NAVSARI AGRICULTURAL UNIVERSITY

Restructured and Revised Syllabi of Post-graduate Programmes

Agricultural Engineering

Year 2022

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NAVSARI AGRICULTURAL UNIVERSITY

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Foreword

Presently we are at the dawn of an age of unprecedented technological change. Every day the technologies are astonishing through innovation, refinement and refurbishment. If we will not keep ourselves updated with the pace of refinement of the technologies, we may expel out of the development. Being a pillar of higher education and research in the field of agriculture and allied sciences, our responsibilities are double. Our education system needs to be rejuvenated instantaneously to develop competency and fundamental principles of the society. In anticipation of this, central government introduced National Education Policy-2020 which is more flexible, holistic and multi-disciplinary. The ICAR is sensible enough and has striving best to bring necessary reforms in agricultural education through constituting National Core Group (NCG) and BSMA Committees for revision and restructuring of Post-graduate and Doctoral syllabi of agriculture and allied sciences. The committee has thoroughly restructured the syllabus of Masters' and Doctoral programmes in 79 disciplines, introduced new courses under the dynamic leadership of stalwarts of agricultural sciences Dr. T. Mohapatra (DG ICAR & Secretary DARE, New Delhi), Dr Arvind Kumar (Chairman, NCG), Dr R.C. Agrawal (DDG Agri. Edn) and to his predecessor Dr N. S. Rathore, Dr. G. Venkateshwarlu (Member-Secretary, NCG and former ADG, EQR) and Dr. P. S. Pandey (ADG, EP & HS). To restructure and articulate the entire syllabi of agriculture and allied sciences, 19 different BSMA Committees performed outstanding job in many marathon meetings and brain storming sessions.

Since the syllabi was restructured and articulated considering national significance, there would have been few topics which does not fetch national attention, however, are indispensible from the Gujarat agriculture point of view. Therefore, to implement these recommendations in all the SAUs of Gujarat *viz*., Navsari Agricultural University, Navsari, Junagadh Agricultural University, Junagadh, Anand Agricultural University and Sardarkrushinagar Dantiwada Agricultural University, Dantiwada we reviewed and added certain topics without imposing much stress in the semester. We have not compromised with any of the content prepared by the expert team so that our student does not remain deprived of any opportunity in national level competition. I personally thanks all my colleges Vice Chancellors of SAUs of Gujarat Dr. K. B. Kathiria (AAU, Anand), Dr. R. M. Chauhan (SDAU, Dantiwada), Dr. N. K. Gontia (JAU, Junagadh) for showing faith in NAU, Navsari and bestowing the responsibilities of Nodal University for the finalizing the same. All the faculty members of all the SAUs of Gujarat has done marvelous work of reviewing these and provided their suggestion to make it more relevant to Gujarat state in the close coordination of Dr. T.R. Ahlawat, Nodal Director of Research & Dean PGS, NAU, Navsari. I acknowledge their contribution and congratulate them for coming out with this excellent document.

Jay Jawan, Jai Kisan, Jay Jay Garvi Gujarat

Date : 20-07-2022
Navsari

(Z. P. Patel)

Prof. (Dr.) Naredra Kumar Gontia
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Message

Indian Agriculture is evolving and advancing adopt against a variety of challenges and problems. The scientists of one of the world's largest National Agricultural Research System (NARS) including ICAR institutes and State Agricultural Universities (SAUs) are working hard to ensure the sustainable growth of the Indian agriculture despite these challenges. The Indian Council of Agricultural Research (ICAR) constituted 19 BSMA (broad subject matter area) committees with eminent agricultural scientists, academics, and subject matter specialists and revised the Post Graduate syllabus of Agriculture, and allied sciences in India so that the students can equip themselves with knowledge of recent developments and future technologies. According to the Ancient Indian Vedic Education System "The basic aim of all training, whether literary or vocational, should be to make the student fit to become a useful member of society". The State Agricultural Universities of Gujarat are always working on the same concept by leading in the country to take the challenge to implement the modern education system as well as syllabus. I am glad to know that the publication on "BSMA syllabus for SAUs of Gujarat" has been prepared for revision and restructuring of Post-graduate and Doctoral syllabi as per recommendation of ICAR-BSMA along with consideration of local need. The adoption of BSMA syllabus will make the competent PG students of SAUs of Gujarat to fall into step with knowledge of modern and emerging technologies. I convey my gratitude to all the members of various BSMA committees for SAUs of Gujarat for their fruitful inputs. I complement the efforts of Director of Research and Dean, PG Studies of Navsari Agricultural University, Navsari for compilation of this report to ensure timely implementation of BSMA in SAUs of Gujarat and also to his counter parts at JAU, AAU and SDAU.

Date : 23-07-2022
Junagadh

(Naredra Kumar Gontia)

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Message

Review and revision in curriculum are imperative means not only to modify the program, but also enable teachers to espouse the ways curriculum interacts with learners in a real education milieu. It becomes more valued for post graduate programs in agricultural streams, as it takes care of interests/abilities of both the learners and teachers. The key paybacks remain elimination of needless contents, introduction of latest/updated smart methods of teaching, newer content/knowledge/practices, better connectiveness across students' theory courses and learning practices, and object-based learning experiences with recent technological impacts.

ICAR and SAUs are incessantly striving to fetch essential reforms in this direction for quality assurance in higher agricultural education. Based upon rigorous efforts from National Core Group and 19 Broad Subject Matter Area (BSMA) Committees (casing 79 disciplines), revision and restructuring of Post-graduate and Doctoral syllabi has been successfully attained by having fruitful consultation with all the stakeholders to harness opportunities across various disciplines of agriculture and allied sciences. It will certainly cater the need of paradigm shift in academic regulations to comply with various provisions of recently implemented National Education Policy-2020. It looks very pleasing to realize that the respective Committees have taken due care by adhering towards core functional elements of NEP-2020; namely flexibility, multi-disciplinary/holistic approach, better options on elective courses, online courses, internship /entrepreneurship elements. Added attractive ingredients are the teaching-assistantship for Ph.D. scholars, equipping students to attain skillful knowledge & employability with global competitiveness.

I wish to extend my heartful complement and best wishes for ICAR authorities as well as expert faculty members involved with different BSMA committees for their useful efforts. It is certainly going to be a path providing document for guiding demand driven quality PG education across various agricultural and allied disciplines in ICAR-SAU system. My specific and deep sense of gratitude goes to the Vice Chancellors of other 3 SAUs as well as Deans, Directors, Professors, Heads, faculty members and students at four SAUs of Gujarat who contributed nicely by their effective participation and interaction.

Date : 25-07-2022
Anand

(K. B. Kathiria)

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Preface

It is indeed awesome that our agriculture and allied education system has been in the coziest hand since its instigation. The resonance of this is well echoed through the series of incredible revolutions in agriculture which have been true architecture of economic and social structure of the nation. Looking at the burgeoning population and multiple challenges to the society, we need to stretch out to a greater strength to ensure perpetual prosperity. Recently government introduced National Education Policy-2020 which shall usher in a paradigm shift in the education system. Accordingly, ICAR, New Delhi constituted a National Core Group (NCG) and 19 Broad Subject Matter Area (BSMA) Committees for restructuring of Master's and Ph.D. curriculum, syllabi and academic regulations for the disciplines under agricultural sciences. SAUs of Gujarat are passionate to bring necessary reforms to assure the admirable education to their apprentices and aspirants.

We are indeed fortunate that Navsari Agricultural University, Navsari got a chance to serve as Nodal Institute to coordinate the implementation of various recommendations of the recommendation of BASMA in all the disciplines of SAUs under the dynamic leadership of Hon Vice Chancellor Dr. Z.P. Patel. We had three tiers system for the refinement of the same, where in the first subject specialists of all the SAUs in the chairmanship of identified convener thoroughly studied and recommended suggestions, which were further discussed at the university level and recommended. Finally we had a meeting at NAU, Navsari and finalized all the suggestions in the presence of all the Vice Chancellors, Director of Research & Dean PGS, Deans and Principals of various faculties of all the SAUs. I am indeed very much grateful to the all the Hon Vice Chancellors, Dr. Z. P. Patel (NAU, Navsari), Dr. K. B. Kathiria (AAU, Anand), Dr. R. M. Chauhan (SDAU, Dantiwada), Dr. N. K. Gontia (JAU, Junagadh) for showing confidence in me and my predecessor Dr. S. R. Chaudhary. I sincerely admire the help and guidance received from my counterparts Dr. M. K. Jhala (AAU, Anand), Dr. B. S. Deora (SDAU, Dantiwada) and Dr. D. R. Mehta (JAU, Junagadh) for their superb support. I am also thankful to all the staff members of the office of Director of Research & Dean PGS for their wonderful support in various activities of coordinating and compiling.

The commitment and cooperation of all the conveners, Deans & Principals, Registrars of all the SAUs of Gujarat is sincerely acknowledged.

I hope these curriculum, syllabi and academic regulations would come out true to its anticipated benefits to various provisions of National Education Policy-2020.

Date : 22-07-2022
Navsari

T. Ah

(T. R. Ahlawat)

NAVSARI AGRICULTURAL UNIVERSITY

AAU

ICAR

Contents

Farm Machinery and Power Engineering

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	Advanced Manufacturing Technologies	2+1
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 508	Application of Engineering Properties in Food Processing	2+1
ME 501	Mechatronics and Robotics in Agriculture	2+0
ME-504	Vibrations	3+0
ME-507	Fatigue Design	2+1
ME-515	Computer Aided Design	2+1
REE 503	Biomass Energy Conversion Technologies	2+1
REE 513	Agro Energy Audit and Management	2+1
CE 501	Dimensional Analysis and Similitude	2+0
CE 510	Experimental Stress Analysis	2+1
MATH 501	Finite Element Methods	2+1
MATH 502	Numerical Methods for Engineers	2+1
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.

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
	Unit I	
1.	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
	Unit II	
6.	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
	Unit III	
10.	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
	Unit IV	
17.	Traction devices: Tyres, type, size, selection mechanics of traction devic-es.	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
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Measurements of soil shear strength by in-situ by 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, R., & Vanden Berg, G. E. (2013). *Soil Dynamics in Tillage and Traction*. New Delhi, India: Scientific Publishers.
- John B. L., Paul K. T., David W. S., & Makoto, H. (2012). *Tractors and their Power Units(4th ed.)*. New York, USA: Van Nostrand Reinhold.
- Koolen, A. J., & Kuipers, H. (1983). *Agricultural Soil Mechanics*. Heidelberg, Germany: Springer-Verlag.
- McKyes, E. (1989). *Agricultural Engineering Soil Mechanics*. Amsterdam, Netherland: Elsevier science publishers.
- McKyes E. (2016). *Soil Cutting and Tillage. Developments in Agricultural Engineering*-7. Amsterdam, Netherland: Elsevier Science Publisher.

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
5.	Lab testing and evaluation of nozzles	1
6.	Field testing of rotavator	1
7.	Lab analysis of soil sample after rotavator operation	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	4
	Total	**16**

X. Suggested Reading

- John B. L., Paul K. T., David W. S., & Makoto, H. (2012). *Tractors and their Power* Units *(4th ed.)*. New York, USA: Van Nostrand Reinhold.
- *Indian Standard Codes for Agricultural Implements*. Published by BIS, New Delhi.
- Inns, F M. (1995). *Selection, Testing and Evaluation of Agricultural Machines and Equipment.* FAO Service Bull. No.-115.
- Mehta, M. L., Verma, S. R., Rajan, P. & Singh, S. K.(2019). *Testing and Evaluation of Agricultural Machinery*. Delhi, India: Daya Publishing House.
- *Nebraska Tractor Test Code for Testing Tractor*, Nebraska, USA.
- Smith, D. W., Sims, B. G., & O'Neill, D. H. (1994). *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-exit system, controls, shape, colour coding, dial and indicators. Modern technology for comfort in driving places. Noise and vibration measurement.

