading

- Haan CT. *Hydrologic Modeling of Small Watershed*.
- Singh VP. 2010. *Rainfall-Runoff Modeling* (Vol. I)—Prentice Hall, New York.
- Singh VP. 2010. *Environmental Hydrology*. Springer, New York.

I. Course Title : Soil and Water Conservation Structures

II. Course Code : SWCE 503

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint students with the planning and design of soil and water conservation structures, their stability checks and mechanized soil conservation techniques.

V. Theory

Unit I

Design, planning and layout of soil and water conservation structures. Criteria of selection of appropriate structures as per soil, land use and climatic conditions.

Unit II

Design and construction of earthen dam, stability analysis of land slopes and soil mass including landslides.

Unit III

Hydrological and structural design including stress analysis. Hydraulic jump and energy dissipaters for soil conservation structures.

Unit IV

Seepage through dams, flow net and determination of uplift pressure in drop structures, design of energy dissipaters.

Unit V

Design of water harvesting structures, construction, maintenance and utilization of stored water. Mechanized construction techniques for soil and water conservation structures.

VI. Practical

Numerical approach on probability distribution functions. Stability analysis and structural design of masonry water harvesting structures. Design of earthen dams and other energy dissipating structures. Cost analysis of water harvesting structures. Field visit to already constructed water harvesting structures in the nearby area/ watershed.

VII. Learning outcome

The student will be able to design the soil and water conservation structures as well as permanent gully control structures and water harvesting structures. They can have understanding of mechanized construction of soil and water conservation structures.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1	Introduction and need of Soil and Water Conservation in agricultural watershed	1
2	Runoff process and factors affecting it and estimation of runoff using various methods	3
3	Analysis of rainfall data, Probability concepts in the design of structures	3
4	Introduction, classification and functional requirement of soil and water conservation structures-Straight Drop spillway, chute spillway and drop inlet spillway	1
5	Specific energy and specific force	2
6	Hydraulic jump and its application, type of hydraulic jump, energy dissipation due to jump, jump efficiency, relative loss of energy	2
7	Straight drop spillway- Components and their functions, hydrologic, hydraulic and structural design	4

S.No.	Topic	No. of Lectures
8	Drop inlet spillway- Components and their functions, hydrologic, hydraulic and structural design	2
9	Chute Spillway- Components and their functions, hydrologic, hydraulic and structural design	3
10	Criteria of selection of appropriate structures as per soil, land use and climatic conditions	1
11	Design of energy dissipaters in soil and water conservation structures	1
12	Introduction, types, design, criteria and construction of earthen dam, causes of failure of earthen dam, retaining wall and its design	3
13	Stability analysis of land slopes and soil mass including landslides, seepage control in earthen dams, flow net in earthen dams	2
14	Water harvesting: principles, importance and issues. Water harvesting techniques: classification based on source, storage and use. Runoff harvesting: short-term and long-term harvesting techniques, purpose and design criteria.	3
15	Mechanized construction techniques for soil and water conservation structures	1
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Study of various probability distribution function for rainfall analysis	1
2.	Construction of specific energy and specific force diagram	2
3.	Measurement of hydraulic jump parameters and amount of energy dissipation	1
4.	Hydrologic and hydraulic design of a straight drop spillway	1
5.	Determination of uplift force and construction of uplift pressure diagram	1
6.	Determination of loads on headwall and construction of triangular load diagram	1
7.	Stability analysis of a straight drop spillway	1
8.	Hydraulic design of a chute spillway	1
9.	Design of drop inlet spillway	1
10.	Design of energy dissipating structures	1
11.	Design of earthen dam	1
12.	Seepage analysis in earthen embankment	1
13.	Design of water harvesting structures	1
14.	Economic analysis of water harvesting structures	1
15.	Field visit to already constructed water harvesting structures in the nearby area/watershed.	1
	Total	**16**

X. Suggested Reading

- Mahnot SC, Singh PK and Chaplot PC. 2011. *Soil and Water Conservation and Watershed Management*. Apex Publishing House, Udaipur.
- Murty VVN. 1988. *Land and Water Management Engineering*. Second Edition Kalyani Publishers, New Delhi.
- Singh Gurmel C, Venkataraman G, Sastri and Joshi BP. 1991. *Manual of Soil and Water conservation Practices*. Oxford and IBH Publishing Co. Pvt. Ltd, New Delhi.

- Singh PK. 2000. *Watershed Management* (*Design and Practice*). e-media publications, Udaipur.
- Suresh R. 2006. *Soil and Water Conservation Engineering*. Fourth Edition Standard Publishers and Distributors, Delhi.
- Singh Raj Vir. 2003. *Watershed Management*. Second Edition, Yash Publishing, Bikaner.

I. Course Title : Stochastic Hydrology

II. Course Code : SWCE 504

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint students about the stochastic processes in hydrology including statistical characteristics of hydrological time series data, modeling hydrologic uncertainty and analysis of multivariate hydrologic series,

V. Theory

Unit I

Hydrologic cycle, Systems concept, Hydrologic systems model. Classification of hydrologic models, Statistical, stochastic and deterministic approaches. Statistical characteristics of hydrological data, probability distribution of hydrologic variables. Deterministic and stochastic hydrology, Cause and effect analysis. Hydrologic time series analysis – nature, stationarity and ergodicity, components of time series, trend, periodicity and stochastic parts, parameter estimation of probability distributions. Analysis of hydrologic extremes.

Unit II

Multivariate regression analysis, correlation analysis, correlation coefficient and its significance in regional analysis. Developing prediction equation by simple and multiple linear regression. Reliability of the Model.

Unit III

Stochastic Process: Classification, stationary process. Time series: Classification, component of time series. Methods of investigation: Auto correlation coefficient, moving average process, auto regressive process, auto regressive moving average process, auto regressive integrated moving average process. Spectral analysis, analysis of multivariate hydrologic series.

Unit IV

Thomas Fiering model, Box Jenkins model. Model formulation: Parameter estimation, calibration and validation. Application to hydrologic data. Generation and forecasting. Regional flood frequency analysis. Transformations, Hypothesis testing.

Unit V

Modeling hydrologic uncertainty. First order Markov process, Markov chain, Data generation, Hydrologic time series analysis, Modelling of hydrologic time series.

VI. Practical

To estimate various statistical parameters of the hydrologic variables, estimating missing data in historical series, various parameter estimation methods like method of moments, method of maximum likelihood, method of mixed moments, probability of weighted moments fitting discrete and continuous distribution functions to variables, application of transformation techniques to historical data for estimating variables at different return periods, determining correlation and regression coefficients, analyzing multivariate regression, autocorrelation coefficient for independent and correlated events, fitting ARMA models, fitting Markov models of first and second order, regional frequency analysis, time series analysis of the historical data, estimating and fitting Thomas Fiering Model.

VII. Learning outcome

The students are enabled to understand the stochastic process of hydrology including statistical based analysis of hydrological time series data. They are exposed to stochastic and deterministic modeling of small watersheds.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Hydrologic cycle, Systems concept, Hydrologic systems model	1
2.	Hydrological models, processes and systems - Physical Characterization of watersheds; Rainfall measurements	1
3.	Classification of hydrologic models, Statistical, stochastic and deterministic approaches	1
4.	Statistics and probabilities in hydrology – Basic concepts – Experiment, Sample space, element, event, complement, intersection, disjoint, union, statistical parameters; Uncertainty in hydrological event; Statistical homogeneity, Permutation, combination, probability, conditional probability; Independent events, random variables, discrete and continuous sample space, Probability and Return period	3
5.	Statistics and probabilities in hydrology- Frequency Analysis – Mean, Median, Mode, Variance, Frequency Analysis - Standard deviation, Coefficient of Variance, Skewness, Kurtosis Theorems on Probability; Total probability theorem and Baye's theorem	3
5.	Statistics and probabilities in hydrology- Discrete and Continuous probability - Random Variable and Variate; Probability Distribution of hydrological variables; Co-relation and regression analysis.	3
6.	Introduction and examples of stochastic processes; Specification of stochastic process- nature, stationarity and ergodicity, components of time series,	2
7.	Hydrologic time series analysis –trend, periodicity	1
8.	Stochastic time series analysis- Methods of analysis -Auto correlation coefficient,	1
9.	Stochastic time series analysis- moving average process, auto regressive process,	2
10.	Stochastic time series analysis- auto regressive moving average process,	2
10.	Stochastic time series analysis- auto regressive integrated moving average process.	2
11.	Spectral analysis, analysis of multivariate hydrologic series	2
12.	Thomas Fiering model, Box Jenkins model	2
13.	Model formulation: Parameter estimation, calibration and validation.	2
14.	Application to hydrologic data	2
15.	Generation and forecasting- Regional flood frequency analysis Transformations,	1
16.	Hypothesis testing	1
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Development of regression models	1
2.	Estimation of missing data in historical series	1
3.	Parameter estimation-Method of Moments	1
4.	Parameter estimation-method of maximum likelihood	1
5.	Parameter estimation- method of mixed moments, Probability of weighted moments	1
6.	Fitting discrete and continuous distribution functions to variables	1
7.	Transformation techniques to historical data for estimating variables at different return periods	1
8.	Regression analysis, Correlation analysis,	1
9.	Analyzing multivariate regression,	1
10.	Autocorrelation coefficient for independent and correlated events,	1
11.	Fitting ARMA models to rainfall runoff data	1
12.	Fitting Markov models of first and second order,	1
13.	Regional frequency analysis,	1
14.	Estimating parameters of Thomas Fiering Model	1
15.	Fitting of Thomas Fiering Model	1
	Total	**15**

X. Suggested Reading

- Clarke RT. *Mathematical Models in Hydrology*. FAO Publication.
- Haan CT. 2002. *Statistical Methods in Hydrology*. Iowa State Press.
- Kotteguda NT. 1982. *Stochastic Water Resources Technology*. The Macmillan Press, New York.
- McCuen RH and Snyder WM. *Hydrological Modelling–Statistical Methods and Applications*. Prentice Hall Inc., New York.
- Yevjevich V *Stochastic Processes in Hydrology*. Water Resources Publications, Colorado.

I. Course Title : Watershed Management and Modeling

II. Course Code : SWCE 505

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint students with watershed management concept and its benefit for sustainable rural development through participatory approach, including environmental impact as well as policy frame work.

V. Theory

Unit I

Concept of watershed, its hydrological and geomorphological characteristics. Status of watershed management programs in India. Problems of desertification and degradation.

Unit II

Concept of watershed management and sustainability, participatory approach and operational watershed. Surveys, monitoring, reclamation and conservation of agricultural and forest watersheds, hill slopes and ravines.

Unit III

Watershed management research instrumentation and measurement, problem identification, simulation and synthesis. Rainfed farming and drought management. Modeling of flood and drought phenomenon.

Unit IV

Use of Remote Sensing and GIS in watershed management and modeling. Watershed modeling approaches, mathematical bases and structure of existing watershed models.

Unit V

Environmental impact assessment of watersheds. Quantitative evaluation of management techniques. National land use policy, legal and social aspects. Case studies of watershed management.

VI. Practical

Selection and delineation of a watershed. Benchmark surveys. Preparation of watershed land use map. Preparation of watershed development proposal. Preparation of watershed evaluation and impact assessment report. Application of watershed models for evaluation of conservation treatments. Use of Remote Sensing and GIS in watershed management and modeling.

VII. Learning outcome

The students will be able to understand different conservation practices and their effect on watershed behavior. They can also estimate the geomorphologic parameters of particular watershed which is quite useful for watershed planning and development of watershed models.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1	Concept of watershed, its hydrological and geomorphological characteristics	2
2	Status of watershed management programs in India	2
3	Problems of desertification and degradation	2
4	Concept of watershed management and sustainability, participatory approach and operational watershed	3
5	Surveys, monitoring, reclamation and conservation of agricultural and forest watersheds, hill slopes and ravines	3
6	Watershed management research instrumentation and measurement, problem identification, simulation and synthesis	2
7	Rainfed farming and drought management	2
8	Modeling of flood and drought phenomenon	2
9	Use of Remote Sensing and GIS in watershed management and modeling	2
10	Watershed modeling approaches, mathematical bases and structure of existing watershed models	3
11	Environmental impact assessment of watersheds	2
12	Quantitative evaluation of management techniques	2
13	National land use policy, legal and social aspects	2
14	Case studies of watershed management	3
	Total	**32**

IX. List of Practicals

S.No.	Topic	No of Practicals
1	Selection and delineation of a watershed	3
2	Benchmark surveys	2
3	Preparation of watershed land use map	2
4	Preparation of watershed development proposal	3
5	Preparation of watershed evaluation and impact assessment report	2
6	Application of watershed models for evaluation of conservation treatments	2
7	Use of Remote Sensing and GIS in watershed management and modelling	2
	Total	**16**

X. Suggested Reading

- Dhaliwal GS Hansra BS and Ladhar SS. 1993. *Wetlands, their Conservation and Management*. Punjab Agricultural University, Ludhiana.
- Dhruvanarayana VV, Sastry G and Patnaik US. *Watershed Management*. Publ. and Inf. Dv., ICAR, Krishi Anusandhan Bhavan, New Delhi.
- Singh RV. 2000. *Watershed Planning and Management*. Second Edition Yash Publishing House, Bikaner.
- Suresh R. 2017. *Watershed Planning and Management*. Standard Publication and Distribution, Delhi.
- Tideman EM. 1999. *Watershed Management* (*Guidelines for Indian Conditions*). Omega Scientific Publishers, New Delhi.

I. Course Title : Flow Through Porous Media

II. Course Code : SWCE 506

III. Credit Hours : 2+0

IV. Aim of the course

To provide comprehensive knowledge to the students in aquifer and fluid properties, unsaturated flow theory and movement of groundwater in fractured and swelling porous media.

V. Theory

Unit I

Aquifer and fluid properties, forces holding water in soils, hydrodynamics in porous media and limitations of governing laws.

Unit II

Differential equations of saturated flow, initial and boundary conditions. Dupuit and Business approximations and linearization techniques.

Unit III

Stream functions, potential functions and flow net theory. Analysis of seepage from canals and ditches.

Unit IV

Unsaturated flow theory, Infiltration and capillary rise flux dynamics. Movement of groundwater in fractured and swelling porous media.

Unit V

Hydro-dynamic dispersion in soil-aquifer system. Velocity hydrograph, flow characteristics at singular points, examples of velocity hydrograph, solution by complex velocity, solution of triangular dam, drainage in retaining structures, influence of seepage on stability of slopes, drainage methods for stability of slopes.

VI. Learning outcome

The students will be able to understand physical properties of flow through porous media. Competence on various laws governing dynamics of flow through porous media. Understanding of hydrodynamics in porous media, governing laws and boundary conditions.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Aquifer and its classification, properties of aquifers and fluids	1
2.	Forces responsible for holding water in soil and movement, hydrostatic pressure distribution	1
3.	Porosity, permeability and hydraulic conductivity: its importance in fluids flow	1
4.	Hydrodynamics in porous media: Continuum approach to porous media, Representative Elementary Volume (REV), linear and aerial porosity, velocity and specific discharge relationship in porous medium	3
5.	Generalization of Darcy Law in isotropic and anisotropic layered porous medium, deviation from Darcy Law and limitations of governing laws in flow through porous media	3
6.	Saturated flow: Differential equations for flow through saturated medium, initial and boundary conditions, types of boundary conditions, boundary and initial value problems	3
7.	Dupuit and Boussinesq approximations and linearization: Dupuit assumption and equation, Boussinesq linearization Techniques and solutions	3
8.	Unsaturated flow theory: Continuity and conservation equations for a homogeneous fluid in non-deforming medium and deforming medium, continuity equation for compressible fluid and moveable solid matrix	6
9.	Infiltration and capillary rise flux dynamics, movement of groundwater in fractured and swelling porous media	2
10.	Stream and potential functions: Stream functions in two and three dimensional flow, potential functions and flow net theory	3
11.	Analysis of seepage from canals and ditches	2
12.	Hydro-dynamic dispersion in soil-aquifer system: Hydro-dynamic dispersion, derivation of dispersion and diffusion equation	3
13.	Velocity hydrograph: Flow characteristics at singular points, examples of velocity hydrograph, solution by complex velocity, solution of triangular dam, drainage in retaining structures, influence of seepage on stability of slopes, drainage methods for stability of slopes	3
	Total	**34**

X. Suggested Reading

- Bears J. 1972. *Dynamics of Fluids in Porous Media*. American Elsevier Publishing Co. Inc. New York.

- Bear J and Arnold V. *Modeling Groundwater Flow and Pollution*. D. Reidel Publishing Company.
- Collins RE. 1961. *Flow of Fluids through Porous Materials*. Reinhold publishing cooperation, New York.
- Core AT *Flow in Porous Media*.
- De Wiest Roger JM. 1969. *Flow through Porous Media*. Academic press, New York.
- Helmut K *Soil Physics*. pp. 7-79.
- Verruijt A. 1982. *Theory of Groundwater Flow*. 2nd Edn., Macmillan, London

I. Course Title : GIS and Remote Sensing for Land and Water Resource Management

II. Course Code : SWCE 507/IDE 507

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint students with recent technology of RS and GIS including satellite data analysis, digital image processing and thematic mapping of land use, surface and ground water.

V. Theory

Unit I

Physics of remote sensing, electromagnetic radiation (EMR), interaction of EMR with atmosphere, earth surface, soil, water and vegetation. Remote sensing platform, monitoring atmosphere, land and water resources: LANDSAT, SPOT, ERS, IKONOS and others, Indian Space Programme.

Unit II

Satellite Data analysis: Visual interpretation, digital image processing, image pre-processing, image enhancement, image classification and data merging.

Unit III

Definition: Basic components of GIS, map projections and co-ordinate system, spatial data structure-raster, vector, spatial relationship, topology, geodatabase models, hierarchical network, relational, object-oriented models, integrated GIS database-common sources of error–data quality: Macro, micro and usage level components, meta data, Spatial data transfer standards.

Unit IV

Thematic mapping, measurements in GIS: Length, perimeter and areas. Query analysis, reclassification: Buffering, neighbourhood functions, map overlay: Vector and raster overlay: Interpolation, network analysis, digital elevation modelling. Analytical Hierarchy Process, Object oriented GIS–AM/FM/GIS, Web Based GIS.

Unit V

Spatial data sources: 4M GIS approach water resources system, Thematic maps, rainfall runoff modelling, groundwater modelling, water quality modelling and flood inundation mapping and modelling. Drought monitoring, cropping pattern change analysis, performance evaluation of irrigation commands. Site selection for artificial recharge, reservoir sedimentation.

VI. Practical

Familiarization with the Remote sensing instruments and satellite imagery. Aerial

Photograph and scale determination with stereoscope. Interpretation of satellite imageries and aerial photographs. Determination of Parallaxes in images. Introduction to digital image processing software and GIS software and their working principles. Generation of digital elevation model (DEM) for land and water resource management. Case studies on mapping, monitoring and management of natural resources using remote sensing and GIS.

VII. Learning outcome

Students will be able to use satellite remote sensing to perform image analysis and classification for developing thematic maps. Able to integrate satellite data with GIS to undertake recourse mapping and planning studies.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction and brief history of RS and GIS, applications of RS and GIS	1
2.	Physics of remote sensing. Electromagnetic radiation (EMR), interaction of EMR with atmosphere, earth surface, soil, water and vegetation	1
3.	Remote sensing platforms: Monitoring atmosphere, land and water resources: LANDSAT, SPOT, ERS, IKONOS and others. Indian Space Programme	2
4.	Satellite data analysis. Visual interpretation.	1
5.	Digital image processing- Image pre-processing, Image enhancement, Image classification, data merging.	3
6.	Basic components of GIS- Map projections and co-ordinate system.	2
7.	Spatial data sources,Thematic maps	1
7.	Spatial data structure: Raster, vector data, Spatial relationship-Topology	1
8.	Geodatabase models: Hierarchical, network, relational, object-oriented models. Integrated GIS database	3
9.	Data quality, Common sources of error, Macro, micro and Usage level components, Meta data and Spatial data transfer standards	2
10.	Measurement in GIS- Length, perimeter and areas	1
10.	Query analysis. Reclassification, Buffering and Neighbourhood functions	1
11.	Map overlay: Vector and raster overlay	1
12.	Interpolation and network analysis	1
13.	Digital elevation modelling. Analytical Hierarchy Process. Object oriented GIS, AM/FM/GIS and Web Based GIS	3
14.	GIS approach to Rainfall runoff modelling, Flood inundation mapping and modelling	2
15.	GIS approach to Groundwater modelling and water quality modelling	2
16.	Site selection for artificial recharge. Reservoir sedimentation	1
17.	Drought monitoring	1
18.	Performance evaluation of irrigation commands	1
19.	Cropping pattern change analysis	1
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Familiarization with the remote sensing instruments and satellite imagery	1
2.	Methods of establishing ground truth survey and Comparison between ground truth and remotely sensed data	2
3.	Aerial Photograph and scale determination with stereoscope	1
4.	Interpretation of satellite imagery and aerial photograph	1
5.	Determination of Parallaxes in images	1
6.	Demonstration on GPS; Provision of Ground Control by GPS in different mode	1
7.	Introduction to digital image processing software	1
8.	Introduction to GIS software	1
9.	Data input; Data editing and Topology creation -Digitization of point, line & polygon features	
10.	SRTM & CARTO DEM download from web and Georeferencing of an image	1
11.	Delineation of Watershed, DEM generation: slope, Aspect, flow direction, Flow accumulation, Drainage, network and morphometric analysis	2
12.	LULC by supervised classification and LULC by unsupervised classification	1
13.	Application of Remote Sensing data and GIS for water quality parameters	
14.	Temporal satellite data analysis for vegetation condition, crop water requirement calculation	1
15.	Erosion mapping using aerial and satellite Data	1
	Total	**17**

X. Suggested Reading

- Ian HS, Cornelius and Steve C. 2002. *An Introduction to Geographical Information Systems*. Pearson Education, New Delhi.
- James BC and Randolph HW. 2011. *Introduction to Remote Sensing*. The Guilford Press.
- Lilles TM and Kiefer RW. 2008. *Remote Sensing and Image Interpretation*. John Wiley and Sons.
- Paul Curran PJ. 1985. *Principles of Remote Sensing*. ELBS Publications.
- Rees WG. 2001. *Physical Principles of Remote Sensing*. Cambridge University Press.

I. Course Title : Climate Change and Water Resources

II. Course Code : SWCE 508

III. Credit Hours : 3+0

IV. Aim of the course

To acquaint students about the concept of climate change and its impact on surface and ground water resources. To understand adaptation and mitigation strategy under climate change scenario.

V. Theory

Unit I

The climate system: Definitions, climate, climate system, climate change. Drivers of climate change, characteristics of climate system components: Greenhouse effect, carbon cycle, wind systems. Trade winds and the Hadley Cell, ozone hole in the stratosphere, El Nino, La Nina– ENSO, teleconnections.

Unit II

Impacts of climate change: Observed and projected, global and Indian scenario, observed changes and projected changes of IPCC: Impacts on water resources, NATCOM Report, impacts on sectoral vulnerabilities, SRES, different scenarios, climate change impacts on ET and irrigation demand.

Unit III

Tools for vulnerability assessment: Need for vulnerability assessment, steps for assessment, approaches for assessment. Models: Quantitative models, Economic models, impact matrix approach, Box models, Zero-dimensional models, Radioactive-convective models, Higher-dimension models, EMICs (Earth-system models of intermediate complexity), GCMs (global climate models or general circulation models), Sectoral models.

Unit IV

Adaptation and mitigation water: Related adaptation to climate change in the fields of ecosystems and biodiversity, agriculture and food security, land use and forestry, human health, water supply and sanitation, infrastructure and economy (insurance, tourism, industry and transportation), Adaptation, vulnerability and sustainable development.

Unit V

Sector specific mitigation: Carbon dioxide capture and storage (CCS), bio-energy crops, biomass electricity, hydropower, geothermal energy, energy use in buildings, land-use change and management, cropland management, afforestation and reforestation. Potential water resource conflicts between adaptation and mitigation. Implications for policy and sustainable development.

Case studies: Water resources assessment case studies: Ganga Damodar Project, Himalayan glacier studies, Ganga valley project. Adaptation strategies in assessment of water resources. Hydrological design practices and dam safety, operation policies for water resources projects. Flood management strategies, drought management strategies, temporal and spatial assessment of water for irrigation, land use and cropping pattern, coastal zone management strategies.

VI. Learning outcome

The students will be able to understand climate change concept particularly on surface and ground water. Students can have in depth knowledge about adaptation and mitigation strategies in respect of climate change.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Definitions- climate, climate system, climate change; Drivers of climate change	3
2.	Climate system and its components; wind systems, carbon cycle, Greenhouse effect, Trade winds and the Hadley Cell, ozone hole in the stratosphere, El Nino, La Nina– ENSO, teleconnections	3
3.	Climate scenarios- SRES, RCP, Scenario based observed and projected climate changes in Indian and global context	3

S.No.	Topic	No. of Lectures
4.	IPCC projected climate change impacts on water resources, NATCOM Report-impacts on ET and irrigation demand	3
5.	Vulnerability assessment: Need, steps for assessment, approaches for assessment	2
6.	Models: Quantitative models, Economic models, impact matrix approach, Box models, Zero-dimensional models, Radioactive-convective models, Higher-dimension models, EMICs (Earth-system models of intermediate complexity), GCMs (global climate models or general circulation models), Sectoral models	4
7.	Adaptation to climate change in the fields of ecosystems and biodiversity, agriculture and food security, land use and forestry, human health, water supply and sanitation, infrastructure and economy (insurance, tourism, industry and transportation)	4
8.	Sector specific mitigation: Carbon dioxide capture and storage (CCS)	2
9.	Sector specific mitigation: bio-energy crops, biomass electricity, hydropower, geothermal energy, energy use in buildings	2
10.	Sector specific mitigation: land-use change and management, cropland management, afforestation and reforestation	2
11.	Potential water resource conflicts between adaptation and mitigation	2
12.	Implications for policy and sustainable development.	2
13.	Case studies- Ganga Damodar Project, Himalayan glacier studies, Ganga valley project	5
14.	Adaptation strategies in assessment of water resources- Temporal and spatial assessment of water for irrigation, land use and cropping pattern	2
15.	Adaptation strategies in assessment of water resources- Hydrological design practices and dam safety, operation policies for water resources projects	3
16.	Flood management strategies, coastal zone management strategies.	3
	Total	**45**

VIII. Suggested Reading

- Majumdar PP and Nagesh KD. *Floods in a Changing Climate: Hydrological Modelling*. Cambride University Press, New York.
- Pathak H, Agarwal PK and Singh SD. *Mitigation in Agriculture: Methodology for Assessment and Application*. Division of Environmental Sciences, IARI New Delhi.
- Rao YS, Zhang TC Ojha, Gurjar BR, Tyagi RD, Kao CM (eds). *Climate Change Modelling, Mitigation, and Adaptation*. American Society of Civil Engineers.
- Srinivasa RK and Nagesh KD. *Impact of Climate Change on Water Resources with Modelling Techniques and Case Studies*. Springer publications, New York.
- Tamim Y and Caitlin AG. *Climate Change and Water Resources*. Springer Publication.

I. Course Title : Numerical Methods in Hydrology

II. Course Code : SWCE 509

III. Credit Hours : 2+0

IV. Aim of the course

To acquaint students about the concept of linear space, triangular and quadrilateral shape functions, isoparametric elements and transformation of coordinates.

V. Theory

Unit I

Review of finite difference operators. Concept of linear space and basis functions. Approximating from finite dimensional sub spaces.

Unit II

Variational and weighted residual methods. Langrange polynomials. Triangular and quadrilateral shape functions.

Unit III

Isoparametric elements and transformation of coordinates. Basis functions in three dimensions.

Unit IV

Galerkin finite element solution of Laplace, diffusion and dispersion-convection equations.

Unit V

Method of collocation, application in surface and sub surface hydrology.

VI. Learning outcome

The students are able to understand numerical methods in hydrology by having in-depth knowledge of linear space and finite element solution in surface and sub-surface hydrology.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1	Review of finite difference operators	2
2	Concept of linear space and basis functions	3
3	Approximating from finite dimensional sub spaces	3
4	Variational and weighted residual methods	2
5	Langrange polynomials	2
6	Triangular and quadrilateral shape functions	3
7	Isoparametric elements and transformation of coordinates.	3
8	Basis functions in three dimensions	3
9	Galerkin finite element solution of Laplace	3
10	Diffusion and dispersion-convection equations	3
11	Method of collocation	2
12	Application in surface and sub surface hydrology	3
	Total	**32**

VIII. Suggested Reading

- Bear J and Verruijt A. 1987. *Modeling Groundwater Flow and Pollution*. 414 pp. Dordrecht, Boston.
- Carr JR. 1995. *Numerical Analysis for the Geological Sciences*. 592 pp. Prentice-Hall, Englewood Cliffs NJ.
- George H and Patricia W. 2000. *Numerical Methods in the Hydrological Sciences*. American Geophysical Union, Florida Avenue, NW.
- Gerald CF and Wheatley PO. 1999. *Applied Numerical Analysis*. 6th ed., 768 pp, Addison-Wesley, Reading, MA.
- Middleton GV. 2000. *Data Analysis in the Earth Sciences using MATLAB* 260 pp., Prentice Hall, Saddle River NJ.

- Wang HF and Anderson MP. 1982. *Introduction to Groundwater Modeling: Finite Difference and Finite Element Methods*. 237 pp, W.H. Freeman and Co., San Francisco.

I. Course Title : Dryland Water Management Technologies

II. Course Code : SWCE 510

III. Credit Hours : 2+0

IV. Aim of the course

To provide detail knowledge about analysis of severity of drought assessment and various dry land water management technologies suitable for conservation, harvesting and enhancing productivity of rainfed areas.

V. Theory

Unit I

Drought severity assessment: Meteorological, hydrological and agricultural methods. Drought indices. GIS based drought information system, drought vulnerability assessment and mapping using GIS. DPAP programme, drought monitoring constraints, limiting crop production in dry land areas. Types of drought, characterization of environment for water availability, crop planning for erratic and aberrant weather conditions.

Unit II

Stress physiology and crop resistance to drought, adaptation of crop plants to drought, drought management strategies. Preparation of appropriate crop plans for dry land areas. Mid contingent plan for aberrant weather conditions.

Unit III

Land shaping and land development for soil moisture conservation. Improvement of tillage and soil management by implements and engineering practices. Soil and moisture conservation for rainfed lands through improved implements and engineering practices. Gel technology.

Ex-situ measures: Water harvesting-micro catchments. Design of small water harvesting structures: Farm Ponds, percolation tanks their types and design, recycling of runoff water for crop productivity.

Unit IV

Crops and cropping practices related to soil and moisture conservation. Fertility management in dryland farming. Planning and development of watersheds from engineering view point. Case studies.

Unit V

Application of aerial photography in surveys and planning of watersheds for rainfed agriculture.

Use of Remote Sensing in soil moisture estimation.

VI. Learning outcome

The students will be able to understand drought severity assessment techniques alongwith new and appropriate methods of rainwater conservation and harvesting technologies for rainfed areas.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Drought severity assessment: Meteorological, hydrological and agricultural methods	2
2.	Drought indices	1
3.	GIS based drought information system, drought vulnerability assessment and mapping using GIS	2
4.	DPAP programme, drought monitoring constraints, limiting crop production in dry land areas	2
5.	Types of drought: characterization of environment for water availability	1
6.	Types of drought: crop planning for erratic and aberrant weather conditions	1
7.	Stress physiology and crop resistance to drought	1
8.	Adaptation of crop plants to drought and drought management strategies	1
9.	Preparation of appropriate crop plans for dry land areas	2
10.	Mid contingent plan for aberrant weather conditions	1
11.	Land shaping and land development for soil moisture conservation	1
12.	Improvement of tillage and soil management by implements and engineering practices	2
13.	Soil and moisture conservation for rainfed lands through improved implements and engineering practices	2
14.	Introduction of Gel technology for conservation measures	1
15.	*Ex-situ* measures: Water harvesting-micro catchments	1
16.	Design of small water harvesting structures: Farm Ponds	1
17.	Design of small water harvesting structures: percolation tanks their types and design	2
18.	Recycling of runoff water for crop productivity	1
19.	Crops and cropping practices related to soil and moisture conservation	1
20.	Fertility management in dryland farming	1
21.	Planning and development of watersheds from engineering view point	2
22.	Planning and development of watersheds - Case studies	1
23.	Application of aerial photography in surveys and planning of watersheds for rainfed agriculture	1
24.	Use of Remote Sensing in soil moisture estimation	1
	Total	**32**

VIII. Suggested Reading

- Das NR. 2007. *Tillage and Crop Production*. Scientific Publishers.
- Dhopte AM. 2002. *Agro Technology for Dryland Farming*. Scientific Publ.
- Gupta US. 1995. *Production and Improvements of Crops for Drylands*. Oxford & IBH
- Singh RP. 1988. *Improved Agronomic Practices for Dryland Crops*. CRIDA.
- Singh RP. 2005. *Sustainable Development of Dryland Agriculture in India*. Scientific Publ.
- Singh RV. 2003. *Watershed Planning and Management*. Second Edition. Yash Publishing House, Bikaner.
- Singh SD. 1998. *Arid Land Irrigation and Ecological Management*. Scientific Publishers.

Course Title with Credit Load
Ph.D. in Soil and Water Conservation Engineering

Major Courses (Requirement: 12 Credits)

Course Code	Course Title	Credit Hours
*SWCE 601	Advances in Hydrology	2+1
*SWCE 602	Soil and Water Systems Simulation and Modeling	2+1
SWCE 603	Reservoir Operation and River Basin Modeling	2+1
SWCE 604	Modeling Soil Erosion Processes and Sedimentation	2+1
SWCE 605	Waste Water Treatment and Utilization	3+0
SWCE 606	Hydro-Chemical Modeling	2+0
	Total	**13+4**

Minor Courses (Requirement: 06 Credits)

Course Code	Course Title	Credit Hours
IDE 603	Hydro-Mechanics and Ground Water Modeling	3+0
IDE 604	Soil-Water-Plant-Atmospheric Modeling	2+1
IDE 606	Multi Criteria Decision Making System	2+0
CSE 503	Neuro-Fuzzy Application in Engineering	2+1
CSE 506	Digital Image Processing	2+1
	Any other course(s) of other department can be taken as per recommendations of the students advisory committee	

Supporting Courses (Requirement: 05 Credits)

Course Code	Course Title	Credit Hours
*CPE-RPE	Research and Publication Ethics	1+1
	Courses from subject matter fields (other than Major and Minor) relating to area of special interest and research problem can be taken as per recommendations of the student's advisory committee.	

*Course has been made compulsory by UGC for PhD students. Course code and its detailed course outline to be adopted in toto as recommended by UGC.

List of other Essential Requirements

Course Code	Course Title	Credit Hours
SWCE 691	Seminar-I	0+1
SWCE 692	Seminar-II	0+1
SWCE 699	Thesis Research	0+75

Course Contents
Ph.D. in Soil and Water Conservation Engineering

I. Course Title : Advances in Hydrology

II. Course Code : SWCE 601

III. Credit Hours : 2+1

IV. Aim of the course

To provide comprehensive knowledge to the students about hydrologic models, flood frequency analysis and formulation of statistical models.

V. Theory

Unit I

Hydrologic models, processes and systems. Uncertainty in hydrological events. Statistical homogeneity.

Unit II

Probabilistic concept. Frequency analysis. Probability distribution of hydrological variables. Confidence intervals and hypothesis testing.

Unit III

Simple and multiple linear regressions, correlation, statistical optimization and reliability of linear regression models. Analysis of hydrologic time series and modeling. Auto–correlation, correlogram and cross-correlation analysis.

Unit IV

Markov processes, stochastic hydrologic models including Markov chain models. Generation of random variates. Hydrology of climate extremes. Area-duration-frequency curves. Regional flood frequency analysis.

Unit V

Formulation of various steps involved in formulation of statistical models and their application in hydrology.

VI. Practical

Parametric and non parametric test of time series data. Development of probabilistic and deterministic models for time series data of rainfall and runoff. Development of hydrologic models and frequency analysis for specified data set using SPSS and other software used in hydrologic modeling.

VII. Learning outcome

The students will be able to develop the hydrologic modeling and find out their trend as well as periodic component. To develop the stochastic and deterministic models for forecasting precipitation for prediction of floods and droughts.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Hydrologic models, processes and systems	1
2.	Uncertainty in hydrologic events risks, uncertainty	1
3.	Statistical homogeneity in hydrologic processes	1
4.	Probability, total probability theorem, Bayes theorem	2
5.	Moment generating function, statistical parameters	1
6.	Probability distribution of hydrologic variables	2
7.	Confidence interval one sided, two sided, Hypothesis testing test statistics	2
8.	Regression analysis, simple regression, confidence interval on regression coefficient, regression line, inference on regression	3
9.	Multiple linear regression	2
10.	Optimization of regression coefficients, Statistical optimization and reliability of linear regression models	3
11.	Time series analysis, components, stationarity, Auto correlation, correlograms, Cross correlation analysis	3
12.	Generating processes, Markov process- first order, higher order	2
13.	Statistical principles and techniques for time series modeling	2
14.	Markov chain models, Examples of Markov chain models in hydrology	2
15.	Autoregressive models, Autoregressive modeling of annual time series, Examples of autoregressive modeling	3
16.	Hydrology of climate extremes. Area-duration-frequency curves. Regional flood frequency analysis	2
17.	Formulation of various steps involved in formulation of statistical models and their application in hydrology	2
	Total	**34**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Study of parametric and non parametric test of time series data	4
2.	Development of probabilistic models for time series data of rainfall and runoff	2
3.	Development of deterministic models for time series data of rainfall and runoff	2
4.	Development of hydrologic models for specified data set using SPSS and other software used in hydrologic modeling	2
5.	Development of frequency analysis for specified data set using SPSS and other software used in hydrologic modeling	2
6.	Development of the stochastic models for forecasting precipitation for prediction of floods and droughts	2
7.	Development of deterministic models for forecasting precipitation for prediction of floods and droughts	2
	Total	**16**

X. Suggested Reading

- Garg SK. 1987. *Hydrology and Water Resources Engineering*. Khanna Publications.
- Hann CT. *Advanced Hydrology*. Oxford Publications House.
- Linseley RK Jr, Kohler MA and Paulhus JLH. 1975. *Applied Hydrology*. McGraw Hill.
- Mutreja KN. 1986. *Applied Hydrology*. Tata McGraw Hill.
- Singh VP. 2010. *Hydrological Modelling*. Springer, New York.

I. Course Title : Soil and Water Systems Simulation and Modeling

II. Course Code : SWCE 602

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint students about the rainfall-runoff models, sediment model, overland and channel flow simulation and decision support systems using simulation models.

V. Theory

Unit I

Models and their classification, simulation procedure. Rainfall-runoff models. Infiltration models, evapo-transpiration models, structure of a water balance model.

Unit II

Overland and channel flow simulation. Modeling approaches and parameters. Stream flow statistics. Surface water storage requirements.

Unit III

Flood control storage capacity and total reservoir capacity. Surface water allocations. Palaeo-channels. Ground water models.

Unit IV

Design of nodal network. General systems frame work. Description of the model. Irregular boundaries. Decision support system using simulation models. Monte-Carlo approach to water management.

Unit V

Stanford watershed model and input data requirements of various hydrologic modeling systems. Soil water assessment tool (SWAT). Groundwater modeling and solute transport.

VI. Practical

Rainfall-runoff models. Infiltration models. Stanford watershed model (SWM). Channel flow simulation problems. Stream flow statistics. Model parameters and input data requirements of various software's of surface hydrology and groundwater. Hydrologic modeling system. Soil water management model. Soil water assessment tool (SWAT). Catchments simulation hydrology model. Stream flow model and use of dimensionless unit hydrograph. Generalized groundwater models.

