Course Title with Credit Load
M.Tech in Farm Machinery and Power Engineering

Major Courses (Requirement: 20 Credits)

Course Code	Course Title	Credit Hours
FMPE 501*	Soil Dynamics in Tillage and Traction	2+1
FMPE 502*	Testing and Evaluation of Agricultural Equipment	2+1
FMPE 503*	Ergonomics and Safety in Farm Operations	2+1
FMPE 504	Design of Tractor systems	2+1
FMPE 505	Design of Farm Machinery-I	2+1
FMPE 506	Design of Farm Machinery-II	1+1
FMPE 507*	Management of Farm Power and Machinery System	2+1
FMPE 511	Principles of Automation and Control	2+1
FMPE 512	Principles of Hydraulic and Pneumatic Systems	2+1
FMPE 513	Applied Instrumentation in Farm Machinery	2+1
FMPE 514	Systems Simulation and Computer Aided Problem Solving in Engineering	1+1
FMPE 515	Computer Aided Design of Machinery	0+2
FMPE 516	Advance Manufacturing Technologies	2+0
FMPE 517	Machinery for Precision Agriculture	2+1
FMPE 518	Machinery for Horticulture and Protected Agriculture	2+0

*Compulsory Course

Minor Courses (Requirement: 08 Credits)

Course Code	Course Title	Credit Hours
PFE 511	Engineering Properties of Biological Materials	2+1
ME 501	Mechatronics and Robotics in Agriculture	2+0
ME-504	Vibrations	2+1
ME-507	Fatigue Design	2+1
ME-515	Computer Aided Design	2+1
REE 503	Biomass Energy Conversion Technologies	2+1
REE 516	Agro Energy Audit and Management	2+1
CE 501	Dimensional Analysis and Similitude	1+1
CE 510	Experimental Stress Analysis	2+1
MATHS 501	Finite Element Methods	1+1
MATHS 502	Numerical Methods for Engineers	2+0
CSE 501	Big Data Analytics	2+1
CSE 502	Artificial Intelligence	2+1
CSE 505	Database Management System	2+1

Any other course(s) of other department other than course(s) from major can be taken as per recommendations of the student's advisory committee.

Supporting Courses (Requirement: 06 Credits)

Course Code	Course Title	Credit Hours
*STAT 501	Statistical Methods for Research Works	2+1
	Courses from subject matter fields (other than Major and Minor) relating to area of special interest and research problem can be taken as per recommendations of the student's advisory committee.	

*Compulsory Course

Common Courses (Requirement: 05 Credits)

Course Code	Course Title	Credit Hours
*PGS 501	Library and Information Services	0+1
*PGS 502	Technical Writing and Communications Skills	0+1
*PGS 503	Intellectual Property and its management in Agriculture	0+1
*PGS 504	Basic Concepts in Laboratory Techniques	0+1
*PGS 505	Agricultural Research, Research Ethics and Rural Development Programmes	0+1

*Compulsory Course

List of Other Essential Requirements

Course Code	Course Title	Credit Hours
FMPE 591	Masters' Seminar	0+1
FMPE 599	Masters' Research	0+30

Course Contents
M.Tech in Farm Machinery and Power Engineering

I. Course Title : Soil Dynamics in Tillage and Traction
II. Course Code : FMPE 501
III. Credit Hours : 2+1

IV. Aim of the course

To have an understanding of the principles of soil mechanics as applied to interaction of tillage tools and traction devices with soil in terms of soil forces and deformation during for soil cutting and generation of traction.

V. Theory

Unit I

Characterization of state of stress in a point: Derivation, representation by Mohr's Circle. Coulomb's law of friction and cohesion. Measurement of soil resistance properties: Direct shear box, torsion shear apparatus, tri-axial apparatus. Soil behaviour considerations: Soil water pressure and movement. Critical state soil mechanics: Soil stress-strain behavior, 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 dimensions: Hettiaratchi, Reece-Godwin and Spoor. Three dimensional wedges: McKyes and Ali, Grisso models. Dynamic effect: Inertial forces, change in soil strength. Concept of critical depth. Complex tool shapes: Curved tools-shank and foot tools-mould board plough. Soil Loosening and manipulation: Measurement of soil loosening and its efficiency. Draft force efficiency: Loosening and pulverization efficiency. Soil mixing and inversion: Soil properties, tool shape, tool speed and tool spacing.

Unit IV

Traction devices: Tyres, type, size, selection mechanics of traction devices. Maximum traction force: Soil deformation and slip, estimation of contact areas. Sinkage in soil: Rolling resistance, Bekker's formulae, McKyes formulae. Soil compaction by agricultural vehicles and machines.

VI. Practical

Measurements of soil shear strength by in-situ shear box apparatus and soil friction by friction plate. Measuring cone penetrometer resistance and working out tractive coefficients for tyres. Measurement of in-situ shear strength of soil by torsional vane shear apparatus. Solving problems on stress in soil. Solving problems on soil

properties. Solving problems of tool forces. Problems on tillage tool forces, wheel slippage, tyre deflection, design and performance of traction devices.

VII. Learning outcome

The student will be able to understand the principles that govern manipulation of soil by tillage tools.

The student will be able to apply the principles of soil mechanics to theoretically calculate the forces on tillage tools during soil cutting and forces generated by tractor wheels.

VIII. Lecture schedule

S.No.	Topic	No of Lectures
1.	**Unit I** Characterization of state of stress in a point: Derivation, representation by Mohr's Circle.	2
2.	Coulomb's law of friction and cohesion.	**1**
3.	Measurement of soil resistance properties: Direct shear box, torsion shear apparatus, tri-axial apparatus.	2
4.	Soil behaviour considerations: Soil water pressure and movement.	1
5.	Critical state soil mechanics: Soil stress-strain behaviour, shear rate effects	2
6.	**Unit II** Soil cutting forces: The universal earthmoving equation, two dimensional cases, smooth vertical blade, smooth and rough raked blades in cohesive soil, unconstrained tool to soil adhesion.	3
7.	The shape of failure surfaces.	2
8.	Hettiaratchi's calculations, effect of soil weight.	2
9.	Soil cutting force by method of trial wedges.	2
10.	**Unit III** Extension of theory to three dimensions: Hettiaratchi, Reece-Godwin and Spoor.	2
11.	Three dimensional wedges: McKyes and Ali, Grisso models. Dynamic effect: Inertial forces, change in soil strength.	2
12.	Concept of critical depth.	1
13.	Complex tool shapes: Curved tools-shank and foot tools-mould board plough.	1
14.	Soil Loosening and manipulation: Measurement of soil loosening and its efficiency.	1
15.	Draft force efficiency: Loosening and pulverization efficiency.	1
16.	Soil mixing and inversion: Soil properties, tool shape, tool speed and tool spacing.	2
17.	**Unit IV** Traction devices: Tyres, type, size, selection mechanics of traction devices.	1
18.	Maximum traction force: Soil deformation and slip, estimation of contact areas.	1
19.	Sinkage in soil: Rolling resistance, Bekker's formulae, McKyes formulae.	2
20.	Soil compaction by agricultural vehicles and machines.	1
		32