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.	Principles of applied anthropometry in ergonomics	1
10.	Availability of anthropometric database for Indian agricultural workers	1
11.	Definitions and possible applications of anthropometric dimensions	2
12.	Workspace and equipment design	1
13.	Different modes of force application	1
14.	Design of manual handling tasks	1
15.	Biomechanics aspects in machine design	1
16.	Mid-semester examination	1
17.	Human posture, posture stresses and its role in design of agricultural machinery	1
18.	Work place design for standing and seated workers	2
19.	Human factors in tractor seat design	1
20.	Entry–exit system, controls, shape, colour coding, dial and indicators	1
21.	Noise and vibration measurement techniques	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
29.	Safety gadgets for tractors and trailers	1
30.	Standard/ codes for agricultural machinery safety	1
	Total	**32**

IX. List of Practical

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 and vibration measurement in tractors	1
8.	Calibration of human subject on bicycle ergometer/ treadmill	2
9.	Measurement of physiological parameter, viz. heart/ pulse rate	1
10.	Measurement of oxygen consumption under laboratory conditions	1
11.	Case study of accidents and safety on tractors and trailers	1
12.	Case study of accidents and safety on chaff cutters and threshers	1
13.	Practical examination	1
	Total	**16**

X. Suggested Reading

- Bridger, R. S. (2009). *Introduction to Ergonomics*. Boca Rotan, USA: CRC Press.
- Sanders, M. S., & McCormick, E. J. (2000). *Human Factors in Engineering and Design (7th ed.).*USA: McGraw Hill.
- Astrand, P., Rodahl, K., Dahl, H. A., & Stromme, S. B. (2003). *Textbook of Work Physiology Physiological Basis of Exercise*. USA: McGraw Hill.
- Gite, L. P. (2009). *Anthropometric and Strength Data of Indian Agricultural Workers for Farm Equipment Design*. Bhopal, India: Central Institute of Agricultural Engineering.
- Gite, L. P., Agrawal, K. N., Mehta, C. R., Potdar, R. R., & Narwariya, B. S. (2019). *Handbook of Ergonomical Design of Agricultural Tools, Equipment and work Places*. New Delhi , India: Jain Brothers.
- Mehta, C. R., Kumar, A., Gite, L.P., & Agrawal, K.N. (2022). *Ergonomics and Safety in Agriculture.* New Delhi, India: ICAR.
- Tayyari, F. & Smith, J. L. (1997). Occupational Ergonomics. London, Chapman& Hall.

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, brake, 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 and brake	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 and brake	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

- John B. L., Paul K. T., David W. S., & Makoto, H. (2012). *Tractors and their Power Units (4^{th} ed.)*. New York, USA: Van Nostrand Reinhold.
- Macmillan, R. H. (2002). *The Mechanics of Tractor – Implement Performance and Worked Example.* Australia: University of Melbourne.
- Sharma, P. C., & Agarwal, D. K. (2000). *Machine Design*. Delhi, India: S K Kataria and Sons.

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.

VI. 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.

VII. 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.	3
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
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	2
18.	Case studies	2
	Total	**32**

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.	2
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	**16**

X. Suggested Reading

- Bernacki, H., Haman, J., & Kanafojski, C. (1972). *Agricultural Machines Theory and Construction, Volume 1*. Virginia, USA: U.S. Dept. of Commerce, National Technical Information Service.
- Bosoi, E.S., Verniaev, O.V., Smirnov I. I., & Sultan-Shakh, E.G. (1990). *Theory, Construction and Calculations of Agricultural Machinery - Vol.-I.* New Delhi, India: Oxonian Press Pvt.
- Gill, R., & Vanden Berg, G. E. (2013). *Soil Dynamics in Tillage and Traction*. New Delhi, India: Scientific Publishers.
- Sharma, D. N. & Mukesh, S. (2013). *Farm Machinery Design Principles and Problems (3rd ed.)*. New Delhi: India. Jain Brothers.
- Yatsuk, E. P. (1981). *Rotary Soil Working Machines Construction, Calculation and Design.* New Delhi, India: American Publishing Co. Pvt. Ltd.

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. Targets for pesticide deposition. Formulation of pesticides. Multidisciplinary nature of pesticide application.	1
2.	Spray droplets. Hydraulic nozzles. Power operated hydraulic sprayer design principles. Controlled droplet application. Spray drift and its mitigation. Pesticide calculation examples.	2
3.	Air assisted hydraulic sprayer design principles. Electrostatically charged sprayers.	1
4.	Aerial spraying systems. Use of drones for spraying. Design of spray generation and application issues.	1
5.	Introduction to combine harvesters; Construction, equipment subsystems, power sub systems.	1
6.	Crop harvesting: Plant properties, physical and mechanical properties of plant stem, plant bending modelling.	1
7.	Properties of plant grain: Physical, mechanical, grain damage. Properties of MOG; Mechanical and aerodynamic.	1
8.	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.	2
9.	Corn header: Working elements, snapping roll design, stalk grasping and drawing process. Corn ear detachment: Stalk cutting and chopping.	1
10.	Cereal threshing and separation, Design of tangential and axial threshing units. Performance indices of threshing units.	1

11.	Modelling material kinematics in different threshing units. Factors influencing the threshing process and power requirement.	1
12.	Separation process and design of straw walker.	1
13.	Cleaning Unit process and operation. Grain pan: Chaffer and bottom sieve. Blower design and flow orientation.	1
14.	Design of conveying system for grain. Straw choppers and shredders.	1
	Total	**16**

IX. List of Practicals

S.No.	Practical	No of Practicals
1.	Measurement of spray characters for different nozzles.	2
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	**16**

X. Suggested Reading

- Bernacki,H., Haman, J., & Kanafojski, C. (1972). *Agricultural Machines Theory and Construction, Volume 1*. Virginia, USA: U.S. Dept. of Commerce, National Technical Information Service.
- Bindra, O. S., & Singh, H. (1971). *Pesticides Application Equipments.*New Delhi: India, Oxford & IBH Publishing Co.
- Bosoi, E. S., Verniaev, O. V., Smirnov I. I., & Sultan Shakh, E. G. (1987). C*onstruction and Calculations of Agricultural Machinery – Vol.-II*. New Delhi: India, Oxonian Press Pvt. Ltd.
- Miu, P. (2016). *Combine Harvesters Modeling and Design.* Boca Raton, USA: CRC Press.
- Matthews, G. A., & Thornhill, E. W. (1994). *Pesticide Application Equipment for Use in Agriculture part 2*. Rome, Italy: FAO.
- Sharma, D. N. & Mukesh, S. (2013). *Farm Machinery Design Principles and Problems (3rd ed.)*. New Delhi: India. Jain Brothers.

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	4
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	**16**

X. Suggested Reading

- Carveille, L. A. (1980). *Selecting Farm Machinery*. USA: Louisiana Cooperative Extn. Services Publication.
- Culpin, C. (1996). *Profitable Farm Mechanization.* London, UK: Lock Wood and Sons.
- FAO. (1990). *Agricultural Engineering in Development: Selection of Mechanization Inputs.* Rome, Italy: FAO Agricultural Services Bull.-84.
- Hunt, D. (1979). *Farm Power and Machinery Management.*USA: Iowa State University Press.
- Kapoor, V. K. (2012). *Operation Research: Concepts, Problems and Solutions.* India: Sultan Chand and Sons.
- Singh, S., & Verma, S. R. (2009). *Farm Machinery Maintenance and Management*. New Delhi, India: Directorate of Information and Publications of Agriculture, ICAR, KAB-I.

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 drivemotor 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	2
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
7.	PLC programming	3
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	**16**

X. Suggested Reading

- https://nptel.ac.in/downloads/108105063/
- Manesis, S., & Nikolakopoulos, G. (2018). *Introduction to Industrial Automation(1st ed.)*. USA: CRC Press.

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	2
2.	Study of various hydraulic motors	2
3.	Study of various hydraulic valves	2
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	**16**

X. Suggested Reading

- Anthony, E. (2003). *Fluid Power with Applications*. Singapore, Malaysia: Pearsons Education Pvt. Ltd.
- Krutz, G. (1984). *Design of Agricultural Machines*. USA: John Wiley and Sons.
- Majumdar, S. R. (2003). *Oil Hydraulics Systems: Principles and Maintenance*. India: Tata McGraw Hill Co.
- Merritt, H. E. (1991). *Hydraulic Control System*. USA: 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.	Topic	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

	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.	Practical	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, E. E. (1966). *Mechanical Measurement and Instruments*. New York, USA: The Ronald Press Company.
- Doeblin, E. O. (2004). *Measurement System- Application and Design*. Tata McGraw Hill
- Nakra, B. C., & Chaudhary, K. K. (2009). *Instrumentation, Measurement and Analysis (3rd ed.)*. Tata McGraw Hill.
- Nachtigal, C. L. (1990). *Instrumentation and Control. Fundamentals and Application*. Wiley Series in Mechanical Engineering.
- Oliver, F. J. (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 discrete 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. Computer modeling, computing environments software development process.	1
3.	Modular design, top down design, structured programming, – algorithm design.	1
4.	Program composition, quality control- testing and documentation software strategy.	1
5.	Approximation- round off errors- accuracy and precision – definitions, number system in the computer- truncation errors.	1
6.	Nature of simulation, systems models and simulation. Discrete event simulation, time advance mechanisms, components of discrete event simulation model.	1
7.	Principles of simulation of singular server queuing system. Programme organization and logic for single server queuing system. Development of algorithm, single server queuing system.	1
8.	Solving roots of equation in computers, graphical method. Developing algorithm for bisection method, false position method.	1
9.	Application of roots of equation to gas laws, open channel flows and electric circuits, vibration analysis.	1
10.	Solving linear algebraic equation in engineering practices.	1
11.	Developing algorithm for Gaussian elimination. Pitfalls of elimination methods and remedies.	1
12.	Overview of LU decomposition. LU decomposition algorithms, calculating inverse of matrix.	1
13.	Application of linear algebraic equation to statically determinate truss, Circuit analysis and spring mass system.	1
14.	Introduction to optimization in engineering, Formulation of problems. One dimensional unconstrained optimization, development of algorithm for golden sections and quadratic interpolation.	1
15.	Application of optimization to design of tank and waste water treatment problem and power transfer circuits.	1
16.	Formulating engineering problems using ordinary differential equation. Solving ordinary differential equation using computers, Euler's method and modelling of engineering systems, computers, Runge-kutta method.	1
	Total	**16**

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
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.* New Delhi: India: Tata McGraw Hill Publishing Company limited.
- Chapra, S. C., & Canale, R. P. (1994). *Introduction to Computing for Engineers (2nd ed.).*New York, USA: McGraw Hill International Edition.
- Dent, J. B., & Blackie, M. J. (1979). *System Simulation in Agriculture.* London, UK: Applied Science Publishers Ltd.
- Law, A. M. (2015). *Simulation Modeling and Analysis.* New York, USA: McGraw Hill International Edition.
- Schilling, R. J., & Harries, S. L. (2002). *Applied Numerical Methods for Engineers Using MATLAB and C.*Singapore , Malaysia: Thomson Asia Pvt. Ltd.
- Veerarajan, T., & Ramachnadran, T. (2004). *Numerical Methods with Programmes in C and C++.* New Delhi, India: Tata McGraw Hill Publishing Company limited.

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.	2
3.	Working with blocks, block commands. Exercise in simple assembly in orthographic.	2
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.	2
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., & Doyle, R. (2007). *SolidWorks® For Dummies®* (٢nd ed.). Wiley Publishing, Inc.
- Shih, R. H. (2021). *AutoCAD 2021. 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.

VI. 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.

VII. Learning outcome

The students will be able to select suitable manufacturing technique to fabricate different components used in Farm machinery.

VIII. 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**

IX. 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**

X. Suggested Reading

- Begeman, M. L., Ostwald, P. F., & Amstead, B. H. (1979). *Manufacturing Processes: SI Version (7th ed.)*. John Wiley and Sons.
- Chapman, P. A. J. (1996). *Workshop Technology, Part III(3rd ed.)*. CBS Publisher and distributors Pvt. Ltd.
- Gupta, R. B. (2017). *Production Technology, Vol I - Production Process*. New Delhi, India: Satya Prakashan.
- Hoyos, L. (2010). *Fundamentals of Tool Design (6th Edition)*. USA: American Society of Tool and Manufacturer Engineers.
- Jain, R. K. (1994). *Production Technology: A Textbook for Engineering Students*. New Delhi, India: Khanna Publishers.
- Polukin, P., Gringerg, B., Kantenik, S., Zhadan, V., & Vasilye, D. *Metal Process Engineering*. Moscow, Russia: MIR Publishers.