VII. Learning outcome

The students will be able to develop the model for overland and channel flow simulation, which can be used for watershed management and planning and also able to simulate the ground water and surface water by developing the ground water model and runoff models.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1	Models and their classification, simulation procedure	2
2	Rainfall-runoff models	3
3	Infiltration models, evapo-transpiration models, structure of a water balance model	2

S.No.	Topic	No. of Lectures
4	Overland and channel flow simulation	2
5	Modeling approaches and parameters. Stream flow statistics	2
6	Surface water storage requirements	1
7	Flood control storage capacity and total reservoir capacity	2
8	Surface water allocations	1
9	Palaeo-channels	1
10	Ground water models	2
11	Design of nodal network	1
12	General systems frame work	1
13	Description of the model	1
14	Irregular boundaries	1
15	Decision support system using simulation models	2
16	Monte-Carlo approach to water management	2
17	Stanford watershed model and input data requirements of various hydrologic modeling systems	2
18	Soil water assessment tool (SWAT)	2
19	Groundwater modeling and solute transport	2
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Rainfall-runoff models	2
2.	Infiltration models	1
3.	Stanford watershed model (SWM)	1
4.	Channel flow simulation problems	1
5.	Stream flow statistics	2
6.	Model parameters and input data requirements of various software's of surface hydrology and groundwater	2
7.	Hydrologic modeling system. Soil water management model	2
8.	Soil water assessment tool (SWAT). Catchments simulation hydrology model	2
9.	Stream flow model and use of dimensionless unit hydrograph	1
10.	Generalized groundwater models	2
	Total	**16**

X. Suggested Reading

- Biswas AK. 1976. *Systems Approach to Water Management*. McGraw Hill.
- Cox DR and Mille HD. 1965. *The Theory of Stochastic Processes*. John Wiley & Sons.
- Eagleson PS. 1970. *Dynamic Hydrology*. Mc Graw Hill.
- Himmel Blau DM and Bischoff KB. 1968. *Process Analysis and Simulation Deterministic Systems*. John Wiley & Sons.
- Linsley RK, Kohler MA and Paulhus JLH. 1949. *Applied Hydrology*. McGraw Hill.
- Schwar RS and Friedland B. 1965. *Linear Systems*. McGraw Hill.
- Ven Te Chow, David R Maidment and Mays LW. 1998. *Applied Hydrology*. McGraw Hill.

I. Course Title : Reservoir Operation and River Basin Modeling

II. Course Code : SWCE 603

III. Credit Hours : 2+1

IV. Aim of the course

To provide comprehensive knowledge to the students about water management plans, demand analysis and water resources planning in river basins including stochastic and deterministic modeling.

V. Theory

Unit I

Water resources system analysis: Techniques, concept, objectives and applications.

Unit II

Identification and evaluation of water management plans. Demand analysis, policy formulation. Water resources planning objectives. Water resources planning under uncertainty.

Unit III

Definition of terminologies and basic concepts. Theories and principles of IRBM processes/phases in integrated river basin management. River basins, river functions. Human interventions and impacts. River basins in India, related case studies. Water resources planning in river basins. Operational management, tools and methods. Monitoring, acquisition and processing of water resource data.

Unit IV

Statistical methods. Decision support systems. Deterministic river basin modeling. Stream flow estimation, estimating reservoir storage, mass diagram analysis, sequent peak analysis, single and multi-reservoir operation models. Economics and finance.

Unit V

Stochastic river basin modeling: Single reservoir design and operation, multisite river basin models, stochastic linear programming operation models.

VI. Practical

Development of regression models, stochastic models and deterministic models for river basin based on stream flow data. Estimation of reservoir storage and preparation of operation models.

VII. Learning outcome

The students will be able to develop the model for effective water resources planning for river basins, identification and evaluation of water management plans as well as in-depth knowledge of stochastic and deterministic modeling.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction–Concepts of Systems and Systems Analysis; Techniques, objectives and applications	2
	Applications of Water resources system analysis	1
2.	Identification and evaluation of water management plans-water demand analysis, Water resources planning objectives	2
3.	Water resource planning and management approaches-Top-Down Planning and Management; Bottom-Up Planning and Management Integrated Water Resources Management	1
4.	Water resource management policy formulation, Water resources planning under uncertainty	1

S.No.	Topic	No. of Lectures
5.	River basins, river functions, Theories and principles of IRBM processes/phases in integrated river basin management	1
6.	Human interventions and impacts in in integrated river basin management	1
7.	River basins in India- related case studies	1
8.	Water resources planning in river basins- Operational management, tools and methods	2
9.	Water resources planning in river basins - Monitoring, acquisition and processing of water resource data	2
10.	Economic Considerations in Water Resources Planning	1
10.	Deterministic river basin modeling-Stream flow estimation, estimating reservoir storage, mass diagram analysis, sequent peak analysis	2
11.	Deterministic river basin modeling- Reservoir Sizing; Reservoir Operation – standard operating policy, optimal operating policy; multi-reservoir systems,	6
12.	Concept of Reliability	1
13.	Stochastic river basin modeling: Basic probability theory,	2
14.	Single reservoir design and operation-Chance constrained Linear Programming for reservoir operation and design	3
15.	Stochastic river basin modeling: multisite river basin models,	1
	Model Formulations and Case Studies- Conjunctive use of ground and surface water; Crop yield optimization, Multi-basin and multi-reservoir systems	3
	Total	**33**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Development of regression models	1
2.	Regression analysis	1
3.	Correlation analysis	1
4.	Simple Linear Regression and coefficient of determination	1
5.	Discrete and Continuous probability - Random Variable and Variate	1
6.	Deterministic models for river basin based on stream flow data	1
7.	Stochastic models for river basin based on stream flow data	1
8.	Stochastic river basin modeling	1
9.	Stochastic linear programming operation models	1
10.	Single and multi-reservoir operation models	1
11.	Evaluation of water management plans	1
12.	Evaluation of demand analysis	1
13.	Stream flow estimation	1
14.	Estimation of reservoir storage	1
15.	Preparation of operation models	1
16.	Deterministic river basin planning model	1
	Total	**16**

X. Suggested Reading

- Chaturvedi MC 1984. *System Approach to Water Resources Planning and Management*.
- Loucks DP *et al*. 1980. *Water Resources System Planning and Analysis*. Prentice Hall, NJ.
- Major DC and Lenton RL. 1979. *Applied Water Resources System Planning*. Prentice Hall Inc., New Jersey.

I. Course Title : Modeling Soil Erosion Processes and Sedimentation

II. Course Code : SWCE 604

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint students about the concept of modeling upland erosion, reservoir sedimentation and sediment yield models for estimation of soil erosion.

V. Theory

Unit I

Mechanics of soil erosion. Erosion-sedimentation systems of small watersheds. Overland flow theory and simulation. Basic theory of particle and sediment transport. Sediment deposition processes.

Unit II

Modeling upland erosion and component processes. Modes of transport and transport capacity concept and computation. Channel erosion. Erosion and sediment yield measurement and estimates.

Unit III

Reservoir sedimentation surveys and computation. Classification of models, structure and mathematical bases of sediment yield models. Nature and properties of sediment: Individual and group of particles. Critical tractive force, lift and drag forces. Shield's analysis.

Unit IV

Calibration and testing of models. Universal soil loss equation, its modification and revisions. Stochastic and dynamic sediment yield models.

Unit V

Evaluation of erosion control measures. Computer models used for hydrologic and/ or watershed modeling.

VI. Practical

Computation of soil erosion index. Estimation of soil erodibility factor. Design of erosion control structures. Computation of suspended load and sediment load using empirical formulae. Application of sediment yield models. Prediction of sediment loss. Computation of reservoir sedimentation, sounding method.

VII. Learning outcome

The students will be able to estimate the sediment from the particular watershed by using various instruments. Development of the common understanding of mechanics of sediment transportation process and remedies to reduce sedimentation of watersheds

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Mechanics of soil erosion	1
2.	Erosion-sedimentation systems of small watersheds	1
3.	Overland flow theory and simulation	2
4.	Basic theory of particle and sediment transport. Sediment deposition processes	2

S.No.	Topic	No. of Lectures
5.	Modeling upland erosion and component processes	2
6.	Modes of transport and transport capacity concept and computation	2
7.	Channel erosion	1
8.	Erosion and sediment yield measurement and estimates	1
9.	Reservoir sedimentation surveys and computation	2
10.	Classification of models, structure and mathematical bases of sediment yield models	2
11.	Nature and properties of sediment: Individual and group of particles	2
12.	Critical tractive force, lift and drag forces	2
13.	Shield's analysis	2
14.	Calibration and testing of models	2
15.	Universal soil loss equation, its modification and revisions	2
16.	Stochastic and dynamic sediment yield models	2
17.	Evaluation of erosion control measures	2
18.	Computer models used for hydrologic and/or watershed modeling	2
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Computation of soil erosion index	2
2.	Estimation of soil erodibility factor	2
3.	Design of erosion control structures	4
4.	Computation of suspended load and sediment load using empirical formulae	2
5.	Application of sediment yield models	2
6.	Prediction of sediment loss	2
7.	Computation of reservoir sedimentation, sounding method	2
	Total	**16**

X. Suggested Reading

- Garde RJ and Ranga Raju KG. 1977. *Mechanics of Sediment Transport and Alluvial Stream Problems*.Wiley Eastern Ltd.
- Morgan RPC (Ed. D A Davison). 1986. *Soil Erosion and Conservation*. ELBS.
- Longman USDA. 1969. *A Manual on Conservation of Soil and Water*. Oxford & IBH.
- Tripathi RP and Singh HP. 1993. *Soil Erosion and Conservation*. Publisher- New Age International, New Delhi.

I. Course Title : Waste Water Treatment and Utilization

II. Course Code : SWCE 605

III. Credit Hours : 3+0

IV. Aim of the course

To acquaint students about types of waste water and the various treatment measures alongwith the utilization of waste water in agriculture and other sectors.

V. Theory

Unit I

Types of waste water, causes of pollution, analysis of pollutants in the waste effluents, Biological wastewater treatment, biological sludge treatment. Biological systems: Fundamentals of microbiology and biochemistry, bioenergetics and metabolism, kinetics of biological growth. Process analysis: Reaction rates, effect of temperature on reaction rate, enzyme reaction and kinetics, effect of temperature on reaction rate. Reactor analysis, residence time distribution.

Unit II

Sewerage system: Domestic wastewater characteristics, flow equalization, population equivalent, treatment flow chart. Primary, secondary and tertiary treatment of domestic wastewater. Downstream wastewater treatment for reuse and recycle. Need for downstream processing. Guidelines for wastewater recycling. Small and package plants for wastewater treatment.

Unit III

Activated sludge process: Substrate utilization and biomass growth, Monod's kinetics, estimation of kinetic parameters. Process Description and its Modification, Process design, process performance evaluation, trouble shooting. Nitrogen removal-Biological nitrification and denitrification.

Unit IV

Activated sludge process design for nutrient removal. Process operation: (F/M), mean cell residence time, oxygen requirement. Biological and chemical phosphorus removal, Sedimentation of activated sludge. Advanced activated sludge process-Sequencing Batch reactor, Oxidation ditch and membrane bioreactors.

Unit V

Biofilm process: Trickling filter, biotower, rotational biological contactor, integrated activated sludge and biofilm processes. Stabilization ponds and aerated lagoons: Types and their description, design, operation and maintenance. Anaerobic processes: Process description, process design, operation and maintenance, sludge digestion. Sludge treatment-thickening, dewatering-mechanical and sludge drying beds. Utilization of waste water in agriculture and other sectors.

VI. Learning outcome

Students will be able to have in-depth knowledge about waste water treatment methods, sewerage system, activated sludge process, biofilm process. The student will also expose to use of waste water in agriculture and other sectors.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Status of wastewater in India, Sources of contamination and characterization of urban and rural wastewater for irrigation	2
2.	Water quality: Physical, chemical and biological parameters of wastewater	2
3.	Wastewater quality requirement: Potable water standards, wastewater effluent standards, water quality indices. Irrigation water quality standards both national and global and guidelines for their restricted and unrestricted uses.	2
4.	Different types of wastewater, pollutants and contaminants.	1
5.	Impact of wastewater on ecosystem, eutrophication, biomagnification, water borne diseases.	2
6.	Key drivers of wastewater use in agriculture and existing approaches for regulating wastewater reuse in agriculture	2

S.No.	Topic	No. of Lectures
7.	Selection of appropriate forestry trees, fruits, vegetables, oilseeds and food grain crop for wastewater utilization and practices used for irrigation	3
8.	Health Risks Associated with the Use of Wastewater for Irrigation	1
9.	Wastewater treatment methods: Physical, chemical and biological.	3
10.	Choice of (Cost-Effective) Wastewater Treatment Systems for Irrigation	2
11.	General water treatments: Wastewater recycling, constructed wetlands, reed bed system.	2
12.	Carbon foot prints of wastewater reuse. Environmental standards.	2
13.	Management of health and environmental risks of wastewater irrigation	1
14.	Regulation and environmental impact assessment (EIA): Environmental standards-CPCB Norms for discharging industrial effluents to public sewers. Valuation of environmental impacts.	3
15.	Impact on groundwater resources and soil health, EIA process, Stages of EIA-monitoring and auditing. Environmental clearance procedure in India	3
16.	Economics of wastewater irrigation	1
	Total	**32**

VIII. List of Practicals

S.No.	Topic	No. of Practicals
1.	Study on physical, chemical and biological parameters of wastewater	1
2.	Determination of EC and pH of wastewater	1
3.	Determination of BOD of wastewater	1
4.	Determination of COD of wastewater	1
5.	Determination of TSS and TDS of wastewater	1
6.	Determination RSC of wastewater	1
7.	Determination of e-coli in the wastewater	1
8.	On field demonstration of wastewater use for the irrigation	1
9.	Determination of nutrient (N, P and K) concentration in wastewater	2
10.	Field demonstration of impact of waste water on eco-system and human health.	1
11.	Study on various wastewater treatment methods	2
12.	Study on effect of wastewater on contamination of ground water	1
13.	Visit of village pond treatment nearby area	1
14.	Visit of sewerage treatment plant nearby area	1
	Total	**16**

IX. Suggested Reading

- Droste RL. 1997. *Theory and Practice of Water and Wastewater Treatment*. John Wiley.
- Metcalf and Eddy. 2003. *Wastewater Engineering*. 4th Ed., McGraw Hill.
- Qasim SR. 1999. *Wastewater Treatment Plants – Planning, Design and Operation*. CRC Press, Florida.
- Ramalho RS. *Wastewater Treatment*. Wiley.

I. Course Title : Hydro-Chemical Modeling

II. Course Code : SWCE 606

III. Credit Hours : 2+0

IV. Aim of the course

To provide comprehensive knowledge to the students about hydrodynamics of flow through porous media and development of analytical, statistical and numerical models.

V. Theory

Unit I

Review of hydrodynamics in flow through porous media. Miscible displacement, physical processes.

Unit II

Breakthrough curves and mathematical models for miscible displacement. Hydrodynamic dispersion convection equations and its solutions.

Unit III

Statistical models for dispersion. Gaseous (CO_2 and O_2) diffusion equation.

Unit IV

Heat flow through soil by conduction. Concept of adsorption in solute transport.

Unit V

Analytical and numerical models of contaminant transport in unsaturated soil profile and groundwater aquifers.

VI. Learning outcome

Students will be able to demonstrate understanding of hydrodynamics of fluid transport through modeling and will be able to do water quality analysis of lakes and reservoir based physical and chemical characteristics. Develop water reclamation and water reuse plans for irrigation and industries.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Review of hydrodynamics in flow through porous media	7
2.	Miscible displacement, physical processes, breakthrough curves	2
3.	Mathematical models for miscible displacement	5
4.	Hydrodynamic dispersion convection equation and its solutions	4
5.	Heat flow through soil by conduction	2
6.	Concept of adsorption in solute transport	2
7.	Analytical and numerical models of contaminant transport in unsaturated soil profile and groundwater aquifers.	6
8.	Statistical models for dispersion	3
9.	Gaseous (CO_2 and O_2) diffusion equation.	3
	Total	**34**

VIII. Suggested Reading

- Larry W Mays 1996. *Water Resources Handbook*. Mc Graw Hill.
- Metcalf and Eddey 1994. *Wastewater Treatment Engineering and Reuse*. John Wiley.
- Soli J Arceivala 1998. *Wastewater Treatment for Pollution Control*. Tata Mc Graw-Hill.

Details of Minor Courses
Department of Electrical Engineering and Information Technology

I. Course Title : Big Data Analytics

II. Course Code : CSE 501

III. Credit Hours : 2+1

IV. Aim of the course

To understand principles of analyzing and mining big data and to use simple tools to extract useful information from big data sets.

V. Theory

Unit I

Data analysis, data matrix attributes. Data: Algebraic and geometric view, probabilistic view.

Unit II

Basics of data mining and CRISP-DM, organizational and data understanding, purposes, Intents and limitations of data mining, database, data warehouse, data mart and data set, types of data, privacy and security, data preparation, collation and data scrubbing.

Unit III

Data mining models and methods, correlation, association rules, k-means, clustering understanding of concept, preparation and modelling.

Unit IV

Discriminant analysis, linear regression, logistic regression, understanding, preparation and modeling.

Unit V

Decision trees, neural networks, understanding, preparation and modeling.

VI. Practical

Introduction to OpenOffice and RapidMiner in data analytics and mining. Preparing RapidMiner, Importing data, handling missing data, data reduction, handling Inconsistent data, attribute reduction. Performing different analysis using RapidMiner or suitable software.

VII. Learning outcome

Capability to understand the principles behind analysis of big data and apply the same using simple tools.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Data analysis, data matrix attributes	2
2.	Algebraic and geometric view, probabilistic view.	4

S.No.	Topic	No. of Lectures
3.	Basics of data mining and CRISP-DM	2
4.	Organizational and data understanding	3
5.	Intents and limitations of data mining, database, data warehouse, data mart and data set	4
6.	Types of data, privacy and security, data preparation, collation and data scrubbing.	4
7.	Data mining models and methods, correlation, association rules	6
8.	K-means, clustering understanding of concept, preparation and modelling.	5
9.	Discriminant analysis, linear regression, logistic regression, understanding, preparation and modeling.	5
10.	Decision trees, neural networks, understanding, preparation and modeling.	5
	Total	**40**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Working of OpenOffice and RapidMiner	3
2.	Preparing RapidMiner Dataset	3
3.	Handling the inconsistent data, missing data, attribute reduction	4
4.	Performing analysis on dataset using RapidMiner	3
	Total	**13**

X. Suggested Reading

- Dr Matthew *North Data Mining for the Masses A Global Text Project Book* ISBN: 0615684378ISBN-13: 978-0615684376.
- Mohammed J Z, Troy and Wagner M Jr. *Data Mining and Analysis: Fundamental Concepts and Algorithms*. Universidade Federal de Minas Gerais, Brazil. Cambridge University Press ISBN 978-0-521-76633-3 Hardback.

I. Course Title : Artificial Intelligence

II. Course Code : CSE 502

III. Credit Hours : 2+1

IV. Aim of the course

To introduce students with techniques and capabilities of artificial intelligence (AI) and enable them to do simple exercises.

V. Theory

Unit I

Definitions of intelligence and artificial intelligence. What is involved in intelligence? Disciplines important to AI. History of development of AI. Different types of AI. Acting humanly, Turing test. AI systems in everyday life. Applications of AI.

Unit II

Classical AI, concept of expert system, conflict resolution, multiple rules, forward chaining, backward chaining. Advantages and disadvantages of expert system. Fuzzy logic and fuzzy rules. Fuzzy expert systems.

Unit III

Problem solving using AI, search techniques, breadth first search, depth first search, depth limited search, bidirectional search, heuristic search, problems and examples. Knowledge representation, frames, methods and demons, correlations, decision trees, fuzzy trees.

Unit IV

Philosophy of AI, Penrose's pitfall, weak AI, strong AI, rational AI, brain prosthesis experiment, the Chinese room problem, emergence of consciousness, technological singularity, Turing test.

Unit V

Modern AI, biological brain, basic neuron model, perceptrons and learning, self-organizing neural network, N-tuple network, evolutionary computing, genetic algorithms, agent methods, agents for problem solving, software agents, multi agents, hardware agents.

VI. Practical

Prolog language, syntax and meaning of Prolog programs, Lists, operators, arithmetic. Using structures: Example programs, controlling backtracking, input and output. more built-in procedures, programming, style and technique, operations on data structures. Advanced tree representations, basic problem-solving strategies, depth-first search strategy, breadth-first search strategy.

VII. Learning outcome

Ability to understand and apply principles of AI in solving simple problems to enable them to get insight into working of AI based systems.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Definitions of intelligence and artificial intelligence. Disciplines important to AI. History of development of AI.	2
2.	Different types of AI. Acting humanly, Turing test. AI systems in everyday life. Applications of AI.	2
3.	Classical AI, concept of expert system, conflict resolution, multiple rules, forward chaining, backward chaining.	3
4.	Advantages and disadvantages of expert system. Fuzzy logic and fuzzy rules. Fuzzy expert systems.	3
5.	Problem solving using AI, search techniques, breadth first search, depth first search	4
6.	Depth limited search, bidirectional search, heuristic search, problems and examples.	4
7.	Knowledge representation, frames, methods and demons, correlations, decision trees, fuzzy trees.	3
8.	Philosophy of AI, Penrose's pitfall, weak AI, strong AI, rational AI, brain prosthesis experiment,	2
9.	Chinese room problem, emergence of consciousness, technological singularity, Turing test.	3
10.	Modern AI, biological brain, basic neuron model, perceptrons and learning, self-organizing neural network,	3
11.	N-tuple network, evolutionary computing, genetic algorithms,	2
12.	Agent methods, agents for problem solving, software agents,	2
13.	Multi agents, hardware agents.	1
	Total	**31**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Prolog language, syntax and meaning of Prolog programs, Lists, operators, arithmetic.	4
2.	Using structures: Example programs, controlling backtracking, input and output. more built-in procedures, programming, style and technique, operations on data structures.	5
3.	Advanced tree representations, basic problem-solving strategies, depth-first search strategy, breadth-first search strategy.	5
	Total	**14**

X. Suggested Reading

- GNU PROLOG *A Native Prolog Compiler with Constraint Solving over Finite Domains* Edition 1.44, for GNU Prolog version 1.4.5 July 14, 2018.
- Ivan Bratko, *Prolog Programming for Artificial Intelligence*.
- Warwick K. 2012. *Artificial Intelligence: The Basics* ISBN: 978-0-415-56482-3 (hbk).

I. Course Title : Neuro-Fuzzy Application in Engineering

II. Course Code : CSE 503

III. Credit Hours : 2+1

IV. Aim of the course

To learn the basic concept of neural network models and fuzzy logic based models and apply fuzzy reasoning and fuzzy inference to solve various agricultural engineering problems

V. Theory

Unit I

Basic concepts of neural networks and fuzzy logic, differences between conventional computing and neuro-fuzzy computing, characteristics of neuro-fuzzy computing.

Unit II

Fuzzy set theory: Basic definitions, terminology, formulation and parameters of membership functions. Basic operations of fuzzy sets: Complement, intersection, vision, T-norm and T- conorm. Fuzzy reasoning and fuzzy Inference: Relations, rules, reasoning, Inference systems, and modeling. Applications of fuzzy reasoning and modelling in engineering problems.

Unit III

Fundamental concepts of artificial neural networks: Model of a neuron, activation functions, neural processing. Network architectures, learning methods. Neural network models: Feed forward neural networks, back propagation algorithm, applications of feed forward networks, recurrent networks, hopfield networks, hebbian learning, self organizing networks, unsupervised learning, competitive learning.

Unit IV

Neuro–fuzzy modelling: Neuro-fuzzy inference systems, neuro-fuzzy control.

Unit V

Applications of neuro-fuzzy computing: Time series analysis and modelling, remote sensing, environmental modelling.

VI. Practical

Training algorithms of artificial neural networks: Basic models, learning rules, single layer and multi-layer feed-forward and feedback networks, supervised and unsupervised methods of training, recurrent networks, modular networks. Fuzzy systems: Fuzzy sets, operations on fuzzy sets, fuzzy relations, measures, fuzzy logic, fuzzy logic controller, integrated hybrid systems. Adaptive neuro-fuzzy inference systems, coactive neuro-fuzzy modelling, classification and regression trees, data clustering algorithms like k-means, fuzzy c-means, mountain and subtractive clustering, rule based structure identification, neuro-fuzzy control, case studies. Use of available software for fuzzy logic and neural networks.

VII. Learning outcome

The students will be able to have the basic concept of neural network models and fuzzy logic-based models and will be in a position to apply fuzzy reasoning and fuzzy inference for various problems of agricultural engineering. They will also learn to develop different types of neural network models.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Basic concepts of neural networks and fuzzy logic, differences between conventional computing and neuro-fuzzy computing, characteristics of neuro-fuzzy computing.	3
2.	Fuzzy set theory: Basic definitions, terminology, formulation and parameters of membership functions.	3
3.	Basic operations of fuzzy sets: Complement, intersection, vision, T-norm and T- conorm. Fuzzy reasoning and fuzzy Inference: Relations, rules, reasoning, Inference systems, and modeling.	4
4.	Applications of fuzzy reasoning and modelling in engineering problems.	3
5.	Fundamental concepts of artificial neural networks: Model of a neuron, activation functions, neural processing. Network architectures, learning methods.	3
6.	Neural network models: Feed forward neural networks, back propagation algorithm, applications of feed forward networks	3
7.	recurrent networks, hopfield networks, hebbian learning, self-organizing networks, unsupervised learning, competitive learning.	4
8.	Neuro–fuzzy modelling: Neuro-fuzzy inference systems, neuro-fuzzy control.	3
9.	Applications of neuro-fuzzy computing: Time series analysis and modelling, remote sensing, environmental modelling.	4
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Training algorithms of artificial neural networks: Basic models, learning rules, single layer and multi-layer feed-forward and feedback networks, supervised and unsupervised methods of training, recurrent networks, modular networks	5
2	Fuzzy systems: Fuzzy sets, operations on fuzzy sets, fuzzy relations, measures, fuzzy logic, fuzzy logic controller, integrated hybrid systems. Adaptive neuro-fuzzy inference systems, coactive neuro-fuzzy modelling, classification and regression trees,	5

S.No.	Topic	No. of Lectures
3	data clustering algorithms like k-means, fuzzy c-means, mountain and subtractive clustering, rule based structure identification, neuro-fuzzy control, case studies. Use of available software for fuzzy logic and neural networks	6
	Total	**16**

X. Suggested Reading

- Jang, JS R, Sun C Tand Mizutan E 1997. *Neuro-Fuzzy and Soft Computing*. Prentice Hall
- Simon Haykin NJ. 1994. *Neural Networks. A Comprehensive Foundation*. McMillan College Publishing Company.
- Klir George J and Forger TA. 1995. *Fuzzy Sets, Uncertainty and Information*. Prentice Hall of India, Pvt. Ltd, New Delhi.
- Kosko B. 1997. *Neural Networks and Fuzzy Systems*. Prentice Hall of India Pvt. Ltd, New Delhi.
- Rao V and Rao H. 1996. *C++ Neural Networks and Fuzzy Logic*. BPB Publications, New Delhi.

I. Course Title : Soft Computing Techniques in Engineering

II. Course Code : CSE 504

III. Credit Hours : 2+1

IV. Aim of the course

To learn the basic concepts of soft computing techniques like neural networks, genetic algorithms and fuzzy systems and apply these techniques for real time problem solving.

V. Theory

Unit I

Introduction to control techniques, need of intelligent control. Architecture for intelligent control. Symbolic reasoning system, rule based systems, the artificial intelligence approach. Knowledge representation and expert systems. Data pre-processing: Scaling, Fourier transformation, principle component analysis and wavelet transformations.

Unit II

Concept of artificial neural networks (ANN) and basic mathematical model, network structures, activation function, back propagation, network size and pruning McCulloch-Pitts neuron model, simple perceptron, adaline and madaline neural networks, feed-forward multi-layer perceptron. Learning and training the neural network. Networks: Hopfield network, self-organizing network and recurrent network. Neural network based controller. Case studies: Identification and control of linear and nonlinear dynamic systems.

Unit III

Genetic algorithm (GA): Basic concept and detail algorithmic steps, adjustment of free parameters. Solution of typical control problems using GA. Concept of other search techniques like tabu search and ant-colony search for solving optimization problems.

Unit IV

Introduction to crisp sets and fuzzy sets, basic fuzzy set operation and approximate reasoning. Introduction to Fuzzy logic modelling and control of a system. Fuzzification, inference and defuzzification. Fuzzy knowledge and rule bases.

Unit V

Fuzzy modeling and control schemes for nonlinear systems. Self-organizing fuzzy logic control. Implementation of fuzzy logic controller. Stability analysis of fuzzy control systems. Intelligent control for SISO/MIMO nonlinear systems. Model based multivariable fuzzy controller.

VI. Practical

To work on data transformations, brief review on statistical criteria for termination of epochs, deciding the input output and hidden layers and neutrons for ANN problems, working on different algorithms of ANN to different problems in agricultural engineering, working with different fuzzy relations, propositions, implications and inferences, working with defuzzification techniques and fuzzy logic controllers, concept of coding, selection, crossover, mutation and application of genetic programming for global optimization, use of available software for application of soft computing techniques.

VII. Learning outcome

To enable students to apply modern engineering techniques which are useful for solving nonlinear and complex functions and to develop application of different soft computing techniques like genetic algorithms, fuzzy logic, neural networks and their combination to real world problems.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction to control techniques, need of intelligent control. Architecture for intelligent control.	3
2.	Symbolic reasoning system, rule based systems, the artificial intelligence approach.	3
3.	Knowledge representation and expert systems.	2
4.	Data pre-processing: Scaling, Fourier transformation, principle component analysis and wavelet transformations.	2
5.	Concept of artificial neural networks (ANN) and basic mathematical model, network structures, activation function, back propagation, network size and pruning McCulloch-Pitts neuron model	3
6.	Simple perceptron, adaline and madaline neural networks, feed-forward multi-layer perceptron. Learning and training the neural network.	3
7.	Networks: Hopfield network, self-organizing network and recurrent network. Neural network based controller. Case studies: Identification and control of linear and nonlinear dynamic systems	3
8.	Genetic algorithm (GA): Basic concept and detail algorithmic steps, adjustment of free parameters. Solution of typical control problems using GA.	3
9.	Concept of other search techniques like tabu search and ant-colony search for solving optimization problems.	2
10.	Introduction to crisp sets and fuzzy sets, basic fuzzy set operation and approximate reasoning.	2

S.No.	Topic	No. of Lectures
11.	Introduction to Fuzzy logic modelling and control of a system. Fuzzification, inference and defuzzification.	2
12.	Fuzzy knowledge and rule bases.	2
13.	Fuzzy modeling and control schemes for nonlinear systems. Self-organizing fuzzy logic control.	2
14.	Implementation of fuzzy logic controller. Stability analysis of fuzzy control systems.	2
15.	Intelligent control for SISO/MIMO nonlinear systems. Model based multivariable fuzzy controller.	2
	Total	**36**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	To work on data transformations, brief review on statistical criteria for termination of epochs, deciding the input output and hidden layers and neutrons for ANN problems,	3
2.	Working on different algorithms of ANN to different problems in agricultural engineering, working with different fuzzy relations,	2
3.	propositions, implications and inferences, working with defuzzification techniques and fuzzy logic controllers, concept of coding,	3
4.	selection, crossover, mutation and application of genetic programming for global optimization, use of available software for application of soft computing techniques.	4
	Total	**12**

X. Suggested Reading

- David EG. *Genetic Algorithms*.
- Rajasekaran S and Vijayalakshmi Pai GA. 2017.*Neural Networks, Fuzzy Logic and Genetic Algorithm, Synthesis and Applications*. PHI Learning Pvt. Ltd.
- Ross TJ. 1997. *Fuzzy Logic with Fuzzy Applications*. McGraw Hill Inc.
- Simon H. 2003. *Neural Networks: A Comprehensive Foundation*. Pearson Edition.
- Sivanandam SN and Deepa SN. 2011. *Principles of Soft Computing*. Wiley India Pvt. Ltd., 2nd Edition.
- Sivanandam SN and Deepa SN. 2013. *Principles of Soft Computing*. Wiley India.

I. Course Title : Digital Image Processing

II. Course Code : CSE 506

III. Credit Hours : 2+1

IV. Aim of the course

To give an overview of digital image processing including visual perception, image formation, spatial transformations, image enhancement, color image representation and processing, edge detection, image segmentation and morphological image processing.

V. Theory

Unit I

Digital image fundamentals, elements of visual perception, light and the electromagnetic spectrum, image sensing and acquisition, image sampling and quantization, basic relationships between pixels, linear and nonlinear operations.

Unit II

Image enhancement in the spatial domain, basic gray level transformations, histogram processing, basics of spatial filtering, smoothing spatial filters, sharpening spatial filters.

Unit III

Color image processing, color fundamentals, color models, pseudo color image processing, basics of full-color image processing, color transformations, smoothing and sharpening, color segmentation.

Unit IV

Image segmentation, detection of discontinuities, edge linking and boundary detection, thresholding, region-based segmentation, segmentation by morphological watersheds.

Unit V

Morphological image processing, dilation and erosion, opening and closing, extensions to gray-scale images.

VI. Practical

To write program to read and display digital image, image processing program using point processing method, program for image arithmetic operations, program for image logical operations, program for histogram calculation and equalization, program for geometric transformation of image, understand various image noise models and to write programs for image restoration and to remove noise using spatial filters. Brief outline of image processing tools.

VII. Learning outcome

This course introduces digital image processing. It focuses on the theory and algorithms underlying a range of tasks including acquisition, formation, enhancement, segmentation and representation.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction and Fundamentals, Motivation and Perspective, Applications, Components of Image Processing System,	3
2.	Element of Visual Perception, A Simple Image Model	1
3.	Sampling and Quantization.	2
4.	Light and the electromagnetic spectrum, image sensing and acquisition	2
5.	Basic relationships between pixels, linear and nonlinear operations	2
6.	Image Enhancement in Spatial Domain	2
7.	Introduction; Basic Gray Level Functions	2
8.	Histogram Specification	2
9.	Basics of spatial filtering, smoothing spatial filters, sharpening spatial filters	2
10.	Color image processing, color fundamentals	1
11.	Color models, pseudo color image processing	1
12.	Color transformations, smoothing and sharpening, color segmentation.	2
13.	Image segmentation, detection of discontinuities	1

S.No.	Topic	No. of Lectures
14.	Edge linking and boundary detection, thresholding, region-based segmentation	2
15.	Segmentation by morphological watersheds	1
16.	Morphological image processing, dilation and erosion	2
17.	Opening and closing, extensions to gray-scale images	2
	Total	**30**

IX. List of Practical

S.No.	Topic	No. of Practicals
1.	Display digital image, image processing program using point processing method, program for image arithmetic operations	3
2.	Program for image arithmetic operations, image logical operations, histogram calculation and equalization	4
3.	Program for geometric transformation of image, understand various image noise models	4
4.	Programs for image restoration and to remove noise using spatial filters	4
5.	Brief outline of image processing tools	1
	Total	**16**

X. Suggested Reading

- Jayaraman S, Esakkirajan S and Veerakumar T. *Digital Image Processing*. Tata McGraw Hill Publication.
- Rafael CG and Richard EW. *Digital Image Processing*. Third Edition, Pearson Education.
- Sridhar S. *Digital Image Processing*. Oxford University Press.

Department of Civil Engineering

I. Course Title : Dimensional Analysis and Similitude

II. Course Code : CE 501

III. Credit Hours : 2+0

IV. Aim of the course

To acquaint the students with importance of analysis of dimensions and similitude principles in structuring mathematical/simulation models of various processes under different constraint variables.

V. Theory

Unit I

Introduction, Dimensions, Dimensional homogeneity, Non-dimensional parameter, Methods of dimensional analysis: Rayleigh's method, Buckingham-Pi theorem, Choice of variables, Model analysis, Examples on various applications, Dimensional analysis and Intermediate Asymptotic.

Unit II

Model studies, Model classification, Dimensionless numbers: Reynolds model, Froude's model, Euler's Model, Webber's model, Mach model, Scale effects, Distorted models, Model laws.

Unit III

Similitude: Types of similarities (geometric-kinematic and dynamic similarity), force ratios, similarity laws. Model analysis: Physical models. Similarity methods for nonlinear problem types of models, Scale effect. Numerical problems on Reynolds's and Froude's Model.

Unit IV

Use and scope of mathematical modeling, Principles of model formulation, Role and importance of steady-state and dynamic simulation, Classification of models, Model building, Modeling difficulties, Degree-of-freedom analysis, Selection of design variables.

VI. Learning outcome

The students will be able to analyze complex problems using dimensional analysis and to develop rules for experiments with scale models and provide basis for analyses and calculations, including simplifications and assumptions made, when formulating mathematical models.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction, Dimensions, Dimensional homogeneity, Non-dimensional parameter	2

S.No.	Topic	No. of Lectures
2.	Methods of dimensional analysis: Rayleigh's method, Buckingham-Pi theorem, Choice of variables	3
3.	Model analysis, Examples on various applications, Dimensional analysis and Intermediate Asymptotic	2
4.	Model studies, Model classification, Dimensionless numbers: Reynolds model	3
5.	Froude's model, Euler's Model, Webber's model, Mach model, Scale effects	3
6.	Distorted models, Model laws.	2
7.	Similitude: Types of similarities (geometric-kinematic and dynamic similarity), force ratios, similarity laws	3
8.	Model analysis: Physical models. Similarity methods for nonlinear problem types of models, Scale effect	3
9.	Numerical problems on Reynolds's and Froude's Model	3
10.	Use and scope of mathematical modeling, Principles of model formulation	2
11.	Role and importance of steady-state and dynamic simulation	2
12.	Classification of models, Model building, Modeling difficulties	2
13.	Degree-of-freedom analysis, Selection of design variables	2
	Total	**32**

VIII. Suggested Reading

- Barenblatt GI. 1987. *Dimensional Analysis*. Gordon and Breach Science, New York.
- Langhar HL. 1951. *Dimensional Analysis and the Theory of Models*. Wiley, New York.
- Murphy G. 1950. *Similitude in Engineering*. The Ronald Press Company, New York.
- Zohuri Bahman. *Dimensional Analysis and Self-Similarity Methods for Engineers and Scientists*. Springer Publications, New York.

I. Course Title : Water Quality and Pollution Control

II. Course Code : CE 502

III. Credit Hours : 2+1

IV. Aim of the course

To acquire in-depth knowledge of water quality parameters, water quality standards, source of water pollution and multiple use of water.

V. Theory

Unit I

Physical and chemical properties of water, suspended and dissolved solids, EC and pH, major ions. Water quality (Physical, Chemical and Bacteriological) investigation, Sampling design, Samplers and automatic samplers. Data collection platforms, Field kits, Water quality data storage, analysis and inference, Software packages. Water quality indices. Water quality for irrigation. Salinity and permeability problem, saline water irrigation root zone salinity, interaction of irrigation and drainage.

Unit II

Sources and types of pollution, organic and inorganic pollutants. BOD–DO relationships, impacts on water resources. NPS pollution and its control, Eutrophication control. Water treatment technologies, Constructed wetlands.

Unit III

Multiple uses of water. Reuse of water in agriculture. Low cost waste water treatment technologies Economic and social dimensions. Packaged treatment units, soil-based water treatment methods, reverse osmosis and desalination in water reclamation.

Unit IV

Principles of water quality, water quality classification, water quality standards, water quality indices, TMDL Concepts. Water quality models. Soil crop and other practices for use of poor quality water.

VI. Practical

Determination of pH, total solids, dissolved and suspended solids, chlorides, sulphates, turbidity, dissolved oxygen, hardness. Preparation of water quality map of watershed in GIS environment. Visit of water polluted site of nearby area.