IX. List of Practicals

S.No.	Topic	No of Practicals
1.	Measurements of soil shear strength by *in-situ* shear box apparatus and soil friction by friction plate.	3
2.	Measuring cone penetrometer resistance and working out tractive coefficients for tyres.	2
3.	Measurement of *in-situ* shear strength of soil by torsional vane shear apparatus.	1
4.	Solving problems on stress in soil.	2
5.	Solving problems on soil properties.	2
6.	Solving problems of tillage tool forces.	1
7.	Problems on wheel slippage and tyre deflection.	3
8.	Problems on design and performance of traction devices.	1
9.	Practical examination	1
	Total	**16**

X. Suggested Reading

- Gill WR and Van den Berg GE. 1968. *Soil Dynamics in Tillage and Traction.*
- Handbook 316, *Agricultural Research Service*, US Department of Agriculture, Washington DC, 1968.
- John BL, Paul KT, David WS and Makoto H. 2012. *Tractors and their Power Units.* 4th Edition. Springer Science & Business Media, ISBN: 81-239 0501-7, ASAE ISBN: 0-929355-72-5.
- Koolen AJ and Kuipers H. 1983. *Agricultural Soil Mechanics.* Springer-Verlag ISBN 13:978-3-642-69012-9.
- McKyes E. 1989. *Agricultural Engineering Soil Mechanics*, Elsevier science publishers B.V., P.O. Box 211, 1000 AE Amsterdam, the Netherlands.
- McKyes E. 2016. *Soil Cutting and Tillage: Vol 7.* Developments in Agricultural Engineering Elsevier R Science Publisher SBV.

I. Course Title : Testing and Evaluation of Agriculture Equipment

II. Course Code : FMPE 502

III. Credit Hours : 2+1

IV. Aim of the course

To enable the student to learn the procedure for testing of different farm machinery and the concept behind evaluation of different performance parameters of farm machinery and the standards adopted therein.

V. Theory

Unit I

Importance and significance of testing and types of testing. Test equipment, usage and limitations. Test procedures and various test codes: National and International.

Unit II

Laboratory and field testing of tillage and sowing machinery: Sub-soiler, laser land leveler, mould board Plough, disc plough, rotavator, cultivator, disc harrow, seed cum fertilizer drill and planter.

Unit III

Laboratory and field testing of manual and power operated intercultural machinery and plant protection machine.

Unit IV

Laboratory and field testing of reaper, thresher and chaff cutter.

Unit V

Laboratory and field testing of straw combine and combine harvester. Review and interpretation of test reports. Importance and need of standardization of components of agricultural equipment.

VI. Practical

Laboratory and field testing of selected farm equipment: Tillage, sowing and planting. Material testing of critical components. Accelerated testing of fast wearing components.

VII. Learning outcome

The student will be able to test farm machinery, prepare performance reports and also analyze the performance reports to find the suitability of a machinery for a given farm operation.

VIII. Lecture Schedule

S.No	Topic	No. of Lectures
1.	Introduction, various test codes, Test programs, testing terminology, procedures and type of testing systems	2
2.	Study of different types of Dynamometer	2
3.	Stationary diesel engine performance testing	2
4.	Tractor Test Codes and Data Interpretation Estimation of error	2
5.	Testing and evaluation of tillage machinery	2
6.	Testing and evaluation of seed-cum-fertilizers drills/planters	3
7.	Testing and evaluation of manually and power operated Sprayers	3
8.	Testing and evaluation of reapers and straw combines	1
9.	Testing and evaluation of combine harvester and threshers	3
10.	Testing and evaluation of manually and power operated chaff cutters	2
11.	Testing and evaluation of advanced machinery	2
12.	Reliability in Engineering with emphasis on agricultural machinery	2
13.	Discussion on Farm machinery codes	2
14.	Interpretations of the information given in different codes on farm machinery	1
15.	Formulation of test-code for machines that do not have any code.	2
16.	Current topics/discussion	1
	Total	**32**

IX. List of Practicals

S.No.	Topic	No of Practicals
1.	Lab testing of Stationary diesel engine for full load, variable load and governor test	2
2.	Lab Testing and evaluation of seed-cum-fertilizers drills	1
3.	Lab Testing and evaluation of seed-cum-fertilizers planters	1
4.	Lab Testing and evaluation of knapsack Sprayers	1

S.No.	Topic	No of Practicals
5.	Lab Testing and evaluation of nozzles	1
6.	Field testing of rotavators	1
7.	Lab testing of rotavators for soil sample analysis	1
8.	Testing and evaluation of reapers	1
9.	Testing and evaluation of combine harvester and threshers	1
10.	Testing and evaluation of chaff cutters	1
11.	Testing and evaluation of laser land leveler	1
12.	Case study of test reports of different agricultural implements	3
	Total	**15**

X. Suggested Reading

- Barger E L, Liljedahl J B and McKibben E C. 1967. *Tractors and their Power Units*. Eastern Wiley 4th Edition.
- *Indian Standard Codes for Agricultural Implements*. Published by BIS, New Delhi.
- Inns F M. 1986. *Selection, Testing and Evaluation of Agricultural Machines and Equipment*. FAO Service Bull. No.115.
- Mehta M L, Verma S R, Rajan P and Singh S K 2019. *Testing and Evaluation of Agricultural Machinery*. Daya Publishing House, Delhi.
- *Nebraska Tractor Test Code for Testing Tractor*, Nebraska, USA.
- Smith D W, Sims B G and O'Neill D H 2001. *Testing and Evaluation of Agricultural Machinery and Equipment -Principle and Practice*. FAO Agricultural Services Bull. 110.

I. Course Title : Ergonomics and Safety in Farm Operations

II. Course Code : FMPE 503

III. Credit Hours : 2+1

IV. Aim of the course

To understand the principles of the science of Ergonomics and its application to farm machinery in order to reduce drudgery in the use of tools and equipment and also make them safe and comfortable to operate.

V. Theory

Unit I

Description of human-machine systems. Ergonomics and its areas of application in the work system. History of ergonomics. Modern ergonomics.

Unit II

Anthropometry: Its role in daily life, principles in workspace and equipment design, design of manual handling tasks and application in equipment design. Human postures: Postural stress and its role in design of farm machinery.

Unit III

Human factors in tractor seat design: Entry system, controls, shape, colour coding, dial and indicators. Modern technology for comfort in driving places.

Unit IV

Physiological parameters: Psychological and mental stresses and their measurement techniques. Human energy expenditure: Calibration of subjects, human workload and its assessment.

Unit V

Safety considerations and operators protective gadgets in farm operations. Standards/codes for tractors and agricultural machinery safety.

VI. Practical

Identifying role of ergonomics in our daily life. Measurement of anthropometric dimensions of agricultural workers and establishing relationship between them. Determination of human requirements for field operation with manually operated equipment. Assessment of psychological/general load for specific agricultural operations. Calibration of human subject on bicycle ergometer and/ or treadmill for its energy output and physiological parameters like heart rate, oxygen consumption rate under laboratory conditions. Case studies of agricultural accidents and safety measure.