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	2
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	**32**

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	1
	Total	**16**

X. Suggested Reading

- Clay, S. A., Clay, D. E., & Bruggeman, S. A. (2017). *Practical Mathematics for Precision Farming.* Madison, USA: American Society of Agronomy, Crop Science Society and Soil Science Society of America.
- Henten, E. J. V., Goense, D., & Lokhorst, C. (2009). *Precision Agriculture*. Wageningen Academic Publishers.
- Ram, T., Lohan, S. K., Singh, R., & Singh, P. (2014). *Precision Farming: A New Approach*. New Delhi, India: Astral International Pvt. Ltd.
- Shannon, D. K., Clay, D. E., & Kitchen, N. R.(2018). *Precision Agriculture Basics.* American Society of Agronomy. Madison, USA: Crop Science Society and Soil Science Society of America.
- Singh, A. K., & Chopra, U. K. (2007). *Geoinformatics Applications in Agriculture*. New Delhi , India: New India Publishing Agency.

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	2
3.	Machinery for field preparation for vegetables (Disc harrows, Disc plough, offset rotavator, subsoiler, 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	2
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	**32**

VIII. Suggested Reading

- Bell, B., & Cousins, S. (1997). *Machinery for Horticulture*. Old Pond Publishing Ltd.
- FAO. (2017).*Good Agricultural Practices for Greenhouse Vegetable Production in the South East European countries.* Rome, Italy: FAO.
- Ponce, P., Molina, A., Cepeda, P., Lugo, E., & MacCleery, B. (2014*). Greenhouse Design and Control (1st ed.).*CRC Press.

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+0
FMPE 614	Ergonomics in Working Environment	2+1
	Total	**17+6**

Minor Courses (Requirement: 06 Credits)

Course Code	Course Title	Credit Hours
REE 609	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.

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. (2018). *Advances in Agricultural Machinery and Technologies*. Boca Raton: CRC Press. https://doi.org/10.1201/9781351132398.
- Edwards, G. T. C., Hinge, G., Skou-Nielsen, N., & 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 ed.).*USA: American Society of Agricultural and Biological Engineers.

I. Course Title : Advances in Machinery for Precision Agriculture
II. Course Code : FMPE 602
III. Credit Hours : 2+1 Aim of the course

Detailed study of the hardware system used in precision agriculture (PA) and techniques of using them in precision agriculture.

IV. 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.

V. 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.

VI. 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.	2
8.	Interpolation, reclassification, image classification, band math and interpretation of analysis.	1
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. Microwave radiation and Gamma rays to estimate volume	1
12.	Different types of grain moisture sensors	1
13.	Fan speed sensor, elevator speed sensor, header position, yield monitor data	2
14.	Yield monitors for non-grain crops	1

15.	Sources of soil variability, general soil sampling basics, systematic variability. 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	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Simple programming for automating precision farming calculations	2
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	**16**

X. Suggested Reading

- Clay, D. E., Clay, S. A., & Bruggeman, S. A. (2017). *Practical Mathematics for Precision Farming*. Madison, USA: American Society of Agronomy.
- Ram, T., Lohan, S. K., Singh, R., & Singh, P. (2014). *Precision Farming: A New approach*. New Delhi, India: Astral International Pvt. Ltd.

- Shannon, D. K., Clay, D. E., & Kitchen, N. R. (2018). *Precision Agriculture Basics*. Madison, USA: American Society of Agronomy.
- Singh, A. K., & Chopra, U. K. (2007). *Geoinformatics Applications in Agriculture*. New Delhi, India: New India Publishing Agency.
- Van-Henten, E. J., Goense, D., & Lokhorst, C. (2009). *Precision Agriculture*. Wageningen, Netherlands : Wageningen Academic Publishers.

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

To learn the principles behind conservation of energy and to analyze agricultural systems in terms of energy flow and balance.

V. Theory

Unit I

Energy Sources for Agriculture, Energy requirement of different operations in agricultural production systems viz. crop, livestock and aquaculture. Economic Impacts of Energy Prices on Agriculture

Unit II

Energy conservation through proper management and maintenance of farm machinery, planning and management of agricultural production systems for energy conservation and energy returns assessment.

Unit III

Development of energy model of farm for efficient energy management in a given agricultural production system.

Unit IV

Design of integrated energy supply system, Assessment of energy conservation technology.

Unit V

Case studies on application of various techniques of energy conservation and management. Energy use planning and forecasting for a given system.

VI. Learning outcome

Visualizing an agricultural systems in terms of energy balance and ability to create systems that are energy efficient, determine what farm practices use the most energy for producing a crop; describe farm equipment options for reducing energy use and describe management options for reducing energy use.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction	1
2.	Sources and Classification of energy	3
3.	Energy coefficients	2
4.	Energy requirements for wheat production	3

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	2
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	2
13.	Energy requirements for fish production	2
14.	Energy requirements for meat and milk production	2
15.	Limits of energy conservation	3
16.	Energy planning, management and forecasting in agriculture	4
17.	Design of integrated energy supply system	4
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	4
	Total	**48**

Suggested Reading

- Jochen, B., & Guangnan, C. (2017). *Sustainable Energy Solutions in Agriculture.* Boca Rotan, USA: CRC Press.
- Mittal, J. P., Panesar, B. S., Singh, S., Singh, C. P., & Mannan, K. D. (1987). *Energy in Production Agriculture and Food Processing*. Ludhiana, India: ISAE Publication.
- Pimental, D. (1980). *Handbook of Energy Utilization in Agriculture*. Boca Rotan, USA: CRC Press.
- Singh, S., & Singh, R. S. (2014). *Energy for Production Agriculture*. New Delhi, India: ICAR.
- Stanhil, G. (*ed.*) (1984). *Energy and Agriculture*. Springer-Verlag Berlin.

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	No. of Lectures
	Unit I	
1.	Soil condition and soil strength determining factors.	1
2.	General aspects of mechanical behaviour 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.	2
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
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.	2
	Total	**16**

X. Suggested Reading

- Birkas, M. (2014). *Book of Soil Tillage*. Godollo, Hungary: SzentIstvan University Press.
- Koolen, A. J., & Kuipers, H. (1983). *Agricultural Soil Mechanics*. New York, USA: Springer-Verlag.

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 GeeClough. 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 Lectures
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
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., & O'Brien, J. (2004). *Terramechanics: Land Locomotion Mechanics*. Lisse, Netherlands: CRC Press.
- Macmillan, R. H. (2010). *The Mechanics of Tractor-Implement Performance: Theory and Worked Examples: A Textbook for Students and Engineers*. Melbourne, Australia : University of Melbourne.

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
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	3
	Total	**16**

X. Suggested Reading

- Hunt, D. R. (1986). *Engineering Models for Agricultural Production*. Westport, USA: AVI Pub. Co.
- Hunt, D., & Wilson, D. (2015). *Farm Power and Machinery Management*. Illinois, USA : Waveland Press.
- Singh, S., & Verma, S. R. (2009). *Farm Machinery Maintenance and Management*. New Delhi, India: ICAR.

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, E. S., Sultan-Shakh, E. G., Smirnov, I. I., & Verniaev, O. V. (2016). *Theory, Construction and Calculation of Agricultural Machines*. New Delhi, India: Scientific Publishers.
- Kanafozski, C., & Karwowiki, T. (1976). *Agricultural Machines: and Construction. Vol. I & II*. Washington DC, USA: US Dept. of Agriculture and National Science Foundation.
- Kepner, R. A., Bainer, R.,& Barger, E. L. (2017). *Principles of Farm Machinery*. New Delhi, India: CBS publishers and Distributors Pvt. Ltd.

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
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, P. O., Rodahl, K., Dahl, H. A., & Stromme, S. B. (2003). *Textbook of Work Physiology: Physiological Bases of Exercise*. Champaign IL: Human Kinetics.
- Bridger, R. S. (2009). *Introduction to Ergonomics (3rd ed.)*. Boca Raton, USA: CRC Press.
- Gite, L. P., Majmudar, J., Mehta, C.R., & Khadatkar, A. (2009). *Anthropometric and Strength Data*

of Indian Agricultural Workers for Farm Equipment Design. Bhopal, India: Central Institute of Agricultural Engineering.

- Gite, L. P., Agrawal, K. N., Mehta, C. R., Potdar, R. R., & Narwariya, B. S. (2019). *Handbook of Ergonomical Design of Agricultural Tools, Equipment and work Places*. New Delhi, India: Jain Brothers.
- Kroemer, K. H. E., & Grandjean, E. (1997). *Fitting the Task to the Human: A Textbook of Occupational Ergonomics (5th ed.)*. Philadelphia, USA: Taylor & Francis.
- Mehta, C. R., Kumar, A., Gite, L.P., & Agrawal, K.N. (2022). *Ergonomics and Safety in Agriculture.* New Delhi, India: ICAR.
- Pearsons, K. (2003). *Human Thermal environments: The Effects of Hot, Moderate and Cold Environment on Human Health, Comfort and Performance*. New York, USA: Taylor and Francis.
- Sanders, M. S., & McCormick, E. J. (1993). *Human Factors in Engineering and Design*. New York, USA: McGraw Hill.

Irrigation and Drainage Engineering

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	2+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
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	**31+11**

*Compulsory Courses

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 510	Energy, Ecology and Environment	3+0
CE 501	Dimensional Analysis and Similitude	2+0
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	2+1
MATH 502	Numerical Methods for Engineers	2+1
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.	

List of Other Essential Requirements

Course Code	Course Title	Credits
IDE 591	Masters Seminar	1+0
IDE 599	Masters Research	0+30

Course Content

M.Tech in Irrigation and Drainage Engineering

I	**Course Title**	**: Design of Surface Irrigation Systems**
II	**Course Code**	**: IDE 501**
III	**Credit Hours**	**:2+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.

Unit V

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 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.

VIII 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.

IX 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
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.	4
9	Hydraulics: Design and operation of sprinkler and trickle irrigation systems	3
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
	Integrated approach to irrigation water management	2
	Total	**32**

X 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	Measurement of wetting bulb under point source and line source of irrigation	1
13	Visit to mechanized farms	1
	Total	**16**

XI 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.

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.

VII 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
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.	1
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	2
8	Planning, design and installation of surface and subsurface drainage systems for waterlogged and saline soils	2

9	Theories of vertical and horizontal subsurface drainage systems	1
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	**32**

VIII 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 rai2nfall 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

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 V

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**

X 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
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

XI Suggested Reading

- Jos´eLiria Montanes. 2006 Hydraulic Canals. *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 modelling 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	2
2	Functions of the root systems	2
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	**32**

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	2
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	**16**

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
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 andtheir compatibility, precautions, frequency, duration and injection rate, Emitter clogging and prevention	2
9	Performance evaluation of drip irrigation system	1
8	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**

X 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**

XI 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. BatsfordLtd, 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.

IV 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.

V 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.

VI 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.

VII Lecture Schedule

S. No	Topic	No. of Lectures
1	Water Resources of India. Occurrence, movement of groundwater and storage of groundwater in geological formation	1
2	Study of hydro geological formation in India	1
3	Principal of Groundwater flow. Interaction between surface water and groundwater.	1
4	Natural and artificial groundwater recharge. Conjunctive use ofsurface and groundwater	1
5	Groundwater balance and fluctuation of water table beneath recharge sites	1
6	Delineation of groundwater potential zones using RS and GIS	1
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	1
10	Unsteady state flow to fully penetrating wells in unconfined, confined and leaky aquifer	2
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	2
13	Flow net analysis for groundwater flow	1
14	Steady and Unsteady flow in Multi aquifers	1
15	Flow analysis in interfering multiple wells	1
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	1
23	Calibration and validation of models	2
	Total	**32**

VIII 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	2
	Total	**16**

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 : Remote Sensing and GIS 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

Sensor Characteristics and tracking systems, Photogrammetry, Satellite data analysis. Visual / Image interpretation. Digital image and its processing. Image pre-processing. Image enhancement. Image classification. Data merging. GPS.