VII. Learning outcome

The students will be able to understand water quality standards which are quite important for drinking and irrigation purposes. They will also be exposed to source and type of pollution along with multiple uses of water.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Physical and chemical properties of water, suspended and dissolved solids, EC and pH, major ions. Water quality (Physical, Chemical and Bacteriological) investigation	3
2.	Sampling design, Samplers and automatic samplers. Data collection platforms, Field kits, Water quality data storage, analysis and inference	3
3.	Software packages. Water quality indices. Water quality for irrigation	2
4.	Salinity and permeability problem, saline water irrigation root zone salinity, interaction of irrigation and drainage	3
5.	Sources and types of pollution, organic and inorganic pollutants. BOD–DO relationships, impacts on water resources	3
6.	NPS pollution and its control, Eutrophication control. Water treatment technologies, Constructed wetlands	3
7.	Multiple uses of water. Reuse of water in agriculture. Low cost waste water treatment technologies	3
8.	Economic and social dimensions. Packaged treatment units, soil-based water treatment methods, reverse osmosis and desalination in water reclamation	3
9.	Principles of water quality, water quality classification	3
10.	water quality standards, water quality indices	2
11.	TMDL Concepts. Water quality models	2
12.	Soil crop and other practices for use of poor quality water	2
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Determination of pH, total solids, dissolved and suspended solids	4
2.	Determination of chlorides, sulphates, turbidity	3

S.No.	Topic	No. of Practicals
3.	dissolved oxygen, hardness	4
4.	Preparation of water quality map of watershed in GIS environment	4
5.	Visit of water polluted site of nearby area	1
	Total	**16**

X. Suggested Reading

- Abbasi T and Abbasi SA. *Water Quality Indices.* Elsevier Publications, New York.
- Chin and David A. 2006. *Water Quality Engineering in Natural Systems.* Wiley – Interscience.
- Claude E. Boyd. *Water Quality an Introduction*. Springer Publications.
- Eaton AD, Clesceri LS, Rice EW and Greenburg AE (eds). 2005. *Standard Methods for the Examination of Water and Wastewater*. 21st edn. American Public Health Association, Washington, DC.
- Thomann RV and Mueller JA. 1987. *Principles of Surface Water Quality Modelling and Control*. Harper and Row Publishers.
- Wesley W, Wallender PE and Kenneth K. Tanji, Sc.D. *Agricultural Salinity Assessment and Management*. ASCE Press.

I. Course Title : Experimental Stress Analysis

II. Course Code : CE 510

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint the students with importance of analysis of stress, analysis of strain, stress-strain relationship under different constraint conditions in 2-D plane as well as 3-D plane.

V. Theory

Unit I

Strain and stress – strain relationship. Generalized Hook's Law. Strain Gauges-Mechanical, optical, electrical, acoustical and pneumatic etc and their use.

Unit II

Different types of electrical resistance strain gauges. Semi-conductor strain gauges. Rosette analysis. Strain gauge circuits. Strain measurements at high temperatures.

Unit III

Two dimensional and three dimensional photo-elastic method of strain analysis. Bifringent coatings and scattered light in photo-elasticity.

Unit IV

Brittle coating methods. Moiré's method of strain analysis. Grid method of strain analysis. Photo elastic strain gauges.

VI. Learning outcome

The students will be able to analyze stress, strain and their interrelationships when they are subjected to different end conditions in two dimensional and three dimensional planes and provide basis for analyses and calculations, including simplifications and assumptions made, when formulating for stress and strain.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Strain and stress – strain relationship. Generalized Hook's Law	3
2.	Strain Gauges- Mechanical, optical, electrical, acoustical and pneumatic etc.	3
3.	Use of different strain gauges. Types of electrical strain gauges.	3
4.	Semi-conductor gauges. Rosette analysis. Strain gauge circuits.	32
5.	Strain measurements at high temperatures.	2
6.	Two dimensional photo-elastic method of strain analysis.	3
7.	Three dimensional photo-elastic method of strain analysis.	3
8.	Bifringent coatings and scattered light in photo-elasticity.	3
9.	Brittle coating methods	3
10.	Moir's method of strain analysis.	2
11.	Grid method of strain analysis. Photo elastic strain gauges.	2
	Total	**32**

VIII. List of Practicals

S.No.	Topic	No. of Practicals
1.	Cementing of an electrical resistance strain gage on a structural member	1
2.	To find the gage factor for a resistance type strain gage.	1
3.	To measure strain at centre of bream when loaded at greater points by making use of two strain gages one at top surface and 2nd at bottom both along longitudinal direction and fixing both in first and second arm of the bridge.	3
4.	To measure the modulus of elasticity of the beam making use of four strain gages, two on top and two on bottom, one on longitudinal and one in transversal direction on each face of the beam.	3
5.	Deter mine the tension produced in a circular shaft by using strain gages cemented perpendicular to each other.	1
6.	Determine the bending moment produced in a circular shaft by using a rectangular shaft.	1
7.	To align the circular polariscope.	1
8.	Study the plane polariscope and circular polariscope with different light field arrangements.	1
9.	Study of Moiré fringe apparatus and its applications in analysis of structures.	2
10.	Calibrate the photoelastic material by use of rectangular beam under pure bending.	2
	Total	**16**

IX. Suggested Reading

- Srinath LS, Raghavan MR, Lingaiah K, Gargesha G, Pant B and Ramachandra K. Experimental Stress Analysis, McGraw-Hill.
- Dally JW and Riley WF. *Experimental Stress Analysis*, McGraw-Hill.
- Singh S. *Experimental Stress Analysis*, Khanna Publishers.

Department of Mechanical Engineering

I. Course Title : Mechatronics and Robotics in Agriculture

II. Course Code : ME 501

III. Credit Hours : 2+0

IV. Aim of the course

To introduce the fundamentals of mechatronics and the concepts behind designing mechatronic systems and their subsystems and its application in automation in agriculture.

V. Theory

Unit I

Introduction to mechatronics: Basic definitions, key elements of mechatronics, historical perspective, the development of the automobile as a mechatronic system. Mechatronic design approach, functions of mechatronic systems, ways of integration, information processing systems, concurrent design procedure for mechatronic systems.

Unit II

System interfacing, instrumentation, and control systems.Input/output signals of a mechatronic system, signal conditioning, microprocessor control, microprocessor numerical control, microprocessor input/output control.

Unit III

Microprocessor based controllers and microelectronics: Introduction to microelectronics, digital logic, overview of control computers, microprocessors and microcontrollers, programmable logic controllers, digital communications.

Unit IV

Technologies of robot: Sub systems, transmission system (Mechanics), power generation and storage system, sensors, electronics, algorithms and software. Servo motor drives types and applications. Stepper motor and its concept. Industrial robots: Classification and sub systems. Defining work space area.

Unit V

Application of robots in agriculture: Harvesting and picking, weed control, autonomous mowing, pruning, seeding, spraying and thinning, phenotyping, sorting and packing. Utility platforms. Use of different agrobots in agriculture.

VI. Learning outcome

Ability to understand agricultural machinery that is built on concepts of mechatronics and ability to use robotic machinery in agriculture.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction to Mechatronics: Basic definitions, key elements of mechatronics,	2
2.	Historical perspective, the development of the automobile as a mechatronic system	1
3.	Mechatronic design approach, functions of mechatronic systems, ways of integration, information processing systems, concurrent design procedure for mechatronic systems.	3
4.	System interfacing, Instrumentation, and control systems	2
5.	Input/output signals of a mechatronic system, signal conditioning	2
6.	Microprocessor control, microprocessor numerical control, microprocessor input/output control	2
7.	Microprocessor based controllers and microelectronics	2
8.	Introduction to microelectronics, digital logic, overview of control computers	2
9.	Microprocessors and microcontrollers, programmable logic controllers, digital communications.	3
10.	Technologies of robot: Sub systems, transmission system (Mechanics), power generation and storage system	2
11.	sensors, electronics, algorithms and software. Servo motor drives types and applications	2
12.	Stepper motor and its concept. Industrial robots: Classification and sub systems. Defining work space area.	2
13.	Application of robots in agriculture: Harvesting and picking, weed control	2
14.	autonomous mowing, pruning, seeding, spraying and thinning	2
15.	phenotyping, sorting and packing. Utility platforms. Use of different agrobots in agriculture.	3
	Total	**32**

VIII. Suggested Reading

- Alciatore DG and Histand MB. 2002. *Introduction to Mechatronics and Measurement System*. McGraw Hill Pvt Limited, New Delhi.
- Robert HB. 2002. *Mechatronic Hand Book*. CRC Press.
- Shakhatreh and Fareed. 2011. *The Basics of Robotics*. Lahti University of Applied Sciences Machine and Production Technology.

I. Course Title : Refrigeration Systems

II. Course Code : ME 502

III. Credit Hours : 2+1

IV. Aim of the course

To acquire the skills required to model, analyse and design different refrigeration processes and components.

V. Theory

Unit I

Reversed Carnot cycle, Carnot, Brayton and aircraft refrigeration systems.

Unit II

Vapour compression refrigeration systems: Use of p-h chart, effect of pressure changes on COP, sub cooling of condensate on COP and capacity, super heating, single stage, multi-stage and cascade systems.

Unit III

Vapour absorption systems: Theory of mixtures, temperature-concentration and enthalpy concentration diagrams, adiabatic mixing of two systems, diabatic mixing, throttling process, ammonia water and water lithium-bromide systems.

Unit IV

Thermoelectric refrigeration systems: Advantages, comparison with vapour compression system. Vortex tube refrigeration system and its thermodynamic analysis. Ultra low temperature refrigeration. Ejection refrigeration. Water refrigeration: Centrifugal and steam jet refrigeration systems, characteristics of steam jet refrigeration system, effect of boiler efficiency on overall COP, actual steam jet system, two-fluid jet refrigeration.

VI. Practical

Numerical on air refrigeration cycle, Study of vapour compression refrigeration systems, Determination of the coefficient of performance of the refrigeration system, Study of vapour absorption (electrolux) refrigeration systems, Study and application of P-V, T-s and P-h chart in refrigeration, Study and performance testing of domestic refrigerator, Study of domestic water cooler, Study of actual and theoretical COP of Cascade Refrigeration System, Visit to cold storage plants.

VII. Learning outcome

After studying this course, students shall be able to analyse air and vapour compression refrigeration cycle, and perform thermodynamic analysis of absorption, steam jet, thermoelectric and vortex tube refrigeration systems.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Reversed Carnot cycle, Carnot cycle	2
2.	Brayton refrigeration systems	2
3.	Aircraft refrigeration systems	4
4.	Vapour compression refrigeration systems, Single stage vapour compression refrigeration, Use of p-h chart	3
5.	Effect of pressure changes on COP, sub cooling of condensate on COP and capacity, super heating	2
6.	Multi-stage vapour compression refrigeration systems	3
7.	Cascade vapour compression refrigeration systems	2
8.	Vapour absorption systems: Theory of mixtures, temperature-concentration and enthalpy concentration diagrams, adiabatic mixing of two systems, diabatic mixing, throttling process,	3
9.	Ammonia water vapour absorption systems.	1
10.	Water lithium-bromide vapour absorption systems.	1
11.	Thermoelectric refrigeration systems: Advantages, comparison with vapour compression system.	1
12.	Vortex tube refrigeration system and its thermodynamic analysis.	1
13.	Ultra low temperature refrigeration.	3
14.	Water refrigeration, Centrifugal refrigeration	1
15.	Ejection refrigeration, Steam jet refrigeration systems, characteristics of steam jet refrigeration system, effect of boiler	

S.No.	Topic	No. of Lectures
	efficiency on overall COP, actual steam jet system, two-fluid jet refrigeration.	3
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Numerical on air refrigeration cycle	2
2.	Study of vapour compression refrigeration systems	1
3.	Determination of the coefficient of performance of the refrigeration system	1
4.	Study of vapour absorption (electrolux) refrigeration systems	2
5.	Study and application of P-V, T-s and P-h chart in refrigeration	3
6.	Study and performance testing of domestic refrigerator,	2
7.	Study of domestic water cooler	1
8.	Study of actual and theoretical COP of Cascade Refrigeration System	2
9.	Visit to cold storage plants.	2
	Total	**16**

X. Suggested Reading

- Ahmadul A. *Refrigeration and Air Conditioning*. PHI India.
- Arora CP. *Refrigeration and Air Conditioning*. McGraw-Hill India Publishing Ltd.
- Arora R. *Refrigeration and Air Conditioning*. Prentice Hall of India.
- Crouse and Anglin. *Automobile Air Conditioning*. McGraw Hill Publications.
- Dossat RJ. *Principles of Refrigeration*. Pearson Education.
- Jordon and Prister. *Refrigeration and Air Conditioning*. Prentice Hall of India Pvt. Ltd.
- Prasad M. *Refrigeration and Air Conditioning*. New Age International Publisher.
- Stocker WF and Jones JW. *Refrigeration and Air Conditioning*. McGraw-Hill.

I. Course Title : Mechanism Analysis and Synthesis

II. Course Code : ME 503

III. Credit Hours : 2+1

IV. Aim of the course

The objective of the course is to understand the analysis and synthesis of mechanisms and to learn the graphical and analytical techniques commonly used in the synthesis of mechanisms.

V. Theory

Unit I

Kinematics of mechanisms, analysis and synthesis, mobility, systematic of mechanisms, deriving other mechanisms from linkages, Relative motion, instantaneous center method, Kennedy's theorem. Graphical and analytical methods of kinematic analysis.

Unit II

Computer - Aided analysis of mechanisms. Synthesis of linkages for path generation, function generation, Graphical techniques. Relative pole method and method of inversion. Analytical kinematics synthesis of linkages, Freudenstein's method, Loop closure equations based on complex variable approach,

Unit III

Gears and their motion-Analysis and Synthesis of epicyclic gear trains.

Unit IV

Cams-follower system; standard follower motions and combinations, importance of follower acceleration in cam system dynamics, terms related to cam design - their importance. Cam synthesis - graphical cam profile layout for a desired follower motion. Analytical determination of cam profile co-ordinates for disc cam operating common types of follower.

VI. Practical

Graphical solutions of mechanisms relating to velocity and acceleration. Problems on computer-aided analysis and synthesis of mechanisms. Analysis and design problems of gear trains, cam profile design.

VII. Learning outcome

The Student will be able to design mechanisms for better accuracy and productivity. The student will Get familiar with design process of the mechanisms for functional requirements.

VIII. Lecture Schedule

S.No.	Topics	No. of Lectures
1.	Introduction & basic concepts.	2
2.	Kinematics of mechanisms, analysis and synthesis, mobility, systematic of mechanisms, deriving other mechanisms from linkages	3
3.	Determination of velocity and acceleration using graphical method and analytical methods (relative velocity and acceleration, instantaneous centers), Kennedy's theorem. Graphical and analytical methods of kinematic analysis	4
4.	Computer - Aided analysis of mechanisms. Synthesis of linkages for path generation, function generation, Graphical techniques. Relative pole method and method of inversion	3
5.	Analytical kinematics synthesis of linkages, Freudenstein's method, Loop closure equations based on complex variable approach	5
6.	Introduction to spur, helical, spiral, bevel and worm gears, law of gearing, nomenclature, velocity of sliding between two teeth in mesh.	3
7.	Gears and their motion-Analysis and Synthesis of epicyclic gear trains	4
8.	Cams-follower system; standard follower motions and combinations, importance of follower acceleration in cam system dynamics, terms related to cam design	4
9.	Cam synthesis - graphical cam profile layout for a desired follower motion. Analytical determination of cam profile co-ordinates for disc cam operating common types of follower.	4
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Graphical solutions of mechanisms relating to velocity and acceleration (4 different mechanisms to be studied)	4
2.	Problems on computer-aided analysis and synthesis of mechanisms	4

S.No.	Topic	No. of Practicals
3.	Analysis and design problems of gear trains	5
4.	Cam profile design	3
	Total	**16**

X. Suggested Reading

- Erdman A, Sandor G and Kota S. 2001. *Mechanism Design: Analysis and Synthesis* Pearson India Pvt Ltd, New Delhi.
- Sandor GI, Erdman AG. 1984. *Advanced Mechanism Design: Analysis and Synthesis* Pearson. Facsimile edition.
- Ballaney PL. 2003. *Theory of Machines*. - Khanna Publishers, New Delhi.
- Rattan. SS. 2014. *Theory of Machines*, McGraw Hill Pvt Ltd, New Delhi.
- Khurmi RS and Gupta 2020. *Theory of Machines*. Eurasia Publishing House (P) Ltd, New Delhi.

I. Course Title : Vibrations

II. Course Code : ME 504

III. Credit Hours : 3+0

IV. Aim of the course

To enable the students to design vibration control sytem,and balancing of rotating and reciprocating masses.

V. Theory

Unit I

Vibration motion and its terminology. Undamped free vibrations, equations of motion- natural frequency. Energy method, Rayleigh method; effective mass principle of Virtual work. Equivalent spring stiffness in parallel and in series. Harmonic analysis and Fourier Series

Unit II

Damping - viscous, solid, coulomb equivalent dampers. Viscosity damped free vibrations, Logarithmic decrement. Forced vibrations with harmonic excitation and rotating unbalance. Energy dissipated by damping

Unit III

Forced vibration with damping, Vibration isolation and force and motion transmissibility. Two degree of freedom systems. Principal modes of vibration, co-ordinate coupling. Vibration absorbers

Unit IV

Free vibration equation of motion for multi-degree of freedom systems. Influence coefficients and Maxwell's reciprocal theorem, stiffness coefficients. Numerical methods for finding natural frequencies for multi-degree of freedom systems.

Unit V

Vibration of lumped parameter systems and continuous systems. Lagrange equations. Vibration measuring instruments, Vibrometers, velocity pickups, Accelerometer and frequency measuring instruments. Applications of vibrations. Vibration control, balancing of rotating and reciprocating machines, design of vibration isolators.

VI. Learning outcome

The student will be able to understand the concept of vibrations, analyze the mathematical modeling of the multidegree freedom systems and able to design vibration isolators.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Vibration motion and its terminology.	2
2.	Undamped free vibrations, equations of motion- natural frequency.	2
3.	Energy method, Rayleigh method; effective mass principle of Virtual work.	2
4.	Equivalent spring stiffness in parallel and in series.	1
5.	Harmonic analysis and Fourier Series.	2
6.	Damping - viscous, solid, coulomb equivalent dampers.	3
7.	Viscosity damped free vibrations, Logarithmic decrement	3
8.	Forced vibrations with harmonic excitation and rotating unbalance	2
9.	Energy dissipated by damping. Forced vibration with damping,	3
10.	Vibration isolation and force and motion transmissibility.	2
11.	Two degree of freedom systems. Principal modes of vibration co-ordinate coupling	3
12.	Vibration absorbers,	2
13.	Free vibration equation of motion for multi-degree of freedom systems.	2
14.	Influence coefficients and Maxwell's reciprocal theorem, stiffness coefficients.	3
15.	Numerical methods for finding natural frequencies for multi-degree of freedom systems.	3
16.	Vibration of lumped parameter systems and continuous systems.	3
17.	Lagrange equations. Vibration measuring instruments, Vibrometers, velocity pickups	3
18.	Accelerometer and frequency measuring instruments.	2
19.	Applications of vibrations. Vibration control, balancing of rotating and reciprocating machines	3
20.	Design of vibration isolators.	2
	Total	**48**

VIII. Suggested Reading

- V.P. Singh.2014. *Mechanical Vibrations*. Dhanpat Rai and Comopany, New Delhi
- Rao S S. 2010.*Mechanical Vibrations*. Pearson Education, Delhi
- Srinivas P.1983. *Mechanical Vibration Analysis*. Tata McGraw Hill Company
- Limited, New Delhi
- Daniel J Inman.2013. *Engineering Vibration*. Prentice Hall, New Jersey

I. Course Title : Fatigue Design

II. Course Code : ME 507

III. Credit Hours : 2+1

IV. Aim of the course

The course provides an understanding on fatigue design considerations of mechanical components. The causes of fatigue in brittle and ductile materials are taught with focus on crack initiation, propagation and fracture.

V. Theory

Unit I

Theories of failure, maximum normal stress, maximum shear stress and distortion energy theory, failure of ductile materials, failure of brittle materials.

Unit II

Stress concentration and its evaluation, stress concentration of ductile and brittle materials under static loading and under dynamic loading, determining geometric stress concentration factors, designing to avoid stress concentration.

Unit III

Fatigue of machine components, mechanism of fatigue failure, fatigue failure models and their considerations in design of machine elements, fatigue loads. Fatigue testing and presentation of fatigue data. Influence of stress conditions on fatigue strength/endurance limit of metals. Low and high cycle fatigue

Unit IV

Cumulative fatigue damage. Designing for finite and infinite life. Improving fatigue resistance of machine elements. Stress corrosion. Corrosion fatigue.
Practical Fatigue tests on testing machine(s) for specimens of different materials having different discontinuities/stress raisers and various surface conditions. Determination of correlation between fatigue limit and ultimate strength of material. Problems in fatigue design of common machine component.

VI. Learning outcome

The students is able to understand technical aspects and principles of fatigue design. The student can design the engineering product having good durability and long fatigue life

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1	Introduction to cyclic loading and Fatigue Design	1
2	Types of Loads and Stresses, Different theories of Failure like maximum normal stress, maximum shear stress and distortion energy theory etc.	3
3	Determining stress concentration based on geometric stress concentration factors, Design considerations to avoid stress concentration of ductile and brittle materials.	3
4	Mechanical failure. Macroscopic failure modes, Behavior of brittle and ductile materials in fatigue and stress concentration. Fracture in brittle and ductile materials, characteristics of fracture surfaces, inter-granular and intra-granular failure.	4
5	Cleavage and micro-ductility, growth of fatigue cracks, The ductile/brittle fracture transition, temperature for notched and unnotched components. Fracture at elevated temperature.	3
6	Fatigue of machine components, mechanism of fatigue failure. Low and high cycle with examples mean stress R ratio, strain and load control. S-N curves.	4
7.	Goodman's rule and Miners rule. Micro-mechanisms of fatigue damage, fatigue limits and initiation and propagation control, leading to a consideration of factors enhancing fatigue resistance.	3

S.No.	Topic	No. of Lectures
8.	Fatigue loads and mathematical models. Fatigue testing and presentation of fatigue data, Influence of stress conditions on fatigue strength/endurance limit of metals.	3
9.	Total life and damage tolerant approaches to life prediction. Fatigue failure models and their considerations in design of machine elements. Cumulative fatigue damage and Designing for finite and infinite life	2
10.	Methods to improve fatigue resistance of machine elements. Improvement of fatigue strength by chemical/metallurgical processes such as nitriding, flame hardening, case carburizing. Fatigue strength enhancement by mechanical work, cold rolling, peening, shot peening.	3
11.	Environmental Assisted Cracking: Stress corrosion cracking, Hydrogen embrittlement, Corrosion fatigue. Creep: Creep curves, Mechanisms of creep, Stress rapture test, Life prediction, High temperature alloys.	3
	Total	**32**

VIII. List of Practicals

S.No.	Topic	No. of Practicals
1.	Load measurement using Load indicator, Load Cells	1
2.	Strain measurement using Strain Gauge	1
3.	Stress measurement using strain rosette	1
4.	Determination of Fatigue strength measurement of S45C or alike material under same loading condition for different stress concentrations factors (like holes, notches, sharp corners for at least 5 different samples). Comparison to be listed.	5
5.	Study to improvement Fatigue Design based on at least 5 different processes like flame hardening, case carburizing, nitriding, shot peening, peening etc or alike processes.	5
6.	Determination of correlation between fatigue limit and ultimate strength of commercially available S45C material for three different samples	3
	Total	**16**

IX. Suggested Reading

- Lessells, J.M. 1955. *Strength and resistance of metals*. John Wiley & sons, Michigan.
- T.L. Anderson. 2005. *Fracture Mechanics Fundamentals and Applications*. CRC press, Boca Raton.
- Bhandari V.B.2019. *Design of Machine Elements*. Mcgraw Hill Education Pvt Ltd, New Delhi
- Peterson, R.E. 1953 *Stress Concentration Design Factors*. John Wiley & Sons, New York.
- Meguid, S.A.1989 Engineering *Fracture Mechanics*. John Wiley & Sons, New York
- Kare Hellan.1985. *Introduction to Fracture Mechanics*. Mc Graw Hill Book Co, New York.

I. Course Title : Computer Aided Design

II. Course Code : ME 515

III. Credit Hours : 2+1

IV. Aim of the course

The **course** provides an understanding on computer aided design. It provides in depth knowledge about 2-d drawing, 3-D Modeling and finite element analysis for optimum product design.

V. Theory

Unit I

Introduction to computer aided design, scope of computer aided machine design, design process and design environments. Geometric modeling and interactive graphic, engineering analysis, design review and automated drafting, modeling, viewing,

Unit II

3-D solid modeling, boundary representation, constructive solid geometry, feature based modeling. Computer aided analysis and synthesis of common mechanical components, a bar, a beam and a shaft, comparison with analytical results.

Unit III

Application of numerical methods and optimization techniques to machine design problems, Computer aided selection of standard mechanical components. Introduction to FEM. FEA using two dimensional and three dimensional elements; plain strain and plain stress problems, finite element mesh, automatic meshing techniques, limitations of FEM.

Practical Computer aided design problems for machine components, use of standard software, CAD models for other applications. Development of FEM models for analysis of a bar, beam and a shaft. Practice in using an FEM software on other real life problems like spanners, connecting rods.

VI. Learning outcome

The students can design a product having better accuracy, less errors, increased productivity and shorter lead times with the help of CAD.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1	Introduction to Engineering Design, design steps and computer aided design.	2
2	Software and workstation selection for CAD. Design process with and without CAD	3
3	Input and output devices, Display devices; GKS, IGES and STEP; Modeling and viewing, Application areas of CAD.	3
4	Wireframe model, solid modeling, Boundary Representation (B-rep), Constructive Solid Geometry (CSG).	3
5	Mass, volumetric properties calculations; surface modeling, concepts of hidden-line removal and shading: Mechanical Assembly Kinematics analysis and simulation	3
6	Parametric Modeling Technique. Non-parametric and parametric representation of curves.	2
7	Parametric representation of Hermite Cubic, Beizer and B-spline curves; Surface and its analysis. Representation of Analytical and synthetic surfaces.	2
8	Numerical methods and optimization techniques to engineering design problems	3
9	Overview of FEM, Advantages and applications, recent advance in FEM, FEA software Basic principles and general procedure of FEM	3
10	Analyzing simple machine elements and comparing with analytical results of simple machine elements like bar, beam and a shaft.	4

S.No.	Topic	No. of Lectures
11	Simple Project. Mathematical modelling and design calculations of machines.	4
	Total	**32**

VIII. List of Practicals

S.No.	Topic	No. of Practicals
1.	Introduction to 2-D drawing. Use of any relevant software	2
2.	Study of drawings in First angle and third angle projections	1
3.	2-D assembly drawing and generation of BOM	1
4.	3-D Modeling. GKS, IGES and STEP; Modeling and viewing. Use of relevant software	3
5.	Assembly Design	2
6.	Introduction to FEA software. Mesh generation (Nodes and elements). Use of any other relevant software for FEA	3
7.	Practice on Boundary conditions like loads and constraints.	2
8.	Study of static and dynamic loading conditions. Study of Machine elements like bars, beams and shafts or other machine elements.	2
	Total	**16**

IX. Suggested Reading

- Mikell P. Groover, Emory W. Zimmers.2000 *CAD/CAM Computer Aided Design and Manufacturing*, PHI,
- Zeid Ibraham.1991. *CAD/CAM - Theory and Practice*, Tata McGraw Hill, New Delhi
- Chandandeep Grewal & Kuldeep Sareen.2007. *CAD/CAM Theory and Concepts*. S.Chand, New Delhi
- P.N Rao.2010. *CAD/CAM*. Tata McGraw Hill, New Delhi

Department of Maths, Statistics and Physics

I. Course Title : Finite Element Methods

II. Course Code : MATH 501

III. Credit Hours : 2+1

IV. Theory

Unit I

Introduction. Historical background, Stress equilibrium, boundary condition,stress strain relation, potential energy and equilibrium. Rayleigh-Ritz method. Galerkin method.

Unit II

coordinates and shape functions, potential energy approach,element stiffness matrix,Galerkin approach, assembly of global stiffness matrix. The finite element equation, boundary conditions.

Unit III

Trusses: Two dimensional problems, modeling by constant strain triangle, two dimensional iso-parametric elements, the four-node quadrilateral.

Unit IV

Scalar field problems, steady state heat transfer, torsion, potential flow, seepage and fluid flow index, dynamic analysis, principles.

V. Practical

Use of simple FEM software for FEM software for understanding, principles of FEM. Working out simple problems using LISA or any simple software with understanding of operation. Solving one dimensional problem. Solution to planar and spatial trusses, solving simple two-dimensional problems, Axisymmetric problems, solution of problems with two dimensional iso-parametric elements,solving simple beams and frames, three dimensional problems, solution to heat transfer problems and flow problems.

Learning outcome

Ability to formulate problems based on use of FEM and solve them using software tools.

VI. Lecture Schedule

S.No.	Topic	No.of Lectures
1.	Introduction. Historical background, Stress equilibrium, boundary condition	4
2.	Stress strain relation, potential energy and equilibrium, Rayleigh-Ritz method, Galerkin method.	4
3.	coordinates and shape functions, potential energy approach,element stiffness matrix	3

S.No.	Topic	No.of Lectures
4.	Galerkin approach, assembly of global stiffness matrix, The finite element equation, boundary condition	3
5.	Trusses: Two dimensional problems,	3
6.	modeling by constant strain triangle	3
7.	two dimensional iso-parametric elements, the four-node quadrilateral.	3
8.	Scalar field problems, steady state heat transfer	3
9.	torsion, potential flow,	3
10.	seepage and fluid flow index, dynamic analysis, principles.	3
	Total	**32**

VII. List of Practicals

S.No.	Topic	No.of Practicals
1.	Use of simple FEM software for FEM software for understanding, principles of FEM.	3
2.	Working out simple problems using LISA or any simple software with understanding of operatio	3
3.	Solving one dimensional problem, Solution to planar and spatial trusses	2
4.	Solving simple two-dimensional problems, Axisymmetric problems	2
5.	Solution of problems with two dimensional iso-parametric elements	2
6.	Solving simple beams and frames	2
7.	Three dimensional problems, solution to heat transfer problems and flow problems.	2
	Total	**16**

VIII. Suggested Reading

- Tirupathi R, Patla C and Belegundu AD. 1999. *Introduction to Finite Element in Engineering*. Prentice Hall of India Pvt. Ltd, New Delhi
- Singiresu RaoS. 2001. *The Finite Element Method in Engineering*. Butter worth Heinemann, New Delhi.
- Rajasekaran S 1999. *Finite Element Analysis in Engineering Design*. Wheeler Publishing, Division of A.h.Wheeler and Co. Ltd, Allahabad.
- *Tutorials and Reference Guide*, LISA Finite Element Analysis Software Version 8.0.0 2013

I. Course Title : Numerical Methods for Engineers

II. Course Code : MATH 502

III. Credit Hours : 2+1

IV. Aim of the course

To expose students to various numerical methods for solving algebraic equations, ordinary and partial differential equations.

V. Theory

Unit I

Solution of Algebraic Equations: Solution of non-linear and transcendental equations in one or more than one variable using bisection, false position, iteration, Newton Raphson, Secant methods. Solution of linear simultaneous equations: Matrix inversion, Gauss elimination, Gauss Jordan, LU decomposition methods, ill-conditioned systems.

Unit II

Solution of Ordinary Differential Equations: Initial Value Problem, Taylor series method, Picard's method, Euler method, Modified Euler method, RK class and predictor corrector class methods. Stiff ODE's and Gear's methods. Boundary Value Problem, Shooting methods, finite difference method. Use of Method of weighted residuals and orthogonal collocation and Galerkin technique to solve BVP in ODEs

Unit III

Eigen values and Eigen vectors: Maximum and minimum eigenvalue by Power spectral and Inverse Power Method, all eigenvalues by Fadeev-Leverrier method. Introduction to diagonalization and QR Factorization.Approximation Theory.

Unit IV

Finite difference formulae: Forward and backward differences, Richardson's extrapolation, interpolation formulae, polynomial forms, linear interpolation, Lagrange interpolation polynomial, Newton interpolation polynomial.

Unit V

Solution of Partial Differential Equations: Classification of PDEs(Parabolic, elliptical and hyperbolic equation), Elliptical equations, standard five pointsformula, diagonal five-point formula. Solution of Laplace equation by Liebman's iteration method.Poisson's equation and its applications.Solution of parabolic equations by Bender–Schmidt method, Bender-Schmidt recurrence equation, Crank-Nicholson difference method.

VI. Practical

Use of EXCEL Sheet and MATLAB: Application of EXCEL Sheet and MATLAB to solve the Engineering problems

VII. Learning outcome

Ability to solve algebraic equations, ordinary and partial differential equations coming across in Agricultural Engineering problems using various numerical methods, ability to use latest software's towards numerical problems.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Solution of Algebraic Equations: Solution of non-linear and transcendental equations in one or more than one variable using bisection method.	2
2.	Solution of Algebraic Equations: Solution of non-linear and transcendental equations in one or more than one variable using false position methods.	1
3.	Solution of Algebraic Equations: Solution of non-linear and transcendental equations in one or more than one variable using iteration.	1
4.	Solution of Algebraic Equations: Solution of non-linear and transcendental equations in one or more than one variable using Newton Raphson, Secant methods.	1
5.	Solution of linear simultaneous equations: Matrix inversion, Gauss elimination, Gauss Jordan method.	2

S.No.	Topic	No. of Lectures
6.	Solution of linear simultaneous equations: LU decomposition methods, ill-conditioned systems.	2
7.	Solution of Ordinary Differential Equations: Initial Value Problem, Taylor series method, Picard's method, Euler method, Modified Euler method	2
8.	Solution of Ordinary Differential Equations: RK class and predictor corrector class methods. Stiff ODE's and Gear's methods.	1
9.	Eigen values and Eigen vectors: Maximum and minimum eigenvalue by Power spectral and Inverse Power Method.	2
10.	Eigen values and Eigen vectors: all eigenvalues by Fadeev-Leverrier method	2
11.	Introduction to diagonalization and QR Factorization. Approximation Theory.	2
12.	Finite difference formulae: Forward and backward differences, Richardson's extrapolation, interpolation formulae, polynomial forms.	2
13.	Finite difference formulae: linear interpolation, Lagrange interpolation polynomial, Newton interpolation polynomial.	2
14.	Solution of Partial Differential Equations: Classification of PDEs (Parabolic, elliptical and hyperbolic equation)	2
15.	Elliptical equations, standard five pointsformula, diagonal five-point formula.	2
16.	Solution of Laplace equation by Liebman's iteration method. Poisson's equation and its applications.	2
17.	Solution of parabolic equations by Bender–Schmidt method	2
18.	Solution of parabolic equations by Bender-Schmidt recurrence equation, Crank-Nicholson difference method.	2
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Solution of Algebraic Equations: Solution of non-linear and transcendental equations in one or more than one variable using bisection method.	1
2.	Solution of Algebraic Equations: Solution of non-linear and transcendental equations in one or more than one variable using false position methods.	1
3.	Solution of Algebraic Equations: Solution of non-linear and transcendental equations in one or more than one variable using iteration.	1
4.	Solution of Algebraic Equations: Solution of non-linear and transcendental equations in one or more than one variable using Newton Raphson, Secant methods.	1
5.	Solution of linear simultaneous equations: Matrix inversion, Gauss elimination, Gauss Jordan method.	1
6.	Solution of linear simultaneous equations: LU decomposition methods, ill-conditioned systems.	1
7.	Solution of Ordinary Differential Equations: Initial Value Problem, Taylor series method, Picard's method, Euler method, Modified Euler method	1
8.	Solution of Ordinary Differential Equations: RK class and predictor corrector class methods. Stiff ODE's and Gear's methods.	1

S.No.	Topic	No. of Lectures
9.	Eigen values and Eigen vectors: Maximum and minimum eigenvalue by Power spectral and Inverse Power Method.	1
10.	Eigen values and Eigen vectors: all eigenvalues by Fadeev-Leverrier method	1
11.	Introduction to diagonalization and QR Factorization. Approximation Theory.	1
12.	Finite difference formulae: Forward and backward differences, Richardson's extrapolation, interpolation formulae, polynomial forms.	1
13.	Finite difference formulae: linear interpolation, Lagrange interpolation polynomial, Newton interpolation polynomial.	1
14.	Solution of Partial Differential Equations: Classification of PDEs (Parabolic, elliptical and hyperbolic equation), Elliptical equations, standard five points formula, diagonal five-point formula.	1
15.	Solution of Laplace equation by Liebman's iteration method. Poisson's equation and its applications.	1
16.	Solution of parabolic equations by Bender–Schmidt method, Bender-Schmidt recurrence equation, Crank-Nicholson difference method.	1
	Total	**16**

X. Suggested Reading

- Anderson T W 1958. *An Introduction to Multivariate Statistical Analysis*. John Wiley.
- Dillon W R and Goldstein M. 1984. *Multivariate Analysis - Methods and Applications*. John Wiley.
- Electronic Statistics Text Book: http://www.statsoft.com/textbook/stathome.html
- Goon A M, Gupta M K and Dasgupta B. 1977. *An Outline of Statistical Theory*. Vol. I. The World Press.
- Goon A M, Gupta M K and Dasgupta B. 1983. *Fundamentals of Statistics*. Vol. I. The World Press.
- Hoel P G. 1971. *Introduction to Mathematical Statistics*. John Wiley.
- Hogg R V and Craig T T. 1978. *Introduction to Mathematical Statistics*. Macmillan.
- Montgomery and Runger 2014. *Applied Statistics and Probability for Engineers*. John Wiley
- Morrison D F. 1976. *Multivariate Statistical Methods*. McGraw Hill.
- Siegel S, Johan N and Casellan Jr. 1956. *Non-parametric Tests for Behavior Sciences*. John Wiley.

I. Course Title : Numerical Analysis

II. Course Code : Math 506

III. Credit Hours : 2+1

IV. Aim of the course

To provide understanding and application of basic numerical techniques for evaluation and approximation of roots of polynomials, solution of differential equations, numerical differentiation and integration.

V. Theory

Unit I

Computational errors, absolute and relative errors, difference operators, divided differences, interpolating polynomials using finite differences, Hermite interpolation, piecewise and spline interpolation, bivariate interpolation.

Unit II

Numerical solution of algebraic and transcendental equations by bisection, secant and Newton-Raphson's Methods, solution of polynomial equations by Birge-Vieta's, Bairstow's and Graffe's root squaring methods.

Unit III

Numerical differentiation based on interpolation, finite differences and undetermined coefficients. Numerical integration using methods based on interpolation and undetermined coefficients.

Unit IV

Numerical solution of ordinary differential equations of first order and first degree by Runge -Kutta method and predictor-corrector methods. Solution of linear system of equations, Gaussian elimination method, pivoting and scaling, factorization method, iterative techniques, inverse of a matrix, computation of eigen values and eigen vectors.

VI. Practical

Tutorials on: divided differences, Hermite and spline interpolation, bivariate interpolation, roots of algebraic and transcendental equations by Newton-Raphson's method, bisection method, Birge-Vieta's method, Bairstow's and Graffe's root squaring methods for polynomial equations, numerical evaluation of derivatives and integral, Runge-Kutta and predictor- corrector methods, Gaussian elimination method, factorization method, iterative techniques, inverse of a matrix, eigen values and eigen vectors.

VII. Learning outcome

To understand basic numerical methods and apply them to solve higher engineering problems.