VII. Learning outcome

The student will be able to apply the concepts of ergonomics in the design of agricultural tools and equipment and also evaluate the ergonomic suitability of such equipment.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction to ergonomics, definition of ergonomics	1
2.	Operator- machine-environment system approach	1
3.	Relative advantages of man and machine, ergonomics in daily life	1
4.	Importance of ergonomics in agriculture and farm machinery	1
5.	History of ergonomics, modern ergonomics	1
6.	Man machine environment components, broad objectives of ergonomics	1
7.	Basic issues and processes under ergonomics for design and development of machine	1
8.	Anthropometry and its uses in daily life	1
9.	First hourly examination	1
10.	Principles of applied anthropometry in ergonomics	1
11.	Availability of anthropometric database for Indian agricultural workers	1
12.	Definitions and possible applications of anthropometric dimensions	2
13.	Workspace and equipment design	1
14.	Different modes of force application	1
15.	Design of manual handling tasks	1
16.	Biomechanics aspects in machine design	1
17.	Mid-semester examination	1
18.	Human posture, posture stresses and its role in design of agricultural machinery	1
19.	Work place design for standing and seated workers	2
20.	Human factors in tractor seat design	1
21.	Entry system, controls, shape, colour coding, dial and indicators	1
22.	Modern technology for safety and comfort in driving place	1
23.	Physiological and psychological parameters for ergonomic evaluation	1
24.	Physiological and psychological stresses and measurements techniques	1
25.	Human work load assessment, human energy expenditure	1
26.	Calibration of subjects – concept, importance and techniques	1
27.	Accidents and safety in agriculture operations, general safety guidelines	1
28.	Safety feeding systems for threshers and chaff cutters	1

S.No.	Topic	No. of Lectures
29.	Safety gadgets for tractors and trailers	1
30.	Standard/ codes for agricultural machinery safety	1
	Total	**32**

IX. List of Practicals

S.No.	Topic	No of Practicals
1.	Identify role of ergonomics in our daily life	1
2.	Measurement of anthropometric dimensions of agriculture workers and establishing relation between them	2
3.	Measurement of strength parameters	1
4.	Determination of human requirements of field operation with manual operated equipment	2
5.	Assessment of psychological/ general load for agricultural operations	1
6.	Assessment of stress on eyes by specific agricultural operation	1
7.	Noise measurement in tractors	1
8.	Calibration of human subject on bicycle ergometer	1
9.	Calibration of human subject on treadmill	1
10.	Measurement of physiological parameter, viz. heart/ pulse rate	1
11.	Measurement of oxygen consumption under laboratory conditions	1
12.	Case study of accidents and safety on tractors and trailers	1
13.	Case study of accidents and safety on chaff cutters and threshers	1
14.	Practical examination	1
	Total	**16**

X. Suggested Reading

- Bridger R S 2009. *Introduction to Ergonomics*. CRC Press, Boca Rotan, USA
- Sanders M S and McCormick E J 2000. *Human Factors in Engineering and Design*. McGraw Hill. 7th edition
- Astrand P, Rodahl K, Dahl H A and Stromme S B 2003. *Textbook of Work Physiology - Physiological Basis of Exercise*. McGraw Hill.
- Gite L P 2009. *Anthropometric and Strength Data of Indian Agricultural Workers for Farm Equipment Design*. Central Institute of Agricultural Engineering, Bhopal.
- Gite L P, Agrawal K N, Mehta C R, Potdar R R and Narwariya B S. 2019. *Handbook of Ergonomical Design of Agricultural Tools, Equipment and work Places*. Jain Brothers, New Delhi.

I. Course Title : Design of Tractor Systems

II. Course Code : FMPE 504

III. Credit Hours : 2+1

IV. Aim of the course

To introduce the student to the principles that direct the design of a tractor and its subsystems and enable the student to apply the concept of machine design in designing the subsystems and critical components.

V. Theory

Unit I

Design and types, research, development, design procedure, technical specifications

of tractors, modern trends in tractor design and development, special design features of tractors in relation to Indian agriculture.

Unit II

Engine related terminology. Selection of stroke-bore ratio. Design of engine components; Piston, connecting rod, cylinder, cylinder head, crank shaft etc.

Unit III

Design of tractor systems like clutch, gearbox, steering, steering geometry, turning force, hydraulic system & hitching, chassis, operator's seat, work-place area and controls. Tire selection, aspect ratio etc.

Unit IV

Mechanics of tractor stability. Computer aided design and its application in farm tractors.

VI. Practical

Engine design calculations, transmission component design calculations. Extensive practices on the computer aided design packages.

VII. Learning outcome

The student will have an overview of the philosophy guiding the design of a tractor and also design tractor systems and components.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
	Unit I	
1.	Design and types, research, development, design procedure, technical specifications of tractors, modern trends in tractor design and development, special design features of tractors in relation to Indian agriculture.	3
	Unit II	
2.	Engine related terminology. Selection of stroke-bore ratio.	1
3.	Design of engine components: Piston, connecting rod, cylinder, cylinder head, crank shaft etc.	3
	Unit III	
4.	Design of tractor clutch	2
5.	Design of tractor gearbox	3
6.	Tractor steering system, functional requirements, steering geometry, turning force	2
7.	Steering system design parameters and design procedure	2
8.	Hydraulic system & hitching – principles of operation	2
9.	Hydraulic system - Design parameters and design procedures including design of pump, cylinder etc.	2
10.	Design of chassis	2
11.	Human factors in tractor design. Design of operator's seat	2
12.	Work-place area and controls	2
13.	Tire selection, aspect ratio etc.	1
	Unit IV	
14.	Mechanics of tractor stability. Dynamic and static analysis of forces acting on farm tractor, case studies.	3
15.	Computer aided design and its application in farm tractors	2
	Total	**32**

IX. List of Practicals

S.No.	Practical	No. of Practical
1.	Engine design calculations - Stroke-bore ratio determination - Design of radiator - Balancing of crankshaft	2
2.	Engine design calculations - Calculation of volumetric/thermal efficiencies	1
3.	Transmission component design calculations - Design of clutch	1
4.	Transmission component design calculations - Design of gear box and calculation of speed ratios	2
5.	Design of Ackerman steering. Calculation of turning radius.	1
6.	Design of brakes (mechanical and hydraulic)	2
7.	Design of hydraulic system	2
8.	Calculation for determination of centre of gravity of tractor, moment of inertia and stability	3
9.	Practice on the Computer Aided Design (CAD) packages for design of various components	2
	Total	**16**

X. Suggested Reading

- Barger EL Liljedahl JB and McKibben EC. 1967. *Tractors and their Power Units*. Wiley Eastern Pvt. Ltd.
- Macmillan RH. 2002. *The Mechanics of Tractor – Implement Performance and Worked Example*. University of Melbourne, Australia.
- Sharma PC and Agarwal DK. 2000. *Machine Design*. S K Kataria and Sons, Delhi.

I. Course Title : Design of Farm Machinery I

II. Course Code : FMPE 505

III. Credit Hours : 2+1

IV. Aim of the course

To understand the interaction of tillage tools with soil and design the components of the tillage tools based on their requirement and also to learn how the systems of planting machinery are designed.