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

Application of remote sensing, 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
8	Spatial data structure: Raster, vector data, Spatial relationship-Topology	1
9	Geodatabase models: Hierarchical, network, relational, object-oriented models. Integrated GIS database	3
10	Data quality, Common sources of error, Macro, micro and Usage level omponents, Meta data and Spatial data transfer standards	2
11	Measurement in GIS- Length, perimeter and areas.	1
12	Query analysis. Reclassification, Buffering and Neighbourhood functions.	1
13	Map overlay: Vector and raster overlay	1
14	Interpolation and network analysis	1
15	Digital elevation modelling. Analytical Hierarchy Process. Object oriented GIS, AM/FM/GIS and Web Based GIS.	3
16	GIS approach to Rainfall runoff modelling, Flood inundation mapping and modelling.	2
17	GIS approach to Groundwater modelling and water quality modelling,	2
18	Site selection for artificial recharge. Reservoir sedimentation	1
19	Drought monitoring	1
20	Performance evaluation of irrigation commands	1
21	Cropping pattern change analysis	1
	Total	**32**

X 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/ Interpretation of satellite imagery and aerial photograph, LULC by supervised classification and LULC by unsupervised classification	3
3	Aerial Photograph and scale determination with stereoscope, Determination of Parallaxes in images	1

4	Demonstration on GPS; Provision/ collection of Ground Control Points by GPS in different mode	1
5	Introduction to digital image processing software/, Introduction to GIS software	1
6	Data input; Data editing and Topology creation -Digitization of point, line & polygon features	2
7	SRTM & CARTO DEM, Satellite image download from web and Georeferencing of an image	2
8	Delineation of Watershed, DEM generation: slope, Aspect, Contour, flow direction, Flow accumulation, Drainage, network & morphometric analysis	3
9	Application of Remote Sensing data and GIS for water quality Parameters, Temporal satellite data analysis for vegetation condition, crop water requirement calculation, Erosion mapping using aerial and satellite Data-Case study	2
	Total	**16**

XI Suggested Reading

- Charles Elach and Jakob van Zyl. 2006. *Introduction to the Physics and Techniques ofRemote 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*. TheGuilford 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 wastewaters, 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
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**

X 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**

XI 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*
- 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 behaviour 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**

X 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**

XI 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.

V Theory

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.

VI 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.

VII 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.

VIII 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
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	1
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	**12**

X 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**

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 pump sets 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
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**

X 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 modelling.

VII Lecture Schedule

S. No	Topic	No. of Lectures
1	Principles of heat, mass and momentum transport	2
2	Transport of radiant energy, radiation 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
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	4
7	Transportation problem and solution procedure	3
8	Geometric programming	2

9	Dynamic programming	3
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	**32**

X 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	2
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	**16**

XI 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
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, repairing 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*. KalyaniPublishers, 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.

Unit V

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	Topic	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	2

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 (Arduino , Rasbery ,PCB)	3
12	Digital signal processor	2
13	Application-specific integrated circuit	3
14	Field programmable 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	**48**

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.

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.

Unit V

Applications in surface irrigation automation, automation based on volume, time, fertigation scheduling, water logging, salinity, oxygen diffusion systems, etc.

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.

VI Lecture Schedule

S. No	Topic	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	2
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 (Arduino , Rasbery ,PCB)	3
12	Digital signal processor	2
13	Application-specific integrated circuit	3
14	Field programmable 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	**48**

VII 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 609	Energy Planning, Management and Economics	3+0
	Any other course(s) of other department can be taken asper recommendations of the student's advisory committee.	

List of other Essential Requirements

Course Code	**Course Title**	**Credit Hours**
IDE 691	Doctoral Seminar-I	1+0
IDE 692	Doctoral Seminar-II	1+0
IDE 699	Doctoral 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. analysing 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. analysing 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, analysing 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

Sr. No	Topic	No. of Lectures
1	Geospatial analysis of hydraulic properties of soil: Geospatial analysis, Spatial interpolation, Data quality assessment, Vegetation analysis, Correlation analysis	2
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: Analysing 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	2
14	Drip irrigation in command area development	2
15	Mulching and its effect on crop productivity, analysing moisture and temperature profiles with time and depth, Effect of shading and mulching on crop productivity, vapour phase movement	2
	Total	**32**

X List of Practicals

S. No.	Topic	No. of Practicals
1	Study of geospatial analysis of soil properties	1
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
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	2
13	Analysis of moisture and temperature profiles with time and depth	1
14	Development of seasonal and dated production functions for forecasting crop yield	1
	Total	**16**

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. Hysteresis, 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.

VIII 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.

X 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	4
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	**32**

XI List of Practicals

S. No.	Topic	No. of Practicals
1	Steady state drainage flow problems	3
2	Unsteady state drainage flow problems	4
3	Measurement of capillary potential	1
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**

XII 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.

VII 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.

VIII Lecture Schedule

S. No	Topic	No. of Lectures
1	Concept of soil aquifer system	1
2	Flow of water in partially saturated soils	2
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	3
6	Unsaturated flow models	2
7	Numerical modelling of groundwater flow	2
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	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	**48**

X 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	2
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	3
6	Thermodynamics of flow through plant cells	3
7	Dynamics of water movement through soil plant atmosphere system	3
8	Stomatal aperture, photosynthesis and actual evapotranspiration relationship	3
9	Production functions of evapotranspiration	4
10	Evapotranspiration 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	**32**

X **List of Practicals**

S. No.	Topic	No. of Practicals
1	Estimation of potential evapotranspiration using FAO 56 Penman Monteith equation	3
2	Estimation of potential evapotranspiration using FAO Cropwat model	1
3	Estimation of potential evapotranspiration using FAO ETo calculator	1
4	Measurement of ET parameters under open condition	2
5	Measurement of ET parameters under protected cultivation	2
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	1
	Total	**16**

XI **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.

VII 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	

VIII 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	

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 andApplications*. Chapman and Hall/CRC.
- Tzeng GH and Huang JJ. 2013. *Fuzzy Multiple Objective Decision Making*. Chapman and Hall/ CRC.

Processing and Food Engineering

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	3+0
	Total	**34+17**

*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 510	Energy, Ecology and Environment	3+0
REE 515	Energy Management in Food Processing Industries	1+1
FMPE 502	Testing and Evaluation of Agriculture Equipment	2+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+1
CSE 502	Artificial Intelligence	2+1
MATH 501	Finite Elements Methods	2+1
MATH 502	Numerical Methods for Engineers	2+1
CE 501	Dimensional Analysis and Similitude	2+0
	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.	

List of Other Essential Requirements

Course Code	Course Title	Credit Hours
PFE 591	Masters Seminar	1+0
PFE 599	Masters 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.	2
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	2
19.	Mass transfer applications in food processing.	2
	Total	**32**

IX. List of Practicals

S. No.	Topic	No. of Practicals
1	Solving problems on steady conduction	1
2	Solving problems on steady conduction with 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	2
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	**16**

X. Suggested Reading

- Bird RB, Stewart WE, Lightfoot EN 2006. *Transport Phenomena (2nd Ed.)*, John Wiley & Sons. ISBN: 978-0-470-11539-8
- Raj B 2012. *Introduction to Transport Phenomena: Momentum, Heat and Mass*, PHI. ISBN 978-8120345188
- Geankoplis CJ. 2015. *Transport Processes and Separation Process Principles (Includes Unit Operations) (4th Ed.)*, Pearson Education India, ISBN: 978-9332549432
- Coulson JM, Richardson JF, Backhurst JR, Harker JH. 2002. *Chemical Engineering*. Vol. 2 (5th Ed.), Elsevier, ISBN: 9780750644457
- Earle RL. 1985. *Unit Operations in Food Processing*. Pergamon Press.
- Holman JP, Bhattacharyya S. 2017. Heat Transfer. McGraw Hill.
- Welti-Chanes J, Velez-Ruiz JF, Barbosa-Canovas GV. 2002. *Transport Phenomena in Food Processing*. CRC Press ISBN: 9781566769938.
- McCabe WL, Smith JC, Harriott P. 2005. *Unit Operations of Chemical Engineering (7th Ed.)*. McGraw's Hill.
- Plawsky JL. 2020. *Transport Phenomena Fundamentals (4th Ed.)*, Routledge Taylor & Francis Group, ISBN: 9781138080560.
- Datta AK. 2001. Transport Phenomena in Food Process Engineering, Himalaya Publishing House.

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	3
7.	Study of drying equipments	3
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	**32**

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
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: 978-0-12812018-7
- 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.
- Sharma HK and Kumar N. 2022. *Agro-Processing and Food Engineering*, Springer
- Earle RL. 1985. *Unit Operations in Food Processing*. Pergamon Press.
- Ibarz A and Barbosa-Canovas GV. 2002. *Unit Operations in Food Engineering*, CRC Press
- Jafari SM. 2001. *Engineering Principles of Unit Operations in Food Processing*, Woodhead Publishing

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 physicochemical 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.	3
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.	4
	Total	**32**

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.	2
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	**16**

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.
- Sharma HK, Kumar N. 2022. *Agro-Processing and Food Engineering*, Springer

I. Course Title : Horticultural Crops Process Engineering
II. Course Code : PFE 504
III. Credit Hours : 2+1 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.

IV. 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.

V. 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.

VI. Learning outcome

Student's capability to mill and process (value added products) all kinds of horticultural crops as per requirement of food industries.

VII. 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.	2
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.	2
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	**32**

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	
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
12	Determination of solid gain and moisture loss during osmotic dehydration in fruits	1
13	Study of components and design of controlled atmosphere storage	2
14	Study of quality evaluation of fruits and vegetables	2
	Total	**16**

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.
- Sharma HK, Kumar N. 2022. *Agro-Processing and Food Engineering*, Springer
- 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
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.
- Sharma HK, Kumar N. 2022. *Agro-Processing and Food Engineering*, Springer
- 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
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 determine water 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.	4
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.	4
	Total	**32**

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 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.

IV. 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.	2
17.	A.C. conductivity and dielectric constant, method of determination.	2
18.	Energy absorption from high frequency electric field.	2
19.	Application of engineering properties in design and operation of agricultural equipment and structures.	3
	Total	**32**

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
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	2
	Total	**16**

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.
- Sharma HK, Kumar N. 2022. *Agro-Processing and Food Engineering*, Springer
- 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.	2
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.	2
16.	Food Safety Management Systems (FSMS), Traceability.	2
	Total	**32**

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
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	**16**

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.
- FSSAI (2021) Manual for Food Safety Officers (2nd Ed), Food Safety and Standards Authority of India, New Delhi

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.	3
16.	HACCP in food processing industries.	2
	Total	**32**

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.	2
9.	Design of plate and packed tower.	2
10.	Visit to related food industry.	2
	Total	**16**

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, technoeconomic feasibility analysis of the project as needed in food industries.

VIII. **Lecture Schedule**

S. No.	Topic	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.	1
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.	1
	Total	**16**

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	6
	Total	**16**

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.	2
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	**16**

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/seedprocessing-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.	3
7.	PERT, CPM.	3
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	**32**

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.	3
7	To conduct SWOT analysis for different Start-ups.	3
	Total	**16**

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 and case 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
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.	3
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.	3
	Total	**32**

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.
- Pandey PH. 2014. *Principles and Practices of Agricultural Structures and Environmental Control*, Kalyani Publishers
- O P Singhal. 2002. *Farm Structure*, Aman Publishing House

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) 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	2
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
16.	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	3
	Total	**32**

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
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.	2
15.	Visit to dairy plant.	1
	Total	**16**

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*). WileyBlackwell.
- 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
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.	2

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.	2
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	**32**

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	2
10.	Shelf life studies on different meat, fish and milk products	2
11.	Visit to processing plants	1
	Total	**16**

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.
- Ahmed T. 1997. *Dairy Plant Engineering & Management*, Kitab Mahal

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 reuse 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	2
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
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	2
	Total	**32**

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.	2
	Total	**16**

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 Aim of the course

To acquaint and equip the students with the concept of thermodynamic properties of air and its application in food processing.