VIII. Lecture Schedule

S.No.	Topic	No. of lectures
1.	Computational errors, absolute and relative errors	1
2.	Difference operators,	2
3.	Divided differences	2
4.	Interpolating polynomials using finite differences	2
5.	Hermite interpolation	2
6.	Piecewise interpolation	2
7.	Spline interpolation	2
8.	Bivariate interpolation.	1
9.	Bisection Method, secant method	2
10.	Newton-Raphson's method,Birge-Vieta's, method	2
11.	Bairstow's and Graffe's root squaring methods.	2
12.	Numerical differentiation based on interpolation, finite differences and undetermined coefficients.	2
13.	Numerical integration using methods based on interpolation and undetermined coefficients	2
14.	Numerical solution of ordinary differential equations of first order and first degree by Runge -Kutta method	2
15.	Predictor-corrector method	1
16.	Gaussian elimination method, pivoting and scaling	1
17.	Factorization method, iterative techniques	2

S.No.	Topic	No. of Practicals
18.	Inverse of a matrix, computation of eigen values and eigen vectors	2
	Total	**32**

IX. List of Practical

S.No.	Topic	No. of Practicals
1.	Divided differences	1
2.	Hermite Interpolation	1
3.	Spline interpolation	1
4.	Bivariate interpolation	1
5.	Bisection method	1
6.	Bivariate interpolation	1
7.	Secant Method	1
8.	Newton-Raphson's method	1
9.	Birge-Vieta's method	1
10.	Bairstow's Method	1
11.	Graffe's root squaring methods	1
12.	Numerical evaluation of derivatives and integral	1
13.	Runge-Kutta method	1
14.	Predictor- corrector methods	1
15.	Gaussian elimination method, factorization method,	1
16.	Iterative techniques, inverse of a matrix, eigen values and eigen vectors	1
	Total	**16**

X. Suggested Reading

- Gerald CF and Wheatley PO. 2003. *Applied Numerical Analysis,* Pearson, 7th Edition,
- Jain MK, Iyengar SRK and Jain RK. 2012. *Numerical Methods for Scientific and Engineering Computation*, New Age International Publishers, 6th edition.
- Chappra SC. 2014. *Numerical Methods for Engineers*, McGraw-Hill Higher Education; 7th edition.
- Mathew JH, *Numerical Methods for Mathematics*, Science and Engineering, Prentice Hall, (1992) 2nd edition,
- Burden RL and Faires JD. 2004. *Numerical Analysis*, Brooks Cole, 8th edition.
- Atkinson K and Han W. 2004. *Elementary Numerical Analysis*, John Willey & Sons, 3rd Edition.

I. Course Title : Numerical Methods for Ordinary and Partial Differential Equations

II. Course Code : Math 507

III. Credit Hours : 2+1

IV. Aim of the course

To provide understanding and application of basic numerical techniques for evaluation and approximation of ordinary and partial differential equations.

V. Theory

Unit I

Interpolation, Approximation, least square and uniform approximation.

Unit II

Numerical differentiation and integration, Numerical solution of ordinary differential equations by single step and multi-step methods

Unit III

Various difference schemes for solutions of partial differential equations of parabolic, elliptic and hyperbolic types

Unit IV

Solution of differential equations by finite element methods

VI. Practical

Tutorials on: evaluation of derivatives and integrals by numerical methods, single step and multistep methods for solution of ordinary differential equations, solution of parabolic, hyperbolic and elliptic equations by finite difference methods. Finite element methods

VII. Learning outcome

To understand basic numerical techniques and apply them to solve ordinary and partial differential equations.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Interpolation	3
2.	Approximation	3
3.	Least square approximation	2
4.	Uniform approximation	2
5.	Numerical differentiation	3
6.	Numerical integration	3
7.	Numerical solution of ordinary differential equations by single step method	3
8.	Numerical solution of ordinary differential equations by multi-step method	3
9.	Various difference schemes for solutions of partial differential equations of parabolic type	2
10.	Various difference schemes for solutions of partial differential equations of elliptic type	2
11.	Various difference schemes for solutions of partial differential equations of hyperbolic type	2
12.	Solution of differential equations by finite element methods	4
	Total	**32**

IX. List of Practical

S.No.	Topic	No. of Practicals
1.	Evaluation of derivatives by numerical methods	2
2.	Evaluation of integrals by numerical methods	2
3.	Single step method for solution of ordinary differential equation	2
4.	Multistep method for solution of ordinary differential equation	2
5.	Solution of parabolic equations by finite difference method	2
6.	Solution of hyperbolic equations by finite difference methods	2
7.	Solution of elliptic equations by finite difference methods	2
8.	Finite Element methods	2
	Total	**16**

X. Suggested Reading

- Gerald CF and Wheatley PO. 2003. *Applied Numerical Analysis*, Pearson, 7th Edition.
- Jain MK, Iyengar SRK and Jain RK. 2012. *Numerical Methods for Scientific and Engineering Computation*, New Age International Publishers, 6th edition.
- Chappra SC. 2014. *Numerical Methods for Engineers*, McGraw-Hill Higher Education; 7th edition.
- Mathew JH. 1992. *Numerical Methods for Mathematics*, Science and Engineering, Prentice Hall, 2nd edition,
- Burden RL and Faires JD. 2004. *Numerical Analysis*, Brooks Cole, 8th edition.
- Atkinson K and Han W. 2004. *Elementary Numerical Analysis*, John Willey & Sons, 3rd Edition.

I. Course Title : Statistical Methods for Research Workers

II. Course Code : STAT 501

III. Credit Hours : 2+1

IV. Aim of the course

To expose students to various statistical techniques for analysis of data and interpretation of results.

V. Theory

Unit I

Probability and probability distributions. Principle of least squares. Linear and non-linear regression. Multiple regression. Correlation analysis. Selection of variables. Validation of models. Sampling techniques. Determination of sample size. Sampling distribution of mean and proportion.

Unit II

Hypothesis testing. Concept of p-value. Student's t-test. Large sample tests. Confidence intervals. ANOVA and testing of hypothesis in regression analysis. Analysis of variance for one way and two way classification (with equal cell frequency).Transformation ofdata.

Unit III

Advantages and disadvantages of nonparametric statistical tests. Scales of measurements. Run-test. Sign test. Median test. Wilcoxon-Mann Whitney test. Chi-square test. Kruskal-Walli's one way and Friedman's two way ANOVA by ranks. Kendall's Coefficient of concordance.

VI. Practical

Fitting of distributions. Sample and sampling distributions. Correlation analysis. Regression analysis (Multivariate, quadratic, exponential, power function, selection of variables, validation of models, ANOVA and testing of hypothesis). Tests of significance (Z-test, t-test, F-test and Chi-square test). Analysis of variance. Non-parametric tests.

VII. Learning outcome

The students will be able to understand different techniques for analyzing the data of their research work.

VIII. Lecture Schedule

S.No.	Topics	No. of Lectures
1.	Elementary statistics	
2.	Probability theory	2
3.	Probability distributions (Binomial, Poisson and Normal)	3
4.	Sampling techniques, Determination of sample size	2
5.	Sampling distribution of mean and Proportion	1
6.	Hypothesis testing concept of p-value	1
7.	Large sample (mean, proportion)	1
8.	Student's t-test (Single mean, Difference of mean for independent samples and paired observations) and F-test	3
9.	Analysis of variance (one way and two way), Transformation of data	2
10.	Correlation analysis and testing (Bivariate, Rank, Intra-class, Partial, Fisher's Z-transformation)	2
11.	Multiple linear regression and model validation	2
12.	Testing of coefficient of determination and regression coefficient	2
13.	Selection of variables in regression (forward substitution method and step-wise regression)	1
14.	Non-Linear regression (Quadratic, exponential and Power)	2
15.	Introduction to Non-parametric and scales of measurements	1
16.	Chi-square test (Goodness of fit, Independence of attributes, homogeneity of variances)	2
17.	One Sample test (Sign test, Median test, Run rest,)	2
18.	Two sample test (Wilcoxon Sign test, Mann Whitney test, Chi square test for two independent samples)	1
19.	K-Sample (Kruskal-Walli's test and Friedman's two way ANOVA)	2
20.	Kendall's coefficient of concordance	1
	Total	**33**

IX. List of Practicals

S.No.	Topics	No. of Practicals
1.	Elementary statistics	1
2.	Probability distributions (Binomial, Poisson and Normal)	1
3.	Sampling techniques, Determination of sample size, Sampling distribution of mean and Proportion	1
4.	Large sample (mean, proportion)	1
5.	Student's t-test (Single mean, Difference of mean for independent samples and paired observations) and F-test	1
6.	Analysis of variance (one way and two way), Transformation of data	2
7.	Correlation analysis and testing (Bivariate, Rank, Intra-class, Partial, Fisher's Z-transformation)	1
8.	Multiple linear regression and model validation	1
9.	Testing of coefficient of determination and regression coefficient	
10.	Selection of variables in regression (Forward substitution method and step-wise regression)	1
11.	Non-Linear regression (Quadratic, exponential and Power)	2
12.	Introduction to Non-parametric and scales of measurements	
13.	Chi-square test (Goodness of fit, Independence of attributes, homogeneity of variances)	2
14.	One Sample test:Sign test, Median test, Run rest, Two sample test: Wilcoxon Sign test, Mann Whitney test, X^2 test for two independent samples	1

S.No.	Topic	No. of Practicals
15.	K-Sample: Kruskal-Walli's test and Friedman's two way ANOVA, Kendall's coefficient of concordance	1
	Total	**16**

X. Suggested Reading

- Anderson T W 1958. *An Introduction to Multivariate Statistical Analysis*. John Wiley.
- Dillon W R and Goldstein M. 1984. *Multivariate Analysis - Methods and Applications*. John Wiley.
- Electronic Statistics Text Book: http://www.statsoft.com/textbook/stathome.html
- Goon A M, Gupta M K and Dasgupta B. 1977. *An Outline of Statistical Theory*. Vol. I. The World Press.
- Goon A M, Gupta M K and Dasgupta B. 1983. *Fundamentals of Statistics*. Vol. I. The World Press.
- Hoel P G. 1971. *Introduction to Mathematical Statistics*. John Wiley.
- Hogg R V and Craig T T. 1978. *Introduction to Mathematical Statistics*. Macmillan.
- Montgomery and Runger 2014. *Applied Statistics and Probability for Engineers*. John Wiley
- Morrison D F. 1976. *Multivariate Statistical Methods*. McGraw Hill.
- Siegel S, Johan N and Casellan Jr. 1956. *Non-parametric Tests for Behavior Sciences*. John Wiley.

I. Course Title : Experimental Designs

II. Course Code : Stat 502

III. Credit Hours : 1+1

IV. Aim of the course

To acquaint and equip the students with the basic principles of theory of designs and analysis of experiments.

V. Theory

Unit I

Basic principles of experimental designs. Uniformity trials. Completely randomized design, randomized block design and latin square designs. Multiple comparison tests.

Unit II

Missing plot techniques. Analysis of covariance. Factorial experiments:2^2, $2^3$and 3^2. Split plot design. Strip plot design. Factorial in split plot design.

Unit III

Crossover designs. Balanced incomplete block design. Response surface designs. Groups of experiments.

VI. Practical

Uniformity trials. Completely randomized design. Randomized block and latin square designs. Missing plot and analysis of covariance Split plot designs. Factorial in split plot design. Strip plot designs. Cross over and balanced incomplete block designs. Groups of experiments.

VII. Learning outcome

The students will be able to plan and design the experiments for their research.

They will also be exposed to statistical software for the analyzing the data pertaining to designs of this course.

VIII. Lecture Schedule

S.No.	Topics	No. of Lectures
1.	Basic principles of experimental designs,	1
2.	Completely randomized design	1
3.	Randomized block design	1
4.	Latin square design	1
5.	Multiple comparison tests	1
6.	Missing plot techniques	1
7.	Analysis of covariance	1
8.	Factorial experiments	2
9.	Split plot design	1
10.	Strip plot design	1
11.	Factorial in split plot design	1
12.	Crossover designs	1
13.	Balanced incomplete block design	1
14.	Response surface designs	1
15.	Groups of experiments	1
	Total	**16**

IX. List of Practicals

S.No.	Topics	No. of Practical
1	Completely randomized design	1
2	Randomized block design	1
3	Latin square design	1
4	Multiple comparison tests	1
5	Missing plot techniques	1
6	Analysis of covariance	1
7	Factorial experiments	3
8	Split plot design	1
9	Strip plot design	1
10	Factorial in split plot design	1
11	Crossover designs	1
12	Balanced incomplete block design	1
13	Response surface designs	1
14	Groups of experiments	1
	Total	**16**

X. Suggested Reading

- Cochran WG and Cox GM 1957. *Experimental Designs*. 2nd Ed. John Wiley.
- Dean AM and Voss D 1999. *Design and Analysis of Experiments*. Springer.
- Design Resources Server: www.iasri.res.in/design.
- *Examination of Theory and Practice*. John Wiley.
- Federer WT 1985. *Experimental Designs*. MacMillan.
- Fisher RA 1953. *Design and Analysis of Experiments*. Oliver & Boyd.
- Montogomery 2013. *Design and analysis of experiments*. John Wiley & Sons.
- Nigam AK and Gupta V K 1979. *Handbook on Analysis of Agricultural Experiments*. IASRI Publ.
- Pearce SC 1983. *The Agricultural Field Experiment: A Statistical Examination of Theory and Practice*. John Wiley & Sons

ANNEXURE I

List of BSMA Committee Members for Agricultural Engineering

Name and designation	Address	Specialization
1. **Dr J K Singh** Dean (Retd),	G.B. Pant University of Agriculture and Technology, Pantnagar	Chairman
2. **Dr Jaskarn Singh Mahal** Director of Extension Education Former Dean	College of Agricultural Engg. and Technology),	Convener
3. **Dr T B S Rajput** Emeritus Scientist	Indian Agricultural Research Institute, New Delhi	Member
4. **Dr A K Mehta** Professor & Head	College of Technology and Engineering, MPUAT, Udaipur	Member
5. **Dr S K Jha** Principal Scientist	Division of Post-Harvest Technology, New Delhi	Member
6. **Dr D Manohar Jesudas** Professor & Head	Department of Agricultural Machinery & Research Centre, TNAU, Coimbatore	Member
7. **Dr P K Singh** Professor	Department of Soil and Water Engineering, MPUAT, Udaipur	Member
8. **Dr Atul Mohod** Head, Department of Agricultural Engineering	Dr B.S. Konkan Krishi Vidyapeeth, Dapoli	Member

ANNEXURE II

Consultantion Process

Details of BSMA Committee Meeting Held

S. No.	Date	Organizing Institute
1.	Oct 22, 2018	PAU Ludhiana
2.	Feb 4-5, 2019	PAU Ludhiana
3.	March 25-26, 2019	TNAU, Coimbatore
4.	June 3-4, 2019	AAU, Anand Gujarat

Restructured and Revised
Syllabi of Post-graduate Programmes
Vol. 4

Food Technology

- Processing Technology
- Process Engineering
- Safety and Quality

Contents

Acknowledgements
(Food Technology)

The teaching and processing of food on commercial scale is of much recent origin and the number of teaching institutions and of research are countable on fingers. Like, dairy processing, food processing technology also started on the same pattern about two decades back. Indian Council of Agricultural Research recommended a 4 year undergraduate programme through its Dean's committee in year 2016 for different agriculture and allied fields. On completion of the exercise of Deans committee the next step of improving and developing Masters and Doctoral program by constituting Broad Subject Matter Area (BSMA) Committees for revision and uniformity in curricula and regulations. The narration in this manuscript is the outcome of BSMA on Food Technology meetings held at various locations and feedback from various institutions and invited specialists from other institutions and the industry.

During the course of this exercise, two meeting and two workshops were held at different institutions of the country with a view to obtain the status as well as the experiences of the faculty across the institutions and then deliberate on them with all enabling the committee to synthesize and make suitable recommendations to be used while framing the course titles and contents and decide the teaching weightage in terms of credits. Subsequently, the formation of course contents were assigned to a specialist group from amongst the committee members. These groups took the assignments to their respective places for completion. Such assignments were first presented in the next meeting/workshop for discussion and further moderations in view of some additional inputs received from other scientists. In this way the whole exercise took place for master's as well as Doctoral courses. Though, the work was vast but with due diligence and vigil by all of us, the matter reached to the desired stage of satisfactory completion. For all to happen, a word of gratefulness and gratitude to all need complements individually as well as combinedly.

First of all the Committee is beholden to Dr Trilochan Mohapatra, Secretary, DARE and Director General, ICAR, for reposing faith in the Committee and giving opportunity and guidance to examine, revise, and update the post graduate and doctoral curricula to build quality human resources and to fortify academic standards in our vitally important agriculture sector. The Committee is deeply indebted to Dr N.S. Rathore, and to his predecessor Dr R.C. Agrawal, Deputy Director General (Edn.), ICAR, New Delhi for their indulgence and guidance. Sincere gratitude to Dr G. Venkateshwarlu, Assistant Director General (EQR) for his humble and precise approach to support in numerous ways, along with Dr K.L. Khurana, Retired Principal Scientist, Education Division, Indian Council of Agricultural Research New Delhi to work as a bridge between the BSMA and ICAR.

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The Committee would like to place on record its gratitude to all the Vice-Chancellors/ Director of Institutes, Deans and other stakeholders for their tremendous support in completing this challenging task.

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Thanks, are also expressed to the participants of industry at different locations and sharing the training and skill needs of human resource for the future food processing industry.

Our heart core feelings to all the staff of Education Division ICAR and staff of different institutes who supported in organization of meetings/workshop and development of course for their support like a fraternity.

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Discipline: Processing Technology

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 4

Food Technology
– Processing Technology

Preamble

The efficient use of resources is the growing concern for all involved in food production, processing, distribution and retailing. The unique features of the raw materials of the food processing industries such as seasonality, perishability and variability in conjunction with sophistication required for processing to maintain high quality standards, necessitates special attention towards focused availability of qualified technical manpower, effective technologies and efficient machinery. The food industries in the country need modernization to face the challenges of the globalization. Government of India is also paying special attention to this important sector and associated stakeholders. Efficient utilization of resources will definitely help in manufacturing of nutritious and healthy food but also help in fostering economic development and therefore, improving livelihoods by promoting access to domestic, regional and international markets.

Over the years significant growth in processing technology have resulted in development of various value-added processed food products of very high quality and improvement in existing manufacturing processes. This motivated the BSMA committee for Food Science and Technology to enrich the content and syllabus of the MTech and PhD programmes in the area of Food Processing Technology. This will hopefully produce competent food technologists to handle resources from farm-to-factory-to-consumers and cater the various sectors of food processing industries.

The content and course are developed by keeping in mind the development and advancement in food technology globally. New techniques and advancement in food processing technology and new packaging techniques are introduced. Moreover, a new course is introduced named as Industrial Manufacturing of food and beverage which gives exposure to understand raw material quality, processing and production of food and beverage on industrial scale. Many new courses are introduced, viz. Frozen and Concentrated Foods, Aseptic Processing and Packaging, Traditional Foods, Technologies of Convenience Foods, Food Powders and Premixes, Food Business Management. A new subject Global Food Laws and Regulations is introduced which helps the food industry to export the food product to the world as per their specifications and regulations. New courses like Novel Technologies for Food Processing and Shelf Life Extension, Food Manufacturing Technology, Formulation of Standards of Food Products, Packaging and Labeling are introduced in PhD programme through which the students will develop and formulate new product, new technology and helps in developing the regulations of different food products.

The proposed curricula and quality measures should render Food Technology as an intellectually more stimulating discipline and an economically rewarding profession to attract talent and investment.

Course Title with Credit Load
M.Tech. in Processing Technology

Major Courses

Course Code	Course Title	Credit Hours
FPT 501	Emerging Technologies in Food Processing*	2+1
FPT 502	Emerging Technologies in Food Packaging*	2+1
FPT 503	Industrial Manufacturing of Food and Beverages*	2+1
FPT 504	Food Material and Product Properties	2+1
FPT 505	Cocoa and Chocolate Processing Technologies	2+1
FPT 506	Spices, Herbs and Condiments	2+0
FPT 507	Meat, Poultry, Fish and Egg Processing	2+1
FPT 508	Nutraceuticals and Specialty Foods	2+1
FPT 509	Frozen and Concentrated Foods	1+1
FPT 510	Aseptic Processing and Packaging	2+1
FPT 511	Traditional Foods	2+1
FPT 512	Technologies of Convenience Foods	2+1
FPT 513	Food Powders and Premixes	2+1
FPT 514	Food Ingredients and Additives	2+1
FPT 515	Flavour Chemistry and Technology	2+1
FPT 516	Bioprocessing and Separation Technology	2+1
FPT 517	Enzymes in Food Processing	2+1
FPT 518	Food Process Automation and Modelling	2+0
FPT 519	Zero Waste Processing	2+0
FPT 520	Special Problem/ Summer Internship	0+2

*Compulsory Rest of the courses will be decided by the students advisory committee keeping the minimum limits set for award of degree.

Minor Courses

Course Code	Course Title	Credit Hours
FPE 502	Engineering Properties of Food Materials	3(2+1)
FPE 504	Bioprocessing and Down Stream Engineering	3(2+1)
FPE 506	Numerical Technique and Stimulation	2(1+1)
FPE 508	Food Safety and Storage Engineering	3(2+1)
FSQ 503	Advanced Food Chemistry	3(2+1)
FSQ 504	Global Food Laws and Regulations	2(2+0)
FSQ 506	Process and Products Monitoring for Quality Assurance	2(2+0)
FSQ 508	Management of Food By-products and Waste	3(2+1)

Supporting Courses

Course Code	Course Title	Credit Hours
BSH 501	Research Methodology	2+0
BSH 502	Food Informatics	1+1
FBM 501	Post-Harvest Management	2+1
FBM 502	Food Business Management	2+0
FBM 503	Food Processing Entrepreneurship and Start up	0+1
FPE 505	Energy Management and Auditing in Food Industry	2+1
FSQ 521	Food Safety Management Systems and Certification	2+1
FSQ 523	Quality Concepts and Chain Traceability	2+0
FPE 510	Operation Research	2+1

Common Courses

S. No.	Course Title	Credit Hours
1.	Library and Information Services	1
2.	Technical Writing and Communications Skills	1
3.	Intellectual Property and its Management in Agriculture	1
4.	Basic Concepts in Laboratory Techniques	1
5.	Agricultural Research, Research Ethics and Rural Development Programmes	1

These courses are available in the form of e-courses/MOOCs. The students may be allowed to register these courses/similar courses on these aspects, if available online on SWAYAM or any other platform. If a student has already completed any of these courses during UG, he/she may be permitted to register for other related courses with the prior approval of the HoD/BoS.

Seminar

Course Code	Course Title	Credit Hours
1	Seminar	1+0

Course Contents
M.Tech. in Processing Technology

I. Course Title : Emerging Technologies in Food Processing
II. Course Code : FPT 501
III. Credit Hours : 2+1
IV. Theory

Unit I

Membrane Technology: Pressure activated membrane processes: MF, UF, NF and RO and their industrial application. Membrane distillation. Supercritical fluid extraction: Concept, property of super critical fluids SCF, extraction methods, application in food processing.

Unit II

Microwave and radio frequency processing: Advantages, mechanism of heat generation, application in food processing: microwave blanching, sterilization and finish drying. Hurdle technology: Concept and Principle, Preservation techniques as hurdles and their principles, hurdle tech foods.

Unit III

High Pressure processing: Concept, equipment for HPP treatment, mechanism of microbial and enzyme inactivation and its application in food processing, effect on food constituents.
Ultrasonic processing: Properties of ultrasonic, types of equipment, application of ultrasonic as processing technique.

Unit IV

Newer techniques in food processing: principle and application of High intensity light, pulse electric field, ohmic heating, IR heating, inductive heating, cold plasma, and pulsed X-rays in food processing and preservation, Cryo-processing of foods Nanotechnology: Principles and applications in foods.

V. Practical

- To evaluate the characteristics of treated water using RO system
- To study production and characteristics of treated water using, microfiltration, UF, NF and RO system
- To study the effect of ultrafiltration process on fruit juices quality
- To study suitability and production of fruit juices using ultrafiltration
- To study the effect of microfiltration process on milk quality
- To study super critical fluid extraction system and to carry out extraction of bioactive compound from selected samples
- To carry out extraction of lycopene from tomato using SCFE system
- To study microwave system and to evaluate the effect of different power on drying characteristics of selected vegetable products

- To study microwave blanching of vegetable and determination of blanching efficacy
- To study the ultrasonicator and evaluate the effect of ultrasonication on micro-organism in sample
- To study the ultrasonicator and to evaluate the effect of ultrasonication on extracted juice yield from fruit pomace
- To evaluate the different pre-treatment on oil yield from oil seed cake
- To prepare nano emulsion and study of their characteristics
- To study ohmic heating system and to study the processing of fruit pup using ohmic heating system
- To visit food industries utilizing advance food processing techniques
- To study the effect of different drying techniques/ hybrid drying techniques on fruits and vegetables.

VI. Suggested Reading

- Gould GW, 2000. *New Methods of Food Preservation*, CRC Press.
- Barbosa-Canovas, 2002. *Novel Food Processing Technologies*, CRC Press.
- Dutta AK &Anantheswaran RC. 1999. *Hand Book of Microwave Technology for Food Applications*, CRC Press.
- Sun DW, 2015. *Emerging Technologies for Food Processing*, Elsevier Ltd.
- Kudra T and Mujumbar AS, 2009. *Advanced Drying Technologies*, CRC Press.
- Nema PK, Kaur BP and Mujumdar AS, 2018. *Drying Technologies for Foods: Fundamentals and Applications*, CRC Press

I. Course Title : Emerging Technologies in Food Packaging

II. Course Code : FPT 502

III. Credit Hours : 2+1

IV. Theory

Unit I

Active and intelligent packaging: Active Packaging Techniques and intelligent Packaging Techniques, current use of novel Packaging Techniques, consumers and novel Packaging Oxygen, ethylene and other scavengers: Oxygen scavenging technology, selecting right types of oxygen scavenger, ethylene scavenging technology, carbon dioxide and other scavengers.

Antimicrobial food packaging: Antimicrobial agents, constructing antimicrobial packaging systems, factors affecting the effectiveness of antimicrobial packaging.

Unit II

Non-migratory bioactive polymers (NMBP): Advantages of NMBP, Inherently bioactive synthetic polymers: types and application, Polymers with immobilized bioactive compounds and their applications.

Time Temperature labels and indicators (TTIs): Defining and classifying TTIs, Requirements for TTIs, development of TTIs, Maximizing the effectiveness of TTIs, Application of TTIs- to monitor shelf-life, and optimization of distribution and stock rotation, leakage indicators, oxygen indicators, micro indicators etc.

Freshness indicator in packaging: Compounds indicating the quality of packaged food products, freshness indicators, pathogen indicators, other methods for spoilage detection.

Self-heating/rehydrating packages.

Unit III

Packaging-flavour interaction: Factors affecting flavor absorption, role of food matrix, role of differing packaging materials, flavour modification and sensory quality, Study of packaging materials compatibility with foods.

Developments in modified atmosphere packaging (MAP): Permeability properties of polymer packaging, measurement of permeability – water and gases. Selection criteria of packaging films, Novel MAP gas, testing novel MAP applications, applying high oxygen MAP.

Recycling packaging materials: Recyclability of packaging plastics, improving the recyclability of plastics packaging, testing safety and quality of recycled materials, uses of recycled plastics in packaging.

Unit IV

Green plastics for food packaging: Problems of plastic packaging wastes, range of biopolymers, developing novel biodegradable materials.

Edible Films and Coatings: Properties, types, sources, applications, advantages, disadvantages, theories of plasticization, challenges and opportunities.

PFS machine, seal and closures.

Safety and legislative aspects of packaging: Regulatory considerations, plastic, metal, paper and glass packaging.

V. Practical

- Determination of WVTR in different packaging materials
- Determination of GTR in different packaging materials.
- Study of different ethylene scavengers and their analysis
- Study of different oxygen scavengers systems and their analysis
- Application of anti-microbial packaging for moisture sensitive foods
- Evaluation of chemical residue migration from package to food
- Application of MAP packaging in selected foods
- Study of TTI label, leakage indictors etc.
- Determination of oxidative changes in packaged foods
- Comparative evaluation of flexible and rigid packages for fragile foods
- Packaging of foods under inert atmosphere.
- To study textural characteristics of selected fruit/ vegetable under MAP storage
- Shelf life evaluation and mode up of packaged food product.
- Determination of oil and grease resistant test for packaging films
- Determination of respiration rate in fresh fruits and vegetables
- Determination of shelf life of fresh fruits and vegetables by using edible coating and films.
- Effect of edible coating and films on respiration behaviour, chemical, physical and sensory characteristics of fresh fruits and vegetables.
- Visit to food packaging material manufacturing industry

VI. Suggested Reading

- Ahvenainen R, 2001. *Novel Food Packaging Techniques*, CRC Press.
- Robertson GL, 2012. *Food Packaging*, CRC Press.
- Hanlon, JF, Kelsey RJ and Forcinio H. 1998. *Handbook of Package Engineering*, CRC Press.
- Painy FA, 1992. *A Handbook of Food Packaging*, Blackie.
- Rooney ML, 1988. *Active Food Packaging*, Chapman & Hall.
- Coles R and Kirwan M, 2011. *Food and Beverage Packaging Technology*, Wiley-Blackwell.
- Han J and Han J, 2005. *Innovations in Food Packaging*, Academic Press.

- Yam K and Lee D, 2012. *Emerging Food Packaging Technologies*, Woodhead Publishing.

I. Course Title : Industrial Manufacturing of Food and Beverages
II. Course Code : FPT 503
III. Credit Hours : 2+1

IV. Theory

Unit I

Grain products: Industrial manufacturing of grain based products: formulation, processes, machinery and material balance of baked, rolled, shredded, puffed, flaked, roasted products.
Extrusion technology: Importance and applications of extrusion in food processing; Pre and post extrusion treatments; Manufacturing process of extruded products; Change of functional properties of food components during extrusion. Breakfast cereals, RTE/RTC foods, instant premixes, functional foods.

Unit II

Fruit and vegetable products: Industrial manufacturing of fruit and vegetable based products: formulation, processes, machinery and material balance of minimally processed, Retorted products, IMF, high moisture stable foods, IQF; Machines and equipment for batch and continuous processing of fruit and vegetable products.

Unit III

Chocolates and candies: Coating or enrobing of chocolate (including pan-coating); Maintenance, safety and hygiene of bakery plants.
Fats and oils processing: Technology of refined oil, winterized oil, hydrogenated fat, texturized fat, by-products of fat/oil processing industries – oil seed protein isolates; Quality standards of fats and fatty foods; Antioxidants and its mechanism of application.

Unit IV

Beverages: Production technology of beer and wine
Non-alcoholic beverages: Carbonated beverages: carbonation equipment, -ingredients-preparation of syrups-Filling system-packaging-containers and closures. Non-carbonated beverage: Coffee bean preparation-processing-brewing-decaffeination- instant coffee, Tea types-black, green, Fruit juices and beverages,. Flash pasteurization, Aseptic Packaging of beverages Tea/coffee and cocoa beverages, Grain based and malted beverages.
Packaged drinking water: types, manufacturing processes, quality evaluation and raw and processed water, methods of water treatment, BIS quality standards of bottled water; mineral water, natural spring water, flavoured water, carbonated water.

V. Practical

- Preparation of cereals based fried snack foods
- Preparation of cereal, pulses based ready-to-eat snack food by extrusion cooking their quality evaluation
- Preparation of cereal grain based puffed products
- Development of instant food premixes
- Preparation of cereal and legume based roasted snack
- Preparation of flaked rice product

- To study the effect of roasting time and temperature on quality of pop-corn
- Determination of shelf-life and packaging requirements of snack food products
- Preparation of fruits/vegetable based ready to serve beverages and quality evaluation
- Heat classification of milk powders.
- Determination of degree of browning-chemical/physical methods.
- Determination of quality of packaged drinking water.
- Preparation of wine and beer
- Preparation of soy milk.
- Determination of quality of canned food.

VI. Suggested Reading

- Edmund WL, 2001. *Snack Foods Processing*, CRC Press.
- Gordon BR. 1990. *Snack Food*, Springer US.
- Frame ND, 1994. *Technology of Extrusion Cooking*, Springer US
- O'Brien RD, 2008. *Fats and Oils: Formulating and Processing for Application*, CRC Press.
- Davis B, Lockwood A, Alcott P and Pantelidis L, 2012. *Food and Beverage Management*, CRC Press.
- Kunze W, 2010. *Technology: Brewing and Malting*, VLB.
- Dhillon PS and Verma S, 2012. *Food and Beverage: Production Management for Hospitality Industry*, Abhijeet Publications.
- Bamforth CW, 2006. *Brewing: New Technologies*, Woodhead Pub.

I. Course Title : Food Material and Product Properties

II. Course Code : FPT 504

III. Credit Hours : 2+1

IV. Theory

Unit I

Introduction: Biomaterials and their properties in relation to processing and product development.

Physico-chemical characteristics: Shape, sphericity, size, volume, microstructure, density, porosity, surface area, coefficients of friction and angle of repose and influence of constituents on processing.

Unit II

Mechanical and rheological properties: Flow behaviour of granular and powdered food materials, rheological models, creep phenomenon, stress – strain - time effects and relationships, and techniques of model fitting, Elastic vs. textural characteristics and textural profile analysis of food products.

Unit III

Thermal, electrical and optical properties: Specific heat, thermal conductivity, phase transition, thermodynamics-basic principles and laws, Thermodynamic properties of moist air, kinetics of water absorption, heat capacity, thermal diffusivity, electrical resistance and conductance, dielectric constant, reflectivity, transmittivity and absorptivity of incident rays.

Food microstructure: Methods and systems for food microstructure, determination of light microscopy, transmission electron microscopy, scanning electron microscopy, other instrumentation and techniques, image analysis: image acquisition, image processing, measurement analysis.

Unit IV

Functional properties: Dextrinization, Gelatinisation, Crystallisation, gelation, foaming, coagulation, denaturation and syneresis, foaming, emulsification.

Sensory attributes: Sensory properties and correlation with objective indices, microstructure and its relation to texture from their mechanical models and its examination.

Sorption behaviour of food: sorption isotherm, modelling.

V. Practical

- To determine physical dimension and shape for suitability of processing and packaging of food materials
- To determine bulk, true density and porosity of samples
- To determine the angle of repose using rough and smooth surface
- Analysis of powder characteristics using powder flow analyser.
- To determine the mixing and strength characteristics of wheat flour using faringograph/ mixograph/ mixolab
- To determine the amylolytic activity using falling number of wheat flour
- Development of stress and strain curve and to study viscosity of Newtonian and non-Newtonian fluid
- Effect of temperature on viscosity profile of a food sample
- Texture profile analysis of foods samples.
- Effect of temperature on textural profile of food
- Determination of thermal properties of foods using DSC.
- To estimate dielectric constant of foods
- Organoleptic evaluation of food materials
- TEM and SEM, image analysis and image processing techniques
- To determine water activity of food
- To determine colour value of food, viz. Lab, whiteness index, yellow index, browning index

VI. Suggested Reading

- Rao MA and Rizvi SSH, 1986. *Engineering Properties of Foods*, Marcel Dekker.
- Aguilera JM & Stanley DW, 1999. *Microstructural Principles of Food Processing and Engineering*, Springer.
- Mohsenin NN, 1986. *Physical Properties of Plant and Animal Materials*, Gordon & Breach Science.
- Bourne MC, 1981. *Food Texture and Viscosity; Concept and Measurement*, Academic Press.
- Steffe JF, 1992. *Rheological Methods in Food Process Engineering*, Freeman Press.
- Aguilera JM, 1999. *Micro Structure: Principles of Food Processing Engineering*, Springer.
- Rahman MS, 2009. *Food Properties Handbook*, CRC Press.
- Serpil S & Sumnu SG, 2006. *Physical Properties of Foods*, Springer-Verlag.
- Pomeranz Y, 1991. *Functional Properties of Food Components*, Academic Press

I. Course Title : Cocoa and Chocolate Processing Technologies

II. Course Code : FPT 505

III. Credit Hours : 2+1

IV. Theory

Unit I

Introduction: Cocoa, Occurrence, chemistry of the cocoa bean, analysis of cocoa beans, processing of raw bean, changes taking place during fermentation of cocoa bean

Cocoa processing: processing of cocoa bean- Cleaning, roasting, alkalization, cracking and fanning; Nib grinding for cocoa liquor, cocoa butter and cocoa powder; processing of roast bean; chemical changes during various stages of processing

Unit II

Chocolates: Types, ingredients, chemistry of chocolate manufacture, Mixing, Refining, Conching, Tempering, moulding etc. to obtain chocolate slabs, chocolate bars. Dark, milk and white chocolate and their manufacturing processes

Unit III

Enrobed and other confectionary products: Compound Coatings & Candy Bars, Tempering technology, Chocolate hollow figures, Chocolate shells, Enrobing technology, Manufacture of candy bars, Presentation and application of vegetable fats. Production of chocolate mass

Unit IV

Packaging, quality and storage of chocolates.

V. Practical

- Anatomical structure of cocoa beans
- Effect of fermentation on cocoa beans
- Roasting of cocoa beans
- Effect of roasting on cocoa beans
- Effect of packaging on quality of cocoa beans
- Production of cocoa liquor
- Production of cocoa butter
- Effect of crunching on chocolate
- Effect of tempering on chocolate
- Fat expulsion during chocolate storage
- Production of milk chocolate
- Production of dark chocolate
- Effect of packaging on quality of chocolate
- Effect of storage temperature on chocolate quality

VI. Suggested Reading

- Minifie, BW, 1999. *Chocolate, Cocoa and Confectionery Technology*. Springer Science & Business Media.

I. Course Title : Spices, Herbs and Condiments

II. Course Code : FPT 506

III. Credit Hours : 2+0

IV. Theory

Unit I

Introduction: Status and scope of spice processing industries in India; Spices, Herbs and seasonings: sources, production, selection criteria, classification on the basis of origin, physical characteristic.

Major spices: Post-Harvest Technology composition, processed products of following spices (1) Ginger (2) Chilli (3) Turmeric (4) Onion and garlic (5) Pepper (6) Cardamom

Unit II

Minor spices, herbs and leafy vegetables: All spice, Annie seed, sweet Basil, Caraway seed, Cassia, Cinnamon, Clove, Coriander, cumin, Dill seed, nutmeg, mint, Rose merry, saffron, sage

Processing technology of Spices: Chemical composition, processing methods, equipment's used; recent developments in processing

Unit III

Processing effect on spice quality: Effect of processing on spice quality, contamination of spices with micro-organisms and insects

Unit IV

Spice Essential Oils: methods of extraction, isolation, and encapsulation,
Spice Oleoresins: method of extraction, isolation, separation equipment
Spices quality evaluation: Criteria for assessment of spice quality

V. Suggested Reading

- Reineccius G. 2005. *Flavour Chemistry and Technology*. CRC Press.
- Heath HB, 1986. *Flavour chemistry and Technology*. AVI Publ.
- Piggott JR, Paterson A. 1994. *Understanding Natural Flavours*. Springer US

I. Course Title : Meat, Poultry, Fish and Egg Processing

II. Course Code : FPT 507

III. Credit Hours : 2+1

IV. Theory

Unit I

Meat Industry: Meat and meat products in India-an Industrial profile. Meat production and trade practices. Prospects and problems in production of fresh meat in India, Research and Development activities on meat, fish and poultry products. Gross and microstructure of muscle. Mechanism of muscle contraction and relaxation: Organization of skeletal muscle from gross structure to molecular level. Muscle Communication (sarcolemma, sarcoplasmic reticulum, Innervation). Muscle metabolism. Different types of connective tissues and their relevance to properties of meat. Myofilament proteins and their major functions. Nervous tissue, nerves and the nature of stimuli, membrane potential in nerve and muscle, Events that occur during relaxation and contraction.

Unit II

Cattle and beef, sheep and mutton, pig and pork and their fabrication: Breeds, Pre-slaughter care, ante and post mortem, slaughter, handling of offal (edible and inedible). Cuts of beef, pork and mutton.

Meat inspection and grading: Application and Enforcement of inspection laws, elements of inspection (sanitation, antemortem inspection, post-mortem inspection, condemnation, product inspection, laboratory inspection, labelling). Identification of inspected products, product inspection, types of grades, factors used to establish quality grades, conformation, fleshing and finish.