V. Theory

Unit I

Farm machinery design: Modern trends, tasks and requirements, economic considerations of durability, reliability and rigidity. Physico-mechanical properties of soils. Technological process of ploughing. Wedge. Working process of mould board plough, determination of basic parameters. Design of coulters, shares, mould boards.

Unit II

Constructing of mould board working surface. Design of landside, frog, jointer. Forces acting on plough bottom and their effect on plough balance: Trailed, semi mounted and mounted plough. Draft on ploughs, resistance during ploughing. Design disk ploughs: Concave disk working tools, forces acting.

Unit III

Machines and implements for surface and inter row tillage; Peg toothed harrow,

disk harrows, rotary hoes, graders, rollers, cultivators. Design of V shaped sweeps. Rigidity of working tools. Rotary machines: Trajectory of motion of rotary tiller tynes, forces acting, power requirement. Machines with working tools executing an oscillatory motion.

Unit IV

Methods of sowing and planting: Machines, agronomic specifications. Sowing inter-tilled crop. Grain hoppers: Seed metering mechanism, furrow openers and seed tubes. Machines for fertilizer application: Discs type broadcasters. Organic fertilizer application: Properties of organic manure, spreading machines. Liquid fertilizer distributors. Planting and transplanting: Paddy transplanters, potato planters.

VI. Practical

Design of mould board working surface; Coulter, frog, share, jointer, mould board plough. Trailed, semi mounted and mounted ploughs. Design of disc plough, disc harrow, peg tooth harrow, cultivators, sweeps. Design of rotary tiller. Design of traction and transport devices.

Design of seed drills; Metering mechanism, hopper, furrow opener. Fertilizer spreader, liquid fertilizer applicators and design of its sub systems. Design of paddy transplanters and potato planters.

VII. Learning outcome

The student will be able to appreciate the principles behind the design of tillage tools and planting machinery. He will be able to arrive at design configurations for such machines.

VIII. Lecture Schedule

S.No.	Topic	No of Lectures
1.	Farm machinery design: Modern trends, tasks and requirements, economic considerations of durability, reliability and rigidity.	3
2.	Farm machinery design: economic considerations of durability, reliability and rigidity.	2
3.	Physio-mechanical properties of soils.	1
4.	Technological process of ploughing. Wedge. Working process of mould board plough, determination of basic parameters.	2
5.	Design of coulters, shares, mould boards.	2
6.	Constructing of mould board working surface.	1
7.	Design of landside, frog, jointer.	1
8.	Forces acting on plough bottom and their effect on plough balance: Trailed, semi mounted and mounted plough.Draft on ploughs, resistance during ploughing.	2
9.	Design disk ploughs: Concave disk working tools, forces acting.	2
10.	Machines and implements for surface and inter row tillage: Peg toothed harrow, disk harrows, rotary hoes, graders, rollers, cultivators.	2
11.	Design of V shaped sweeps. Rigidity of working tools.	1
12.	Rotary machines: Trajectory of motion of rotary tiller tynes, forces acting, power requirement.	2
13.	Machines with working tools executing an oscillatory motion.	1
14.	Methods of sowing and planting: Machines' agronomic specifications. Sowing inter-tilled crop, Grain hoppers Seed metering mechanism Furrow openers and seed tubes.	2

S.No.	Practical	No. of Lectures
15.	Machines for fertilizer application: Discs type broadcasters.	1
16.	Organic fertilizer application: Properties of organic manure spreading machines. Liquid fertilizer distributors.	2
17.	Planting and transplanting: Paddy transplanters, potato planters.	1
18.	Case studies	2
	Total	**30**

IX. List of Practicals

S.No.	Practical	No of Practicals
1.	Design of mould board: Coulter, frog, share	1
2.	Design of mould board: mould board plough working surface, jointer.	1
3.	Trailed, semi mounted and mounted ploughs.	1
4.	Design of disc plough	1
5.	Design of disc harrow	1
6.	Design of peg tooth harrow	1
7.	Design of cultivators and sweep.	1
8.	Design of rotary tiller.	1
9.	Design of traction and transport devices.	1
10.	Design of seed drills: Metering mechanisms	1
11.	Design of seed drills: hopper and furrow opener.	1
12.	Design of Fertilizer application equipment: fertilizer spreaders	1
13.	Design of Fertilizer application equipment: liquid fertilizer applicators and design of its sub systems	1
14.	Design of paddy transplanters	1
15.	Design of potato planters.	1
	Total	**15**

X. Suggested Reading

- Bernacki C, Haman J and Kanafajski Cz. 1972. *Agricultural Machines Theory and Construction*. Vol.I. U.S. Dept. of Commerce, National Technical Information Service, Springfield, Virginia 22151.
- Bosoi ES, Verniaev OV, Smirnov II and Sultan-Shakh EG. 1990. *Theory, Construction and Calculations of Agricultural Machinery - Vol. I.* Oxonian Press Pvt. Ltd. No.56, Connaught Circle, New Delhi.
- Gill R and Vanden Berg GE. 2013. *Soil Dynamics in Tillage and Traction*. Scientific Publishers (India) ISBN-10: 8172338031.
- Yatsuk EP 1981. *Rotary Soil Working Machines Construction, Calculation and Design.* American Publishing Co. Pvt. Ltd, New Delhi.

I. Course Title : Design of Farm Machinery-II

II. Course Code : FMPE 506

III. Credit Hours : 1+1

IV. Aim of the course

To learn the engineering principles behind application of pesticides and the systems that implements the same. To learn the concepts behind design of crop harvesting and threshing equipment.

V. Theory

Unit I

Pesticide calculation examples. Multidisciplinary nature of pesticide application. Overview of chemical control integrated pest management. Targets for pesticide deposition. Formulation of pesticides.

Unit II

Spray droplets. Hydraulic nozzles. Power operated hydraulic sprayer design principles. Air assisted hydraulic sprayer design principles. Controlled droplet application. Electrostatically charged sprayers. Spray drift and its mitigation. Aerial spraying systems. Use of drones for spraying: Design of spray generation and application issues.

Unit III

Introduction to combine harvesters: Construction, equipment subsystems, power sub systems. Crop harvesting: Plant properties, physical and mechanical properties of plant stem, plant bending modelling. Properties of plant grain: Physical, mechanical, grain damage. Properties of MOG; Mechanical and aerodynamic.

Unit IV

Design of grain header; Orienting and supporting reel. Plant cutting cutter bar: Working process, cutter bar drive. Knife cutting speed pattern area. Design of auger for plant collection. Corn header: Working elements, snapping roll design, stalk grasping and drawing process. Corn ear detachment: Stalk cutting and chopping.

Unit V

Cereal threshing and separation; Design of tangential and axial threshing units. Performance indices of threshing units. Modelling material kinematics in different threshing units. Factors influencing the threshing process and power requirement. Separation process and design of straw walker. Cleaning Unit process and operation. Grain pan; Chaffer and bottom sieve. Blower design and flow orientation. Design of conveying system for grain. Straw choppers and shredders.

VI. Practical

Measurement of spray characters for different nozzles. Problems on sizing of sprayer components. Design of sprayer for special purpose: Orchard and tall trees. Harvesting machine. Problems on design of cutterbars, reels, platform auger, conveyors. Design of threshing drum: Radial and axial flow type. Design of cleaning and grading systems. Design of blowers.