IV. 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.	4
3.	Thermodynamic properties of moist air.	4
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.	5
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.	5
8.	air distribution and duct design, air flow pattern and control, equipment, components and controls. Instruments for measurement and control of temperature and moisture.	5
9.	Thermal insulation materials for environmental control systems. Comparative performance of these materials.	5
10.	Applications of environmental control in farm buildings, farmstead, green house, dairy industry, poultry shed, potato storage etc.	5
	Total	**48**

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
FMPE 511	Principles of Automation and Control	2+1
REE 610	Renewable Energy for Industrial Application	2+1
ME 501	Mechatronics and Robotics in Agriculture	2+0
CE 501	Dimensional Analysis and Similitude	2+0
	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.	

List of Other Essential Requirements

Course Code	Course Title	Credits
PFE 691	Doctoral Seminar-I	1+0
PFE 692	Doctoral Seminar-II	1+0
PFE 699	Doctoral 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 and latest techniques of food 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, Microwave processing, High pressue processing.

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.	Topic	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	3
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	3
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	**32**

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.	1
10.	Development of experimental setup by students	2
11.	Study of microwave process and equipments	1
12.	Study of High Pressure Processes and equipments	1
	Total	**16**

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*. Vikas Publishing 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
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	3
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	2
	Total	**32**

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.	2
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/ foods.	1
	Total	**16**

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. *Drying Farm Crops*. Lyall Book Depot.
- Kudra and Mujumdar. 2009. *Advanced Drying Technologies*. CRC press.
- Shukla BD and Singh G.2018. *Drying and dryers (Foods and Agricultural Crops)*. Jain Brothers

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.	3
13.	Mathematical models and their application along with pipe line design and pump selection for non-newtonian fluids.	3
14.	Recent advances in textural, rheological and viscoelastic characteristics of foods and their associated mathematical models.	3
	Total	**32**

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 press mud, 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 materials, 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 indifferent 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
8.	To study the various quality parameters of briquettes	1
9.	To study the production of alcohol from waste materials	2
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	**16**

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, fermentation, 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	4
4.	Dynamic Mathematical Model, Analysis of Dynamic Mathematical Models, dynamic and interacting dynamic processes.	4
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.	3
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	**48**

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.	4
2.	Mass balance: steady and unsteady. Problem solving involving blending, separation, drying, growth, recycling etc.	4
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	**32**

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
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.	2
	Total	**16**

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.

Renewable Energy Engineering

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	Food Processing Equipment and Plant Design	1+1
PFE 506	Food Package Engineering	1+1
IDE 511	Design of Pumps for Irrigation and Drainage	2+0
CE 501	Dimensional Analysis and Similitude	2+0
FMPE 515	Computer Aided Design of Machinery	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	2+1
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	

List of other Essential Requirements

Course Code	Course Title	Credit Hours
REE 591	Masters Seminar	1+0
REE 599	Masters 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 and 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.	Demonstration of Different Instruments used for Renewable Energy gadgets measurements.	1
2.	Study of box and parabolic type solar cookers.	1
3.	Study of concentrating type solar cookers.	1
4.	Study of different types of solar water heating system.	1
5.	Study of different types of natural convection solar dryer.	1
6.	Study of different types of forced convection solar dryer.	1
7.	Demonstration of solar photovoltaic system.	1
8.	Study of characteristics of biomass (moisture content, ash content, volatile matter and fixed carbon).	1
9.	Determination biomass calorific value.	1
10.	Demonstration of throatless down draft inverted gasifier.	1
11.	Demonstration of throatless and throat type updraft gasifier.	1
12.	Demonstration of throatless down draft gasifier for power application.	1
13.	Demonstration of briquetting and pelleting machine.	1
14.	Demonstration of wind energy conversion system.	1
15.	Design and efficiency testing of wind energy conversion devices.	1
16.	Design and benefit analysis of energy systems.	1
	Total	**16**

X. Suggested Reading

- Culp, A.W. 1991. *Principles of Energy Conversion*, McGraw Hill pub. Co Inc. New York.
- Duffie, J.A. and Beckman W.A. 1991. *Solar Engineering of Thermal Processes*. John Willey, New York.
- Garg, H.P. and Praksh J. 1976. *Solar Energy, Fundamentals and Applications*. Tata Mc Graw, Hill pub.Co.Inc., New Delhi
- Odum. H.T. and Odum, E.C. 1976. *Energy Basis For Man and Nature*. Mc Graw, Hill Pub. Co.Inc., New York.
- Sukhatme S.P. 1997. *Solar Energy, Principles of Thermal Collection and Storage*. Tata Mc Graw Hill. pub. Co. Ltd., New Delhi.
- Twidell, J.W. & Weir, A.D. 1986. *Renewable Energy Sources*, E & FN Spon Ltd. London.
- Rai G.D. 2001. *Non Conventional Energy Sources*, Khanna Publishers, Delhi.

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
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.	3
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	**32**

IX. List of Practicals

S. No.	Topic	No. of Practicals
1.	Measurements of Solar radiations using different measuring instruments.	2
2.	Estimation of solar energy by model applications.	2
3.	Study of different characteristics of materials used in solar system.	2
4.	Design of solar flat plate collectors.	2
5.	Study of different parameters influenced the solar flat plate collectors.	1
6.	Performance evaluation of solar box type cooker and parabolic solar cooker.	1
7.	Performance evaluation of solar concentrating cooker.	1
8.	Performance evaluation of solar natural convection dryer.	1
9.	Performance evaluation of solar forced circulation dryer.	1
10.	Study of solar water desalination system.	1
11.	Study of Solar refrigeration system.	1
12.	Study of active and passive solar buildings.	1
	Total	**16**

X. Suggested Reading

- Bansal N K, Kleeman MK and Meliss M. 1990. Renewable Energy Sources and Conversion Technologies. Tata Mc Graw, Hill pub.Co.Inc., New Delhi.
- Duffie JA and Beckman WA 2006. *Solar Thermal Engineering Process*. John Willey & Sons, New Jersey.
- Hsien JS. 2014. Solar Energy, Prentice Hall Inc., New Jerssey.
- Garg H P. 1990. Advances in Solar Energy Technology, Springer Publishing Company, Dordrecht, Netherland.
- Kalogirou S A. 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 Ramprasad MS. 1991. Power Generation through Renewable Sources of Energy. Tata McGraw- Hill Pub. Co., New Delhi.
- Sukhatme S P and Nayak J. 2008. Solar 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
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.	Topic	No. of Practicals
1.	Study of characteristics of biomass (moisture content, ash content, volatile matter and fixed carbon).	2
2.	Determination biomass calorific value.	1
3.	Design of bio reactors.	1
4.	Estimation of Stoichiometric air requirement for combustion process.	1
5.	Determination of techno economical feasibility of bio chemical conversion process.	2
6.	Performance evaluation of throatless down draft inverted gasifier.	1
7.	Performance evaluation of throatless and throat type updraft gasifier.	1
8.	Performance evaluation of throatless down draft gasifier for power application.	1

9.	Design of biomass combustor based thermal system.	1
10.	Performance of biomass combustor based drying system.	1
11.	Performance evaluation of pyrolytic converters.	1
12.	Design of waste heat recovery system.	1
	Total	**16**

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.	Study of types of Insulation, refractory's used in gasifier and combustor.	1
6.	Financial Management	1
7.	Energy audit and conservation opportunities in thermal utilities.	2
8.	Energy audit and conservation opportunities in electrical utilities.	2
9.	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 Ram Chandra. 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 & 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.	Study of wind energy Conversion system.	1
3.	Wind velocity mapping and curve analysis.	2
4.	Wind energy instruments and resource assessment.	1
5.	Performance of wind energy conversion system.	1
6.	Design of wind mills.	1
7.	Study of Water pumping wind mills.	1
8.	Performance evaluation of wind aero-generator.	2
9.	Study of Wind turbine loads.	2
10.	Study of Wind energy farms.	1
11.	Economics of wind energy systems.	1
12.	Study solar wind hybrid system.	2
	Total	**16**

X. Suggested Reading

- Cheremision NP. 1978. *Fundamental of Wind Energy*. Ann Arbor Science, Pub. Inc. Michigan.
- Eldridge FR. 1978. *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, Netherland.
- Manwell JF, McGswan JG and Rogers AL. 2012. *Wind Energy Explained – Theory Design and Application*, John Wiley and Sons, New Jersey.
- Power 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 agro based 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 PV Syst, 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
8.	PV software's operation and utilization.	1
9.	Design and estimation of SPV systems components for agro based industrial applications.	1
10.	Study on Battery performance testing.	1
11.	Study of standalone/grid connected SPV system.	1
12.	Commissioning of complete solar PV system.	2
13.	Study of Carbon Nano-Tubes (CNT).	1
14.	Visit to various industries manufacturing the solar photovoltaic system.	2
	Total	**16**

X. Suggested Reading

- Garg HP. 1990. *Advances in Solar Energy Technology*. D. Publishing Company, Tokyo.
- Duffle JA & 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 edition, 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 & 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 Implication for India.* IIASA, Laxenburg, Austria.
- Reddy AKN, Williams RH, Goldenberg J ans Johansson TB. 1987. *Energy for a Sustainable World.* Wiley- Eastern Ltd., New Delhi, India.
- Bansal, N.K. and Dayal M. *Techno Economics of Renewable Power Systems*.
- 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
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.	Measurement of biogas composition using orsat apparatus.	1
2.	Determination of producer gas composition.	1
3.	Preparation of bio diesel using trans-esterification process.	1
4.	Measurement of chemical properties of biodiesel.	1
5.	Study of different equipment and instruments used for evaluating the performance I.C. engines	1
6.	Performance of I.C. engines on alternate fuels (biogas, producer gas and bio diesel).	3
7.	Measurement of flue gas parameters.	1
8.	Thermal applications of alternate fuels (biogas, producer gas and bio diesel).	3
9.	Hydrogen production.	1
10.	Biomass based fuel cell.	1
11.	Integrated biomass-based gasifier for power generation.	1
	Total	**15**

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 bio-methanation 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.	Study different types of biogas plants.	1
2.	Design of biogas plant for solid and liquid wastes.	1
3.	Cost estimation of different biogas plants: KVIC, Janta, Deenbandhu type.	2
4.	Analysis of biogas.	1
5.	Experiment on purification of biogas.	1
6.	Performance evaluation of biogas appliances.	1
7.	Testing of biogas burner for heat transfer, thermal and cooking efficiency	2
8.	Study and testing of biogas for power generation application.	2
9.	Analysis of Bio-digested slurry.	2
10.	Study on use of biogas spent slurry.	1
11.	Study and analysis of carbon credits.	1
	Total	**15**

X. 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 Agricultural Wastes*. National Academy of Sciences, Washington D.C.
- 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, pillers, 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
4.	Energy efficient technology: Efficiency hierarchy, energy dependent activities, energy policies, linkage between energy use and economic growth and environment.	4
5.	Ecosystem: Kinds, transfection, components of ecosystem.	3
6.	Ecosystem development of evaluation, major ecosystem of the world, physical environment and metrology.	3
7.	Climate change: Impact and models.	3
8.	Energy for sustainable development: Development indices, pillars, subsystems, principles and dimensions.	2
9.	Low carbon technologies: Energy efficiency projects, carbon trading.	3
10.	Environment, Environmental degradation.	1
11.	Thermal and chemical pollution, primary and secondary pollutant, air pollution.	3
12.	Water pollution.	1
13.	Unclear energy hazard.	1
14.	Radioactive hazards, mining hazards, land use, oil spills and gas leaks.	3
15.	Global environmental changes: United Nations Framework Convention on Climate Change (UNFCC).	4
16.	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. *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 & Jones WJ. 1974. *Energy, Ecology & 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
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 different types of gasifier (updraft and down draft) using solid biomass.	3
5.	Design of solar photovoltaic plant for a hostel/building/home.	3
6.	Life cycle assessment and financial assessment of a photovoltaic plant for a hostel/building/home.	1
7.	Study on standards of renewable energy systems.	1
8.	Study on test codes of renewable energy systems.	2
9.	Study of HOMER software.	1
	Total	**16**

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 & 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 byproducts/ 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 by-products, 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
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. 1980. *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
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
6.	Study of energy analysis, energy ratio and specific energy value.	1

7.	Case study of energy auditing of agro processing industries.	3
	Total	**15**

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. *Non conventional 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 green house 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, paints and 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. Theory 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 (NDC), 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*	Fuel 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 Modeling 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 to as recommended by UGC.