Unit III

Properties of fresh meat: Perception of tenderness, Factors effecting tenderness, connective tissue, collagen, sarcomere contractile state, Myofibrillar tenderness, marbling. Methods to improve tenderness (Electrical stimulation, aging, Meat colour, Pigments associated with colour, Chemical state of pigments, methods to improve meat colour. Water holding capacity (Net charge effect and stearic effect) Molecular Techniques in meat products, cultured meat etc.

Poultry meat: Kind of poultry, processing of poultry. Special poultry products, Breaded poultry, Smoked turkey, packagedprecooked chicken, Freeze dried poultry meat.

Egg and egg processing: Egg quality, egg preservation, egg powder production

Unit IV

Meat analogues and restructured meat products: Textured plant proteins, processes for preparation of meat analogues and restructured meat products.

Fish processing and fish products: Chemical/Nutritional composition of Fish, Fish in human diet: protein, carbohydrates, lipids, vitamins etc. Selection of raw material for processing of streaking and filleting of fish; production of fish paste, fish oils, sauce, fish protein concentrates. Irradiation of fish and fisheries products, packaging of fish products, quality control and quality assurance. Allergens, toxins and infectious diseases from meat, poultry and fish products.

V. Practicals

- To study the effect of low and high oxygen atmosphere on meat colour.
- To study the chemistry of myoglobin as it relates to the colour of the molecule.
- To understand and compare the action of two meat tenderizing enzymes by applying the technique of electrophoresis.
- To study the structure of the muscle under compound microscope.
- Perform the slaughtering of the poultry birds.
- Identification of different internal organs of poultry birds and their utilization for product preparation.
- Dressing of Fish.
- Determination of total volatile acids in fish,
- Determination of buffering capacity of fish muscle.
- Rapid estimation of hypoxanthine concentration in chill stored fish.
- Determination of glycine in fish muscle.
- Determination of protein fractions in fresh fish.
- Cut out test for canned fishery products.
- Determination of glycogen in fish muscle.
- Industrial visit to meat industry.

VI. Suggested Reading

- Henricksons. 1978. *Meat Poultry and Sea Food Technology*/ Prentice Hall
- Robert RJ. 2012. *Fish Technology*/ Wiley-Blackwell
- Mountney GJ. 1988. *Poultry Meat and Egg Production*/ Springer, Netherlands
- Kerry J, Kerry J. 2002. *Meat Processing*/ Woodhead Publishing and David Ledwood
- Levie A. 1979. *Meat Hand Book*, Avi Pub
- Weiss GH. 1971. *Poultry Processing*. Noyes Data Corporation
- Wheaton FW and Lawson TB. 1985. *Processing of Aquatic Food Products* John Wiley & Sons.
- Mead G. 2004. *Poultry meat processing and quality* Woodhead Publishing
- Sinha R. 2017. *HACCP in Meat, Poultry and Fish Processing*/ Random Publications
- Sahoo J and Chatli MK. 2015. *Textbook on Meat, Poultry and Fish Technology*/ Daya Pub. House.

- Badapanda KC. 2012. *Basics of Fisheries Science*/ Narendra Publishing House
- Sahoo J, Sharma DK and Chatli MK. 2016. *Practical Handbook on Meat Science and Technology*/ Daya Pub. House

I. Course Title : Nutraceuticals and Specialty Foods

II. Course Code : FPT 508

III. Credit Hours : 2+1

IV. Theory

Unit I

Introduction: Defining nutraceuticals and functional foods. Nature, type and scope of nutraceutical and functional foods. Nutraceutical and functional food applications and their health benefits. Nutraceutical compounds and their classification based on chemical and biochemical nature, Innovations in Functional Food Industry for Health and Wellness, Development of biomarkers to indicate efficacy of functional ingredients.

Nutraceuticals and Functional foods: Nutraceuticals/ food components for specific disease such as cancer, heart disease, diabetes, obesity, anti-aging, arthritis, Prebiotics and probiotics; Omega 3 and omega 6 fatty acids, Isoflavones, phenolic compounds, catechins, lycopene, glucosinolates.

Unit II

Specialty Foods: Design of food for infants, children and old age.

Functional Beverage: Selection of ingredients, health benefits and production.

Extraction and delivery system: Non-thermal techniques, bioprocessing techniques, dehydration techniques, effect on bioactive ingredients. Delivery system and controlled release of nutraceuticals

Unit III

Packaging, Storage, labelling: Packaging requirements, storage and storage kinetics on quality of nutraceuticals, interactions of various environmental factors.

Marketing and safety aspects: Marketing and safety and regulatory issues for functional foods and nutraceuticals.

Unit IV

Nutrigenomics: concept of personalized medicine. Use of nanotechnology in functional food industry.

Biological functionality of cruciferous vegetables, tropical, subtropical and temperate fruits, herbs and spices.

V. Practical

- Determination of antioxidant activity of given food sample by different techniques, viz. DPPH, FRAP, ABTS, FRAP.
- Determination of total phenolic content of given food sample.
- Estimation of dietary fibres of given food sample.
- Estimation of lycopene in tomato.
- Estimation of carotenoids of given food sample.
- Determination of total flavonoid content of given food sample
- Effect of heat processing on ascorbic acid
- Determination of vitamins A.

- Estimation of pectic substances in plant sample
- Determination of beta carotene of given food sample.
- To determine gas chromatography for bioactive components analysis.
- To study the effect of drying on bioactive components of food sample
- To study the packaging requirement of functional foods.
- Determination and qualifications of some nutraceutical and functional food compounds by HPLC
- Estimation of â- glucan
- To study the storage kinetics of nutraceutical.
- Estimation of soluble/insoluble fibres of given food sample.

VI. Suggested Reading

- Chadwick R Henson S and Moseley B, 2003. *Functional Foods*, Springer-Verlag.
- Jeffrey Hurst W, 2008. *Methods of Analysis for Functional Foods and Nutraceuticals*, CRC Press.
- Shi J, Mazza G and Maguer M, 2002. *Functional Foods*, CRC Press.
- Wildman REC, 2006. *Handbook of Nutraceuticals and Functional Foods*, CRC Press.
- Vattem DA and Maitin V, 2016. *Functional Foods, Nutraceuticals and Natural Products*, DEStech publications.
- Grumezescu AM, 2016. *Nutraceuticals: Nanotechnology in the Agri-Food Industry*, Elsevier Inc
- Rizvi SSH, 2010. *Separation, Extraction and Concentration Processes in the Food, Beverage and Nutraceutical Industries*, Woodhead Publishing.
- Tomar SK, 2011. *Functional Dairy Foods Concepts and Applications*, Satish Serial Publishing House.
- Gupta RK, Bansal S and Mangal M, 2012. *Health Food Concept, Technology and Scope*, Biotech Books.

I. Course Title : Frozen and Concentrated Foods

II. Course Code : FPT 509

III. Credit Hours : 1+1

IV. Theory

Unit I

Freezing: Glass transitions in frozen foods and biomaterials, Microbiology of frozen foods, Thermo-physical properties of frozen foods, Freezing loads and Freezing time calculation, Innovations in freezing process, freezing methods and equipment. Facilities for the Cold Chain: Cold store design and maintenance, Transportation and storage of of frozen foods, Retail display equipment and management.

Unit II

Quality and safety of frozen foods: Quality and safety of frozen meat and meat product, poultry and poultry products, eggs and egg products, fish and shellfish, and related products, frozen vegetables and fruits, frozen dairy products, frozen ready meals and confectioners.

Unit III

Packaging of frozen foods: Selection of packaging materials, Plastic and paper packaging of frozen foods, Shelf-life prediction of frozen foods.

Unit IV

Concentrated milk: Production and quality of evaporated and condensed milk.

Concentrated juice products: Production and quality of fruits and vegetable juice concentrate, puree and paste, tomato juice concentrates, mango pulp etc.

V. Practical

- Measure the glass transition temperature of food
- Calculate freezing load of food sample
- Calculate freezing time of a frozen foods
- Effect of cold chain on quality of fruits and vegetables
- Effect of cooling on egg quality
- Effect of chilling on meat quality
- Effect of freezing on meat quality
- Production of concentrated milk and check its quality
- Production of evaporated milk and check its quality
- Effect of clarification n juice quality
- Effect of juice concentration on juice concentrate
- Effect of cold and hot break on tomato pulp quality
- Production tomato puree and paste and check its quality

VI. Suggested Reading

- Erickson MC & Hung YC, 1997. *Quality in Frozen Foods*, Springer.
- Hui YH, Legarretta IG, Lim, MH, Murrell KD & Nip WK, 2004. *Handbook of Frozen Foods*, CRC Press.
- Kennedy C J, 2000. *Managing Frozen Foods*, Elsevier.

I. Course Title : Aseptic Processing and Packaging

II. Course Code : FPT 510

III. Credit Hours : 2+1

IV. Theory

Unit I

Introduction: present and future of aseptic processing, Advantages and disadvantages, processing of semi-solid and fluid and particulate foods.

Aseptic processing operations: pre-sterilization, loss of sterility, water-to-product and product-to-water separation, cleaning, control, CIP.

Unit II

Quality Assurance: Effect of aseptic processing on nutrients, microorganisms, in-process and post-process assurance, HACCP, regulatory aspects of processing and packaging, Shelf life modules.

Unit III

Sanitary design and Equipments requirements: Pumps, Heat exchangers, homogenizers, aseptic process and packaging system for retail and institutional packages.

Unit IV

Packaging of aseptic processed foods: Packaging materials characteristics, aseptic filling, sterilization of packaging materials, package design, aseptic packaging system, type of pack and equipments: Fill and seal, Form, fill and seal, Erect, fill and seal, Thermoform, fill, sealed, Blow mold, fill, seal; geometry, materials and size of retail and bulk package, seal and closures.

V. Practical

- Effect of aseptic processing on microbial quality of juice based beverage
- Effect of aseptic processing on vitamins in selected foods.
- Effect of aseptic processing on minerals in selected foods.
- Effect of aseptic processing on colour pigments in selected foods.
- Effect of aseptic processing on browning of milk
- Effect of aseptic processing on viscosity of milk
- Effect of aseptic processing on proteins in selected foods
- Effect of different chemical sterilant on microbial quality of packaging material
- To estimate chemical sterilant residue on packaging materials
- Estimation of package integrity and leakage
- Shelf life models and prediction.

VI. Suggested Reading

- Robertson GL, 2012. *Food Packaging: Principles and Practices*, CRC Press.
- David JRD, Graves RH and Szemplenski T, 2016. *Handbook of Aseptic Processing and Packaging*, CRC Press.
- Reuter H, 1993. *Aseptic Processing of Foods*, CRC Press.
- Willhoft EM, 1993. *Aseptic Processing and Packaging of Particulate Foods*, Springer.

I. Course Title : Traditional Foods

II. Course Code : FPT 511

III. Credit Hours : 2+1

IV. Theory

Unit I

Present status of traditional food products, Globalization of traditional food products; Plans and policies of the Government and developmental agencies.

Overview of heat-desiccated, coagulated, fried, fermented traditional food products

Process technology for Indian bread (chapatti), paratha, stuffed paratha, panipoori

Process technology for Indian fried foods- poori, samosa, sev, fafda, chorafali, Jalebi

Process technology for fermented traditional food and its improvement- pickle, idli, khaman, nan, dahi, dhokla, Spiced buttermilk etc.

Process improvement in production of Indian sweets (Halwasan, kajukatli, carrothalwa, Rabdi, chocolate burfi, Chikki etc).

Process improvement in production of puffed cereals and grains by microwave technique

Unit II

New products based on fruits, vegetables and cereals

Application of membrane technology; microwave heating, steaming, extrusion for industrial production of traditional food products (Shrikhand, Dhokla, wadi, murukku/chakri, Patra, Khandvi)

Utilization and scope of legumes and grains in India for novel food products development like- flour, ready to eat products, flour mixes etc (puranpoli, Idlimix,Wada mix, Gotamix)

Process technology for convenience traditional food products (ready to eat and serve -Curried vegetables, pulses and legumes), chutneys, paste

Use of natural and permitted synthetic preservatives and new packaging systems for traditional food products.

Unit III

Techno-economic aspects for establishing commercial units for traditional products. Introduction to traditional foods of India, composition and nutritive values, microbial and biochemical diversity, quality and food safety challenges Processing& Preservation methods of Sweets & Desserts**:** Kulfi, Falooda, Kheer, khurchan, khoa/mawa, Rabri,jalebi, imarti, Gulab jamun, Peda, petha, rewdi, gajak, milk cake, balushahi, bal mithai, singoni, Ras-malayi,Gulqand, ghevar, rasgolla, chamcham, son halwa, son papri, several varieties of halwa, laddu, barfi & rasgolla.

Unit IV

Traditional fermented foods: Idli, dosa, Vada, khamman dhokla, Dahi (Curd), Srikhand.Processing & Preservation methods of Snacks**:** Gujiya, kachauri, samosa, mirchibada, kofta, potato chips, banana-chips, mathri, bhujiya, fried dhals, bhujia, shakarpara, pakora, vada.

Processing & Preservation methods of Baked Products: Biscuits, Toast, Candies, Cookies, Breads, Roti, Naan, Tandoori Roti, parantha, kulcha, puri, bhatura.

Processing & Preservation methods of Preserves & Beverages: Murabba, sharbat, pana, aampapad, sharbat,

Coconut water, milk (khas, rose), Alcoholic Beverages

Industrialization, Socioeconomic Conditions and Sustainability of Traditional Foods.

V. Practical

- To study the effect of different combination of salt and oil in quality of traditional fermented food product (pickle)
- To study the effect of different starter culture on taste and texture of idli
- To evaluate the shelf life of stuffed paratha under different storage conditions
- To study the effect of time and temperature on quality of fried food products (poori/ panipoori etc.
- To study effect of sugar and Artificial sweeteners in the preparation of kajukatli
- To study the microwave heating in drying of khaman/ dhokla
- To study the effect of cold extrusion on mixing of vermicelli
- To prepare instant carrot halwa mix
- To study the effect of different packaging material on shelf life of traditional Indian food products
- To study the effect of different natural food preservatives in traditional sweets
- Preparation of spiced buttermilk
- Preparation of puffed cereals and grains
- Preparation and quality evaluation of Instant Premixes (Puranmix)
- Preparation of quality evaluation of dried malted moth bean powder
- Preparation of Indian traditional confections (chikki)
- Visit to ethnic food industry (Instant mixes/Pickle making)

VI. Suggested Reading

- Steinkrus KH. 1995. *Handbook of Indigenous Fermented Foods*. CRC Press
- Wickramasinghe P. 2007. *The Food of India OM Book Service*
- Aneja RP, Mathur BN, Chandan RC and Banerjee AK. 2002. *Technology of Indian Milk Products*, India Year Book Publications
- Mangal R. 2013. *Fundamentals of Indian Cooking: Theory and Practice*

I. Course Title : Technologies of Convenience Foods

II. Course Code : FPT 512

III. Credit Hours : 2+1

IV. Theory

Unit I

Overview of grain-based snacks: whole grains – roasted, toasted, puffed, popped and flakes

Coated grains- salted, spiced and sweetened

Flour based snack– batter and dough-based products; *savoury* and *farsans*;formulated chips and wafers, papads.

Fruit and vegetable-based snacks: chips, wafers, papads etc.

Coated nuts – salted, spiced and sweetened products- *chikkis, fried groundnut pakora,*

Unit II

Technology of ready- to- eat baked food products, drying, toasting, roasting and flaking, coating, chipping

Extruded snack foods: Formulation and processing technology, flavouring and packaging

Unit III

Ready-to-cook food products- different puddings and curried, Vegetables, meat and meat food products etc. Technology of instant cooked rice, carrot and other cereals-based food products

Technology of ready to eat instant premixes based on cereals, pulses etc.

Technology for RTE puffed snack- sand puffing, hot air puffing, explosion puffing, gun puffing etc.

Unit IV

Equipment for frying, baking and drying, toasting, roasting and flaking, popping, blending, coating, chipping.

V. Practical

- Preparation of cereals based fried snack foods
- Preparation of legume based fried snack foods
- Preparation of cereal, pulses based ready-to-eat snack food by extrusion cooking and their quality evaluation
- Preparation of cereal grain based puffed products
- To study the effect of frying time and temperature on potato chips
- Development of instant food premixes
- Preparation of cereal and legume based roasted snack
- Preparation of flaked rice product
- To study the effect of roasting time and temperature on quality of pop-corn
- Determination of shelf-life and packaging requirements of snack food products
- Preparation of cereal and legume based roasted snack foods by vacuum frying
- Visit to industries manufacturing snack foods.

VI. Suggested Reading

- Edmund WL 2001. *Snack Foods Processing*. CRC Press
- Frame ND 1994. *Technology of Extrusion Cooking*, Blackie Academic.

- Gordon BR 1997. *Snack Food* AVI Publ.
- Samuel AM. 1976. *Snack Food Technology*. AVI Publ.
- Manley D. 2000. *Technology of Biscuits, Crackersand Cookies* CRC Press
- Deny AV and Dobraszczyk BJ. 2001. *Cereals and Cereal Products*, Aspen Publishers
- Ram S and Mishra B. 2010. *Cereals: Processing and Nutritional Quality*, New India Publishers

I. Course Title : Food Powders and Premixes

II. Course Code : FPT 513

III. Credit Hours : 2+1

IV. Theory

Unit I

Food powder properties: Particle size, shape, particle size distribution, density, Crystalline and amorphous microstructure of powders, cohesive forces in powders, adhesive forces and surface energies, stickiness of powders, surface structure of powders, fluidity of powders, compressibility of powders, mixing property of powders, segregation of powder particles, flow and packing properties

Handling of food powders: Basic flow patterns in storage vessels, storage vessel design, mass-flow operation, the Jenike silo design method, the flow-no flow criterion, Powder conveying: Belt, screw, chain, pneumatic

Unit II

Size reduction and enlargement: Principles, equipment, criteria for selecting comminution process, aggregation and agglomeration, instantization

Encapsulation: Principles, methods of encapsulation, viz. spray drying, coacervation, extrusion, co-crystallization

Unit III

Powder Production: Spray, drum and freeze-drying process and equipments

Undesirable properties: Attrition, segregation, caking, dust explosion hazards, laboratory testing to assess explosion characteristics of dust clouds, safety from dust cloud explosion hazards

Food powder rehydration: Principles of powder rehydration- wettability and sink ability, dispersibility, solubility, improvement of rehydration properties

Surface composition of food powders: Microscopy and spectroscopy techniques for analysing the surface of food powder, factors affecting food powder surface composition, impact of powder surface composition on powder functionality.

Unit IV

Packaging and Storage: Packaging requirements, design of package, effect of environmental factors on quality of food powders, shelf life test and prediction

Food Premix: Formulation, processing and packaging of Vitamin premix, mineral premix, fibres premix for food supplements

V. Practical

- Estimation of bulk properties: bulk density, true density, porosity
- Estimation of reconstitution powder properties: wettability, dispersibility, solubility
- Effect of moisture on lump formation and caking
- Estimate flowability of food powders
- Estimate hygroscopicity of powder

- Estimate glass transition and sticky point temperature of food powder
- Effect of bulk properties on packaging
- Measurement of particle size using particle size analyser
- Measurement of surface properties of food powder using SEM
- Packaging of food powders
- Effect of storage on quality of food powders
- Production of various vitamin premix and its application
- Production of various mineral premix and its application

VI. Suggested Reading

- Hong Yan. 2005. *Food Powders: Physical Properties, Processing, and Functionality*/ Springer US.
- Bhandari BS, Bansal N, Zang M, Schuck P. 2013. *Handbook of Food Powders-Process and Properties*/ Woodhead Publishing
- Yasuo Arai. 1996. *Chemistry of Powder Production* Springer Netherlands
- Masuda H, Higashitani K and Yoshida H. 2006. *Powder Technology: Fundamentals of Particles, Powder beds, and Particle Generation*/ CRC Press

I. Course Title : Food Ingredients and Additives

II. Course Code : FPT 514

III. Credit Hours : 2+1

IV. Theory

Unit I

Introduction: Role of food ingredients and additives in food processing, functions, classification, intentional and unintentional food additives, toxicology and safety evaluation of food additives, beneficial effects of food additives, food additives generally recognized as safe (GRAS), tolerance levels and toxic levels in foods-LD 50 values of food additives.

Preservatives: General mechanism of action; basis of selection; classes; Chemical preservatives: characteristics, antimicrobial spectrum, mechanism of action, toxicology, regulations, application in food.

Unit II

Antioxidants: Characteristics, types/classes/groups, mechanism of action/ working of antioxidants, functions, sources, application in food, limits and toxic effects of synthetic antioxidants, synergistic effects of antioxidants, role of free radicals in human body, Natural antioxidants.

Flavouring agents: Flavour functions, selection; forms; sources; process of flavour creation; natural and synthetic flavouring; extractions methods; production process; application in food.

Emulsifiers and Stabilizers: Characteristics/ functional properties; functions; basis of selection; types; mechanism of emulsion formation; mechanisms of emulsion stabilization and destabilization; application in food.

Unit III

Hydrocolloids: Definition: function and functional properties: sources; application in food.

Sweeteners: Characteristics; classification/types; applications in food; Limits and toxicology of non-nutritive sweeteners.

Colouring agents: Properties; functions; classification; sources of natural and synthetic colours: extraction; applications in food, levels of use, misbranded colours, colour stabilization.

Unit IV

Starch, protein, and lipids, fibres and fructo-oligosaccharides: As functional ingredients; their isolation, modification, specifications, functional properties and applications in foods.

Humectants, clarifying agents, Stabilizers and thickeners, Bleaching and maturing agents, Humectants, Sequestrants/ chelating agents, Anti-caking agents, Buffering agents, Acidulants: definition; characteristics; sources; functions and their application in food processing.

V. Practical

- Determination of benzoic acid in food samples
- Estimation of sulphur dioxide in food samples
- Estimation of sorbic acid in cheese and yoghurt
- Determination of nitrate and nitrites in foods
- Detection and determination of aspartame by thin layer chromatography
- Liquid chromatographic determination of caffeine, benzoate and saccharin in soda beverage
- Identification of natural colours
- Isolation, identification and estimation of synthetic food colours
- TLC detection of antioxidants in fats and oils
- TLC detection of emulsifiers
- Detection of alginates in foods (chocolate, ice cream)
- GC determination of menthol in mentholated pan masala
- Isolation and modifications of protein, starch, lipids, fibres from the raw and processed food samples
- Estimation of various additives mentioned in unit IV

VI. Suggested Reading

- Branen AL, Davidson PM and Salminen S. 2001. Food Additives, Marcel Dekker.
- George AB. 1996. *Encyclopaedia of Food and Colour Additives*, CRC Press.
- Nakai S and Modler HW. 2000. *Food Proteins: Processing Applications*, Wiley VCH.
- Gerorge AB. 2004. *Fenaroli's Handbook of Flavour Ingredients*, CRC Press.
- Branen AL, Davidson PM, Salminen S and Thorngate JH, 2001. *Food Additives*, Marcel Dekker.
- Madhavi DL, Deshpande SS and Salunkhe DK. 1996. *Antioxidants: Technological, Toxicological and Health Perspective*, Marcel Dekker.
- Stephen AM. 2006. *Food Polysaccharides and Their Applications*, CRC Press.
- Smith J and Shum LH. 2011. *Food Additives Data Book*, Wiley-Blackwell.
- Baines D and Seal R. 2012. *Natural Food Additives, Ingredients and Flavorings,* Woodhead Publishing

I. Course Title : Flavour Chemistry and Technology

II. Course Code : FPT 515

III. Credit Hours : 2+1

IV. Theory

Unit I

Introduction: classification of food flavour, chemical compounds responsible for

flavours, difficulties of flavour chemistry research. Anatomy of chemical senses. Chemical compounds classes and their flavour response. Flavour intensifiers: Flavour intensifiers and their effects, Chemistry and technology of various flavour intensifiers.
Flavour Extraction: Methods of flavour extraction, isolation, separation and equipments.

Unit II

Flavour development during biogenesis: Flavour Compounds from Carbohydrates and Proteins, Lipid oxidation. Flavour formulation: Creating and formulating flavour, Synthetic flavours, Blended flavouring, flavour, creation for new products, Delivery of flavours from food matrices.
Flavouring compounds during food processing: Volatile and non-volatile flavouring compounds, non-enzymatic browning reactions.

Unit III

Flavour analysis: Sensory evaluation, discrimination analysis, descriptive analysis, Instrumental analysis (Absorption Spectroscopy (W/VIS), chromatography, mass spectrometry)
Food Flavours in different food products: Principal components and properties, baked products, cheese, milk, meat, fish, wine, coffee, tea, chocolate, fruit and vegetable products and fermented foods

Unit IV

Flavour encapsulation and stabilization: Principles and techniques of flavour encapsulation, types of encapsulation, factors affecting stabilization of encapsulated flavour and their applications in food industry, Packaging and flavour compounds interaction, packaging and storage

V. Practical

- Qualitative identification of different flavouring compounds
- Extraction of essential oil/ flavouring compound of basil leave by hydro distillation
- Extraction of essential oil/ flavouring compound of basil leave by SCFE
- Comparison of the quality of flavouring component obtained by hydro distillation and SCFE
- Extraction of essential oil/ flavouring compound of ginger by SCFE
- Effect of storage conditions on flavouring compound of ginger
- Preparation of flavour emulsions and their stability
- To study effects of staling on food flavours and its adverse effects
- Separation, purification and identification of some flavouring compounds by GC/ MS.
- Sensory evaluation of different flavours
- To check effect of cooking on flavour of food sample
- To check effect of fermentation on food flavour
- To study sugar caramelization reaction for flavour development
- Development of blended food flavour-based products
- To study effects of storage conditions on food flavour
- Encapsulation of flavouring compounds
- To study effects of overdoses of flavours
- To study flavour development on roasting/ baking

VI. Suggested Reading

- Reineccius G. 2005. *Flavour Chemistry and Technology*/ CRC Press
- Heath HB. 1986. *Flavour Chemistry and Technology*/ AVI Publ.
- Piggott JR, Paterson A. 1994/ *Understanding Natural Flavours*. Springer US
- Morton ID, Macleod AJ. 1990. *Food Flavour* Elsevier Science
- Ashurst PR. 1994. *Food Flavourings* Blackie
- Taylor AJ and Linforth RST. 2010. *Food Flavour Technology*/ Blackwell Publishing Ltd
- Hui YH. 2010. *Handbook of Fruit and Vegetable Flavours* Wiley & Sons, Inc
- Bruckner B and Wyllie SG. 2008. *Fruit and vegetable flavour: Recent advances and future prospectus* CRC Press.
- Ferreira V and Lopez R. 2013. *Flavour Science* Academic Press

I. Course Title : Bioprocessing and Separation Technology

II. Course Code : FPT 516

III. Credit Hours : 2+1

IV. Theory

Unit I

Introduction to various separation processes, Gas-Liquid, Gas–Solid, Liquid-Liquid, Liquid-Solid separation; Concept of phase equilibrium, Stage equilibrium, Stage efficiency, Equilibrium concentration; Single stage contact equilibrium, counter-current multiple contact stages, Concept of equilibrium line and operating line, Determination of optimum number of contact stages by analytical and graphical method; Rate of extraction, Rate of gas absorption, Individual and over all mass transfer coefficient; Calculation of tower height for gas absorption for both dilute and concentrated solution. Construction and working mechanism of different extraction equipments like single stage extraction, Multiple stage static bed system, Bollmann extractor, Hildebrandt extractor, Rotocell extractor.

Unit II

Various separation processes Solid Separation Process, Introduction, Concept of size, Shape, Cut-size, Sieving, Magnetic separation, Eddy-current separation, Wet separation, Ballistic separation, Colour separation, Wet Separation Process, liquid-solid and liquid- liquid separation by hydro cyclones, Surface velocity classifier, Elutriators, Impingement separator, Electrostatic precipitation, Distillation: Introduction, boiling point diagram, differential or simple distillation, Flash or equilibrium distillation, Continuous rectification with and without reflux, Reflux ratio, Optimum reflux ratio, Batch distillation, Application of distillation in food processing.

Unit III

Membrane Separation Technology: Introduction to micro-filtration, Ultrafiltration, Reverse osmosis, Electro dialyses, dialyses, physical characteristics of membrane separation, Factors affecting reverse osmosis process, Concentration polarization, Design of reverse osmosis and ultra-filtration systems, Operation layout of the modules, Electrodialysis, per vaporization, Fabrication of membranes, Application of membrane technology in food industry.

Unit IV

Powder Technology: Classification of powder, Separation of powder, Sieving, Air

classification, Factors affecting air classification, Cyclone application, Air separation, Particle size distribution,
Supercritical Fluid Extraction: Introduction, Properties of SCF, Food application, Application of SCFE in analytical technique, Pharmaceutical application.

V. Practical

- Determination of contact equilibrium in counter current and multiple contact model systems.
- Determination of rate of extraction in gas-liquid, gas-solid, liquid-liquid and liquid-solid systems.
- Study of working mechanisms of different extraction equipments.
- Evaluation of physical separation techniques based on size, shape and densities, magnetic, eddy current, ballistic and colour separation,
- Use of air classification, hydyocyclones, electrostatic and distillation techniques for fractionation and separation, application studies on Microfiltration, Ultrafiltration, reverse osmosis and dialysis.

VI. Suggested Reading

- Saravacos GD and Maroulis ZB. 2011. *Food Process Engineering Operations* CRC Press
- Smith PG. 2011. *Introduction to Food Process Engineering* Springer

I. Course Title : Enzymes in Food Processing

II. Course Code : FPT 517

III. Credit Hours : 2+1

IV. Theory

Unit I

Introduction: General Characteristics of Enzymes, Classes and Nomenclature of Enzymes, Enzymatic Reactions, Factors affecting enzyme activity, Enzyme Kinetic, Enzyme Inhibition
Enzyme Production: Selection and sources of commercial Enzymes, Advantages of microbial enzymes, rDNA in enzyme engineering, Problems of scale up, Enzyme extraction and purification

Unit II

Immobilization: Techniques, Advantages and disadvantages, use of immobilized biocatalysts in food processing
Enzymes for protein modification (hydrolysates and bioactive peptides), Enzymes for Lipid modification
Enzymes in cereal processing: Application of enzymes in process of malting, brewing, milling, baking (fungal –amylase for bread making; maltogenic – amylases for anti-staling xylansandpentosanes as dough conditioners; lipases or dough conditioning; oxidases as replacers of chemical oxidants; synergistic effect of enzymes), production of high fructose corn syrup, glucose syrups

Unit III

Enzymes in fruit processing: Applications of enzyme in fruit juice clarification, removal of haziness and bitterness, Uses of enzymes in wine production
Enzymes in meat, fish and milk processing: Meat tenderization and flavour development, fish processing (De-skinning, collagen extraction etc.,) Egg processing, Cheese processing,

Unit IV

Flavour production: Role of enzymes (enzyme-aided extraction of plant materials for production of flavours, production of flavour enhancers such as nucleotides, MSG; flavours from hydrolysed vegetable/animal protein)

Enzymes in the processing of fats and oils: specificity, stability and application of lipases and related enzymes Role of enzymes in hydrolysis of triglycerides, interesterification and randomization. Enzyme allergy.

V. Practical

- To investigate some of the kinetic properties of invertase
- To study time course of the reaction catalysed by alkaline phosphatase.
- To investigate the thermal stability of horseradish peroxidase
- Quantitative estimation of endoglucanase
- Quantitative estimation of exoglucanase
- Quantitative estimation of â galactosidase
- Quantitative estimation of Pectinase
- Quantitative estimation of Protease
- Quantitative estimation of Lipase
- Immobilization of amylase by sodium alginate and comparative evaluation with native enzyme
- To immobilize yeast cells and demonstrate its biological activity by invertase assay
- To carry out amylase fermentation
- To carry out protease fermentation
- To carry out lipase fermentation

VI. Suggested Reading

- Palmer T. 2008. *Enzymes: Biochemistry, Biotechnology and Clinical Chemistry*. East West
- Laskin AI. 2007. *Enzymes and Immobilized Cells in Biotechnology Benjamin*/ Cummings Pub. Co.
- Mansi ME and Bryce C. 2011. *Fermentation Microbiology and Biotechnology* CRC Press
- Price NC and Stevens L. 2000. *Fundamentals of Enzymology* Oxford University Press
- Reed G. 2007. *Enzymes in Food Processing* Academic Press
- Whitehurst RJ and Oort MV. 2010. *Enzymes in Food Technology* Blackwell Publ
- Bayindirli A. 2010. *Enzymes in Fruit and Vegetable Processing: Chemistry and Engineering Applications* CRC Press.

I. Course Title : Food Process Automation and Modelling

II. Course Code : FPT 518

III. Credit Hours : 2+0

IV. Theory

Unit I

Principles of modelling: Linear programming-concepts, graphical and algebraic solution; Simplex method; Duality theory; Post-optimality analysis; Sensitivity analysis; Transportation and assignment models; Computer applications to LP, queuing theory; Project scheduling and management by PERT-CPM; Integer programming; Non-linear programming; Simulation; Goal programming; Decision theory; Markov chains; Sequencing problem.

Food process modelling: The principles of modelling, kinetic modelling, the modelling of heat and mass transfer; introduction diffusion equation, the Navier-stokes equations, heat and mass transfer in porous media Luikov's equation. Modelling thermal processes: cooling and freezing, modelling product heat load during cooling & freezing. Modelling foods with complex shapes, numerical solution of the heat conduction equation with phase change. Modelling thermal processes: heating, introduction, processing of packed and solid foods, continuous heating and cooling processes, Modelling food quality and microbiological safety. Case Studies in Modelling, Control in Food Processes.

Unit II

Food process equipment design: Design considerations of agricultural and food processing equipment. Design of food processing equipment, Dryers, design of dryers. Determination of heat and air requirement for drying grains. Types of heat exchanger. Design of heat exchangers and evaporators. Design of material handling equipment like belt conveyor, screw conveyor, bucket elevator and pneumatic conveyors.

Digital image processing: digital representation of image, morphological image processing – dialation, erosion, opening and closing, line and edge detection, thresholding, segmentation, techniques for finding length, breadth, perimeter, surface area, eccentricity and surface roughness of solids. Machine Vision-Based Measurement Systems for Fruit and Vegetable Quality Control in Postharvest.

Genetic algorithm optimization: traditional optimization techniques and their limitations, non-traditional method, fitness function in biological evolution, computational procedure for optimization of independent parameters using Genetic algorithm.

Artificial neural network modelling: Developing predictive model between independent and dependent parameters by using Artificial neural network –Neural network architecture, weights and bias values of neurons, least square method for NN parameters optimization, matrix representation and computation of the values of NN parameters.

Unit III

Automation in different unit operations of food processing: Raw food material sorting, grading, size reduction, mixing and agitation, thermal processing, dehydration, packaging, CIP, quality control. Bottle Washing Machine Automation, Bottling Plant Drive System, Demineralization Plant Control System, Labelling Machine Control system, Charger level automation, Reverse Osmosis plant automation, Thermal plant automation, Dehydration and freezing plant automation.

V. Suggested Reading

- Najim K. 1989. *Process Modeling and Control in Chemical Engineering* - CRC Press
- Das H. 2005. *Food Processing Operations Analysis*. Asian Books Private Limited
- Ahmed J and Rahman S. 2012. *Handbook of Food Process Design*.Wiley-Blackwell
- Tijskens LMM, Hertog MLATM and Nicolai BM. 2001. *Food Process Modelling*. Woodhead Publishing
- Bernd H. 2017. *Measurement, Modeling and Automation in Advanced Food Processing*. Springer International Publishing
- Moreira RG. 2001. *Automatic Control for Food Processing Systems* Aspen publishers

I. **Course Title** : **Zero Waste Processing**
II. **Course Code** : **FPT 519**
III. **Credit Hours** : **2+0**

IV. Theory

Unit I

Introduction: Food processing waste and by-product, ISO 14000 for environmental management system, biochemical and nutritional aspects of food processing by-products. Waste minimization: Chain management issues and good housekeeping Procedures, minimise energy use in food Processing, minimise water use in food processing.

Unit II

Food waste separation: microbiological risk management, Effects of postharvest changes in quality on the stability of plant co-products, Separation technologies for food wastewater treatment and product recovery.

Unit III

Co-product recovery techniques: Enzymatic extraction and fermentation for the recovery of food processing products, Supercritical fluid extraction and other technologies for extraction of high-value food processing co-products, Membrane and filtration technologies, recovery of nutraceuticals, micronutrients, functional ingredients, Natural dyes.

Unit IV

Waste management and co-product recovery: Meat, cereal, dairy, fish, fruit and vegetable, vegetable oil, plantation crops processing, waste management of food packaging. Food processing waste water treatment and gas production from solid food processing

V. Suggested Reading

- Waldron K. 2009. *Handbook of Waste Management and Co-product Recovery in Food Processing* Woodhead Publishing
- Arvanitoyannis IS. 2007. *Waste Management for the Food Industries* Academic Press
- Nout MJR and Sarkar PK. 2013. *Valorisation of Food Processing By-Products* CRC Press

Course Title with Credit Load
Ph.D. in Processing Technology

Major Courses

Course Code	Course Title	Credit Hours
FPT 601	Novel Technologies for Food Processing and Shelf Life Extension	3+0
FPT 602	Food Packaging	3+0
FPT 603	Food Manufacturing Technology	3+0
FPT 604	Plant Food Products	3+0
FPT 605	Food Process Modeling and Scale up	3+0
FPT 606	Animal Food Products	3+0
FPT 607	Special Problem	0+2

Minor Courses

Course Code	Course Title	Credit Hours
FPE 601	Concentration and Drying Engineering	3+0
FPE 603	Food Handling and Storage Engineering	3+0
FSQ 603	Quality Assurance in Food Supply Chain	3+0
FSQ 604	Formulation of Standards of Food Products, Packaging and Labeling	2+0

Supporting

Course Code	Course Title	Credit Hours
FPE 605	Food Analytical Techniques	1+2
FSQ 607	Sensory Evaluation of Foods	2+0

Seminar

Course Code	Course Title	Credit Hours
FPT 698	Seminar I	1+0
FPT 699	Seminar II	1+0

Course Contents
Ph.D. in Processing Technology

I. Course Title : Novel Technologies for Food Processing and Shelf Life Extension

II. Course Code : FPT 601

III. Credit Hours : 3+0

IV. Theory

Recent advances in novel food processing technology; Membrane processing, Supercritical fluid extraction, Microwave and radio frequency processing, High Pressure processing, Ultrasonic processing, Ozonization, Plasma Technique, Novel drying techniques. Various techniques to increase shelf life and shelf life prediction.

V. Suggested Reading

- Gould GW. 2000. *New Methods of Food Preservation*, CRC Press.
- Barbosa-Canovas, 2002. *Novel Food Processing Technologies*, CRC Press.
- Dutta AK and Anantheswaran RC, 1999. *Hand Book of Microwave Technology for Food Applications*, CRC Press.
- Sun DW. 2015. *Emerging Technologies for Food Processing*, Elsevier Ltd.
- Kudra T and Mujumbar AS. 2009. *Advanced Drying Technologies*, CRC Press.
- Kilkast D and Subramanium P. 2000. *The Stability and Shelf Life of Food*. CRC Press.
- Doona C J and Feeherry F E. 2007. *High Pressure Processing of Foods*. Blackwell Publishing Ltd.

I. Course Title : Food Packaging

II. Course Code : FPT 602

III. Credit Hours : 3+0

IV. Theory

Recent advances in active and intelligent packaging like Antimicrobial food packaging, Non-migratory bioactive polymers, Freshness indicator, Recycling, biodegradable packaging, Edible Films and Coatings, aseptic packaging, self heating and hydrate packages.

V. Suggested Reading

- Ahvenainen R. 2001. *Novel Food Packaging Techniques*, CRC Press.
- Rooney ML. 1988. *Active Food Packaging*, Chapman & Hall.
- Coles R and Kirwan M. 2011. *Food and Beverage Packaging Technology*, Wiley-Blackwell.
- Han J and Han J. 2005. *Innovations in Food Packaging*, Academic Press.
- Yam K and Lee D. 2012. *Emerging Food Packaging Technologies*, Woodhead Publishing.
- Mihindukulasuriya SDF and Lim LT. 2014. *Nanotechnology Development in Food Packaging-a Review. Trends in Food Science and Technology*, 149-167.
- Souza VGL and Fernando L. 2016. *Nano-particles in Food Packaging-Biodegradibility and Potential Migration to Food – A Review. Food Packaging and Shelf Life*, 63-70.