VII. Learning outcome

The student will know the principles behind the design of crop spraying equipments and harvesting and threshing machinery.

VIII. Lecture Schedule

S.No.	Topic	No of Lectures
1.	Overview of chemical control integrated pest management.	1
2.	Targets for pesticide deposition. Formulation of pesticides.	1
3.	Multidisciplinary nature of pesticide application.	1
4.	Pesticide calculation examples.	2

S.No.	Topic	No of Lectures
5.	Spray droplets. Hydraulic nozzles. Power operated hydraulic sprayer design principles.	2
6.	Controlled droplet application. Spray drift and its mitigation.	1
7.	Air assisted hydraulic sprayer design principles. Electrostatically charged sprayers.	2
8.	Aerial spraying systems. Use of drones for spraying:	1
9.	Design of spray generation and application issues.	1
10.	Introduction to combine harvesters; Construction, equipment subsystems, power sub systems.	1
11.	Crop harvesting: Plant properties, physical and mechanical properties of plant stem, plant bending modelling.	1
12.	Properties of plant grain: Physical, mechanical, grain damage.	2
13.	Properties of MOG; Mechanical and aerodynamic.	2
14.	Design of grain header; Orienting and supporting reel. Plant cutting cutter bar.	2
15.	Working process, cutter bar drive. Knife cutting speed pattern area.	1
16.	Design of auger for plant collection.	1
17.	Corn header: Working elements, snapping roll design, stalk grasping and drawing process. Corn ear detachment: Stalk cutting and chopping.	2
18.	Cereal threshing and separation, Design of tangential and axial threshing units. Performance indices of threshing units.	2
19.	Modelling material kinematics in different threshing units. Factors influencing the threshing process and power requirement.	1
20.	Separation process and design of straw walker.	1
21.	Cleaning Unit process and operation. Grain pan: Chaffer and bottom sieve. Blower design and flow orientation.	2
22.	Design of conveying system for grain. Straw choppers and shredders.	2
	Total	**32**

IX. List of Practicals

S.No.	Practical	No of Practicals
1.	Measurement of spray characters for different nozzles.	1
2.	Problems on sizing of sprayer components.	1
3.	Design of spraying units – manual	1
4.	Design of spraying units – powered	1
5.	Design of sprayer for special purpose: Orchard and tall trees.	1
6.	Design of agitation units – mechanical and hydraulic	1
7.	Harvesting machines: Problems on design of shear type cutting mechanism	1
8.	Harvesting machines: Problems on design of impact type harvesting mechanism	1
9.	Harvesting machines: Problems on design of platform auger and conveyors.	1
10.	Harvesting machines: Problems on design of reels	1
11.	Design of threshing drum: Radial flow type.	1
12.	Design of threshing drum: Axial flow type.	1
13.	Design of cleaning systems.	1
14.	Design of grading systems.	1
15.	Design of blowers.	1
	Total	**15**

X. Suggested Reading

- Bernacki C, Haman J and Kanafajski Cz 1972. *Agricultural Machines Theory and Construction.* Vol-I. U.S. Department of Commerce, National Technical Information Service, Springfield, Virginia22151.
- Bindra, OS and Singh H. 1971. *Pesticides Application Equipments.* Oxford & IBH Publishing Co., New Delhi.
- Bosoi ES, Verniaev OV, Smirnov II and Sultan-Shakh EG. 1987. C*onstruction and Calculations of Agricultural Machinery - Vol.II.* Oxonian Press Pvt. Ltd. New Delhi.
- Miu P. 2016. *Combine Harvesters Modeling and Design.* CRC Press, Boca Raton, USA ISBN 13:978-1-4822-8237-5
- Thornhill EW and Matthews GA. 1995. *Pesticide Application Equipment for Use in Agriculture* Vol II. Mechanically powered equipment FAO Rome.

I. Course Title : Management of Farm Power and Machinery System

II. Course Code : FMPE 507

III. Credit Hours : 2+1

IV. Aim of the course

To understand how principles of management are applied to farm machinery systems to make them more effective and profitable.

V. Theory

Unit I

Importance and objectives of farm mechanization in Indian agriculture, its impact, strategies, myths and future needs. Estimation of operating cost of tractors and farm machinery. Management and performance of power, operator, labour. Economic performance of machinery, field capacity, field efficiency and factors affecting field efficiency.

Unit II

Tractor power performance in terms of PTO, drawbar and fuel consumption. Power requirement problems to PTO, DBHP.

Unit III

Selection of farm machinery, size selection, timeliness of operation, optimum width and problem related to its power selection. Reliability of agricultural machinery. Replacement of farm machinery and inventory control of spare parts.

Unit IV

Systems approach to farm machinery management and application of programming techniques to farm machinery selection and scheduling. Network Analysis: Transportation, CPM and PERT, dynamic programming, Markov chain.

VI. Practical

Study of latest development of different agricultural equipment and implements in India and other developing countries. Size selection of agricultural machinery. Experimental determination of field capacity of different farm machines. Study of farm mechanization in relation to crop yield. Determination of optimum machinery system for field crop and machine constraints. To develop computer program for the selection of power and machinery.

VII. Learning outcome

The student will be able to understand how farm machinery is selected and operated to make them economically viable.

VIII. Lecture Schedule

S.No.	Topic	No of Lectures
1.	Importance and scope of farm mechanization in Indian Agriculture	1
2.	Cost analysis of Farm Machinery and tractor, Breakdown analysis, Inflation.	2
3.	Measurement of power performance (PTO power, drawbar power and fuel consumption) of tractor and power tiller	3
4.	Study of field capacity and field efficiency of different farm machinery and factor affecting them	1
5.	Selection of Farm Machinery size wrt to power source and timeliness of operation	4
6.	Application of programming technique to problem of farm power and machinery selection.	4
7.	Replacement models, spare parts and inventory control	2
8.	Maintenance and scheduling of operations.	2
9.	Network analysis – transportation	2
10.	Network analysis – critical path method, PERT	2
11.	Network analysis – dynamic programming	3
12.	Network analysis – markov chain	3
13.	Linear programming, multivariable system, simplex algorithm. Theory of network.	3
	Total	**32**

IX. List of Practicals

S.No.	Topic	No of Practicals
1.	Introduction to latest development of advanced agricultural equipment's in India	3
2.	Experimental determination of field capacity of different farm machines	3
3.	Case studies on optimum size selection of agricultural machinery	3
4.	Determination of inventory of different farm machines for a farm of size 50 ha as per regional crop rotations	3
5.	To develop computer program regarding selection of farm machinery size and power requirement for a 10, 50 and 100 ha farm size	3
	Total	**15**

X. Suggested Reading

- Carveille LA. 1980. *Selecting Farm Machinery*. Louisiana Cooperative Extn. Services Publication.
- Culpin C. 1996. *Profitable Farm Mechanization.* Lock Wood and Sons, London.
- FAO. 1990. *Agricultural Engineering in Development: Selection of Mechanization Inputs.* FAO, Agri service Bulletin.
- Hunt D. 1979. *Farm Power and Machinery Management.* Iowa State University Press, USA.
- Kapoor VK. 2012. *Operation Research: Concepts, Problems and Solutions.* Sultan Chand and Sons, India.