Minor Courses (Requirement: 06 Credits)

Course Code	Course Title	Credit Hours
FMPE 612	Farm Machinery Management and Systems Engineering	2+1
ME 501	Mechatronics and Robotics in Agriculture	2+0
PFE 513	Agri-Project Planning and Management	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	

List of other Essential Requirements

Course Code	Course Title	Credit Hours
REE 691	Doctoral Seminar-I	1+0
REE 692	Doctoral Seminar-I	1+0
REE 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 behavior, 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
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 behavior.	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
9.	Study of land fills technology.	1
10.	Study of bio hydrogen production routes.	1
11.	Study of anaerobic fermentation system for industrial applications.	1
12.	Study of shaft power generation through biogas gas technology.	1
13.	Case study of MSW based biogas plants.	1
	Total	15

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, fluidized bed. Liquid fuels: Atomization, vapour concentration, combustion phenomena. Gaseous fuel: Flam 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. Fluidized 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
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
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. 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.	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 methods, 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). Electrogas 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, water fed 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 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, water fed 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.	2
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
9.	Study of magneto hydra dynamic system for energy purpose.	1
10.	Study of heat pump system .	1
	Total	15

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
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	1
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.	2
	Total	**30**

IX. List of Practicals

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 calorific value of solid and liquid fuels.	2
5.	Determination of stoichiometric air requirement of solid fuels.	1
6.	Determination of efficiency of combustion system using solid fuels.	1
7.	Determination of efficiency of combustion system using liquid fuels.	1
8.	Determination of efficiency of combustion system using gaseous fuels.	1
9.	Standard testing of burners for thermal efficiency for solid.	1
10.	Standard testing of burners for thermal efficiency for liquid fuel.	1
11.	Standard testing of burners for thermal efficiency for gaseous fuel.	1
12.	Study of thermogravemetric analyzer (TGA).	1
13.	Study of gas chromatography system for analyzing the gas. compositions of gaseous fuels.	2
	Total	**15**

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 behavior 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 equations, 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 systems contacts 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, municipal and compost treatment. Predigestion of waste. Sensors, ICT and remote sensing technologies for waste management.

VI. Practical

Design principles in waste treatment, equipment specification 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.	1
12.	Biosorption of contact stabilization.	2
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.	Specification 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. Photo galvanic 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
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 Photo galvanic 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
6.	Study of types of batteries used SPV system.	2
7.	Introduction and study of softwares for PV system.	2
8.	Study of ongrid and off grid SPV system.	1
	Total	**15**

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 economics and 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 greenhouse 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 combustor (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 combustor (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. Private Limited, Delhi.

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, trans-esterification 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
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.	Study of biomass pyrolysis system.	1
7.	Preparation of biodiesel using trans-esterification system	1
8.	Performance evaluation of IC engine using biodiesel.	2
9.	Bio oil production by pyrolysis	1
10.	Study of Characteristics of biodiesel and bio oil.	2
11.	Study of different generation of bio fuel.	1
	Total	**15**

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 Entwicklungs technologien–GATE, Germany.

I. Course Title : Energy Modelling and Simulation

II. Course Code : REE 612

III. Credit Hours : 2+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, Basics, system, boundary, interaction, types of models, physical, analogy models.	1

2.	Model applications.	1
3.	Mathematical models: Concepts, input, output model, stochastic, deterministic, empirical models, linear, non-linear models.	1
4.	Modelling concept and application, Energy Modelling, Review of various energy sector models.	1
5.	Energy demand analysis and forecasting, Energy supply assessment and evaluation.	1
6.	Energy demand, supply balancing.	1
7.	Energy modelling in the context of climate change.	1
8.	Model studies in gasification, pyrolysis, biogas, fermentation.	1
9.	Model studies in biodiesel.	1
10.	Model studies in solar, wind technologies.	1
11.	Heat transfer applications, Moving boundary models.	1
12.	Energy economics of energy sources.	1
13.	Investment and cost management in various energy technologies.	1
14.	Economics of energy generation.	1
15.	Energy conservation economics, financial analysis.	1
16.	Energy conservation sensitivity and risk analysis.	1
	Total	**16**

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.	2
	Total	**15**

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.

Soil and Water Conservation Engineering

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	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	**21+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 510	Energy, Ecology and Environment	3+0
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	2+1
MATH 502	Numerical Methods for Engineers	2+1
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.	

List of other Essential Requirements

Course Code	Course Title	Credit Hours
SWCE 591	Masters Seminar	1+0
SWCE 599	Masters 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. Discrete and continuous frequency distribution. Fitting probability 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 using software's.

VIII. Lecture Schedule

S. No.	Topic	No. of Lectures
1.	Concept of probability in design of soil and water conservation structures	2
2.	Discrete and continuous frequency distribution	2
3.	Fitting probability distributions	2

4.	Relevance of soil and water conservation in agriculture and in the river valley projects	2
5.	Layout and planning of soil and water conservation measures	2
6.	Software's for design of conservation structures	1
7.	Productivity loss due to soil erosion	1
8.	Water stress and water excess	1
9.	Types and mechanics of soil erosion	1
10.	Software's for soil loss estimation, WEAP, EPIC	3
11.	Theories of sediment transport	2
12.	Control of runoff and sediment loss	1
13.	Sediment deposition process and estimation of sediment load	2
14.	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
15.	Application of Remote Sensing and GIS in Soil and Water Conservation	4
	Total	**32**

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 soil moisture 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	3
10	Estimation of costs of soil and water conservation measures	2
	Total	**16**

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. Advances and improvements in rational approach. SCS approach criticism and improvements.

Unit-III

Micro climate, estimation methods of evaporation and evapotranspiration. Molecular and eddy transport of water, eddy diffusion, mixing, zero plane displacement, microclimate near the ground.

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
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, Advances and improvements in rational approach. SCS approach criticism and improvements.	3
7.	Molecular and eddy transport of water, eddy diffusion, mixing, zero plane displacement, microclimate near the ground. 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 and evapotranspiration. 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**

IX. List of Practicals

S. No.	Topic	No. of Practicals
1.	Delineation of watershed and study of watershed characteristics	2
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**

X. Suggested Reading

- Andy D. Ward, Stanley W. Trimble, Suzette R. Burckhard, John G. Lyon. 2015 Environmental Hydrology CRC Press.
- Haan CT, Johnson HP and Brakensiek DL. 1982. Hydrologic Modeling of Small Watershed, ASAE Monograph No. 5, American Society of Agricultural Engineers, Michigan.
- Singh V P 1988. Hydrologic Systems: Rainfall-Runoff Modeling (Vol.I) – Prentice Hall, New York.
- Singh VP. 1995. *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
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, Jha MK. 1988. *Land and Water Management Engineering.* Second Edition Kalyani Publishers, New Delhi.
- Singh Gurmel C, Venkataraman G, Sastri and B.P. Joshi 1991. *Manual of Soil & Water conservation Practices*. Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi.
- Singh PK. 2000. *Watershed Management (Design and Practice)*. e-media publications, Udaipur.
- Singh Raj Vir. 2003. *Watershed Management*. Second Edition, Yash Publishing, Bikaner.
- Suresh R. 2006. *Soil and Water Conservation Engineering*. Fourth Edition Standard Publishers and Distributors, Delhi.

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
6.	Statistics and probabilities in hydrology- Discrete and Continuous probability - Random Variable and Variate; Probability Distribution of hydrological variables; Co-relation and regression analysis.	3
7.	Introduction and examples of stochastic processes; Specification of stochastic process- nature, stationarity and ergodicity, components of time series,	2
8.	Hydrologic time series analysis –trend, periodicity	1
9.	Stochastic time series analysis- Methods of analysis -Auto correlation coefficient,	1
10.	Stochastic time series analysis- moving average process, auto regressive process,	2
11.	Stochastic time series analysis- auto regressive moving average process,	2
12.	Stochastic time series analysis- auto regressive integrated moving average process.	2

13.	Spectral analysis, analysis of multivariate hydrologic series	2
14.	Thomas Fiering model, Box Jenkins model	2
15.	Model formulation: Parameter estimation, calibration and validation.	2
16.	Application to hydrologic data	2
17.	Generation and forecasting- Regional flood frequency analysis Transformations,	1
18.	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	2
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	**16**

X. Suggested Reading

- Clarke RT. *Mathematical Models in Hydrology.* FAO Publication.
- Haan CT. 2002. *Statistical Methods in Hydrology.* Iowa State Press.
- Kotteguda N.T. 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	4
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	**32**

VIII. Suggested Reading

- Bear J and Arnold V *Modeling Groundwater Flow and Pollution.* D. Reidel Publishing Company
- Bears J. 1972. *Dynamics of Fluids in Porous Media*. American Elsevier Publishing Co. Inc. New York.
- Collins RE. 1961. *Flow of Fluids through Porous Materials*. Reinhold publishing cooperation, New York.
- De Wiest Roger JM. 1969. *Flow through Porous Media*. Academic press, New York.
- Dullien FAL. 1979. Porous Media: Fluid Transport and Pore Structure, Academic Press.
- Harr, M.E. (1962) Groundwater and Seepage. McGraw-Hill Book Company, New York.
- Helmut Kohnke. 1968. Soil Physics. McGraw-Hill Book Co, New York.
- Scheidegger AE. 1974. The Physics of Flow through Porous Media, University of Toronto Press.
- Verruijt A. 1982. *Theory of Groundwater Flow*. 2nd Edn., Macmillan, London.

I. Course Title : Remote Sensing and GIS 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
8.	Spatial data structure: Raster, vector data, Spatial relationship- Topology	1
9.	Geodatabase models: Hierarchical, network, relational, object-oriented models. Integrated GIS database	3
10.	Data quality, Common sources of error, Macro, micro and Usage level components, Meta data and Spatial data transfer standards	2
11.	Measurement in GIS- Length, perimeter and areas	1
12.	Query analysis. Reclassification, Buffering and Neighbourhood functions	1
13.	Map overlay: Vector and raster overlay	1
14.	Interpolation and network analysis	1

15.	Digital elevation modelling. Analytical Hierarchy Process. Object oriented GIS, AM/FM/GIS and Web Based GIS	3
16.	GIS approach to Rainfall runoff modelling, Flood inundation mapping and modelling	2
17.	GIS approach to Groundwater modelling and water quality modelling	2
18.	Site selection for artificial recharge. Reservoir sedimentation	1
19.	Drought monitoring	1
20.	Performance evaluation of irrigation commands	1
21.	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	1
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 & 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	**16**

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: **R**elated 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
4.	IPCC projected climate change impacts on water resources, NATCOM Report- impacts on ET and irrigation demand	4
5.	Vulnerability assessment: Need, steps for assessment, approaches for assessment	3
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	3
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	**48**

VIII. Suggested Reading

- Srinivasa RK and Nagesh KD. *Impact of Climate Change on Water Resources with Modelling Techniques and Case Studies.* Springer publications, New York.
- Rao YS, Zhang TC Ojha, Gurjar BR, Tyagi RD, Kao CM (eds). *Climate Change Modelling, Mitigation, and Adaptation*. American Society of Civil Engineers.
- Tamim Y and Caitlin AG. *Climate Change and Water Resources.* Springer Publication.
- 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.

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*. 414pp. Dordrecht, Boston.