I. Course Title : Food Manufacturing Technology

II. Course Code : FPT 603

III. Credit Hours : 3+0

IV. Theory

Manufacturing resource planning, Inventory control, Production planning, Production scheduling, Material requirement planning, Resource planning, Capacity requirement planning. Job scheduling,

V. Suggested Reading

- Badiru AB. 2015. *Global Manufacturing Technology Transfer: Africa-USA Strategies, Adaptations, and Management*, CRC Press.
- Hitomi K. 1996. *Manufacturing Systems Engineering: A Unified Approach to Manufacturing Technology, Production Management and Industrial Economics*, CRC Press.
- Yamane Y and Childs T. 2013. *Manufacturing Technology Transfer: A Japanese Monozukuri View of Needs and Strategies*, CRC Press.

I. Course Title : Plant Food Products

II. Course Code : FPT 604

III. Credit Hours : 3+0

IV. Theory

Post-harvest handling of fresh fruits and vegetables, Minimally processed fruits and vegetables, advances in chilling, freezing, and drying, Alcoholic and non-alcoholic beverages; Dough quality measurements; bakery, RTE, RTC products; Hydrogenation, fractionation, winterization, inter-esterification etc. Process for obtaining tailor-made fats and oils; Speciality fats and designer lipids for nutrition and dietetics, Textured Plant proteins.

V. Suggested Reading

- Rodrigues S and Fernandes FAN, 2016**.** Advances in Fruit Processing Technologies, CRC Press.
- Smith DS, Cash JN, Nip WK and Hui YH. 1997. *Processing Vegetables: Science and Technology,* CRC Press.
- Chakraverty A and Singh RP. 2016. *Postharvest Technology and Food Process Engineering*, CRC Press.
- Frame ND. 1994. *Technology of Extrusion Cooking*, Springer US
- O'Brien RD. 2008. *Fats and Oils: Formulating and Processing for Application*, CRC Press.
- Davis B, Lockwood A, Alcott P and Pantelidis L. 2012. *Food and Beverage Management*, CRC Press.
- Dhillon PS and Verma S. 2012. *Food and Beverage: Production Management for Hospitality Industry*, Abhijeet Publications.

I. Course Title : Food Process Modeling and Scale-up

II. Course Code : FPT 605

III. Credit Hours : 3+0

IV. Theory

Recent advances in modeling of high and low temperature processing;Kinetic modeling of microbial growth and its destruction, enzyme inactivation, nutrient retention, Scale up of food processing.

V. Suggested Reading

- Tijskens LMM, Hertog MLATM and Nicolai BM. 2001. *Food Process Modelling*, Woodhead Publishing.
- Ozilgen M. 2011. *Handbook of Food Process Modeling and Statistical Quality Control*. CRC Press.
- Bernd H. 2017. *Measurement, Modeling and Automation in Advanced Food Processing*, Springer.
- Valentas KJ, Clark JP and Levin L. 1990. *Food Processing Operations and Scale-up*. CRC Press.

I. Course Title : Animal Food Products

II. Course Code : FPT 606

III. Credit Hours : 3+0

IV. Theory

Research and development activities on meat, fish and poultry products. gross and microstructure of muscle, Pre-slaughter care, ante and post mortem, slaughter, handling of offal (edible and inedible). Methods to improve tenderness,

Special poultry products, Breaded poultry, packaged precooked chicken, Freeze dried poultry meat. egg preservation, egg powder production. Meat analogues and restructured meat products, production of fish paste, fish oils, sauce, fish protein concentrates. Irradiation of fish and fisheries products, packaging of fish products, quality control and quality assurance. Allergens, toxins and infectious diseases from meat, poultry and fish products.

V. Suggested Reading

- Nollet ML. 2012. *Handbook of Meat, Poultry and Seafood Quality*, Wiley-Blackwell.
- Mountney GJ. 1988. *Poultry Meat and Egg Production*, Springer.
- Robert RJ. 2012. *Fish Technology*, Wiley-Blackwell.
- Mead G. 2004. *Poultry Meat Processing And Quality*, Woodhead Publishing.
- Sahoo J, Sharma DK and Chatli MK. 2016. *Practical Handbook on Meat Science and Technology*, Daya Pub. House.
- Pearson AM and Gillet TA. 1996. *Processed Meat*, Springer.
- Kerry JP, Kerry JF and Ledwood D. 2002. *Meat Processing*, Elsevier.
- Wheaton FW and Lawson TB. 1985. *Processing of Aquatic Food Products*, John Wiley & Sons.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 4

Food Technology
– Process Engineering

Preamble
(Food Process Engineering)

"Food Process Engineering" is a relatively young discipline covering not only factories, equipment and processes but also understanding the product and developing innovative products and packages to satisfy the consumer's needs and wishes. The complexity of the food product and hygienic food production with suitable packaging, compared to chemicals or textile, calls for increasing reliance on the computer in food process research and development. Simulation and modeling constitute an essential step in food process research and development. "Virtualization" becomes a legitimate approach in food engineering research for equipment, mechanization, integrated processing system and hygienic plant design. Further, recent technologies such as Internet of Things, Artificial Intelligence, Nanomaterials, 3D printing, 3D scanning, soft gripping, nondestructive and online/quick analyzing have been found useful for suitable equipment and machineries manufacturing for sustainable food production.

Over the years Food Process Engineering studies emerged as a scientific and industrial discipline describing equipment and means for proper plant operations and environment control considering engineering properties of materials, transport phenomenon, computer aided design, simulation, project engineering and management, post-harvest engineering, storage engineering, additives and preservatives, reaction kinetics, and so on, in ways that preserve value of food and prevent any illness. This was well realized by the 5th Deans' Committee while they chose to have 'Food Process Engineering' as one of the departments at College of Food Technology under Agricultural University setup in the country. Food Process Engineering has been an area of priority for the food industries, processing plants, plant designers, equipment and plant manufacturers, bulk material handling systems, cold storage, supply chain systems and manufacturers, mega kitchen equipment, analytical instruments, ingredient/chemical producers, consumers, retailers, manufacturers, national and international agencies and regulators. Further, need for mechanization of selected indigenous food products and automation has been felt.

To meet the compliances for efficient use of resources, related equipment, instrumentation, plant and building design, establishment and operation for sustainable food manufacturing; competent human resources at various levels such as process engineers, plant engineers, equipment engineers, service engineers, service in-charges, plant in-charge, auditors, designated officers, equipment and instrument handlers, safety officers etc. Development of trained human resource in this scientific and industrial sector is essential for the future growth of food processing and national – international trade from it.

All above requirement of the eco system in an around food sector motivated the BSMA Committee for Food Science and Technology to come up with a new stream of M.Tech. and Ph.D. programme in the area of Food Process Engineering.

Present M. Tech. Food Technology (Process Engineering) course frame work has its parity with national frame work with credit distribution among the different course types core and optional subject with due credits to seminar, research and industrial exposure. Present curriculum at UG level offers adequate introduction on the basic principles of engineering (fluid mechanics, heat transfer, and mass transfer), math, and science (biology, chemistry, and physics) with basics in food chemistry, microbiology, food processing operations, engineering design, analytical techniques, plant sanitation and HACCP. For advancement of knowledge and core competence courses on food engineering operations, engineering properties of food materials and transport phenomenon, computer aided design of food plant machinery and equipment, numerical techniques and simulation etc are kept as compulsory. The course content also offer opportunity to learn testing, inspection, statistical and quality aspect of material and food products for robust knowledge on associated equipment and risk assessment.

Here besides theory teaching practical hands on exposure is also a focus. Other core courses may be selected as per the resources and need analysis which are related to global regulatory and certification requirements, toxicology, food informatics etc. Future researchers as per their interest may find and opportunity to opt for a formal learning on research methodology and advanced food science. Course structure also provides scope for learning across the PG departments. Master students of food process engineering will also have option to study post-harvest management, food processing entrepreneurship and start up, global food laws and regulations, food safety management systems and certification, quality concepts and chain traceability etc.

PhD programme in Food Process Engineering is to assess and design food machinery and associated utilities, AI based automation and robotics, novel process, packaging systems, separation, concentration of required materials etc. So far limited work in this area is taking place in the country and that to under general food technology programmes. The major highlights of PhD programme are a formal course structure focused on the discipline of process engineering with an opportunity to sharpen the assessment, design of machinery, equipment and/or instrument for online/offline quick quality assessment at laboratory or field or in plant. The researchers will be exposed to advances in process engineering, process and equipment validation, food quality and safety assessment, toxicology and risk assessment etc along with food law making process nationally and at international front.

Thus, the M.Tech. programme is intended to offer the industry ready professionals for food processing sector on one hand while they would be given training so that they can ponder upon the industry problems to offer solution either through deep scientific research or problem-solving approach for quick industry solution and immediate response. The programme will also be good for who enjoy quality food production, processing, distribution and retailing or interested in strengthening their proficiency in design and assessment of production management systems.

The programme shall also open new vista for entrepreneurs who intend to diversify in Food Process Engineering aspects. While PhD programme is envisaged to begin a new era of food process engineering research. While proposing this programme it is believed that this programme will also cover research gap in the area and will provide primary data from the country to be used in best quality indigenous equipment and production system manufacturing with compliance to applicable international/ reputed standards and codes which has been lacking in the past. The committee also has taken care that course should also offer knowledge opportunity matching to contemporary global scenario in the field. The committee hopes that the course will meet the expectations of different stakeholders of the sector and learners.

Course Titles with Credit Load
M.Tech. in Process Engineering

Major Courses

Course Code	Course Title	Credit Hours
FPE 501	Emerging Food Engineering Operations*	2+1
FPE 502	Engineering Properties of Food Materials*	2+1
FPE 503	Transport Phenomenon*	2+1
FPE 504	Bio Processing and Down Stream Engineering	2+1
FPE 505	Energy Management and Auditing in Food Industry	2+1
FPE 506	Numerical Techniques and Simulation	1+1
FPE 507	Computer Aided Design of Food Plant Machinery and Equipment	1+2
FPE 508	Food Safety and Storage Engineering	2+1
FPE 509	Equipment, Machine and System Design for Indigenous Food Product	0+2
FPE 510	Operation Research	2+1
FPE 511	Process Control in Food Industries	2+1
FPE 512	Project Engineering and Management	2+1
FPE 513	Food Process Automation and Robotics	2+0
FPE 514	Water and Waste Management	2+1
FPE 515	Special problem/ Summer internship	0+2

*Compulsory Rest of the courses will be decided by the students advisory committee keeping the minimum limits set for award of degree.

Minor Courses

Course Code	Course Title	Credit Hours
FPT 502	Emerging Technologies in Food Packaging	2+0
FPT 503	Industrial Manufacturing of Food and Beverages	2+1
FPT 504	Food Material and Product Properties	2+1
FPT 510	Aseptic Processing and Packaging	2+1
FSQ 503	Advanced Food Chemistry	2+1
FSQ 504	Global Food Laws and Regulations	2+0
FSQ 506	Process and Products Monitoring for Quality Assurance	2+0
FSQ 508	Management of Food By-products and Waste	2+1

Supporting Courses

Course Code	Course Title	Credit Hours
BSH 501	Research Methodology	2(2+0)
BSH 502	Food Informatics	2(1+1)
FBM 501	Post-Harvest Management	3(2+1)
FBM 502	Food Business Management	2(2+0)
FBM 503	Food Processing Entrepreneurship and Start up	1(0+1)
FSQ 505	Food Safety Management Systems and Certification	3(2+1)
FSQ 507	Quality Concepts and Chain Traceability	2(2+0)

Common Courses

S. No.	Course Title	Credit Hours
1	Library and Information Services	1
2	Technical Writing and Communications Skills	1
3	Intellectual Property and its Management in Agriculture	1
4	Basic Concepts in Laboratory Techniques	1
5	Agricultural Research, Research Ethics and Rural Development Programmes	1

These courses are available in the form of e-courses/MOOCs. The students may be allowed to register these courses/similar courses on these aspects, if available online on SWAYAM or any other platform. If a student has already completed any of these courses during UG, he/she may be permitted to register for other related courses with the prior approval of the HoD/BoS.

Seminar

Course Code	Course Title	Credit Hours
FPE 526	Seminar	1(0+1)

Course Contents
M.Tech. in Process Engineering

I. Course Title : Emerging Food Engineering Operations
II. Course Code : FPE 501
III. Credit Hours : 2+1
IV. Theory

Unit I

Ionizing and non-ionizing radiation processing system operations: types of radiations, generation, microwave assisted processing systems, IR assisted processing systems, radio frequency systems, O_3, UV and x-ray assisted processing systems, gamma irradiations systems, e-beam radiation systems and applications.

Unit II

Pulse electric field (PEF) generation system and applications, cold plasma generation systems and applications, high pressure processing systems and applications, ultrasonic processing systems and applications.

Unit III

Extrusion systems, batch and continuous ohmic heating systems and applications, inductive heating systems and applications, applications of nanotechnology.

Unit IV

Drying systems: superheated steam drying, refractance window drying, heat pump drying, freeze drying, spray drying, foam bed drying, microwave drying, instant pressure drop (DIC) drying and hybrid drying systems.

Unit V

Membrane processing systems: UF, MF, NF, reverse osmosis and vapour permeation, pervaporation, membrane distillation. Supercritical fluid extraction: concept, property of near critical fluids (NCF), extraction methods. Cryoprocessing-cryogens properties, systems and their different applications.

V. Practical

- To evaluate the characteristics of treated water and selected liquid foods using membrane systems (NF, UF, RO, etc)
- To study super critical fluid extraction system and application
- To study microwave system and microwave assisted food processing
- To study efficacy of hot water, steam, microwave, ultrasound blanching of selected fruits and vegetables
- To study the ultrasonicator and applications
- To study cryogenic processing applications
- To prepare Nano emulsion and study of their characteristics
- To study ohmic/inductive heating systems applications
- To study cold plasma applications

- To study gamma irradiation applications
- To study drying kinetics using different drying systems
- To study operations in 3 D printing
- Solving problems in food processing and case studies
- Visits of food industries utilizing advance food processing systems.

VI. Suggested Reading

- Datta AK. 2001. *Handbook of Microwave Technology for Food Application*. CRC Press.
- Purkait MK and Singh R. 2018. *Membrane Technology in Separation Science*. CRC Press Taylor and Francis Group.
- Frame ND. 1994. *The Technology of Extrusion Cooking*. Blackie.
- Gould GW. 2012. *New Methods of Food Preservation*. Springer Science & Business Media.
- Berk Z. 2018. *Food process engineering and technology*. Academic press.
- Nema PK, Kaur BP and Mujumdar AS. 2019. *Drying technologies for foods: Fundamentals and applications*. CRC Press
- Meredith RJ. 1998. *Engineers' Handbook of Industrial Microwave Heating* (No. 25). Iet.
- Arvanitoyannis IS. 2010. *Irradiation of food commodities: techniques, applications, detection, legislation, safety and consumer opinion*. Academic Press.
- Yanniotis S. 2008. *Solving problems in food processing and case studies*. Springer

I. Course Title : Engineering Properties of Food Materials

II. Course Code : FPE 502

III. Credit Hours : 2+1

IV. Theory

Unit I

Physical characteristics of different food grains, fruits and vegetables; shape and size, volume and density, porosity, surface area, water activity. Thermal properties: Specific heat, thermal conductivity, thermal diffusivity, phase transition, methods of determination, steady state, transient heat flow. Electrical properties; Dielectric loss factor, loss tangent, temperature dependent electrical conductivity and dielectric constant, method of determination, energy absorption from high-frequency electric field.

Unit II

Magnetic properties: paramagnetism, ferromagnetism, diamagnetism, magnetization, applications for magnetic field forces, magnetic resonance; Electromagnetic properties: electric polarization, temperature dependency, frequency dependency, microwave, conversion of microwaves into heat, penetration depth of microwaves, applications; Optical properties: refraction, colorimetry, near infrared, ultraviolet, applications; Acoustical properties: sound, ultrasonic sound and applications; Radioactivity: types of radiation, radioactive decay, measurement of ionizing radiation, natural radioactivity, applications.

Unit III

Contact stresses between bodies, hertz problems, firmness and hardness, mechanical damage, dead load and impact damage, vibration damage, friction, effect of load, sliding velocity and surface roughness. Friction in agricultural materials, rolling resistance, angle of internal friction, angle of repose, flow of bulk granular materials, aero dynamics of agricultural products, drag coefficients, terminal velocity.

Unit IV

Rheological properties and classification of fluid foods: measurement methods and techniques; Mechanisms and relevant models; Effect of temperature; Compositional factors affecting flow behavior; Viscosity of food dispersions – dilute and semi-dilute systems, concentration effects.

Unit V

Rheology of semi-solid and solid food; Rheological characterization of foods in terms of stress-strain relationship; Viscoelasticity; Transient tests - Creep Compliance and Stress Relaxation; Mechanical models for viscoelastic foods: Maxwell, Kelvin, Burgers and generalized models and their application; Dynamic measurement of viscoelasticity.

Unit VI

Large deformations and failure in foods: fracture, rupture and other related phenomena; Relationship between instrumental and sensory data; Texture Profile Analysis; Instrumental measurements – Empirical and Fundamental methods; Rheometers and Texture Analyzers; Measurement of Extensional viscosity; Acoustic measurements on crunchy foods.

Unit VII

Food structuring: traditional food structuring and texture improvement, approaches to food structuring, extrusion and spinning, structuring fat products, structure and stability, gels, gelation mechanisms, mixed gels, the microstructure of gels, structure-property relations angels.

Unit VIII

Examining food microstructures: light microscopy transmission electron microscopy, scanning electron microscopy, other instrumentation and techniques, image analysis: image acquisition, image processing and analysis.

V. Practical

- Viscosity measurements of fruit juices and semisolid food products
- Comparative analysis of Newtonian and non-Newtonian fluids
- Development of stress and strain curve and to study viscosity of Newtonian and non-newtonian fluids
- Temperature dependent and shear dependent rheology
- Pasting analysis of food; Determination of thermal conductivity, specific heat and glass transition temperature using differential scanning colorimetry (DSC)
- Texture analysis of fruits and vegetable-based products
- Texture analysis of baked foods products (bread/ biscuit)
- Starch characterization using starch master; Dough rheology using doughlab or farinograph
- Determination of microstructures in selected foods using light microscopy
- TEM and SEM, image analysis and image processing techniques; Evaluation of phase transition in colloidal systems, evaluation of structure texture function relations
- Case studies on food properties and applications.

VI. Suggested Reading

- Rao MA, Rizvi SS, Datta AK and Ahmed J. 2014. *Engineering Properties of Foods*. CRC press.

- Figura OL. and Teixeira AA. 2007. *Food Physics: Physical Properties - Measurement and Applications*. Springer Science & Business Media.
- Sahin S and Sumnu SG. 2006. *Physical Properties of Foods*. Springer Science and Business Media.
- Mohsenin NN. 1980. *Thermal properties of foods and agricultural materials.* New York. USA.
- Mohsenin NN. 1986. *Physical properties of plant and animal materials.* Gordon and Breach Science Publishers.
- Peleg M and Bagley EB. 1983. *Physical Properties of Foods*. In *IFT basic symposium series* (*USA*). AVI Pub. Co.
- Ronal J, Felix E, Bengt H, Hans F, Meffert Th., Walter EC and Gilbert V. 1983. *Physical Properties of Foods*. Applied Science Publishers.
- Bourne M. 2002. *Food texture and viscosity: concept and measurement*. Elsevier.
- Norton IT, Spyropoulos F and Cox P. 2010. *Practical food rheology: an interpretive approach*. John Wiley & Sons.

I. Course Title : Transport Phenomenon

II. Course Code : FPE 503

III. Credit Hours : 2+1

IV. Theory

Unit I

Introduction to transport phenomena – Molecular transport mechanism, transport properties and their proportionality constants in momentum, energy and mass transfer.

Unit II

Principles of Steady and unsteady state heat transfer and governing equations; transient heat transfer; Lumped system analysis; Estimation of Conductivity and other thermal properties of foods; overall heat transfer coefficient.

Unit III

Steady-state equations - Momentum transport equations for Newtonian and non-Newtonian fluids, continuity equation in different co-ordinates.

Unit IV

Equations of motion - Navier–Stokes equations and their application in viscous fluid flow between parallel plates and through pipes.

Unit V

Turbulent transport mechanism - Mathematical analysis; eddy viscosity and eddy diffusivity; velocity, temperature and concentration distribution; time smoothing equations. Inter-phase transport in isothermal system - friction factors for various geometries.

Unit VI

Mass transfer - Fick’s law of diffusion, diffusion of gases and liquids through solids, equimodal diffusion, isothermal evaporation of water into air, mass transfer coefficients.

Unit VII

Dimensional analysis – Buckingham Pi-theorem and matrix method, application to transport phenomena, analysis among mass, heat and momentum transfer, Reynolds’ analogy.

Unit VIII

Boundary layer concept - Theoretical and exact solutions for heat, mass and momentum transfer.

V. Practical

- Effects of water concentration and water vapor pressure on the water vapor permeability and diffusion of chitosan films
- Mass transfer description of the osmo dehydration
- Pretreatment efficiency in osmotic dehydration
- Structural effects of blanching and osmotic dehydration pretreatments on air drying kinetics of fruit tissues
- Thermal processing of particulate foods by steam injection (1. Heating rate index for diced vegetables 2. Convective surface heat transfer coefficient for steam)
- Relating food frying to daily oil abuse (1. Determination of surface heat transfer coefficients with metal balls 2. A practical approach for evaluating product moisture loss, oil uptake, and heat transfer)
- Heat and mass transfer during the frying process; Influence of liquid water transport on heat and mass transfer during deep-fat frying
- Numerical simulation of transient two-dimensional profiles of temperature, concentration, and flow of liquid food in a can during sterilization
- Case studies on transport phenomenon and its applications.

VI. Suggested Reading

- Bird RB, Stewart WE and Lightfoot EN. 2007. *Transport phenomena*. John Wiley & Sons.
- Treybal RE. 1980. *Mass transfer operations*. New York.
- Yuan SW. 1969. *Foundations of Fluid Mechanics*. Prentice Hall of India.
- Welti-Chanes J and Velez-Ruiz, JF. (Eds.). 2016. *Transport phenomena in food processing*. CRC press.
- Geankoplis CJ. 2003. *Transport processes and separation process principles:*(*includes unit operations*). Prentice Hall Professional Technical Reference.

I. Course Title : Bioprocessing and Down Stream Engineering

II. Course Code : FPE 504

III. Credit Hours : 2+1

IV. Theory

Unit I

Introduction: Interaction of biochemical engineering, biochemistry and microbiology, Reaction kinetics, kinetics of batch and continuous cultures, process variables, biocatalyst and enzyme kinetics, scope and present status in India in relation to food industry.

Unit II

Fermenter and bioreactors: Transport phenomenon in microbial systems, types of reactor, working principles, aeration and agitation, sterilization and sanitation, advances in continuous fermentation, developments in solid-state fermentation for food applications.

Unit III

Alcoholic beverages: Production of alcoholic beverages: raw materials, culture, fermentation technology of non-distilled beverages (beer and wine) and distilled alcoholic beverages (brandy, whiskey, vodka, rum, gin).

Unit IV

Single Cell Proteins: Single cell proteins production, substrates, factors effecting SCP production, composition, uses, economic parameters and constrains including safety aspects.

Unit V

Organic acids/acidulants: Raw materials, Starters and fermentation conditions, recovery and applications, Case studies production of acetic acid (vinegar), citric acid, lactic acid and gluconic acid.

Unit VI

Biocatalysts in food processing: Sources of enzymes, advantages of microbial enzymes, mechanism of enzyme function, Production and purification of enzymes, immobilization and applications of biocatalysts in food processing, enzyme biosensors.

Unit VII

Down-stream processing: Handling of materials in microbial systems, filtration, centrifugation, sedimentation, chromatography, membrane separation (UF and NF) and electrophoresis, separation and disintegration of cells for product recovery operations. Biological waste treatment and in-plant sanitation.

Unit VIII

Modeling, simulation and scale-up: Bioprocess modeling and simulation and its application in industrial fermentation, scale-up of fermentation processes, design and analysis of biological fermenter and bioreactors.

V. Practical

- Studying biochemical changes during handling of important food items
- Study of fermenter and fermentation process
- Study of bioprocess instrumentation and control system
- Study of bacterial growth in batch culture
- Production and maintenance of starter culture
- Production of enzyme, extraction and purification
- Production of SCP; Production of microbial pigments
- Production of amino acids
- Production of alcohol and alcoholic beverages
- Visit to brewery
- Visit to effluent treatment plant
- Bioprocess modeling and simulation
- Case Studies & Reports.

VI. Suggested Reading

- Schügerl K and Zeng AP. 2010. *Advances in Biochemical Engineering Biotechnology: Tools and Applications of Biochemical Engineering Science*. Springer
- Scheper Th.(Ed). *Advances in Biochemical Engineering and Biotechnology* Series. Springer
- Ghose TK and Fiechter A. 1971. *Advances in Biochemical Engineering-I. Indian Journal of Physics*, 47, 189-192.
- James EB and David FO. 1986. *Biochemical Engineering Fundamentals*. McGraw-Hill Book Co. Inc., New York
- Scheper T, Bajpai P, Bajpai PK, Dochain D, Dutta NN, Ghosh AC, Mathur RK,

Mukhopadhyay A, Perrier M, Rogers PL, Shin HS, Wang B. 1996. *Biotreatment, downstream processing and modelling*. Springer
- Doran PM. 1995. *Bioprocess engineering principles*. Elsevier
- Perry JH. 2007. *Chemical engineers' handbook*, 8e. McGraw-Hill Professional
- Stumbo CR. 2013. *Thermobacteriology in food processing*. Elsevier
- Stanbury PF, Whitaker A and Hall SJ. 2013. *Principles of fermentation technology*. Elsevier
- Hitzmann B 2017. *Measurement, modeling and automation in advanced food processing*. Springer

I. Course Title : Energy Management and Auditing in Food Industry
II. Course Code : FPE 505
III. Credit Hours : 2+1

IV. Theory

Unit I

General Aspects of Energy Management & Energy Audit: Energy scenario, basics of energy and its various forma, material and energy balance, monitoring and targeting and financial management.

Unit II

Energy Auditing Basics: ASHRAE definitions of energy audits, the audit process, pre-site and post-site work, audit report.

Unit III

Energy Accounting and Analysis: Energy Accounting and Analysis, The energy use index, Conditioned area, electricity costs, Thermal energy costs, Energy-using systems, Commercial energy use profiles, Identifying potential measures, Industrial audit Opportunities, Industrial Energy Use Profiles.

Unit IV

Energy economics: Simple payback, time value of money, job simulation experience, making decisions for alternate investments, depreciation, taxes and the tax credit, impact of fuel inflation on life cycle costing.

Unit V

Measurements, Survey instrumentation, and data Collection: General audit instrumentation; co2, temperature, pressure, fluid and fuel flow, combustion gas composition, electrical and light measurement, measuring building losses, application of IR thermograph, infrared radiation and its measurement, measuring electrical system performance.

Unit VI

Energy and Water Conservation Technologies Applied to Food Processing Facilities: Conservation in steam generation and consumption system, energy conservation in heat exchangers, conservation in compressed air system, conservation in power and electrical systems, waste-heat recovery and thermal energy storage in food processing facilities, building envelop audit, energy consumption and saving opportunities.

V. Practical

- Study and practice with energy assessment and auditing instruments

- Performance assessment of motors and variable speed drives
- Performance assessment of pump, fans and blowers
- Performance assessment of refrigeration system
- Performance assessment of heat exchangers
- Performance assessment of furnace
- Performance assessment of boilers
- Conservation possibilities in dairy processing facilities
- Conservation possibilities in grains and oilseeds milling plants
- Conservation possibilities in sugar and confectionary processing facilities
- Conservation possibilities in fruit and vegetable processing facilities
- Conservation possibilities in bakery processing facilities
- Conservation possibilities in meat processing facilities
- Case studies & field reports.

VI. Suggested Reading

- Wang L. 2009. *Energy Efficiency and Management in Food Processing Facilities*. CRC Press
- Thumann A, Niehus T and Younger WJ. 2013. *Handbook of Energy Audits* 9e. Fairmont Press
- Klemes J, Smith R and Kim JK. 2008. *Handbook of water and energy management in food processing*. Elsevier.
- Christopher CS. 2007. *Electric Water: The Emerging Revolution in Water and Energy*. New Society Publishers
- BEE-NPC Cases studies

I. Course Title : Numerical Techniques and Simulation

II. Course Code : FPE 506

III. Credit Hours : 1+1

IV. Theory

Unit I

Modelling and Simulation: Fundamentals of modeling and simulation; Different steps for modeling and simulation, Types of models; Advantages of modeling and simulation, Application areas of simulation.

Unit II

Solution of partial differential equations models: Differential laplace, Poisson, parabolic and hyperbolic equations, Bender – Schmidt method, finite difference method, finite volume method.

Unit III

Optimization: Optimization theory and methods, Graphical and numerical methods of optimization; experimental optimization; linear and nonlinear un-constrain and constrain optimization, multivariate optimization, genetic algorithm, goal driven optimization.

Unit VI

Modelling and simulation applications of some food engineering operations: Thermal processing, convection & osmotic dehydration, spray & freeze drying, deep fat frying; extrusion process; filtration processes; distillation and Extraction processes.

Unit V

Computational fluid dynamics (CFD) applications in food processing.

V. Practical

- Introduction to various features in different spreadsheet softwares
- Solving problems using functions and/or add-Ins and/or Analysis Tool pack in spreadsheets
- Use of software packages for summarization and tabulation of data, obtaining descriptive statistics, graphical representation of data
- Testing linearity and normality assumption, Testing the goodness of fit of different models
- Testing the hypothesis for one sample t-test, two sample t-test, paired t-test, test for large samples - Chi-squares test, F test, Analysis of variance
- Practice on modelling and simulation softwares i.e. MATLAB, FLUENT, GAMBIT, EDEM, Solid works, ANSYS
- Practice on process optimization softwares i.e. SAS, SPSS, Origin Pro, Design Expert(DX), Minitab, Matlab
- Practice on design optimization softwares i.e. Solid works, ANSYS.

VI. Suggested Reading

- Das H. 2005. Food *Processing Operations Analysis*. Asian Books Private Limited
- Denn MM. 1986. *Process Modeling*. Longman
- Holland CD. 1975. *Fundamentals and Modeling of Separation Processes*. Prentice Hall.
- Luyben WL. 1990. *Process Modeling Simulation and Control for Chemical Engineers* 2ed. McGraw Hill.
- Najim K. 1990. *Process Modeling and Control in Chemical Engineering*. CRC
- Aris R. 1999. *Mathematical Modeling, Vol. 1: A Chemical Engineering Perspective* (*Process System Engineering*). Academic Press.
- Kreyszig E. 2005. *Advanced Engineering Mathematics*. John Wiley & Sons publication
- Granato D and Ares G. 2014. *Mathematical and statistical methods in food science and technology*. IFT Press, Wiley Blackwell
- Standard software for modelling, analysis and simulations

I. Course Title : Computer Aided Design of Food Plant Machinery and Equipment

II. Course Code : FPE 507

III. Credit Hours : 1+2

IV. Theory

Unit I

Introduction - Definition of CAD/CAM, product cycle.

Unit II

Automation, CPU, types of memory, input/output devices, data presentation, data and file structures, data base design, design work station.

Unit III

Graphics terminal, operating devices, plotters and other output devices, CPU secondary storage, Turnkey CAD system, selection criteria, evaluation of alternative systems.

Unit IV

Geometric Modeling Techniques - wireframe, surface and solid modeling, Geometric transformations, Graphics standards.

Unit V

CAM - Introduction to Numerical Control (NC) technology, current status of NC, Influence of NC in design & manufacturing.

Unit VI

Computer aided NC programming in APT language, elements of APT language, APT vocabulary, symbols, numbers and scalars, punctuation, definition, statement labels, notations for APT statement format, statements defining point, line, circle, vector, planes and curves, point to point motion.

V. Practical

- Preparation of manual drawings with dimensions from Models and Isometric drawings of objects and machine components
- Preparation of sectional drawings of selected machine parts
- Drawing of riveted joints and thread fasteners
- Demonstration and practice on computer graphics and computer aided drafting using standard softwares such as AutoCAD and/or Inventor and/or Solidworks and/or Creo and/or Catia
- Computer graphics for food engineering applications
- Practice and use of basic and drawing commands on AutoCAD and Solid works
- Generating simple 2-D drawings with dimensioning using AutoCAD and Solidworks
- Small projects using CAD/CAM
- Practice on assembly using Solidwork assembly tool
- Analysis of machine/equipment component for structural parameters using FEM
- Design optimisation of food machine/equipment using goal driven optimization technique
- Kinematic and dynamic analysis of mechanism and machines using Solidworks motion study tool
- Small projects using CAD/CAM
- To study design standards of general food processing equipment and systems

VI. Suggested Reading

- Farin G, Hoschek J and Kim MS. 2002. *Handbook of computer added geometric design*. Elsevier Science
- Goetsch DL. 1988. *MicroCADD: Computer aided design and drafting on microcomputers*. Prentice Hall
- Holah JT and Lelieveld HLM. 2011. *Hygienic design of food factories*. Woodhead publishing house.
- Higgins L and Morrow LC. 1977. *Maintenance Engineering Hand-Book*. McGraw Hill.
- Keating FH. 1959. *Chromium-Nickel Austentic Steel*. Butterworths Scientific Publ.
- Newcomer JL. 1981. *Preventive Maintenance Manual for Dairy Industry*. Venus Trading Co., Anand.
- Stanier W. 1959. *Plant Engineering Hand-Book*. McGraw Hill.

I. Course Title : Food Safety and Storage Engineering

II. Course Code : FPE 508

III. Credit Hours : 2+1

IV. Theory

Unit I

Overview of food microbiology: Foodborne illness, food spoilage, food fermentation, microbiological physiology and food preservation, microbiological analysis, safety management systems. Overview of foodborne pathogens: Bacterial pathogens, food borne viruses and parasites.

Unit II

Chemical safety of foods: nature of chemical hazards in foods, food safety engineering and control of chemical hazards, food allergen control. Intrinsic and extrinsic parameters for microbial growth and heat inactivation: Intrinsic and extrinsic factors affecting microbial growth, factors affecting heat resistance, combining traditional peroration techniques.

Unit III

Kinetics of microbial inactivation: Microbial inactivation kinetics based on food processing methods: thermal, pressure, pulsed electric field, microwave and radio frequency, ohmic and inductive heating etc. Kinetic parameter for the inactivation of pathogens: *Salmonella, Listeria monocytogenes, Staphylococcus aureus, Escherichia coli, Bacillus cereus, Clostridium, Vibrio*, other pathogens.

Unit IV

Predictive microbial modelling: classification of models: Kinetic & probability, Empirical & mechanistic models, Primary, secondary & tertiary models, Deterministic & stochastic models; Description of main models, Modelling growth curves, Modelling inactivation/survival curves, Secondary models, Probability models; Applications of predictive microbial modelling: Hazard analysis critical control point (HACCP) & quantitative risk assessment (QRA), Microbial shelf-life studies, Temperature function integration and temperature monitors, Product research and development, Design of experiments; Predictive microbial modelling and quantitative risk assessment.

Unit V

Process-dependent microbial modeling: Predictive microbial kinetic models, Temperature-dependent microbial growth kinetic models, Irradiation-dependent microbial growth model, Pulsed electric field-dependent microbial growth model, High-pressure-dependent microbial growth model; Process modeling; Integration of process and microbial growth kinetic models.

Unit VI

Storage and handling systems for grains, horticultural and animal based produces; post-harvest physiology of fruits and vegetables; biochemical changes during storage, production, distribution; storage capacity estimate models, ecology, storage factors affecting losses, storage requirements.

V. Practical

- Rapid methods and automation in microbiology: trends and predictions

- Study on phage-based detection of foodborne pathogens
- Study on real-time PCR
- Study on DNA Array
- Study on immunoassay
- Offline and online assessments for food safety for industry
- Storage pest, insects and rodent control
- Study on storage systems and structures, Shelf life evaluation of packaged food products
- Recent advancements in storage and handling systems
- Hygienic design standards and codes for food processing equipment/ system
- Case studies on food safety engineering, guidelines, regulations.

VI. Suggested Reading

- Sun DW. 2015. *Handbook of food safety engineering*. Wiley Black Well Academic Press, Elsevier Ltd
- International Organization for Standardization. 2018. *Food Safety Management Systems: Requirements for Any Organization in the Food Chain*. ISO.
- Shejbal J. 1980. Controlled Atmosphere Storage of Grains. Elsevier.
- Vijayaraghavan S. 1993. Grain Storage Engineering and Technology. Batra Book Service
- Chakraverty A and Singh RP. 2014. Postharvest technology and food process engineering. CRC Press
- Chakraverty A, Mujumdar AS and Ramaswamy HS. 2002. *Handbook of Postharvest Technology: Cereals, Fruits, Vegetables, Tea, and Spices*. CRC Press
- ISO. 22000 Food safety management systems - Requirements for any organization in the food chain. Technical Committee ISO/TC 34, Food products and updates
- Case Studies and Field Reports - Food Safety Engineering

I. Course Title : Equipment, Machine and System Design for Indigenous Food Products

II. Course Code : FPE 509

III. Credit Hours : 0+2

IV. Aim of the course

To develop understanding for mechanization of selected indigenous food products, associated materials of construction, codes and standards, mass balance, specific energy consumption, design, instrumentation, scale of automation, ergonomics, schematics and designing systems/line as a whole.

Students (in group or individual) should be able to evaluate existing production process and categorize whole process in different unit operations such as raw material handling, storage, thermal processing, packaging etc. Computer added design, drafting and simulation of existing system for production and packaging of indigenous food products.

V. Practical

- Visits to indigenous food manufacturing sites and study of existing indigenous food production system
- Study of relevant codes, guidelines and standards for the existing indigenous food production system (product, process, area and personal hygiene)
- Evaluation of available concepts of indigenous food product manufacturing and amelioration
- Computer aided design, drafting and simulation of the selected systems

- Case studies on equipment, machine and system available for the indigenous food products

VI. Suggested Reading

- Holah J and Lelieveld H. (Eds.). 2011. *Hygienic Design of Food Factories*. Elsevier.
- Steinkraus K. 2004. *Industrialization of Indigenous Fermented Foods, Revised and Expanded*. CRC Press.
- Steinkraus KH. 1995. *Handbook of Indigenous Fermented Foods*. CRC press
- Couper JR, Penney WR, Fair JR and Walas SM. 2012. *Chemical Process Equipment - Selection and Design*, 3e. Elsevier
- Saravacos GD and Kostaropoulos AE. 2002. *Handbook of food processing equipment*. Kluwer Academic/Plenum.
- George SG, Kostaropoulos AE. 2015. *Handbook of Food Processing Equipment*, 2e. Springer
- Cramer MM. 2013. *Food plant sanitation: design, maintenance, and good manufacturing practices*, 2e. CRC Press.
- Willey RR. 2006. *Practical Design, Construction and Operation of Food Facilities*. Academic Press
- Baker CG and Christopher GJB (Ed.). 2013. *Handbook of food factory design*. New York, NY: Springer.
- Joshi MV and Mahajani VV. 2000. *Process Equipment Design*, 3e. Macmillan India.
- Brownell LE, Young EH. 1968. *Process equipment design*, 2e. Wiley Eastern Edn. New York
- Ahmad T. 2009. *Dairy Plant Engineering and Management*, 8e. Kitab Mahal
- Hygienic design and sanitary guidelines and related documents/ publications

I. Course Title : Operation Research
II. Course Code : FPE 510
III. Credit Hours : 2+1

IV. Theory

Unit I

Introduction to operations research: Elementary concepts and objectives of Operations Research, Applications of operations research in decision making.