• Singh S and Verma SR. *Farm Machinery Maintenance and Management*. DIPA, ICAR, KAB-I, New Delhi.

I. Course Title : Principles of Automation and Control

II. Course Code : FMPE 511

III. Credit Hours : 2+1

IV. Aim of the course

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

V. Theory

Unit I

Introduction to industrial automation and control: Architecture of industrial automation systems, review of sensors and measurement systems. Introduction to process control: PID control, controller tuning, implementation of PID controllers, special control structures, feed forward and ratio control, predictive control, control of systems with inverse response, cascade control, overriding control, selective control and split range control.

Unit II

Introduction to sequence control: PLCs and relay ladder logic, sequence control, scan cycle, RLL syntax, sequence control structured design approach, advanced RLL programming, the hardware environment, Introduction to CNC machines.

Unit III

Control of machine tools: Analysis of a control loop, introduction to actuators. Flow control valves, hydraulic actuator systems, principles, components and symbols, pumps and motors. Proportional and servo valves. Pneumatic control systems, system components, controllers and integrated control.

Unit IV

Control systems: Electric drives, introduction, energy saving with adjustable speed drives stepper motors, principles, construction and drives. DC motor drives: Introduction to DC-DC converters, adjustable speed drives. Induction motor drives: Introduction, characteristics, adjustable speed drives. Synchronous motor drive-motor principles, adjustable speed and servo drives.

Unit V

Networking of sensors, actuators and controllers, the fieldbus, the fieldbus communication protocol, introduction to production control systems.

VI. Practical

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

VII. Learning outcome

Understanding of the principles behind implementation of systems for automation and control.

VIII. Lecture Schedule

S.No.	Topic	No of Lectures
1.	Introduction to industrial automation and control	1
2.	Architecture of industrial automation systems	1
3.	Review of sensors and measurement systems-I	1
4.	Review of sensors and measurement systems-II	1
5.	Introduction to process control	1
6.	PID control, controller tuning and implementation of PID controllers,	1
7.	Special control structures, feed forward and ratio control	1
8.	Predictive control and control of systems with inverse response	1
9.	Cascade control, overriding control	1
10.	Selective control and split range control.	1
11.	Introduction to sequence control	1
12.	PLCs and relay ladder logic, sequence control and scan cycle,	1
13.	RLL syntax, sequence control structured design approach,	1
14.	Advanced RLL programming and the hardware environment,	1
15.	Introduction to CNC machines.	1
16.	Control of machine tools	1
17.	Analysis of a control loop	1
18.	Introduction to actuators.	1
19.	Introduction to flow control valves,	1
20.	Hydraulic actuator systems, principles, components and symbols	1
21.	Introduction to hydraulic pumps and motors	1
22.	Introduction about proportional and servo valves.	1
23.	Pneumatic control systems, system components and controllers and integrated control.	1
24.	Introduction about electric control systems	1
25.	Electric drives, energy saving with adjustable speed drives	1
26.	Stepper motors, principles, construction and drives.	1
27.	DC motor drives: Introduction to DC-DC converters, adjustable speed drives.	1
28.	Induction motor drives: Introduction, characteristics, adjustable speed drives	1
29.	Synchronous motor drive-motor principles, adjustable speed and servo drives.	1
30.	Networking of sensors, actuators and controllers,	1
31.	The field bus, the field bus communication protocol,	1
32.	Introduction to production control systems.	1
	Total	**32**

IX. List of Practicals

S.No.	Topic	No of Practicals
1.	Control system including characteristics of DC servomotor.	2
2.	AC/DC position control system	1
3.	Temperature control system	1
4.	Step response of second order system	2
5.	Temperature control system using PID level control system	1
6.	Introduction to ladder logic, writing logic and implementation in ladder.	2

S.No.	Topic	No of Practicals
7.	PLC programming	2
8.	Water level controller using programmable logic controller	1
9.	Batch process reactor using programmable logic controller	1
10.	Speed control of AC servo motor using programmable logic controller	1
	Total	**14**

X. Suggested Reading

- https://nptel.ac.in/downloads/108105063/
- Manesis S and Nikolakopoulos G. 2018. *Introduction to Industrial Automation. 1st Edition*, CRC Press. Textbook-ISBN 9781498705400-CAT#K24766

I. Course Title : Principles of Hydraulic and Pneumatic Systems

II. Course Code : FMPE 512

III. Credit Hours : 2+1

IV. Aim of the course

To understand the principles behind operation of hydraulic and pneumatic systems and their components and design simple hydraulic and pneumatic circuits and select components for the same.

V. Theory

Unit I

Hydraulic power, its advantages, applications, properties of hydraulic fluids, viscosity, bulk modulus, density. Concepts of energy of hydraulic systems, laws of fluid flow.

Unit II

Hydraulic pump and motors, principle, capacity, classifications, working, performance. Design of various types of pumps and motors.

Unit III

Actuators, types, design of linear actuator and rotary actuators. Hydraulic rams, gear motors, piston motors and their performance characteristics. Hose, filters, reservoirs, types of circuits, intensifier, accumulator, valves. Valve types: Direction control, deceleration, flow, pressure control, check valve and their working etc.

Unit IV

Hydraulic circuit design. Applications in farm power and machinery: Tractor, combine, farm machinery systems, hydrostatic system etc.

Unit V

Power pack, pneumatic circuits, properties of air. Compressors, types. Design of pneumatic circuits.

VI. Practical

Study of various hydraulic pumps, motors, valves, directional control valves, cylinder piston arrangements, engineering properties of hydraulic fluids, hydraulic system of tractor, power steering system.

VII. Learning outcome

Ability to design simple hydraulic and pneumatic circuits and to select the components for the same. To design hydraulic and pneumatic systems of farm Machinery.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction to hydraulic power, its advantages, applications.	1
2.	Properties of hydraulic fluids, viscosity, bulk modulus, density.	2
3.	Concepts of energy of hydraulic systems, laws of fluid flow.	1
4.	Introduction to hydraulic pump and motor.	1
5.	Principle of hydraulic pump and motor, capacity, classifications, working, performance.	1
6.	Design of various types of hydraulic pumps.	1
7.	Design of various types of hydraulic motors.	1
8.	Actuators, types, design of linear actuator and rotary actuators.	3
9.	Hydraulic rams, gear motors, piston, motors and their performance characteristics.	3
10.	Hose, filters, reservoirs, types of circuits, intensifier, accumulator, valves.	3
11.	Valve types: Direction control, deceleration, flow, pressure control, check valve and their working etc.	4
12.	Hydraulic circuit design.	2
13.	Applications in farm power and machinery: Tractor, combine, farm machinery systems, hydrostatic system etc.	3
14.	Power pack, pneumatic circuits, components of pneumatic systems, properties of air.	3
15.	Compressors, types. Design of pneumatic circuits.	3
	Total	**32**

IX. List of Practicals

S.No.	Practical	No. of Practicals
1.	Study of various hydraulic pumps	1
2.	Study of various hydraulic motors	1
3.	Study of various hydraulic valves	1
4.	Study of various hydraulic directional control valves	2
5.	Study of various hydraulic cylinder piston arrangements	1
6.	Engineering properties of hydraulic fluids	2
7.	Study of hydraulic system of tractor	1
8.	Study of power steering system	1
9.	Study of power pack, pneumatic circuits, components of pneumatic systems	2
10.	Practical examination	1
	Total	**13**

X. Suggested Reading

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

I. Course Title : Applied Instrumentation in Farm Machinery

II. Course Code : FMPE 513

III. Credit Hours : 2+1

IV. Aim of the course

To understand the operation of instruments that is used in design and evaluation of farm machinery and their application.