- Carr JR. 1995. *Numerical Analysis for the Geological Sciences*. 592pp. Prentice-Hall, Englewood Cliffs NJ.
- George H and Patricia W. 2000. *Numerical Methods in the Hydrological Sciences*. American Geophysical Union, Florida Avenue, N.W
- 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* 260pp., Prentice Hall, Saddle River NJ.
- Wang HF and Anderson MP. 1982. *Introduction to Groundwater Modeling: Finite Difference and Finite Element Methods*. 237pp., 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 dryland 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	WasteWater Treatment and Utilization	2+1
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	

List of other Essential Requirements

Course Code	Course Title	Credit Hours
SWCE 691	Doctoral Seminar-I	1+0
SWCE 692	Doctoral Seminar-II	1+0
SWCE 699	Doctoral 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. Theory 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	2
9.	Multiple linear regression	2
10.	Optimization of regression coefficients, Statistical optimization and reliability of linear regression models	2
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	**32**

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 Statistical Methods in Hydrology. Oxford Publications House New Delhi
- Linseley RK Jr, Kohler MA and Paulhus JLH. 1975. *Applied Hydrology*. McGraw Hill.
- Maity R. 2018. Statistical Methods in Hydrology and Hydro-climatology. Springer, New York

- Mutreja KN. 1986. *Applied Hydrology.* Tata McGraw Hill.
- Ramesh SV Teegavarapu, Salas JD and Stedinger JR. 2019. Statistical Analysis of Hydrologic Variables: Methods and Applications, ASCE Publication 1801 Alexander Bell Drive Reston, VA
- Singh VP. 1988. Hydrologic Systems: Rainfall-Runoff Modeling (Vol.I) – Prentice Hall, 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
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*. Mc Graw Hill.
- Schwar RS and Friedland B. 1965. *Linear Systems.* Mc Graw 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
2.	Applications of Water resources system analysis	1
3.	Identification and evaluation of water management plans –water demand analysis, Water resources planning objectives	2
4.	Water resource planning and management approaches-Top-Down Planning and Management; Bottom-Up Planning and Management Integrated Water Resources Management	1
5.	Water resource management policy formulation, Water resources planning under uncertainty	1
6.	River basins, river functions, Theories and principles of IRBM processes/phases in integrated river basin management	1
7.	Human interventions and impacts in in integrated river basin management	1
8.	River basins in India- related case studies	1
9.	Water resources planning in river basins- Operational management, tools and methods	2
10.	Water resources planning in river basins -Monitoring, acquisition and processing of water resource data	2
11.	Economic Considerations in Water Resources Planning	1
12.	Deterministic river basin modeling-Stream flow estimation, estimating reservoir storage, mass diagram analysis, sequent peak analysis	2
13.	Deterministic river basin modeling- Reservoir Sizing; Reservoir Operation – standard operating policy, optimal operating policy; multi-reservoir systems,	5
14.	Concept of Reliability	1
15.	Stochastic river basin modeling: Basic probability theory,	2
16.	Single reservoir design and operation-Chance constrained Linear Programming for reservoir operation and design	3
17.	Stochastic river basin modeling: multisite river basin models,	1
18.	Model Formulations and Case Studies- Conjunctive use of ground and surface water; Crop yield optimization, Multi-basin and multi-reservoir systems	3
	Total	**32**

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
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. DA 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 : 2+1

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. Practical

Study on physical, chemical and biological parameters of wastewater. Determination of EC and pH of wastewater Determination of BOD of wastewater. Determination of COD of wastewater. Determination of TSS and TDS of wastewater. Determination RSC of wastewater. Determination of e-coli in the wastewater .On field demonstration of wastewater use for the irrigation. Determination of nutrient (N, P and K) concentration in wastewater. Field demonstration of impact of waste water on eco-system and human health. Study on various wastewater treatment methods. Study on effect of wastewater on contamination of ground water. Visit of village pond treatment nearby area. Visit of sewerage treatment plant nearby area.

VII. 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.

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
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

- Metcalf and Eddy 2003. *Wastewater Engineering*. 4th Ed., McGraw Hill.
- Droste RL. 1997. *Theory and Practice of Water and Wastewater Treatment*. John Wiley.
- 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	5
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	**32**

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**
II	**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 modeling.

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.

VII Lecture Schedule

S. No.	Topic	No of Lectures
1	Data analysis, data matrix attributes	2
2	Algebraic and geometric view, probabilistic view.	3
3	Basics of data mining and CRISP-DM	1
4	Organizational and data understanding	2
5	Intents and limitations of data mining, database, data warehouse data mart and data set	3
6	Types of data, privacy and security, data preparation, collation and data scrubbing	3
7	Data mining models and methods, correlation, association rules	5
8	K-means, clustering understanding of concept, preparation and modeling.	4
9	Discriminant analysis, linear regression, logistic regression, understanding, preparation and modeling	4
10	Decision trees, neural networks, understanding, preparation and modeling.	5
	Total	**32**

IX List of Practicals

S. No.	Topic	No of Practicals
1	Working of OpenOffice and RapidMiner	4
2	Preparing RapidMiner Dataset	3
3	Handling the inconsistent data, missing data, attribute reduction	4
4	Performing analysis on dataset using RapidMiner	5
	Total	**16**

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.

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	3
6	Depth limited search, bidirectional search, heuristic search, problems and examples.	3
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	**32**

IX List of Practicals

S. No.	Topic	No of Practicals
1	Prolog language, syntax and meaning of Prolog programs, Lists, operators, arithmetic	5
2	Using structures: Example programs, controlling backtracking, input and output. more built-in procedures, programming, style and technique, operations on data structures.	6
3	Advanced tree representations, basic problem-solving strategies, depth-first search strategy, breadth-first search strategy.	5
	Total	**16**

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	4

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	4
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	**32**

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
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 preprocessing: Scaling, Fourier transformation, principal 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 approximatereasoning. 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 fuzzylogic control. Implementation of fuzzy logic controller. Stability analysis of fuzzycontrol systems. Intelligent control for SISO/MIMO nonlinear systems. Model basedmultivariable 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	2
2	Symbolic reasoning system, rule-based systems, the artificial intelligence approach	2
3	Knowledge representation and expert systems.	2
4	Data pre-processing: Scaling, Fourier transformation, principal 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	2
6	Simple perceptron, adaline and madaline neural networks, feed-forward multi-layer perceptron. Learning and training the neural network.	2
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
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	**32**

X 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	4
3	propositions, implications and inferences, working with defuzzification techniques and fuzzy logic controllers, concept of coding	4
4	selection, crossover, mutation and application of genetic programming for global optimization, use of available software for application of soft computing techniques.	5
	Total	**16**

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.

Course Title : Database Management System

Course Code : CSE 505/MCA 571

Credit Hours : 2+1

Aim of the course

Database systems are backbone of any information system, enterprise resource planning, research activities and other activity that require permanence of data storage. This course provides the basic introduction to database system technologies; design, concurrency, security and backup/recovery issues of database management systems. The major focus in this course is the Relational database model.

Theory

Unit I

Database system - Operational Data, Characteristics of database approach, architecture.

Unit II

Overview of DBMS; Data associations - Entities, Attributes and Associations, Relationship among Entities, Representation of Associations and Relationship, Data Model classification.

Unit III

Entity Relationship model; Relational Data Structure- Relations, Domains and Attributes, Relational Algebra and Operations, Retrieval Operations.

Unit IV

Relational Database Design - Anomalies in a Database, Normalization Theory, and Normal forms; Query processing.

Unit V

Distributed Databases- concepts, architecture, design; Structured Query Language (SQL) - Data Definition Language (DDL), Data Manipulation Language (DML).

Unit VI

PL/SQL - Stored procedure, Database triggers; Relational Data Base Management Package.

Practical

E-R diagram construction; SQL - Command Syntax, Data types, DDL Statements, DML Statements, integrity constraints; Triggers, creating stored procedures/ functions; Normalization of database and Case study on a database design and implementation.

Suggested Reading

- Date C.J. 2000. *Introduction to Database System.* Addison Wesley.
- Desai B.C. 2000. *Introduction to Database Systems.*Galgotia Publ.
- Elmasri and Navathe. 2006. *Fundamentals of Database Systems.* 4th Ed. Addison Wesley.
- Garcia-Molina H., Ullman J.D. and Widom J. 2013. *Database Systems: The Complete Book.* Prentice Hall.
- Rob P. and Coronel C. 2006. *Database Systems: Design, Implementation and Management.* 7th Ed. Thomson Learning.
- Silberschartz A, Korth H.F. and Sudarshan S. 1997. *Database Systems Concepts.* Tata McGraw Hill.

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 theelectromagnetic spectrum, image sensing and acquisition, image sampling andquantization, 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, sharpeningspatial filters.

Unit III

Color image processing, color fundamentals, color models, pseudo color imageprocessing, basics of full-color image processing, color transformations, smoothingand sharpening, color segmentation.

Unit IV

Image segmentation, detection of discontinuities, edge linking and boundarydetection, thresholding, region-based segmentation, segmentation by morphologicalwatersheds.

Unit V

Morphological image processing, dilation and erosion, opening and closing, extensionsto 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.

VII 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	2
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	2
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	**32**

IX List of Practicals

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 McGrawHill Publication.
- Rafael CG and Richard EW. *Digital Image Processing.* Third Edition, Pearson Education.
- Sridhar S. *Digital Image Processing.* Oxford University Press.

I Course Title : Process Control System/Principles of Automation and Control

II Course Code : CSE 507/FMPE 511

III Credit Hours : 2+1

IV Aim of the course

To learn the principles behind systems for industrial automation and controlespecially with respect to electronically implemented systems.

V Theory

Unit I

Introduction to industrial automation and control: Architecture of industrialautomation systems, review of sensors and measurement systems. Introduction toprocess 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, selectivecontrol 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, advancedRLL programming, the hardware environment, Introduction to CNC machines.

Unit III

Control of machine tools: Analysis of a control loop, introduction to actuators. Flowcontrol 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 speeddrives 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 fieldbuscommunication protocol, introduction to production control systems.

VI Practical

Control system practical: Characteristics of DC servomotor, AC/DC position controlsystem. ON/OFF temperature control system. Step response of second order system, temperature control system using PID level control system. Automation: Introductionto ladder logic, writing logic and implementation in ladder. PLC programming, water level controller using programmable logic controller. Batch process reactorusing programmable logic controller. Speed control of AC servo motor usingprogrammable logic controller.

VII Learning outcome

Understanding of the principles behind implementation of systems for automationand 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

S. No.	Topic	No of Lectures
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, adjustablespeed 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	2
3	Temperature control system	1
4	Step response of second order system	2
5	Temperature control system using PID level control system	2
6	Introduction to ladder logic, writing logic and implementation in ladder.	2
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	**16**

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

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 modelling, Principles of model formulation, Role and importance of steady-state and dynamic simulation, Classification of models, Model building, Modelling 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
2.	Methods of dimensional analysis: Rayleigh's method, BuckinghamPi 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 modelling, Principles of model formulation	2
11.	Role and importance of steady-state and dynamic simulation	2
12.	Classification of models, Model building, Modelling 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 wetland Agricultural Engineering: Soil and Water Conservation Engineering

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 wate99r	2
	Total	**32**

IX List of Practicals

S. No.	Topic	No. of Lectures
1.	Determination of pH, total solids, dissolved and suspended solids	4
2.	Determination of chlorides, sulphates, turbidity	3
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	3
5.	Strain measurements at high temperatures.	3
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	3
	Total	32

VIII List of Practicals

S. No.	Topic	No. of Lectures
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**

X 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 designingmechatronic systems and their subsystems and its application in automation inagriculture.

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 aerobots 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

Sr.no.	Topic	No. of Lecture
1.	Introduction to Mechatronics: Basic definitions, key elements ofmechatronics.	2
2.	Historical perspective, the development of the automobile as amechatronic system.	1
3.	Mechatronic design approach, functions of mechatronic systems, ways of integration, information processing systems, concurrentdesign 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 controlcomputers.	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 drivestypes and applications	2
12.	Stepper motor and its concept. Industrial robots: Classification andsub 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 differentagrobots in agriculture.	3
	Total	32

X **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 refrigerationprocesses 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 pressurechanges 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 andenthalpy 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 thermodynamicanalysis. Ultra-low temperature refrigeration. Ejection refrigeration. Waterrefrigeration: Centrifugal and steam jet refrigeration systems, characteristics ofsteam jet refrigeration system, effect of boiler efficiency on overall COP, actualsteam jet system, two-fluid jet refrigeration.