Unit II

Linear programming problem: Mathematical formulation of the linear programming problem and its graphical solution, Simplex method.

Unit III

Transportation problem: Definition and mathematical formulation, Initial basic feasible solution, Optimal solution. Assignment problem: Introduction and mathematical formulation, Solution of assignment problem.

Unit IV

Inventory control: Introduction and general notations, Economic lot size models with known demand. Replacement theory: Introduction and elementary concepts, Replacement of items deteriorating with time.

Unit V

Sequencing problem: Introduction and general notations, Solution of a sequencing problem.

Unit VI

Queuing theory: Introduction and classification of queues, Solution of queuing models.

Unit VII

Project planning and network analysis: Introduction and basic definitions in Network Analysis, Rules for drawing network analysis, Critical path method (CPM), Project evaluation and review technique (PERT).

V. Practical

- Studies on application of Linear Programming on food product standardization
- Studies on use of Transportation and Assignment Problems in food plant operations
- Studies on Economic Order Quantity and Replacement Model
- Studies on Sequencing of food plant operations; Studies on Queuing Model
- Network Analysis using CPM and PERT.

VI. Suggested Reading

- Ackoff RK and Sassioni MW. 1978. *Fundamentals of Operations Research*. Wiley Eastern, New Delhi
- Wagner HM. 1978. *Principles of Operations Research, with Applications to Management Decisions*. Prentice Hall of India, New Delhi
- Taha HA. 2007. *Operations Research: An Introduction*. Pearson Prentice Hall, New Jersey
- Goel BS and Mittal SK. 1985. *Operations Research*. Pragati Prakashan, Meerut
- Panneerselvam R. 2012. *Operations Research*. PHI Learning Pvt. Ltd.
- Prasanna C. 2009. *Projects*. Tata McGraw-Hill Publication, New Delhi.
- Nicolas JM. 2003. *Project Management for Business and Technology – Principles and Practices*. Pearson Prentice Hall
- Kerzner H and Kerzner HR. 2017. *Project Management: a Systems Approach to Planning, Scheduling, and Controlling*. John Wiley & Sons.
- Gopalakrishnan P and Ramamoorthy VE. 2005. *Textbook of Project Management*. Macmillan.

I. Course Title : Process Control in Food Industries

II. Course Code : FPE 511

III. Credit Hours : 2+1

IV. Theory

Unit I

Process Control: Dynamic behavior of first/second order systems, Response of first order systems/first order system in series. Block diagrams and transfer functions, Feedback control, P, PI, PID controllers.

Unit II

Measurement of Electrical and Non Electrical Quantities. Motion and displacement measurement: Strain gages, Hall effect devices and Proximity sensors, Large displacement measurement using synchros and resolvers, Shaft encoders. Pressure Measurement: Mechanical devices like Diaphragm, Bellows, and Bourdon tube, Variable inductance and capacitance transducers, Piezo electric transducers, Low pressure and vacuum pressure measurement using Pirani gauge, McLeod gauge, Ionization gauge. Force and Torque Measurement: Load cells and their applications, various methods for torque measurement. Flow measurement differential pressure meter like, Rotameter, Turbine flow meter, Electromagnetic flow meter, hot wire anemometer, Ultrasonic flow meter. Temperature Measurement: Resistance type temperature sensors – RTD & Thermistor Thermocouples & thermopiles, Different types of pyrometers. Humidity measurement and Moisture measurement techniques. Liquid level measurement: Resistive, inductive and capacitive techniques for level measurement, Ultrasonic and radiation methods, Air purge system (Bubbler method).

Unit III

Digital Data Acquisition Systems & Control: Use of signal conditioners, scanners, signal converters, recorders, display devices, A/D & D/A circuits in digital data acquisition. Instrumentation systems. Types of Instrumentation systems. Data–acquisition system. Multiplexing systems. Modern digital data acquisition system.

Unit IV

Industrial Automation. PLC, DCS and SCADA System: Introduction, Basic parts of a PLC, Operation of a PLC, Basic symbols used in PLC realization, Difference between PLC and Hardwired systems, Difference between PLC and computer, Relay logic to ladder logic, Ladder commands, Examples of PLC ladder diagram realization, PLC timers, PLC counters and examples, Classification of PLCs, History of DCS,DCS concepts, DCS hardware & software, DCS structure, Advantages and disadvantages of DCS, Representative DCS, SCADA, SCADA hardware & software.

Unit V

Image Processing Applications: Methodology, Shape analysis, Feature detection and object Location, Three-dimensional processing. Application to food industry: Inspection and inspection Procedures, X-Rayi, Computer vision systems, Electronic nose and Electronic tongue.

Unit VI

Virtual Instrumentation: Introduction to LABVIEW: Virtual instruments, Parts of VI, Project explorer, Front panel and block diagram window, Creating simple VI.

V. Practical

- Study of various for measurement of pressure, temperature, flow, level
- Study of PLC and to program a PLC using Ladder programming & PLC based control of Multi process system
- To make ladder logic diagrams and flow sheet diagrams for control logic
- Study of data loggers- computerized data acquisition and data processing
- Programming and making GUI in LABVIEW and softwares
- Study of SCADA Application Software/ Computerized Control of PC-PLC Based Multi-Process Control System.

VI. Suggested Reading

- McFarlane I. 1995. *Automatic Control of Food Manufacturing Processes, 2e*. Springer Science and Business Media
- Bhanot S. 2008. *Process Control: Principles and Application*. Oxford University Press.
- Singh SK. 2005. *Industrial Instrumentation & Control, 2e*. Tata McGraw-Hill Education.
- Krishnaswamy K. 2003. *Industrial Instrumentation* (Vol. 1). New Age International.
- Liptak BG. 2018. *Instrument Engineers' Handbook, Volume Two: Process Control and Optimization*. CRC press.
- Jain RK. 1988. *Mechanical and Industrial Measurements*. Khanna Publishers.
- Rangan CS, Sarma GR and Mani VSV. 1983. *Instrumentation: Devices and Systems*. Tata McGraw-Hill.
- Patranabis D. 1976. *Principles of Industrial Instrumentation*. Tata McGraw-Hill Publishing.

I. Course Title : Project Engineering and Management

II. Course Code : FPE 512

III. Credit Hours : 2+1

IV. Theory

Unit I

Overview of project management: Functions and viewpoints of management, evolution of project management, forms and environment of project management.

Unit II

Project life cycle; Project selection: Project identification and screening, project appraisal, project charter, project proposal, project scope, statement of work; Feasibility studies

Unit III

Project planning and scheduling: Work breakdown structure, planning and scheduling of activity networks, network scheduling, precedence diagrams, critical path method, program evaluation and review technique, assumptions in PERT modelling, decision CPM, GERT

Unit IV

Project cost estimating: Technical Analysis and introduction to various component of project installation and commissioning cost and their estimation; Types of estimates and estimating methods, dynamic project planning and scheduling, time-cost trade-offs, resource considerations in projects, resource profiles and levelling, limited resource allocation

Unit V

Project implementation, monitoring and control:, project management process and role of project manager, team building and leadership in projects, organizational and behavioral issues in project management, project monitoring and control, PERT/ cost method, earned value analysis

Unit VI

Elements of Cost of Production; Financing of projects: Debt-Equity ratio etc. Introduction to concepts of inflation, location index and their use in estimating plant and machinery cost. Depreciation concept, Indian norms and their utility in estimation, Capital cost estimation, Working capital estimation, Project Evaluation, break-even analysis, ROI, IRR., Discounted cash flow analysis

Unit VII

Project completion and future directions: Project completion and review; Project management: Recent trends and future directions; Computers in project management

V. Practical

- Studies on Market Survey based on enterprise
- Preparation of Project Report
- Project selection, identification, appraisal and scope
- Methods of monitoring and feasibility of projects
- Studies on investment and repayment plants
- Project monitoring and Control – PERT Modeling

VI. Suggested Reading

- Patel JB and Allampalli, D. G. 1991. *A Manual on How to Prepare a Project Report.*
- Patel JB and Modi SS. 1995. *A Manual on Business Opportunity Identification and Selection.*
- *Manual for Entrepreneurs* by EDI Ahmedabad (2005). Tata McGraw Hill Education.
- Chandra P. Projects: Planning, Analysis, Selection,Financing, Implementation, and Review
- Peters MS and Timmerhaus KD. Plant Design and Economics for Chemical Engineers
- Rase HF. *Project Engineering of Process Plants*
- Panneerselvam R. 2012. *Operations Research.* PHI Learning Pvt. Ltd.
- Prasanna C. 2009. *Projects.* Tata McGraw-Hill Publication, New Delhi.
- Nicolas JM. *Project Management for Business and Technology – Principles and Practices.* Pearson Prentice Hall
- Kerzner H and Kerzner HR. 2017. *Project management: a systems approach to planning, scheduling, and controlling.* John Wiley & Sons.
- Gopalakrishnan P and Ramamoorthy VE. 2005. *Textbook of Project Management.* Macmillan.

I. Course Title : Food Process Automation and Robotics

II. Course Code : FPE 513

III. Credit Hours : 2+0

IV. Theory

Unit I

Automated evaluation of food quality, food quality quantization and process control, typical problems in food quality evaluation.

Unit II

Data acquisition: Sampling elaboration with examples, concepts and systems for data acquisition such as: ultrasonic signal acquisition, electronic nose data acquisition, frying data acquisition for quality process control, Image acquisition.

Unit III

Data analysis: Data preprocessing, Static data analysis, Dynamic data analysis, Image processing: Image segmentation, Image feature extraction.

Unit IV

Modeling & prediction: Modeling strategies: Theoretical and empirical modeling, Static and dynamic modeling, Linear statistical modeling, ANN modeling. Prediction and classification, Sample classification based on linear statistical and ANN models, Electronic nose data; One-step-ahead prediction.

Unit V

Control: Process control, Internal model control, Predictive control, Neuro-fuzzy PDC for snack food frying process, Systems integration: Food quality quantization and process control systems integration.

Unit VI

Automation in sorting, thermal processing, fresh produce; Automation in food chilling and freezing; In storage, transport, retail systems; fruit vegetable processing; cleaning, grading, canning etc.

Unit VII

Automation in meat processing, carcass production, separation; before and after chilling; Automation in poultry industry; hanging, conveying, processing, packing;

Automation in sea food processing, in unit operations associated.

Unit VIII

Automatic process control in food industry. Process control methods in food industry, current, future trends. Robotics in food industry, specification of food sector robot, control law algorithm.

V. Practical

- To study different types of sensors for measurement of temperature, pressure, flow and level
- To study interfacing systems for analogue to digital signals
- To study sensors for automated food process control
- To study different logic controlling systems
- To study computer vision systems used in industries
- To study machine vision systems used in industries
- To study optical sensors and online spectroscopy for automated quality and safety inspection of food products
- To study supervisory Control and Data Acquisition (SCADA) and related systems for automated process control in the food industry
- To study different configurations of industrial robots
- To study gripper technologies for food industry robots
- To study wireless sensor networks (WSNs) components in the agricultural and food industries
- To study intelligent quality control systems in food processing based on fuzzy logic
- Application of automation and robotics for bulk sorting, chilling and freezing, meat processing, poultry industry, seafood processing, packaging in confectionery etc in food processing industries
- Case studies and field reports on Food Process Automation and Robotics.

VI. Suggested Reading

- Caldwell DG. (Ed.). 2012. *Robotics and automation in the food industry: Current and future technologies*. Elsevier.
- Dwivedi SN, Verma AK and Sneckenberger JE. 1991. *CAD/CAM robotics and factories of the future*. Springer
- Doeblin EO and Manik DN. 2003. *Measurement systems: applications and design, 5e*. Tata McGraw Hill.
- Kuo BC and Golnaraghi F. 1995. *Automatic control systems*, 9e. Prentice-Hall.
- Rajput RK. 2008. *Robotics and Industrial Automation*, 2e. S. Chand Publishing
- Groover MP, Weiss M, Nagel RN and Odrey NG. 1986. *Industrial Robotics: Technology, Programming, and Applications*. McGraw-Hill.
- Huang Y, Whittaker AD and Lacey RE. 2001. *Automation for Food Engineering: Food Quality Quantization and Process Control*. CRC Press.
- Bhuyan M. 2006. *Measurement and Control in Food Processing*. CRC Press.
- Zude M. 2008. *Optical Monitoring of Fresh and Processed Agricultural Crops*. CRC press.
- Dochain D. 2001. *Automatic Control of Bioprocesses. Control Systems, Robotics and Manufacturing Series*. Wiley-ISTE
- Sun DW. (Ed.). 2012. *Computer Vision Technology in the Food and Beverage Industries*. Elsevier.
- Kress-Rogers E and Brimelow CJ. (Eds.). 2001. *Instrumentation and Sensors for the Food Industry*. Woodhead Publishing.

I. Course Title : Water and Waste Management

II. Course Code : FPE 514

III. Credit Hours : 2+1

IV. Theory

Unit I

Basic considerations: Characterization of different industry effluents and utilization of by-products; Standards for emission or discharge of environmental pollutants from industries. Elements of importance in the efficient management of wastes.

Unit II

Physical and chemical parameters for waste; oxygen demands; BOD, COD and their interrelationships; residues (solids), fats, oils and grease, forms of nitrogen, sulphur and phosphorus, anions and cations, surfactants, colour, odour, taste, toxicity. Unit concept of treatment of food industry effluent, screening, sedimentation floatation as pre- and primary reactants.

Unit III

Primary treatment, secondary and tertiary waste treatments by physical, chemical and biological methods. Effluent and solid waste utilization by Biological oxidations: Objects, organisms, reactions, oxygen requirements, aeration devices systems: lagoons, activated sludge process, oxidation ditches, rotating biological contractors and their variations and advanced modifications.

Unit IV

Wastewater treatment systems. Physical separations, coagulation and flocculation; micro-strainers, filters, ultra-filtration and reverse osmosis; water softening. Physico-chemical separations: activated carbon adsorption, ion-exchange electro-dialysis and magnetic separation. Chemical oxidations and treatment coagulation and flocculation. Disinfection. Handling disposal of sludge.

Unit V

Waste management strategies and value added products from of agri-food processing industry; Recovery of biologicals from fruit, vegetables, dairy, meat, fish and poultry processing industry.

V. Practical

- Determination of Alkalinity, Acidity and pH of a given waste water sample
- Determination of electric conductivity of a given sample
- Determination of hardness (Chlorides and Sulphates) of a given waste water sample
- Determination of Solids in wastewater, Total Solids, Suspended Solids, Dissolved Solids, Volatile Solids, Fixed Solids, Settleable Solids
- Estimation of dissolved oxygen and BOD exerted by the given waste water sample
- Estimation of COD exerted by the given waste water sample
- Determination of Nitrates in waste water
- Determination of Fats, oils and greases in waste water
- Determination of fecal contamination of water- qualitative and quantitative Estimation
- Determination of SPC of different wastes
- Visit of an effluent treatment plant in a food processing industry.

VI. Suggested Reading

- Arvanitoyannis IS. 2010. *Waste management for the food industries*. Academic Press.
- Zall RR. 2008. *Managing food industry waste: Common sense methods for food processors*. John Wiley and Sons.
- Shuler ML, Kargi F, DeLisa M. 2017. *Bioprocess engineering: basic concepts*. Prentice-Hall.
- Waldron KW. (Ed.). 2009. *Handbook of waste management and co-product recovery in food processing*. Elsevier.
- Mattsson B and Sonesson U. (Eds.). 2003. *Environmentally-friendly food processing*. Woodhead publishing.
- Environment (Protection) Act 1986, Govt of India and relevant publications

Course Title with Credit Load
Ph.D. in Process Engineering

Course Code	Course Title	Credit Hours
Major Courses		
FPE 601	Food Machinery and Utility Design	3+0
FPE 602	Concentration and Drying Engineering	3+0
FPE 603	Automation and Robotics	2+0
FPE 604	System Analysis and Optimization	3+0
FPE 605	Food Analytical Techniques	1+2
FPE 606	Food Handling and Storage Engineering	3+0
FPE 607	Separation Engineering	3+0
FPE 608	Novel Food Process Engineering	2+0
FPE 609	Design of Packaging System	2+0
FPE 610	Special problem	0+2
Minor Courses		
FPT 601	Novel Technologies for Food Processing and Shelf Life Extension	3+0
FPT 605	Food Process Modeling and Scale up	3+0
FSQ 603	Quality Assurance in Food Supply Chain	3+0
FSQ 604	Formulation of Standards of Food Products, Packaging and Labeling	2+0
Supportive Courses		
FPE 605	Food Analytical Techniques	1+2
FSQ 607	Sensory Evaluation of Foods	2+0
Seminar		
FPE 631	Seminar I	0+1
FPE 641	Seminar II	0+1

Course Contents
Ph.D. in Process Engineering

I. Course Title : Food Machinery and Utility Design
II. Course Code : FPE 601
III. Credit Hours : 3+0

IV. Theory

Current trends in use of machinery and utilities, utilities for production of indigenous food products, systems used in mass food production, codes and standards applicable, performance assessment, safety and hygiene requirement with respect to machine, products and operator, suitability and scale of automation, innovativeness, environmentally friendly, ergonomics, resource utilization and assessment.

V. Suggested Reading

- Myer K. 2013. *Handbook of Farm, Dairy, and Food Machinery*, 2e. Academic Press
- Hitzmann B. 2017. *Measurement, Modeling and Automation in Advanced Food Processing*. Springer
- Norton RL. 2003. *Design of Machinery*. McGraw-Hill
- Traitler H, Coleman B, Hofmann K. 2014. *Food Industry Design, Technology and Innovation*. Wiley-Blackwell.
- Piramuthu S and Zhou W. 2015. *RFID and Sensor Network Automation in the Food Industry*. Wiley-Blackwell.
- Holah J and Lelieveld H. 2011. *Hygienic Design of Food Factories*. Woodhead Publishing

I. Course Title : Concentration and Drying Engineering
II. Course Code : FPE 602
III. Credit Hours : 3+0

IV. Theory

Recent development in concentration and drying processes, technologies and engineering, problem solving and case studies.

V. Suggested Reading

- Anandharamakrishnan C and Padma IS. 2015. *Spray Drying Techniques for Food Ingredient Encapsulation*. Wiley-Blackwell
- Oetjen GW, Haseley P. 2018. *Freeze-Drying*, 3e. Wiley-VCH
- Krokida M. 2018. *Thermal and Nonthermal Encapsulation Methods*. CRC Press
- Anandharamakrishnan C. 2017. *Handbook of Drying for Dairy Products*. Wiley-Blackwell
- Zhang M, Bhandari B, Fang Z. 2017. *Handbook of Drying of Vegetables and Vegetable Products*. CRC Press
- Prakash O, Kumar A. 2017. *Solar Drying Technology: Concept, Design, Testing, Modeling, Economics and Environment*. Springer Singapore
- Karim A, Law CL. 2017. *Intermittent and Nonstationary Drying Technologies: Principles and Applications*. CRC Press
- Vasile M. 2016. *Advances in Heat Pump-Assisted Drying Technology*. CRC Press
- MengWai W. 2016. *Computational Fluid Dynamics Simulation of Spray Dryers: An Engineer's Guide*. CRC Press

- Reis FR. 2014. *Vacuum Drying for Extending Food Shelf-Life*. Springer International Publishing
- Rodrigues S. 2008. *Advances in Fruit Processing Technologies*. CRC Press
- Angela M and Meireles A. 2008. *Extracting Bioactive Compounds for Food Products Theory and Applications*. CRC Press
- Rivas EO. 2009. *Processing Effects on Safety and Quality of Foods*. CRC Press
- Lebovka NI, Vorobiev E, Cheìmat F. 2012. *Enhancing Extraction Processes in the Food Industry*. CRC Press

I. Course Title : Automation and Robotics

II. Course Code : FPE 603

III. Credit Hours : 2+0

IV. Theory

Rigid-body kinematics, inverse kinematics, newton-euler dynamics of robots, lagrangian dynamics, kane's method in robotics, systems of interacting rigid bodies, trajectory planning for flexible robots, robotic end effectors, sensors, precision positioning of rotary and linear systems, modeling and identification for robot motion control, step motion control by linear feedback methods, force/impedance control for robotic manipulators, robust and adaptive motion control of manipulators, sliding mode control of robotic manipulators, impedance, coordinated motion control of multiple manipulators, robot simulation, geometric vision, interface to virtual environments, flexible robot arms, manufacturing automation, problem solving and case studies.

V. Suggested Reading

- Caldwell DG. 2013. *Robotics and Automation in the Food Industry: Current and Future Technologies*. Woodhead Publishing
- Huang Y, Whittaker AD, Lacey RE. 2001. *Automation for Food Engineering: Food Quality Quantization and Process Control*. CRC Press
- Greeves T and Moore CA. 1995. *Automation in the Food Industry*. Springer
- Sandeep KP. 2011. *Thermal Processing of Foods: Control and Automation*. Wiley-Blackwell
- Derby SJ. 2005. *Design of Automatic Machinery*. Marcel Dekker
- Piramuthu S and Zhou W. 2015. *RFID and Sensor Network Automation in the Food Industry*. Wiley-Blackwell

I. Course Title : System Analysis and Optimization

II. Course Code : FPE 604

III. Credit Hours : 3+0

IV. Theory

Analyzing and creating data flow diagram, system development, requirement elicitation techniques, analysis strategies, creating and validating entity relation diagram, system acquisition, analysis of architectural design, hardware and software specification, moving logical models, and optimizing techniques for food plant systems, implementation, local and total optimization, optimization with and without restrictions; Total optimization techniques, Global search algorithms, Genetic Algorithms, Firefly Algorithm, Particle Swarm Optimization, advanced applications of Matlab and other softwares, problem solving and case studies.

V. Suggested Reading

- Lisnianski A, Frenkel I, Ding Y. 2010. *Multi-state system reliability analysis and optimization for engineers and industrial managers*.
- Huang Y, Whittaker AD, Lacey RE. 2001. *Automation for Food Engineering: Food Quality Quantization and Process Control*. CRC Press
- Haug EJ. 1984. *Computer aided Analysis and Optimization of Mechanical System Dynamics*. Springer
- Zin TT, Lin JCW. 2019. *Big Data Analysis and Deep Learning Applications*. Springer
- Ratner B. 2011. *Statistical and Machine-Learning Data Mining: Techniques for Better Predictive Modeling and Analysis of Big Data*, 2e. CRC Press
- Erdogdu F. 2008. *Optimization in Food Engineering*. CRC Press

I. Course Title : Food Analytical Techniques

II. Course Code : FPE 605

III. Credit Hours : 1+2

IV. Theory

Hands on experience on advance methods, equipment and instruments used for analysis of raw material, food products and confirmation of standards. Offline and online assessment of food properties.

V. Practical

Practice on UV-Visible, IR, Raman, & Mass spectroscopy.
Practice on Fluorescence, Turbidimetric and related techniques.
Practice on NMR/ESR spectroscopy.
Practice on general and advanced chromatographic (HPLC, GC, Paper, TLC/HPTLC, Ion, Flash etc.) techniques.
Practice on biological techniques such as Electrophoresis, PCR/RTPCR, Immunoassays etc
Practice on Immuno based analytical techniques such as ELISA & Lateral flow assay.
Determination of common adherents, colour, flavours and composition using specified methods.
Separation of selected biomolecules (protein, colour, amino acids, fat, colour, flavours, peptides, anti/ nutritional factors, casein etc) using different techniques.
Gel-filtration of biomolecules.
SDS gel electrophoresis and molecular weight determination.
Measurement of size and zeta potential of colloidal solution or emulsion using dynamic light scattering/ particle size analyser.
Practice on purification of selected biomolecules.
Estimation of minerals using AAS.
Determination of specific and non-specific antimicrobial factors of selected biomolecules.
Determination of health benefits of selected biomolecules/ products.
Correlation of offline with online assessment of selected parameters.
Correlation among industrial, national and international methods of selected concerned parameters.

VI. Suggested Reading

- Boziaris IS. 2014. *Novel Food Preservation and Microbial Assessment Techniques*. CRC Press

- Renfu L. 2016. *Light scattering technology for food property, quality and safety assessment*. CRC Press

I. Course Title : Food Handling and Storage Engineering
II. Course Code : FPE 606
III. Credit Hours : 3+0

IV. Theory

Recent development in handling and storage. Bulk storage structure, silos, cold storages, CA storages, Modified atmosphere storage, transportation and cold chain systems, handling and storage low and ambient temperatures, during supply chain, codes and standards, problem solving and case studies.

V. Suggested Reading

- Guineì RPF, Correia PMR. 2013. *Engineering Aspects of Cereal and Cereal-based Products*. Taylor & Francis
- Mascheroni RH. 2012. *Operations in Food Refrigeration*. CRC Press
- Farid MM. 2010. *Mathematical Modeling of Food Processing*. CRC Press
- Teixeira JA and Vicente AK. 2014. *Engineering Aspects of Food Biotechnology*. CRC Press
- Varzakas T, Tzia C. 2014. *Food Engineering Handbook*. CRC Press
- Saravacos GD, Maroulis ZB. 2011. *Food Process Engineering Operations*. CRC Press
- Ron BH Wills, Golding JB. 2015. *Advances in Postharvest Fruit and Vegetable Technology*. CRC Press
- Petr D, Marilyn R. 2015. *Engineering Aspects of Food Emulsification and Homogenization*. CRC Press
- Constantina T, Theodoros V. 2016. *Handbook of Food Processing: Food Safety, Quality, and Manufacturing Processes*. CRC Press

I. Course Title : Separation Engineering
II. Course Code : FPE 607
III. Credit Hours : 3+0

IV. Theory

Recent development in separation processes (absorption, adsorption, extraction, distillation, chromatography, crystallization, flocculation, coagulation and membranes etc), associated material and mass balance, material for construction and interaction with products, resource requirements, design configurations, codes and standards applicable, problem solving and case studies.

V. Suggested Reading

- Field RW, Molnar EB, Lipnizki F, Vatai G. 2017. *Engineering Aspects of Membrane Separation and Application in Food Processing*. CRC Press
- Holland CD. 1983. *Computer Methods for Solving Dynamic Separation Problems*. Mcgraw Hill
- Wankat PC. 2012. *Separation Process Engineering*, 3ed. Prentice Hall
- Sridhar S. 2019. *Membrane Technology*. CRC Press
- Rushton A, Ward AS, Holdich RG. 1996. *Solid-Liquid Filtration and Separation Technology*. Wiley-VCH
- Tewari PK. 2016. *Nanocomposite Membrane Technology*. CRC Press
- Basile A, Figoli A, Khayet M. 2015. *Pervaporation, vapour permeation and membrane distillation: principles and applications*. Woodhead Publishing

- Dickson J, Hu K. 2015. *Membrane Processes for Dairy Ingredient Separation*. John Wiley & Sons
- Hoek EMV, Tarabara VV. 2013. *Encyclopaedia of Membrane Science and Technology*. Wiley
- Levy RV, Jornitz MW, Jornitz MW. 2006. *Sterile Filtration*. Springer-Verlag Berlin Heidelberg
- Chemat S. 2017. *Edible oils: Extraction, Processing, and Applications*. CRC Press

I. Course Title : Novel Food Process Engineering
II. Course Code : FPE 608
III. Credit Hours : 2+0

IV. Theory

Developments in thermal and non-thermal processes such as HPP, SCFE, cryoprocessing, PSE, cold plasma, ultrasonication, radiofrequency, pulse light, microencapsulation, micro fluidization, spray freeze drying, minimal processing, radiation processing, fermentation, novel sensors etc problem solving and case studies.

V. Suggested Reading

- Houška M, Vinagre Silva FVM. 2017. *High Pressure Processing of Fruit and Vegetable Products*. CRC Press
- Lebovka NI, Vorobiev E; Cheìmat F. 2012. *Enhancing Extraction Processes in the Food Industry*. CRC Press
- Passos, and Ribeiro P. 2016. *Innovation in Food Engineering: New Techniques and Products*. CRC Press
- Tokusoglu O, Swanson BG. 2014. *Improving Food Quality with Novel Food Processing Technologies*. CRC, Taylor and Francis
- Koutchma T. 2014. *Adapting High Hydrostatic Pressure (HPP) for Food Processing Operations*. Academic Press
- Ojha KS, Tiwari BK. 2016. *Novel Food Fermentation Technologies*. Springer International Publishing
- Rahman MA, Mukhopadhyay SC, Yu PL. 2014. *Novel Sensors for Food Inspection: Modelling, Fabrication and Experimentation*. Springer International Publishing
- Boziaris IS. 2014. *Novel Food Preservation and Microbial Assessment Techniques*. CRC Press
- Angela A and Meireles A. 2008. *Extracting Bioactive Compounds for Food Products Theory and Applications*. CRC Press
- Rivas EO. 2009. *Processing Effects on Safety and Quality of Foods*. CRC Press

I. Course Title : Design of Packaging System
II. Course Code : FPE 609
III. Credit Hours : 2+0

IV. Theory

Compatibility of packaging material with products, designing of unit and bulk package, developments in smart, intelligent and active packaging, continuous packaging systems for liquid and food, recent development in testing of packaging material and interaction, migrations study, edible packaging, process friendly packaging, shelf life assessment, codes and standards, problem solving and case studies.

V. Suggested Reading

- Ahvenainen R. 2003. *Novel Food Packaging Techniques*. CRC Press
- Piringer OG, Baner AL. 2008. *Plastic Packaging: Interactions with Food and Pharmaceuticals*, 2e. Wiley-VCH
- Piringer OG and Baner AL. 2000. *Plastic Food Packaging Materials: Barrier Function, Mass Transport, Quality Assurance, Legislation*. Wiley-VCH
- Brody AL. 2001. *Active Packaging for Food Applications*. CRC Press
- Sun DW. 2000. *Handbook of Frozen Food Processing and Packaging*. CRC Press
- Angelo CM. 2015. *Edible Food Packaging: Materials and Processing Technologies*. CRC Press
- Robertson GL. 2009. *Food Packaging and Shelf Life A Practical Guide*. CRC Press
- Moskowitz HR, Reisner M, Lawlor JB, Deliza R. 2009. *Packaging Research in Food Product Design and Development*. Wiley-Blackwell
- RinusRijk and Veraart R. 2010. *Global Legislation for Food Packaging Materials*. Wiley-VCH
- Contemporary Food Engineering Series of CRC Press

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 4

Food Technology
– Safety and Quality

Preamble
(Safety and Quality)

Effective food safety and quality management systems are key not only to safeguarding the health and well-being of people but also to fostering economic development and improving livelihoods by promoting access to domestic, regional and international markets. Ensuring food safety is a public health priority. It incurs loss to global trade leading to further food waste, which can no longer be tolerated in a world where many still suffer from hunger. Effective food safety and quality management systems are key not only to safeguarding the health and well-being of people but also to fostering economic development and improving livelihoods by promoting access to domestic, regional and international markets.

Over the years Food Safety and Quality studies immersed as a scientific discipline describing handling, preparation, and storage of food in ways that prevent food-borne illness. This was well realized by the 5^{th} Deans' Committee while they chose to have 'Food Safety and Quality Assurance' as one of the departments at College of Food Technology under Agricultural University setup in the country. Food Safety and Quality has been an area of priority for consumers, retailers, manufacturers and regulators. In the country FSSAI is now taking proactive steps in interest of consumers and to implement science based regulations related to food. This motivated the BSMA Committee for Food Science and Technology to come up with a new stream of M.Tech. and Ph.D. programme in the area Food Safety and Quality.

Food Safety and Quality Management is rapidly gaining importance both at national as well as international levels due to various reasons, viz. implementation of FSS Act 2006, globalization of food trade, harmonization of national standards with CODEX, legal changes at national and international levels etc. To implement the Act in the country, there is a need for human resources at various levels involving different stakeholders in the food chain from farm to fork which includes Auditors, Designated Officers, Adjudicating Officers and Food Safety Officers, Food Auditors, Food Analysts, Food Handlers etc. Development of trained human resource in food safety sector is essential for the future growth of food processing and national – international trade from it.

Present M. Tech. Food Technology (Safety and Quality) course frame work has its parity with national frame work with credit distribution among the different course types core and optional subject with due credits to seminar and research. Present curriculum at UG level offers adequate introduction on the safety and quality basics through that courses related to microbiology, chemistry, nutrition, basic analytical techniques, including the aspects of plant sanitation and HACCP. For advancement of knowledge and core competence courses on food quality, analysis, handling of food pathogens, chain traceability etc are kept as compulsory. The course content also offer opportunity to learn statistical and engineering aspect of quality including robust knowledge on risk assessment.

Here besides theory teaching practical hands on exposure is also a focus. Other core courses may be selected as per the resources and need analysis which are related to global regulatory and certification requirements, toxicology, food informatics etc. Future researchers as per their interest may find and opportunity to opt for a formal learning on research methodology and advanced food chemistry. Course structure also provides scope for learning across the PG departments. Master students of safety-quality will also have option to study Emerging Techniques in Food Packaging, Bio-processing, Down Stream Engineering, Industrial Manufacturing, Numerical Technique and Stimulation, Storage Engineering, Energy Management and Auditing in Food Industry etc.

Ph.D. programme in Safety and Quality is first of its kind in the country which intends to offer Ph.D. on this specialization as a formal degree. So far limited work in this area is taking place in the country and that to under general food technology programmes. The major highlights of Ph.D. programme are a formal course structure focused on the discipline of safety and quality with an opportunity to sharpen the instrumentation skill in a lab course. The researchers will be exposed to advances in food quality and safety assessment, health claim validation, toxicology and risk assessment, etc. along with food law making process nationally and at international front.

Thus the M.Tech. programme is intended to offer the industry ready professionals for food processing sector on one hand while they would be given training so that they can ponder upon the industry problems to offer solution either through deep scientific research or problem solving approach for quick industry solution and immediate response. The programme will also be good for who enjoy quality control job or interested in strengthening their proficiency in design and implementations of quality management systems. The programme shall also open new vista for entrepreneurs who intend to diversify in Food Safety and Quality Aspects. While Ph.D. programme is envisaged to begin a new era of food safety and quality research. While proposing this programme it is believed that this programme will also cover research gap in the area and will provide primary data from the country to be used in international platforms like Codex which has been lacking in the past. The committee also has taken care that course in safety quality should offer knowledge opportunity matching to contemporary global scenario in the field. The committee hopes that the course will meet the expectations of different stakeholders of the sector and learners.

Course Title with Credit Load
M.Tech. in Safety and Quality

Major Courses

Course Code.	Course Title	Credit Hours
FSQ 501	Techniques in Food Quality Analysis*	2+2
FSQ 502	Microbiology of Food Spoilage and Pathogens*	2+1
FSQ 503	Advanced Food Chemistry	2+1
FSQ 504	Global Food Laws and Regulations	2+0
FSQ 505	Food Safety Management Systems and Certification	2+1
FSQ 506	Process and Products Monitoring for Quality Assurance	2+0
FSQ 507	Quality Concepts and Chain Traceability*	2+0
FSQ 508	Management of Food By-products and Waste	2+0
FSQ 509	Special Problem/ Summer Internship	0+2
FSQ 510	Toxicology of Food Ingredients and Products	2+1
FSQ 511	Food Plant Utilities and Sanitation	2+0

*CompulsoryRest of the courses will be decided by the students advisory committee keeping the minimum limits set for award of degree.

Minor Courses

Course Code.	Course Title	Credit Hours
FPT 502	Emerging Technologies in Food Packaging	2+0
FPT 503	Industrial Manufacturing of Food and Beverages	2+1
FPT 504	Food Material and Product Properties	2+1
FPT 514	Food Ingredients and Additives	2+1
FPT 510	Aseptic Processing and Packaging	2+1
FPE 502	Engineering Properties of Food Materials	2+1
FPE 504	Bioprocessing and Down Stream Engineering	2+1
FPE 506	Numerical Technique and Stimulation	1+1
FPE 508	Food Safety and Storage Engineering	2+1

Supporting Courses

Course Code.	Course Title	Credit Hours
BSH 501	Research Methodology	2+0
BSH 502	Food Informatics	1+1
FBM 501	Post-Harvest Management	2+1

Course Code.	Course Title	Credit Hours
FBM 502	Food Business Management	2+0
FBM 503	Food Processing Entrepreneurship and Start up	0+1
FPE 515	Energy Management and Auditing in Food Industry	2+1
FPE 510	Operation Research	2+1

Common Courses

S. No.	Course Title	Credits
1.	Library and Information Services	1
2.	Technical Writing and Communications Skills	1
3.	Intellectual Property and its Management in Agriculture	1
4.	Basic Concepts in Laboratory Techniques	1
5.	Agricultural Research, Research Ethics and Rural Development Programmes	1

These courses are available in the form of e-courses/MOOCs. The students may be allowed to register these courses/similar courses on these aspects, if available online on SWAYAM or any other platform. If a student has already completed any of these courses during UG, he/she may be permitted to register for other related courses with the prior approval of the HoD/BoS.

Seminar

Course Code	Course Title	Credit Hours
FSQ 599	Seminar	0+1

Course Contents
M.Tech. in Safety and Quality

I. Course Title : Techniques in Food Quality Analysis
II. Course Code : FSQ 501
III. Credit Hours : 2+2
IV. Theory

Unit I

Sampling Procedures, Calibration and Standardization: Sub- sampling and its procedures, LOD, LOQ, Internal standards, Reference standards and certified reference materials. Spectroscopy techniques: Operation, calibration and standardization procedures as applicable to particular technique. Principles and applications of pH Meter, Digital analyzer, Auto-analyzer, Ultraviolet-visible spectroscopy (UV-VIS), Infra-Red, Fourier-Transform Infrared Spectroscopy (FTIR), Near Infra Red (NIR), Atomic Absorption spectroscopy (AAS).

Unit II

Chromatography Techniques: Principles, Components and applications of (i) Paper Chromatography-Ascending and Descending-One dimensional & Two dimensional (ii) Thin layer chromatography (iii) Ion Exchange (iv) GC (v) GLC (vi) HPLC (vii) HPTLC (viii) GCMS (ix) LCMS (x) Amino acid Analyzer.

Unit III

Separation Techniques: Dialysis, Gel filtration, Electrophoresis: Principles, components and applications of (i) Paper (ii) Starch (iii) Gel (iv) Agar-gel (v) Polyacrylamide gel (vi) Moving boundary (vii) Immuno electrophoresis. Centrifugation: Types of centrifuge – Ordinary and Ultracentrifuge- Principle and applications.

Unit IV

Principle, Components and Applications of (i) Differential scanning calorimetry (DSC) (ii) Thermogravimetric analysis (TGA) (iii) Isothermal microcalorimetry (IMC) (iv) Thermomechanical analysis (TMA) (v) Isothermal titration caloritmetry (ITC) (vi) Dynamic elemental thermal analysis (DETA) (vii) Nuclear magnetic resonance (NMR) (viii) Scanning electron microscopy (SEM) (ix) Transmission electron microscopy (TEM) (x) X-ray diffraction technique (XRD) (xi) Rapid visco-analyzer (xii) Texture analyzer and (xiii) Micro-dough lab.

V. Practical

- Analysis and characterization of pigment in fruits by UV-VIS.
- Characterization of starches by FTIR spectroscopy.
- Assessment of microstructure of food components by SEM/Reviewing a micrograph obtained through SEM
- Study of thermal denaturation of proteins and food enzymes by DSC.
- Quantization of allergenic proteins by LCMS.