V. Theory

Unit I

Strain gauges, types and applications in two and three dimensional force measurement in farm machinery. Various methods of determining strain/stresses experimentally. Design, selection and analysis of strain gauges.

Unit II

Introduction to transducers (sensors). Active and passive transducers, analog and digital modes, null and deflection methods. Performance characteristics of instruments including static and dynamic characteristics.

Unit III

Load cells, torque meters, flow meters types and principles of working. Devices for measurement of temperature, relative humidity, pressure, sound, vibration, displacement (LVDT) etc. Recording devices and their types. Measuring instruments for calorific value of solid, liquid, and gaseous fuels.

Unit IV

Basic signal conditioning devices, data acquisition system. Micro computers for measurement and data acquisition. Data storage and their application including wireless communication. Application of sensors in farm machinery and power: Tractor and selected farm machinery.

VI. Practical

Calibration of load cells, torque meters, flow meters etc. Experiment on LVDT, strain gauge transducer, speed measurement using optical devices, vibration measurement, making of thermocouples etc, application of sensors in farm machinery like wheel hand hoe, etc.

VII. Learning outcome

The student will be able to select and implement suitable systems for measurement of different parameters like force, torque, speed and pressure etc, that are used in design and evaluation of Farm machinery.

VIII. Lecture schedule

S.No.	Lecture	No. of Lectures
	Unit I	
1.	Strain gauges and its types; working principle, wheatstone bridge measurement, commercial available strain gauges	2
2.	Applications of strain gauges in two and three dimensional force measurement in farm machinery	2
3.	Various methods of determining strain/stresses experimentally.	2
4.	Design, selection and analysis of strain gauges.	2

S.No.	Topic	No of Lectures
	Unit II	
5.	Introduction to transducers (sensors).	1
6.	Active and passive transducers, analog and digital modes, null and deflection methods.	2
7.	Performance characteristics of instruments including static and dynamic characteristics.	2
	Unit III	
8.	Load cells, torque meters, flow meters types and principles of working	3
9.	Devices for measurement of temperature and relative humidity	2
10.	Devices for measurement of pressure and sound	2
11.	Devices for measurement of vibration and displacement (LVDT)	2
12.	Recording devices and their types	1
13.	Measuring instruments for calorific value of solid, liquid, and gaseous fuels	2
	Unit IV	
14.	Basic signal conditioning devices and data acquisition system	1
15.	Micro computers for measurement and data acquisition; general purpose microcontrollers and microprocessors	2
16.	Data storage and their application including wireless communication	2
17.	Application of sensors in farm machinery and power: Tractor and selected farm machinery	2
	Total	**32**

IX. List of Practicals

S.No.	Topic	No of Practicals
1.	Calibration of Load Cells	2
2.	Calibration of Torque Meters	1
3.	Calibration of Flow Meters	1
4.	Experiment on LVDT.	2
5.	Experiment on Strain Gauge	1
6.	Speed measurement using optical devices	2
7.	Vibration Measurement	2
8.	Making of Thermocouples	2
9.	Application of Sensors in Farm Machinery like wheel hand hoe etc.	3
	Total	**16**

X. Suggested Reading

- Ambrosius EE. 1966. *Mechanical Measurement and Instruments*. The Ronald Press Company.
- Doeblin EO. 2004. *Measurement System- Application and Design*. Tata McGrawHill
- Nakra BC and Choudhary KK. 1985. *Instrumentation, Measurement and Analysis*.2nd Edition Tata McGraw Hill.
- Nachtigal CL (Editor). 1990. *Instrumentation and Control. Fundamentals and Application*. Wiley Series in Mechanical Engineering.
- Oliver FJ. 1971. *Practical Instrumentation Transducers*. Hayden book company Inc.

I. Course Title : Systems Simulation and Computer Aided Problem Solving in Engineering

II. Course Code : FMPE 514

III. Credit Hours : 1+1

IV. Aim of the course

To give the student orientation in simulation of continuous and discrete systems especially using computer programme and software.

V. Theory

Unit I

Mathematical modeling and engineering problem solving: Conservation laws and engineering. Computers and software: Software development, structured programming, logical representation. Modular programming. Approximation: Round off errors, truncation errors, significant figures, accuracy and precision.

Unit II

Nature of simulation: Systems models and simulation, discreet event simulation, time advance mechanisms, components of discrete event simulation model, simulation of single server queuing system. Program organization and logic, development of algorithm. Simulation of an inventory system.

Unit III

Solving roots of equation using computers. Application in: Ideal and non-ideal gas laws, open channel flows, design of an electric circuit, vibration analysis. Solving linear algebraic equation on computers: Naïve Gauss Elimination, techniques for improving solutions, LU decomposition and matrix inversion. Application in: Steady state analysis of chemical reactors, statically determinate truss, current and voltage in circuits, spring mass systems.

Unit IV

Optimization techniques. Search techniques: Golden Sections, quadratic interpolation. Application: Optimum design of tank, least cost treatment of waste water, power transfer for circuits. Solving ordinary differential equation on computers: Modeling engineering systems with ordinary differential equation, solution techniques using computers.

VI. Practical

Comparison of analytical and numerical solutions using Spread sheet. Generation of random variables. Generation of discreet and continuous random variate-coding. Implementation of single server queue on computer. Exercises with software packages for roots of equation: Solving linear algebraic equation, curve fitting and optimization. Solving simultaneous equation through Gauss elimination, solving steady state analysis of chemical reactors, statically determinate truss, current and voltage in circuits, spring mass systems on computers. Application of ordinary differential equation to solve mixed reactor problems, predator prey models and chaos.