VI Practical

Numerical on-air refrigeration cycle, Study of vapour compression refrigerationsystems, Determination of the coefficient of performance of the refrigeration system, Study of vapour absorption (Electrolux) refrigeration systems, Study and applicationof P-V, T-s and P-h chart in refrigeration, Study and performance testing of domesticrefrigerator, Study of domestic water cooler, Study of actual and theoretical COPof 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 vapourcompression refrigeration, Use of p-h chart	3
5.	Effect of pressure changes on COP, sub cooling of condensate onCOP 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, temperatureconcentrationand enthalpy concentration diagrams, adiabatic mixingof 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 withvapour 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 boilerefficiency on overall COP, actual steam jet system, two-fluid jetrefrigeration.	3
	Total	**32**

IX List of Practicals

S. No.	Topic	No. of Practical
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 usedin 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 methodsof kinematic analysis.

Unit II

Computer - Aided analysis of mechanisms. Synthesis of linkages for path generation, function generation, Graphical techniques. Relative pole method and method ofinversion. Analytical kinematics synthesis of linkages, Feuerstein's method, Loopclosure 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 offollower acceleration in cam system dynamics, terms related to cam design – theirimportance. Cam synthesis - graphical cam profile layout for a desired followermotion. Analytical determination of cam profile co-ordinates for disc cam operatingcommon types of followers.

VI Practical

Graphical solutions of mechanisms relating to velocity and acceleration. Problemson computer-aided analysis and synthesis of mechanisms. Analysis and designproblems 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.	Topic	No. of Lectures
1.	Introduction & basic concepts.	2
2.	Kinematics of mechanisms, analysis and synthesis, mobility, systematicof mechanisms, deriving other mechanisms from linkages	3
3.	Determination of velocity and acceleration using graphical method andanalytical methods (relative velocity and acceleration, instantaneouscenters), Kennedy's theorem. Graphical and analytical methods ofkinematic analysis	4
4.	Computer - Aided analysis of mechanisms. Synthesis of linkages forpath generation, function generation, Graphical techniques. Relativepole method and method of inversion	3
5.	Analytical kinematics synthesis of linkages, Feuerstein's method, Loop closure equations based on complex variable approach	5
6.	Introduction to spur, helical, spiral, bevel and worm gears, law ofgearing, 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, termsrelated to cam design	4
9.	Cam synthesis - graphical cam profile layout for a desired followermotion. Analytical determination of cam profile co-ordinates for disccam operating common types of followers.	4
	Total	**32**

IX List of Practicals

S. No.	Topic	No. of Practical
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
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* PearsonIndia 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**	: Vibration
II	**Course Code**	: ME-504
III	**Credit Hours**	: 3+0

IV Aim of the course

To enable the students to design vibration control system 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 principleof Virtual work. Equivalent spring stiffness in parallel and in series. Harmonicanalysis and Fourier Series.

Unit II

Damping - viscous, solid, coulomb equivalent dampers. Viscosity damped freevibrations, 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 motiontransmissibility. 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 ccoefficients 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. Lagrangeequations. Vibration measuring instruments, Vibrometer, 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 ofVirtual 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, Logarithmicdecrement.	3
8.	Forced vibrations with harmonic excitation and rotatingunbalance.	2
9.	Energy dissipated by damping. Forced vibration withdamping,	3
10.	Vibration isolation and force and motiontransmissibility.	2
11.	Two degree of freedom systems. Principal modes ofvibrationco-ordinate coupling.	3

12.	Vibration absorbers,	2
13.	Free vibration equation of motion for multi-degree offreedom systems.	2
14.	Influence coefficients and Maxwell’s reciprocaltheorem, stiffness coefficients.	3
15.	Numerical methods for finding natural frequencies formulti-degree of freedom systems.	3
16.	Vibration of lumped parameter systems and continuoussystems.	3
17.	Lagrange equations. Vibration measuring instruments, Vibrometers, velocity pickups	3
18.	Accelerometer and frequency measuring instruments.	2
19.	Applications of vibrations. Vibration control, balancingof 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 Company, 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 ofmechanical 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 anddistortionenergy theory, failure of ductile materials, failure of brittle materials.

Unit II

Stress concentration and its evaluation, stress concentration of ductile and brittlematerials under static loading and under dynamic loading, determining geometricstress 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. Fatiguetesting and presentation of fatigue data. Influence of stress conditions on fatiguestrength/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 are 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 Failurelikemaximum 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 brittleand 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 andun-notched 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 Miner's rule. Micro-mechanisms of fatigue damage, fatigue limits and initiation and propagation control, leading to a consideration of factors enhancing fatigue resistance.	3
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. Fatiguefailure 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, Hydrogenembrittlement, Corrosion fatigue. Creep: Creep curves, Mechanisms ofcreep, Stress rapture test, Life prediction, High temperature alloys.	3
	Total	**32**

VIII List of Practicals

S. No.	Topic	No. of Practical
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, BocaRaton.
- Bhandari V.B.2019. Design of Machine Elements. McGraw Hill Education Pvt Ltd, NewDelhi
- 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 Modelling 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 modelling, boundary representation, constructive solid geometry, feature based modelling. 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.

VI 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.

VII Learning outcome

The students can design a product having better accuracy, less errors, increased productivity, and shorter lead times with the help of CAD.

VIII	Lecture Schedule	
S. No.	Topic	No. of Lectures
1.	Introduction to Engineering Design, design steps and computer aideddesign.	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 Kinematicsanalysis and simulation.	3
6.	ParametricModelingTechnique.Non-parametricandparametricrepresentation of curves.	2
7.	Parametric representation of Hermite Cubic, Bezier 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
11.	Simple Project. Mathematical modelling and design calculations of machines.	4
	Total	**32**

IX	List of Practicals	
S. No.	Topic	No. of Practical
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 Modelling. GKS, IGES and STEP; Modelling 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**

X 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.

VI Learning outcome

Ability to formulate problems based on use of FEM and solve them using software Tools.

VII 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
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**

VIII 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 operation	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**

IX 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 point's formula, 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 problem.

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 false position methods.	1
5	Solution of linear simultaneous equations: Matrix inversion, Gauss elimination, Gauss Jordan method.	2
9	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 redictor corrector class methods. Stiff ODE's and Gear's methods.	1
9	Eigen values and Eigen vectors: Maximum and minimum eigen value 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 point's formula, 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
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 point's 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**

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
18	Inverse of a matrix, computation of eigen values and eigen vectors	2
	Total	**32**

IX List of Practicals

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 Practicals

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**

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 regressions. 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 of data.

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 ways 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. Nonparametric 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.	Topic	No of Lectures
1	Elementary statistics	1
2	Probability theory	2
3	Probability distributions (Binomial, Poisson and Normal)	2
4	Sampling techniques, Determination of sample size	1
5	Sampling distribution of mean and Proportion	1
6	Hypothesis testing concept of p-value	1
7	Large sample (mean, proportion)	2
8	Student's t-test (Single mean, Difference of mean for independent samples and paired observations) and F-test	2

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	1
13	Selection of variables in regression (forward substitution method and step-wise regression)	2
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	**32**

IX List of Practicals

S. No.	Topic	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	1
10	Selection of variables in regression (Forward substitution method and stepwise regression)	1
11	Non-Linear regression (Quadratic, exponential, and Power)	1
12	Introduction to Non-parametric and scales of measurements	1
13	Chi-square test (Goodness of fit, Independence of attributes, homogeneity of variances)	1
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
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 Behaviour 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: 22, 23and 32. 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 analysing the data pertaining to designs of this course.

VIII **Lecture Schedule**

S. No.	Topic	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	1
9	Split plot design	1
10	Strip plot design	1
11	Factorial in split plot design	2
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.	Topic	No of Practicals
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

Non- Gradial Common Courses

Course Title with Credit Load

Non- Gradial Common Courses

Sr. No	Course Code	Course Title	Credit
1	PGS -501	Library and Information Services	(0+1)
2	PGS -502	Technical Writing and Communications Skills	(0+1)
3	PGS -503	Intellectual Property and Its Management In Agriculture	(1+0)
4	PGS -504	Basic Concepts in Laboratory Techniques	(0+1)
5	PGS -505	Agricultural Research, Research Ethics and Rural Development Programmes	(1+0)
6	PGS -506	Advertising and Brand Management	(1+0)
Note: (a) For all the faculties other than M.B.A. (ABM) five courses i.e., (1),(2), (3), (4) and (5) are compulsory. (b) For M.B.A. Faculty, five courses i.e., (1), (2), (3), (5) and (6) are compulsory			

Course Contents

PGS – 501 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.

PGS – 502 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. Chicago Manual of Style. 14th Ed. 1996. Prentice Hall of India.
2. Collins' Cobuild English Dictionary. 1995.
3. Harper Collins. Gordon HM & Walter JA. 1970. Technical Writing. 3rd Ed.
4. Holt, Rinehart & Winston. Hornby AS. 2000. Comp. Oxford Advanced Learner's Dictionary of Current English. 6th Ed. Oxford University Press.
5. James HS. 1994. Handbook for Technical Writing. NTC Business Books.
6. Joseph G. 2000. MLA Handbook for Writers of Research Papers. 5th Ed. Affiliated East- West Press.
7. Mohan K. 2005. Speaking English Effectively. MacMillan India.
8. Richard WS. 1969. Technical Writing.
9. Barnes & Noble. Robert C. (Ed.). 2005. Spoken English: Flourish Your Language.

10. Abhishek. Sethi J & Dhamija PV. 2004. Course in Phonetics and Spoken English. 2nd Ed. Prentice Hall of India.
11. Wren PC & Martin H. 2006. High School English Grammar and Composition. S. Chand & Co.

PGS – 504 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 & 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 & 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 & 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; National Biological Diversity Act, 2003.

PGS – 503 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;
- Neutralization 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, sand bath, water bath, oil bath;
- 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.

PGS – 505 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 & 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.

PGS – 506 ADVERTISING AND BRAND MANAGEMENT (1+0)

LEARNING OUTCOMES

This course investigates various promotional tools used in the communication mix, such as advertising, sales promotion, and publicity, to sell products and services. Concepts include: advertising planning processes, determining advertising and promotional goals and objectives, control and evaluation of advertising and promotional programs, and regulatory issues. Students will develop a comprehensive advertising campaign for a real or imaginary product.

Theory

BLOCK 1: INTRODUCTION

UNIT 1

Introduction to Advertising Management: Integrated Marketing Communications, Setting Goals and Objectives, how advertising works: Segmentation and Positioning Assess the strengths, weaknesses, opportunities and threats (SWOT) of different kinds of promotional campaigns

UNIT 2

Message Strategy: Attention and comprehension, Advertising appeals, Associating Feelings with the Brand, Brand Equity, Image and Personality and Group Influence and word of mouth advertising, Media Planning and Media Strategy, Media Strategy and Tactics, Legal, Ethical and Social concerns of Advertising.

UNIT 3

Consumer Promotions and Trade Promotions: Their purpose and types How to plan and evaluate a successful promotion, The relationship between advertising and promotions, Introduction to Global Marketing, Advertising and sales promotion.

BLOCK 2: BRANDING DECISION

UNIT 1

Major Brand Concepts and branding Decision: Identifying and selecting brand name Building brand personality, image and identity; Brand positioning and re-launch; Brand extension; Brand portfolio; communication for branding Enhancing brand image through sponsorship and even management.

UNIT 2

Managing Brand Equity and Loyalty: Brand Building in Different Sectors - Customers, industrial, retail and service brands. Building brands through Internet, social Media. Building Indian brands for global markets.

TEACHING METHODS/ACTIVITIES:

- Lecture and Discussion

- Case Study
- PPT presentation

SUGGESTED READINGS

- Keller, Kevin Lane; *Strategic Brand Management;* Pearson education, New Delhi Verma, Harsha*: Brand Management;* Excel Books; New Delhi
- Kapferer, Jean Noel; *Strategic Brand Management;* Kogan Page; New Delhi
- Kumar, S. Ramesh; *Marketing and Branding–The Indian Scenario;* Pearson Education; New Delhi Kapoor, Jagdeep ; *24 Brand Mantras*, Sage Publications; New Delhi
- *Sengupta Subroto; Brand Positioning: Strategies for competitive advantage; Tata Mc Graw Hill; New Delhi Clifton, Rita & Simmons., John; Brands and Branding; The Economist; Delhi*

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