- Separate and identification of pesticides in food samples by HPLC.
- Identification and molecular characterization of proteins by SDS-PAGE.
- Quantization of lipids and fatty acids using TLC.
- Assessment of pasting properties of starches and flours/flour-blends using RVA.
- Analysis of textural properties of food products with texture analyzer.
- Comparative rheological study of wheat flour samples of different varieties.
- Differential thermal analysis (DTA) and Thermogravimatric Analysis of a food samples
- A rapid, visual demonstration of protein separation by gel filtration chromatography.
- Amino acid profiling of food samples

VI. Suggested Reading

- Ongkowijoyo P, Luna-Vital DA, de Mejia EG. 2018. *Extraction Techniques and Analysis of Anthocyanins from Food Sources by Mass Spectrometry: An Update Food chemistry*.
- Trimigno A, Marincola FC, Dellarosa N, Picone G and Laghi L. 2015. *Definition of Food Quality by NMR-based Foodomics, Current Opinion in Food Science* 4:99-104.
- Pare JRJ and Bélanger JMR. 2015. *Instrumental Methods of Food Analysis*: Elsevier.
- Cifuentes A. 2012. *Food Analysis: Present, Future, and Foodomics,* ISRN Analytical Chemistry.
- Skoog DA, Holler FJ and Nieman TA. 1998. *Principles of Instrumental Analysis* (5 Ed.): Harcourt, Singapore.

I. Course Title : Microbiology of Food Spoilage and Pathogens

II. Course Code : FSQ 502

III. Credit Hours : 2+1

IV. Theory

Unit I

Food Borne Pathogens, Host Invasion, Pathogenesis, Significance to public health Food hazards and risk factors, Pathogenic foodborne microorganisms – *Salmonella, Pathogenic Escherichia coli* and other *enterobacteriaceae, Staphylococcus aureus, Listeria monocytogenes, Clostridium botulinum, Clostridium perfringens and Bacillus cereus* Other Gram-positive pathogens, *Campylobacter, Brucella, Aeromonas, Vibrio cholerae, Mycobacterium, Shigella.*

Unit II

Fungal and viral food-borne disorders, Food-borne important animal parasites, Mycotoxins, Incidence and behavior of microorganisms in meat, poultry, milk and milk products, fresh agro produce, sea foods.

Unit III

Controlling pathogens and microbial toxin via food processing, Microbial growth and shelf life, Modeling of microbial growth, Safety concerns of food processed through non thermal processing, management of microbial risk and toxin in foods through HACCP, Risk in antimicrobial nano materials, Risk assessment and predictive modeling

Unit IV

Molecular approaches for detection and identification of food borne pathogens, Enzyme Immunoassay (EIA), Enzyme-linked immunosorbent assay (ELISA), Radioimmunoassay (RIA) - instrumentation and applications of each immunoassay technique. DNA: DNA purification, DNA Fingerprinting. PCR/RTPCR (Real time) based analysis and sequencing, Biosensors, Recombinant DNA technology; Microchip based techniques, cDNA and genomic libraries, immunochemical techniques.

V. Practical

- Preparation of common laboratory media and special media for cultivation of bacteria, yeast & molds.
- Isolation and identification of pathogens.
- Coliforms analysis of milk and water samples.
- Identification tests for bacteria in foods: IMVIC urease, catalase, coagulase, gelatin and fermentation (acid/gas).
- Determination of thermal death characteristics of bacteria.
- Determination of DNA and RNA of spoilage microorganism using PCR.
- Detection of DNA of trace components allergens, like nuts using ELISA.
- DNA/RNA based microarray experiment.
- Demonstration of DNA fingerprinting.
- Determination of growth and activity of microorganisms in incubator.
- Determination of preservatives and food colours using Biosensor.
- Process time calculation for an indicator organism
- Microbes responsible recall – case studies.

VI. Suggested Reading

- Ray B and Bhunia A. 2007. *Fundamental Food Microbiology*, 4th Ed. CRC Press, Boca Ratan, FL.
- Food and Drug Administration. *Food-Borne Pathogenic Microorganisms and Natural Toxins Handbook: The Bad Bug Book*.
- Fratamico PM, Bhunia AK and Smith JL. 2005. *Food-Borne Pathogens: Microbiology and Molecular Biology*. Caister Academic Press.
- Juneja VK, Dwivedi HR and ofos JN. (Eds) 2017, *Microbial Control and Food Preservation - Theory and Practice*, Springer
- Schmidt RH and Rodrick GE. 2013 *Food Safety Handbook* Wiley

I. Course Title : Advanced Food Chemistry

II. Course Code : FSQ 503

III. Credit Hours : 2+1

IV. Theory

Unit I

Composition, nutritional and functional value of food: Water activity and sorption phenomenon, Engineered foods and influencing water activity and shelf-life; Chemical reactions of carbohydrates–oxidation, reduction, with acid & alkali; Maillard reaction, Caramelization, Ascorbic acid oxidation, Resistant Starch, Soluble and Insoluble fibre, Pigments and approaches to minimize the impact of food processing, Molecular Mobility.

Unit II

Structure and Properties of proteins; electrophoresis, sedimentation, amphoterism, denaturation, viscosity, gelation, texturization, emulsification, foaming, protein-protein and other interactions in food matrix; Lipids: melting point, softening point, smoke, flash and fire point, turbidity point, polymorphism and polytypism; polymerization and polymorphism, flavor reversion, auto-oxidation and its prevention, fat in food matrix like fat globule in milk, PUFA, MUFA, CLA, ω - fatty acids, trans fatty acids, phytosterol, etc.

Unit III

Description of food flavours; Flavour enhancers, Food acids their tastes and flavours, Principles and techniques of flavour encapsulation, types of encapsulation; Factors affecting stabilization of encapsulated flavour and their applications in food industry.

Unit IV

Processing and packaging induced chemicals and their control – acrylamide, nitrosamines, carcinogenic and genotoxicchlorpropanols such as 3-monochloropropane-1, 2-diol (3-MCPD), PAHs (in grilled and smoked products), dioxine, histamine, ethyl carbamate, furan, bisphenol A or phthalates from plastic materials, microplastics, 4-methylbenzophenone and 2-isopropylthioxanthone from inks, mineral oil from recycled fibres or semicarbazide from a foaming agent in the plastic gasket.

V. Practical

- Estimation of protein content in food samples using spectroscopic methods
- Study of effect of heat on protein denaturation using enzymes
- Study of effect of various salt solutions on solubility of proteins
- Separation of milk proteins by salting out method
- Separation of proteins using chromatographic methods
- Fractionation of proteins
- Extraction and purification of essential oil/ flavouring compound of a natural source
- Study the process of starch retrogradation, gelatinization and modification
- Estimation of crude and dietary fibres in given food sample
- Analysis of resistant starches
- Estimation of various antioxidants, polar compounds and free fatty acids in frying oils
- Extraction and purification of natural plant pigment
- Functional properties and isoelectric point of proteins
- Qualitative and quantitative evaluation of processing and packaging induced chemicals
- Qualitative identification of different flavouring compounds

VI. Suggested Reading

- Fennema OR, Ed., 2008. *Food Chemistry*, Marcel and Dekker, Inc., New York, NY.
- Belitz HD, Grosch W and Schieberle P. 2009. *Food Chemistry*. Springer.
- Varelis P, Melton L and Shahidi F. 2019. *Encyclopedia of Food Chemistry*. Elsevier.
- Cheung P, Mehta CK and Bhavbhuti M. 2015. *Handbook of Food Chemistry*. Springer

I. Course Title : Global Food Laws and Regulations

II. Course Code : FSQ 504

III. Credit Hours : 2+0

IV. Theory

Unit I

International Plant Protection Convention, world organization for animal health (OIE), sanitary and phytosanitary measures (SPS), Codex Alimentarius, FAOLEX, OECD Agriculture and Fisheries, International Trade Centre's Standards Map, FAO Food safety and quality emergency Prevention, JFSCA, Fundamental Principles of food safety governance, Risk Analysis as a Method to Determine the Regulatory Outcome, Increasing Responsibility of Businesses (Private) Risk Assessors, Concept of harmonization of global food laws,

Unit II

EU Food Safety Standards - Regulation 178 of 2002, The European food safety authority (EFSA), A critical overview of the EU food safety policy and standards, COMESA Food Safety Standards - An overview, Case Studies in Food Safety Standards in EU-COMESA Trade, Private voluntary standards (PVS) and EU food safety standards, FDA Food safety modernization Act (FSMA), FSPCA Preventive Controls for Human Food, Foreign Supplier Verification Programs (FSVP), Food Facility Registration, FDA - Current Good Manufacturing Practices (CGMPs)

Unit III

Hazard Analysis & Critical Control Points (HACCP) guidelines, Foreign Food Facility Inspection Program, International and Interagency Coordination, Registration of Food Facilities, Seafood Imports and Exports, Regulation on GM Foods, Regulations on Irradiated foods, Global Regulations on Health Foods, International Law on Adequacy of thermal processing, Grain Fumigation for Export, Law of trading horticultural Products, Safety Frame Applied to Food Applications of Nanotechnology.

Unit IV

Review of Indian Regulatory Scenario in Food and Food Products - Food Safety and Standards (FSS) Act, 2006, FSS Rules and Regulations, Agricultural Produce Act, 1937 (Grading and Marketing), Export (Quality Control & Inspection), Act, 1963 and Rules, Bureau of Indian Standards relevant to food safety, Legal Metrology Act, International Food Control Systems/ Laws

V. Suggested Reading

- Osiemo O. 2018. *Food Safety Standards in International Trade: The Case of the EU and the COMESA*, CRC
- Villarreal AM. 2018. *International Standardization and the Agreement on Technical Barriers to Trade*, Cambridge University Press
- Meulen B, Bremmers H, Purnhagen K, Gupta N, Bouwmeester HL and Geyer L. 2014. *Governing Nano Foods: Principles-Based Responsive Regulation*
- Understanding the Codex Alimentarius, 3rd ed., 2006.
- Vapnek J and Spreij M. 2005. *Perspectives and Guidelines on Food Legislation, with a new model food law for the Development Law Service* FAO Legal Office
- US FDA Website
- European Food Safety Authority (EFSA) website

I. Course Title : Food Safety Management Systems and Certification
II. Course Code : FSQ 505
III. Credit Hours : 2+0

IV. Theory

Unit I

Food safety management systems and its requirements for any organization in the food chain, Block chain concept, Global food safety initiative (GFSI), PAS 220, Prerequisite programs on food safety for food manufacturing, Audits: Introduction, objectives, documentation, responsibilities.

Unit II

Food safety plan overview, Good manufacturing practices and other prerequisite programs, GAP and GMP, Preliminary Steps in Developing a food safety plan, Resources for food safety plans, HACCP, TACCP and VACCP.

Unit III

Biological/ Chemical/ Physical and Economically motivated food safety hazards, Process preventive controls, Food allergen preventive controls, Sanitation preventive controls, supply chain preventive controls, verification and validation Procedures, Record Keeping Procedures, Recall Plan

Unit IV

FSMS and FSSC 22000. ISO 22003, ISO 20005 and traceability in food chain, ISO 14000 series – certification and its importance, ISO 17025 - General requirements for the competence of testing and calibration laboratories, BRC Standard, BRC Storage and Distribution, SQF, Southern Rocklobster Seafood, Retailer programs like Woolworths, Coles, Costco and ALDI, Concept of Auditing.

V. Suggested Reading

- Salazar E. 2013. *Understanding Food Safety Management Systems: A Practical Approach to the Application of ISO-22000:2005*, Create Space Independent Publishing Platform.
- ISO 22000 *Standard Procedures for Food Safety Management Systems*, 2008, Bizmanualz, Inc.
- Dillon M and Griffith C (ed). 2001. *Auditing in the Food Industry - From Safety and Quality to Environmental and Other Audits*, CRC Press
- Inteaz A. 2003. *Food Quality Assurance: Principles and Practices*, CRC Press
- Respective certification documents

I. Course Title : Process and Products Monitoring for Quality Assurance

II. Course Code : FSQ 506

III. Credit Hours : 2+0

IV. Theory

Unit I

Variability of the Production Process - Control chart of the middle values and ranges, Medians and ranges, Middle values and standard deviations, Largest and smallest selected value and other individual values.

Unit II

Automation of the Control of Production Processes, Fluorescence cytometry for the rapid analysis of food microorganisms, Infrared spectroscopic methods,

Unit III

Machine vision for the food industry, Ultrasonic methods, Sampling procedures for on line quality

Unit IV

Evaluation the Capability of Production Process and Machine, Chemical sensors RFID, Analysis of the Current State of the Regulation of Manufacturing Processes

V. Suggested Reading

- Rodríguez MEP. 2018. *Process Monitoring and Improvement Handbook,* Second Edition 2018 by ISBN: 978-0-87389-974-1
- *Food Process Monitoring Systems* 1993, Springer

I. Course Title : Quality Concepts and Chain Traceability

II. Course Code : FSQ 507

III. Credit Hours : 2+0

IV. Theory

Unit I

Quality – Concepts, Quality as wining strategy, Total quality management TQM: Introduction, definitions and principles of operation, Tools and Techniques, such as, quality circles, 5 S Practice, Total quality control (TQC), Total employee involvement (TEI), Problem solving process, Quality function deployment (QFD), Failure mode and effect analysis (FMEA), Fault Tree Analysis (FTA), Kizen, Poka-Yoke, QC Tools, PDCA Cycle, Quality Improvement Tools, TQM implementation and limitations, JH – Autonomous maintenance

Unit II

Introduction, Content, Methods, Advantages and Limitation of: Just –in –Time and Quality Management KANBAN system, Total productive maintenance (TPM), QS 9000. Basic concept, Principle, methodology of contemporary trends: Lean manufacturing, Agile manufacturing, World class manufacturing, Concurrent engineering, Bench marking, Cost of quality (COQ) system.

Unit III

Reliability engineering fundamentals; Failure data analysis; Failure rate; mortality curve; Concept of burn in period; Useful life and wear out phase of a system; Mean time to failure (MTTF); Mean time between failure, (MTBF) and mean time to repair (MTTR); Reliability in terms of Hazard rate and failure density, Measurement systems analysis for accuracy, Probability for quality.

Unit IV

SQC -Statistical quality control– X/ R/ p and c chart, Shewhart and types of control charts, Process capability analysis, process capability index. Acceptance sampling by variables and attributes, design of sampling plans, single, double, sequential and continuous sampling plans, design of various sampling plans for food industry (Note:SQC tables can be used in the examination), Capability analysis. Statistical process control.

Unit V

Traceability in food safety management, Applications of traceability, Traceability challenges, Traceability requirements and standards: ISO 22005, Traceability implementation & application: Traceability data & process flow, Traceability process participants, Traceable item, Batch/Lot and Traceability links management, Food authenticity tools.

V. Suggested Reading

- Montgomery, Jennings andPfund. 2010. *Managing, Controlling and Improving Quality*, Wiley
- Arora KC. 2016 (4th Edition). *Total Quality Management*, S K Kataria& Sons Pub

- Grant EL and Leavenworth RS. 1996.,7th Ed 1996, Statistical Quality Control, McGraw-Hill

I. Course Title : Management of Food By-products and Waste

II. Course Code : FSQ 508

III. Credit Hours : 2+1

IV. Theory

Unit I

Management of Food Waste, Principles of sustainable systems and Green chemistry, Waste management purpose and strategies, Waste & its consequences in pollution and global warming, Food waste classification, Mitigation measures for food processing wastes, Food waste Handling and Management laws – National and international.

Unit II

Approaches to Solid Waste Management - Bio gas and electricity generation, Bioactive compounds extraction, Sourcing natural colour, Valorization, Biofueling, Biofertilizers, Bio-ethanol, Activated carbon, Biochar, other biological approaches, Use for biodegradable plastic, biofertilizers and environmental bioremediation.

Unit III

Approaches to Effluent Waste Management Basic unit operations in wastewater treatment, Anaerobic digestion of organic residues and wastes, Fundamentals and applications of anaerobic digestion for sustainable treatment of food industry wastewater, Effluent treatment strategies for dairy/ brewery/ winery, Common biological treatment processes and on-site treatment systems.

Unit IV

Case studies, commercially viable practices and success stories of value added products of waste and by-products from processing of different plant and animal food products, Food waste for pulp & paper, flavorings and aromas production

V. Practical

- Study of waste utilisation processes by site visit/ site plan studies
- Characterization of effluent for Dissolved solids (TDS), Suspended solids, BoD, CoD,
- Nitrogen (as N), Phosphorus (as P), Alkalinity (as $CaCO3$), Sulphate (as $SO4$), Total organic carbon (TOC)
- Characterization of food waste as feedstock for anaerobic digestion
- Various treatments in use for waste disposal: study on operational precautions;
- Extraction of banana fibre,
- Utilisation of ghee residue in caramel toffee;
- Extraction of volatile oils from organic waste;
- Use of fruit/vegetable residue for the production of cellulose;
- Use of mango kernels for manufacturing of starch;
- Production of pectin/citric acid from organic waste

VI. Suggested Reading

- Wastewater treatment and use in agriculture - FAO irrigation and drainage paper 47, http://www.fao.org/docrep/t0551e/t0551e00.htm#Contents
- Waste Biomass Valor (2017) 8:2209–2227 DOI: 10.1007/s12649-016-9720-0

- Guillermo et. al. A Methodology for Sustainable Management of Food Waste 2017, Waste and Biomass Valorization, Volume 8, Issue 6, pp 2209–2227
- Agricultural Waste Management Systems, Chapter 9, USDA Agricultural Waste Management Field Handbook https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=31493.wba
- Oreopoulou, Vasso, Russ, Winfried (Eds.) Utilization of By-Products and Treatment of Waste in the Food Industry, 2007, Springer
- Anil Kumar Anal (Editor), 2017, Food Processing By-Products and their Utilization, Wiley-Blackbell

I. Course Title : Toxicology of Food Ingredients and Products

II. Course Code : FSQ 510

III. Credit Hours : 2+1

IV. Theory

Unit I

General Concepts in Food Toxicology: Definitions, General principles of food toxicology, Toxicology terminologies – Acute, Subacute, Subchronic and Chronic toxicity and other important terminologies; Classification of toxicants, Food Allergy, Food Toxicity, Food Idiosyncrasy, Common food adulterants, Risk assessment, Common techniques for identification/quantification of food toxins, LD50 and LC50 oral-dermal-inhaled, feeding trials and in vitro tests for toxicology.

Unit II

Toxicology of Food additives: Food additives toxicity, Safety Determination of direct and Indirect Food Additives, Acceptable daily intake (ADI), estimated daily intake (EDI), Interaction in food matrix, Evaluation of new and emerging ingredients, Toxicological Study Requirements as per FSSAI for the approval of non-specified foods/food ingredients,

Unit III

Toxicants and contaminants in food: algal toxins, plant toxins and anti-nutrients, dietary estrogens and antiestrogens, Inherent toxins & allergens, process induced toxicants, toxins from packaging, fumigants, safety challenges in of genetically engineered foods, pesticides, heavy metals, carcinogens, polycyclic aromatic hydrocarbons etc.,

Unit IV

Nutraceuticals and functional foods: toxicity and toxicological clearance from regulator, Interactions of prescription drugs, food, alcohol and nutraceuticals. National and international regulatory aspects of health foods and nutraceuticals.

V. Practicals

- Determination of trypsin inhibitors in legumes
- Estimation of phytates/oxalates in cereals/legumes
- Determination of Acrylamide and 5-hydroxymethylfurfural formation in reconstituted potato chips during frying
- Determination of Hydroxymethylfurfural in Baby Foods
- Metals and toxic Metals e.g. Cd, Hg etc.
- Pesticide residues e.g. Dioxin, Aldrin, Malathion etc.
- Mycotoxins, Argemone, Khesari dal, Ergot, Karnal bunt, Dhatura, etc.

- Allergens, Antibiotic & hormone residues, Veterinary drug residue,
- Other new contaminants and toxins (For example: Cyclopiazonic acid in Buckwheat flour)
- Determination of Naturally Occurring Toxic Substances (NOTS) and Deoxynivalenol (DON)
- Elisa for toxins and allergens

VI. Suggested Reading

- *Introduction to Food Toxicology*: By Takayuki Shibamoto and Leonard F. Bjeldanes. 2nd edition; Academic Press
- *Safety Evaluation of Certain Contaminants in Food*, WHO Food Additives Series: 63, FAO JECFA Monographs 8, http://www.fao.org/3/a-at881e.pdf
- Chapter 30: *Food Toxicology*. In Casarett and Doull's Toxicology: The Basic Science of Poisons by Curtis D. Klaassen. 8th edition; McGraw-Hill Medical Publishing Division
- *Food Toxicology: Current Advances and Future Challenges* by Ashish Sachan, Suzanne Hendrich, 2017, Apple Academic Press
- *Food Toxicology* by Debasis Bagchi, Anand Swaroop, 2016, CRC Press
- General Standard For Contaminants and Toxins in Food and Feed (CODEX STAN 193-1995) Amended up to 2015,www.fao.org/input/download/standards/17/CXS_193e_2015.pdf

I. Course Title : Food Plant Utilities and Sanitation

II. Course Code : FSQ 511

III. Credit Hours : 2+0

IV. Theory

Unit I

General principles of food plant Design and layout, CIP system, sanitizers used in food industry. Personnel hygiene and assessment of surface sanitation by swab and rinse method

Unit II

Sanitation of coolers/chillers/freezers, Design of warehouses, conventional & modern storage structures for fruits, vegetables, meat and marine products, pest and rodent control

Unit III

Waste disposal for Food Plant Hygiene and Sanitation, ETP design and layout, Food hygiene and safety in transportation, with a focus on warehouse storage and refrigerated ships, Process water quality and treatments at plant level, Process plant sanitation - chemistry and water in CIP

Unit IV

Preparation of a sanitation schedule for food preparation area, testing of sanitizers and disinfectants, Steam generation and performance, Boiler operation, forced and induced draught. Flue gas composition and performance analysis, Process air generation, air requirement & supply system. Air Moving and vacuum equipment, Power supply system for food process plants and plant earthing.

V. Suggested Reading

- Marriott NG and Gravani RB. 2006. *Principles of Food Sanitation*, 5th edition
- Rao DG. 2010. *Fundamentals of Food Engineering*, PHI learning Private Ltd.
- James A. 2013. *The Supply Chain Handbook, Distribution Group*.
- FAO, US. 1984. *Design and Operations of Cold Store in Developing*.

Course Title with Credit Load
Ph.D. in Safety and Quality

Course Code	Course Title	Credit Hours
Major Courses		
FSQ 601	Food Quality and Safety Assessment	1+2
FSQ 602	Food Toxicology and Risk Assessment	3+0
FSQ 603	Quality Assurance in Food Supply Chain	3+0
FSQ 604	Formulation of standards of Food Products, Packaging and Labeling	2+0
FSQ 605	Food and Nutraceutical Chemistry	3+0
FSQ 606	Food Microbiology and Safety	3+0
FSQ 607	Sensory Evaluation of Foods	2+0
FSQ 608	Special problem	0+2
Minor Courses		
FPT 601	Novel Technologies for Food Processing and Shelf Life Extension	3+0
FPT 605	Food Process Modeling and Scale up	3+0
FPE 602	Concentration and Drying Engineering	3+0
FPE 606	Food Handling and Storage Engineering	3+0
Supportive Courses		
FPE 715	Food Analytical Techniques	1+2
FSQ 724	Sensory Evaluation of Foods	2+0
	Seminar	
FSQ 698	Seminar I	0+1
FSQ 699	Seminar II	0+1

Course Contents
Ph.D. in Safety and Quality

I. Course Title : Food Quality and Safety Assessment
II. Course Code : FSQ 601
III. Credit Hours : 1+2
IV. Theory

Physical quality - Advances in Quantitative Evaluation of Physical Characteristics of Food as an indicator of quality, modern approaches for colour, texture and microstructure of food

Chemical Quality - Advances in instrumentation used for chemical analysis of foods and methods developed for rapid analytical methods, modern non-destructive testing methods, newer biomarkers for food authenticity, and approaches for using an analyte protectant in gas chromatographic analysis. Review of recent updates on the chemical safety threats such as contaminants from agrochemicals, process, packaging materials and environment.

Biological Quality - Updates in molecular biological approaches for rapid detection, Relevance of metabolomics, transcriptomics and proteomics in food analysis and quality evaluations and current food industry applications, Emerging microbial and other macro-biological threats for foods: mitigation and detection.

V. Practicals

- Lab exercises on food microstructures
- Food authentication, newer approaches in food analysis
- Complex culture isolation and identification
- Molecular methods to detect pathogens
- Individual exercise on design of experiments in food analysis and inter learner parity.
- Protein based detection of genetic modification ingredient
- Detection of 3-monochloropropane-1,2-diol (MCPD) esters, mineral oil saturated hydrocarbons (MOSH) or mineral oil aromatic hydrocarbons (MOAH), or polyfluorinated alkyl substances (PFAS)
- Species differentiation in meat - tryptic digestion of myosine by LC-MS/MS

VI. Suggested Reading

- Donna R and Unnevehr L, *International Trade and Food Safety* ed. Sy J. Buzby. Agricultural Economics Report 828. Washington: Economic Research Service. USDA. 2002.
- Josling T, Roberts D and Orden D, *Food Regulation and Trade: Towards a Safe and Open Global System*. Institute for International Economics. 2004

I. Course Title : Food and Nutraceutical Chemistry
II. Course Code : FSQ 605
III. Credit Hours : 3+0
IV. Theory

Recent advances in mechanism of action and chemical properties of potential and established nutraceutical compounds and their applications in functional foods - Updates in chemistry of Nutraceuticals with diseases modifying indications modifying potential for Allergy, Alzheimer's disease and nutraceuticals, Cardiovascular diseases, Cancer, Diabetes, Eye disorders, Immune system, Inflammation, Obesity, Parkinson's, Alzhaimar etc. Complications and toxicity potential of nutraceuticals, Modern approaches regulatory clearance and ban of nutraceutical.

Regulatory developments in health claims. Disease risk reduction claims and proprietary claims – recent protocols for phytosterols, digestible starch, slowly digestible starch, flavanols, grain/millet fibre, glucomannan, guar gum and hydroxypropyl methylcellulose and fructose etc.

V. Suggested Reading

- Robert EC. 2006. *Handbook of Nutraceuticals and Functional Foods*. 2nd Ed.Wildman.
- Ashwini C *et al*. 2013. *Role of Nutraceuticals in Various Diseases: A Comprehensive Review*. ISSN: 2231-2781.
- Schneeman B. 2015. *Science-Based Regulatory and Policy Considerations in Nutrition,* American Society for Nutrition. Adv. Nutr. 6: 361S–367S, 2015; doi:10.3945/an.114.007013.

I. Course Title : Food Microbiology and Safety

II. Course Code : FSQ 606

III. Credit Hours : 3+0

IV. Theory

Technological advances in starter cultures, Prospective application of food-grade microorganisms and fermenters for food preservation and food safety, Newer approaches on molecular techniques for detection of food borne pathogens, Safety evaluation of novel technologies of processing and food-surface disinfection, Latest software tools for predictive microbiology and microbial risk assessment in foods, Use of next generation sequencing for improving food safety, Role of nanotechnology in microbial food safety, New rapid detection methods including immune chromatographic or "dipstick" assays, commercial kits for indicator and pathogenic bacteria, Microbial bio-sensors and detector system in monitoring of food pathogens and antibiotic/pesticide residues.

V. Suggested Reading

- Fratamico, PM and Bayles DO in Food Borne.
- Verma DK. *Microbiology for Food and Health, Technological Developments and Advances*.
- Sofos J. *Advances in Microbial Food Safety*,1st Edition, Woodhead Publishing

I. Course Title : Sensory Evaluation of Foods

II. Course Code : FSQ 607

III. Credit Hours : 1+1

IV. Theory

Advances in rheological and texture measurement, Current sensory evaluation approaches, Applications and limitations of n e-nose, e-tongue, Data Analysis for Electronic sensory judgment and validation approaches. Computer-aided sensory evaluation of foods, statistical analysis of sensory data.

V. Suggested Reading

- Rao ES. 2013. *Food Quality Evaluation*, Variety Books.
- Meilgard. 1999. *Sensory Evaluation Techniques*, CRC Press
- Maslowitz H. 2000. *Applied Sensory Analysis of Foods*. Vols. I, II. CRC Press.

Syllabus of Supportive Courses

I. Course Title : Post-Harvest Management
II. Course Code : FBM 501
III. Credit Hours : 2+1

IV. Theory

Unit I

Post-harvest handling of F&V. Maturity indices, harvesting and post-harvest handling of fruits and vegetables. Respiration and ripening process. Factors affecting respiration and ripening. Pre and post-harvest factors affecting quality on post-harvest shelf life. Chemicals used for hastening and delaying ripening of fruits and vegetables. Methods of storage – precooling, prestorage treatments, low temperature storage, controlled atmospheric storage, hypobaric storage, irradiation and low cost storage structures, Cleaning & Washing machinery and methods for grading.

Unit II

Packing technology for export. Fabrication of types of containers, cushioning material, vacuum packing, poly shrink packing, specific packing for export of mango, banana, grapes kinnow, sweet orange, and mandarin etc. Principles of preservation by heat, low temperature, chemicals and fermentation. Cut fruits and vegetables.

Unit III

Post-harvest practices for safe storage of food grains. Preparation of threshing, threshers for different crops, parts, terminology, care and maintenance. Winnowing, manual and power operated winnowers. Groundnut decorticators- hand and power operated, principles of working. Maize shellers & castor shellers. Drying- grain drying method and equipment. Grain storage and practices.

Unit IV

Post-harvest technology for major spices (black pepper, cardamom, coriander, cinnamon, ginger, onion and garlic, paprika, saffron, turmeric), their post-harvest diseases and storage pests and their management; Packaging and storage of spices and spice powders.

V. Practical

- Macro quality analysis, grading, packaging.
- Harvesting indices of different vegetable crops;
- Grading and packing of vegetables;
- Practice in judging the maturity of various fruits and vegetables.
- Conservation of zero energy cool chambers for on farm storage.
- Determination of physiological loss in weight (PLW), total soluble solids (TSS), total sugars, acidity and ascorbic and content in fruits and vegetables. Packing methods and types of packing and importance of ventilation.

- Pre-cooling packing methods for export or international trade. Methods of prolonging storage life.
- Effect of ethylene on ripening of banana, sapota, mango, sapota.
- Identification of equipment and machinery used is preservation of fruits and vegetables.
- Preservation by drying and dehydration.
- Visit to local processing units.
- Visit to local market yards and cold storage units.
- Visit to local market and packing industries.

VI. Suggested Reading

- Pantastico B. *Post Harvest Physiology, Handling and Utilization of Tropical and Subtropical Fruits and Vegetables*. The AVI Publishing Co. Inc, Westport
- Ryall, AL and Lipton WJ. *Handling, Storage and Transportation of Fruits & Vegetables.* Vol I. The AVI Pub. Company
- Ryall AL and Peltzer WT. *Handling, Storage and Transportation of Fruits and Vegetables* – Vol II. The AVI Pub. Co.
- Rydstm Heele S. *Post Harvest Physiology and Pathology of Vegetables.* Marcel Dekker

I. Course Title : Food Business Management

II. Course Code : FBM 502

III. Credit Hours : 2+0

IV. Theory

Unit I

Business management; introduction, theories and functions, food industry management; marketing management and human resource development, personal management. Sectors in food industry and scale of operations in India.

Human resource management, study the basics about HR and related policies and capacity mapping approaches for better management. Consumer Behavior towards food consumption, consumer surveys by various institutes and agencies, Various journals on consumer behaviour and market research, Internet based data search.

Unit II

Materials management – types of inventories, inventory costs, managing the inventories, economic order quantity (EOQ). Personnel management – recruitment, selection and training, job specialization. Marketing management – definitions, planning the marketing programmes, marketing mix and four P' s. Financial management – financial statements and rations, capital budgeting. Project management – project preparation evaluation measures.

Unit III

International trade; basics, classical theory, theory of absolute advantage. theory of comparative, modern theory, free trade- protection, methods of protection, quotas, bounties, exchange control, devaluation, commercial treaties, terms of trade, balance of payments, EXIM policy, foreign exchange, mechanics of foreign exchange, GATT, WTO, role of WTO,

International Trade in agriculture. World trade agreements related with food business, export trends and prospects of food products in India.

Unit IV

World consumption of food; patterns and types of food consumption across the globe. Ethnic food habits of different regions. Govt. institutions related to international ad trade; APEDA, Tea board, spice board, wine board, MOFPI etc. management of export import organization, registration, documentation, export import logistics, case studies. Export and import policies relevant to horticultural sector. Project: Consumer Survey on one identified product - both qualitative and quantitative analysis (say, Consumer behavior towards Pickles and Chutneys).

V. Suggested Reading

- David D and Erickson S. 1987. *Principles of Agri Business Management*. Mc Graw Hill Book Co., New Delhi.
- Acharya SS and Agarwal NL. 1987. *Agricultural Marketing in India*. Oxford & ISH Publishing Co., New Delhi.
- Cundiff Higler. 1993. *Marketing in the International Environment*, Prentice Hall of India, New Delhi.
- Batra GS and Kumar N. 1994. *GAD Implications of Denkel Proposals* - Azmol Publications Pvt., New Delhi.
- Phill Kottler. 1994. *Marketing Management* - Prentice Hall of India, New Delhi.

I. Course Title : Food Processing Entrepreneurship and Start-up
II. Course Code : FBM 503
III. Credit Hours : 1+1

IV. Theory

Unit I

Assessing overall business environment in the Indian economy. Overview of Indian social, political and economic systems and their implications for decision making by individual entrepreneurs. Globalisation and the emerging business/ entrepreneurial environment.

Unit II

Concept of entrepreneurship; entrepreneurial and managerial characteristics; managing an enterprise; motivation and entrepreneurship development; importance of planning, monitoring, evaluation and follow up; managing competition; entrepreneurship development programs; Social Responsibility of Business.

Unit III

SWOT analysis, Generation, incubation and commercialization of ideas and innovations. Government schemes and incentives for promotion of entrepreneurship. Government policy on Small and Medium Enterprises (SMEs)/ SSIs. Export and Import Policies relevant to food sector. Venture capital. Contract farming and joint ventures, public-private partnerships. Overview of horti inputs industry. Characteristics of Indian food processing and export industry.
Communication Skills: Structural and functional grammar; meaning and process of communication, verbal and non-verbal communication; listening and note taking, writing skills, oral presentation skills; field diary and lab record; indexing, footnote and bibliographic procedures. Reading and comprehension of general and technical articles, précis writing, summarizing, abstracting; individual and group presentations, impromptu presentation, public speaking; Group discussion. Organizing seminars and conferences.

V. Practical/Assinments/Case studies

- Study of a regulated market,
- Study of a fruit and vegetable market,
- Study of State and Central Warehousing Corporation
- Study of functioning of a regional rural bank and commercial bank for loan.
- Study of food processing enterprise,
- Formulation of project reports for financing food Industry,
- Working out repayment plans,
- Legal Issues in Product Development, Marketing and Market Segments
- Case studies: Innovations in Dairy industry, Bakery industry, fats and oils industry, fruit and vegetable industry, primary and secondary processing of cereals, brewing industry.

Note: In practical of plant design and project engineering a plant design problem should be assigned to a group of (3-4) students. The students should carry out the conceptual design, flow sheeting, material and energy balance calculations, and cost and profitability analysis of any Food Plant.

VI. Suggested Reading

- Hu, R. 2005. *Food Product Design A Computer-Aided Statistical Approach*, Technomic Publishers.
- Moskowitz H R, Saguy S. and Straus T. 2006. *An Integrated Approach to New Food Product Development,* CRC Press
- Moskowitz H R, Porretta S. and Silcher M. 2006. *Concept Research in Food Product Design And Development*, Blackwell Publishing Ltd.
- Peters MS and Timmerhaus KD. 2005. *Plant Designs and Economics for Chemical Engineers*, McGraw Hill, 5th Edition,
- Ahmad T. 2009. *Dairy Plant Engineering and Management*., Kitab Mahal, 8th Edition.

I. Course Title : Research Methodology

II. Course Code : BSH 501

III. Credit Hours : 2+0

IV. Theory

Unit I

Introduction to Research, Objective and importance of research, Types of research, steps involved in research, Ethical considerations in research, Defining research problem, Research design, Methods of research design, Laboratory safety considerations.

Unit II

Sampling techniques, Classification of Data, Methods of Data Food informatics Collection, designing of experiments, characteristics of a good design: selection of variables, design matrix, factorial design, fractional factorial design, Principal Component Analysis, Taguchi methods.

Unit III

Data Analysis and interpretation Data analysis, Statistical techniques and choosing an appropriate statistical technique, Optimization techniques, Bioassays- direct and indirect.

Unit IV

Hypothesis, Hypothesis testing, sampling and Non- sampling errors, Data processing software, statistical inference, Interpretation of results.

Unit V

Technical Writing and reporting of research, referencing and referencing styles, Research journals, Indexing and citation of journals, acknowledgement, conflict of interest, Intellectual property, plagiarism.

V. Suggested Reading

- Creswell JW. *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. Sage publications, 2013.
- Kumar R. *Research Methodology: A Step by Step Guide for Beginners*, 2nd Edition, SAGE, 2005.
- Kothari CR, Garg G. *Research Methodology Methods and Techniques*, New Age International publishers, Fourth Edition.
- Bower JA. 2009. *Statistical Methods for Food Science*, Blackwell Publishing
- Wilson A. *Handbook of Science Communication*, 1998, CRC Press
- Montgomery DC. 2017. *Design and Analysis of Experiments*, Willey
- Snecdecor GW and Cochran WG. 1991. *Statistical Methods*, 8th Edition, Wiley-Blackwell
- Saguy PI. *Computer aided techniques in Food Technology*, 1983, Taylor and Francis

I. Course Title : Food Informatics

II. Course Code : BSH 502

III. Credit Hours : 2+0

IV. Theory

Unit 1

Informatics: Meaning and purpose, Making food-related information available for food researchers, Smart Data searching, Data Retrieval, File search or text search in file on a system, Meta Search Engines. Major centers of food research in India and abroad,

Unit 2

Data bases and Management in Food Processing, Data storage and distribution by using various information technology tools and methods, Computer vision for food detection, segmentation and recognition, 3D reconstruction for food portion estimation Augmented reality for food monitoring.

Unit 3

Evaluation protocols of dietary monitoring/management systems, Mobile computing for dietary assessment Smartphone technologies for dietary behavioral patterns, Dietary behavioral pattern modelling using sensors and/or smartphones

Unit 4

Laboratory Information Management System (LIMS) introduction and applications, LIMS in the food safety workflow, Wearable Food Intake Monitoring Technologies, Computerized food composition (nutrients, allergens) analysis

Unit 5

Chemometric techniques - to gain fundamental understanding of complex food systems through the combination of data from independent measurement techniques, Product lifecycle tracing and tracking – ICT tools and technique

V. Suggested Reading

- *Food Informatics: Applications of Chemical Information to Food Chemistry* Martinez-Mayorga,
- Karina-Medina-Franco,
- *Food Informatics: Sharing Food Knowledge for Research and Development* Nicole J.J.P. Koenderink1, J. Lars Hulzebos1, Hajo Rijgersberg1 and Jan L. Top

ANNEXURE I

List of BSMA Committee Members for Food Technology

Name		Specialization	Address
1.	Dr V.B. Singh	Chairman	Former Dean CDFST and VC, MPUAT, Udaipur, Rajasthan
2.	Dr K.L. Khurana	Member	Coordinator, BSMA for ICAR Education Division and Retd. Principal Scientist Education Division, ICAR, New Delhi
3.	Dr H.N. Mishra	Member	Professor, Dept of Food Technology, AFED, IIT-Kharagpur
4.	Dr Bhupender Singh Khatkar	Member	Dean and Chairperson, Dept of Food Technology, Guru Jambeshwar University of Science & Technology, Hisar, Haryana
5.	Dr Pradyuman Kumar	Member	Professor, Dept of Food Engineering & Technology, SLIET, Sangrur, Punjab
6.	Dr Uday Annapure	Member	Professor and Head, Dept of Food Engineering & Technology, Institute of Chemical Technology, Mumbai
7.	Dr Ashutosh Upadhyay	Member	Professor and Head, Dept of Food Science & Technology, NIFTM, Sonipat
8.	Dr L.K. Murdia	Member	Former Dean, CDFST, MPUAT, Udaipur, Rajasthan
9.	Dr Sudhir Uprit	Convenor	Dean, College of Dairy Science and Food Technology, Kamdhenu Vishwavidyalaya, Raipur, Chhattisgarh

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