VII. Learning outcome

Ability to analyze problems from a systems perspective and apply the principles to simulation of continuous and discrete engineering systems.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction to mathematical modeling in engineering problem solving, comparison of analytical and numerical approaches.	1
2.	Conservation laws applied to engineering, modeling simple system	1
3.	Computer modeling, computing environments software development process.	1
4.	Modular design, top down design, structured programming, – algorithm design.	1
5.	Program composition, quality control- testing and documentation software strategy.	1
6.	Approximation- round off errors- accuracy and precision – definitions, number system in the computer- truncation errors.	1
7.	Nature of simulation, systems models and simulation.	1
8.	Discreet event simulation, time advance mechanisms, components of discreet event simulation model.	1
9.	Principles of simulation of singular server queuing system.	1
10.	Programme organization and logic for single server queuing system.	1
11.	Development of algorithm, single server queuing system.	1
12.	Solving roots of equation in computers, graphical method.	1
13.	Developing algorithm for bisection method, false position method.	1
14.	Application of roots of equation to gas laws, open channel flows.	1
15.	Application of roots of equation to electric circuits, vibration analysis.	1
16.	Solving linear algebraic equation in engineering practices.	1
17.	Developing algorithm for Gaussian elimination.	1
18.	Pitfalls of elimination methods and remedies.	1
19.	Overview of LU decomposition.	1
20.	LU decomposition algorithms, calculating inverse of matrix.	1
21.	Application of linear algebraic equation to statically determinate truss.	1
22.	Application of linear algebraic equation to Circuit analysis.	1
23.	Application of linear algebraic equation to spring mass system.	1
24.	Introduction to optimization in engineering, Formulation of Problems.	1
25.	One dimensional unconstrained optimization, development of algorithm for golden sections.	1
26.	One dimensional unconstrained optimization quadratic interpolation.	1
27.	Application of optimization to design of tank.	1
28.	Application of optimization to waste water treatment problem.	1
29.	Application of optimization to power transfer circuits.	1
30.	Formulating engineering problems using ordinary differential equation.	1
31.	Solving ordinary differential equation using computers, Euler's method.	1
32.	Solving ordinary differential equation using modeling engineering systems, computers, Runge-kutta method.	1
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Exercises in developing simple programmes in C.	1
2.	Demonstration of solutions using analytical and numerical methods for simple problems.	1
3.	Development of programmes for generation of random variables.	1
4.	Writing programme for generating random variates.	1

S.No.	Topic	No of Practicals
5.	Writing programme for event advance mechanism of single server queuing system.	1
6.	Writing programme for arrival module of single server queuing system.	1
7.	Writing programme for departure module of single server queuing system and statistical performance.	1
8.	Writing programme for solution of roots of equation.	1
9.	Solving simple engineering problems using roots of equation.	1
10.	Development of algorithm for Gaussian elimination.	1
11.	Application of Gaussian elimination to mass balance problems and statically determinate truss.	1
12.	Application of Gaussian elimination to analysis of electrical circuits.	1
13.	Development of algorithm for Golden Sections and application.	1
14.	Application of optimization technique to design of tank.	1
15.	Application of optimization technique to waste water treatment.	1
16.	Predator prey models and chaos.	1
	Total	**16**

X. Suggested Reading

- Balagurusamy E. 2000. *Numerical Methods.*Tata McGraw Hill Publishing Company limited, New Delhi.
- Chapra SC and Canale RP. 1994. *Introduction to Computing for Engineers*. 2nd Edition McGraw Hill International Edition, New York.
- Dent JB and Blackie MJ. 1979. *System Simulation in Agriculture.* Applied Science Publishers Ltd., London.
- Law AM. 2015. *Simulation Modeling and Analysis*. McGraw Hill International Edition, New York.
- Schilling RJ and Harries SL. 2002. *Applied Numerical Methods for Engineers Using MATLAB and C.*Thomson Asia Pvt. Ltd. Singapore.
- Veerarajan T and Ramachnadran T. 2004. *Numerical Methods with Programmes in C and C++*. Tata McGraw Hill Publishing company limited, New Delhi.

I. Course Title : Computer Aided Design of Machinery

II. Course Code : FMPE 515

III. Credit Hours : 0+2

IV. Aim of the course

To learn the practice of designing components and assemblies based on computer aided drafting technique.

V. Practical

Learning 2D drafting: Controlling display settings, setting up units, drawing limits and dimension styles. Drawing and dimensioning simple 2D drawings, keyboard shortcuts. Working with blocks, block commands. Exercise in simple assembly in orthographic. Exercise in measuring and drawing simple farm machinery parts. Learning 3D Drafting: Advantages of virtual prototyping-starting the 3D drafting environment, self learning tools, help and tutorials. Familiarizing with user interface, creating files and file organization, structuring and streamlining. Features of document window. Concept of coordinate system: Working coordinate system, model coordinate system, screen coordinate system, graphics exchange standards and

database management system. Working with feature manager and customizing the environment. Planning and capturing design intent. Documentation of design. Using design journal and design binder. Preliminary design review and layout.

Practice in drawing 2D sketches with sketcher and modifying sketch entries. Adding Reference geometry: Planes and axes. Adding relations and working with relations. Dimensioning a sketch. Exercises.

Parts and features: Sketched features and applied features, pattern and mirror features. Documenting design. Assembly: Creating and organizing assemblies, connecting parts and subassemblies with mates. Organizing the assembly by using layouts.

Exercise in creating drawing: Setting up and working with drawing formats, creating drawing views from the 3D model, making changes and modifying dimensions.

Case studies: Measuring and drawing assemblies of farm implements and their components.

VI. Learning outcome

The student will be able to conceptualize spatial concepts and design components and assemblies of Farm machinery and make graphic models using commercial CAD software like Solid Works, Catia and AutoCAD.

VII. List of Practicals

S.No.	Topic	No of Practicals
1.	Learning 2D drafting: Controlling display settings, setting up units, drawing limits and dimension styles.	2
2.	Drawing and dimensioning simple 2D drawings, keyboard shortcuts.	1
3.	Working with blocks, block commands. Exercise in simple assembly in orthographic.	1
4.	Exercise in measuring and drawing simple farm machinery parts.	2
5.	Learning 3D Drafting: Advantages of virtual prototyping-starting the 3D drafting environment, self learning tools, help and tutorials. Familiarizing with user interface, creating files and file organization, structuring and streamlining. Features of document window.	2
6.	Concept of coordinate system: Working coordinate system, model coordinate system, screen coordinate system, graphics exchange standards and database management system.	2
7.	Working with feature manager and customizing the environment. Planning and capturing design intent.	2
8.	Documentation of design. Using design journal and design binder. Preliminary design review and layout.	1
9.	Practice in drawing 2D sketches with sketcher and modifying sketch entries.	2
10.	Adding Reference geometry: Planes and axes. Adding relations and working with relations. Dimensioning a sketch. Exercises.	2
11.	Parts and features: Sketched features and applied features, pattern and mirror features. Documenting design.	2
12.	Assembly: Creating and organizing assemblies, connecting parts and subassemblies with mates.	2
13.	Organizing the assembly by using layouts.	1
14.	Exercise in creating drawing: Setting up and working with drawing formats, creating drawing views from the 3D model, making changes and modifying dimensions.	2
15.	Case studies: Measuring and drawing assemblies of farm implements and their components.	5
	Total	**32**

VIII. Suggested Reading

- Jankowski G and Doyle R. 2007. *SolidWorks® For Dummies®*, 2nd Edition, Published by Wiley Publishing, Inc. ISBN: 978-0-470-12978-4
- Shih R H. 2014. *AutoCAD 2014 Tutorial-First Level: 2D Fundamentals*. SDC Publications

I. Course Title : Advanced Manufacturing Technologies

II. Course Code : FMPE 516

III. Credit Hours : 2+1

IV. Aim of the course

To learn the modern manufacturing techniques and their application to manufacture of different components and assemblies.

V. Theory

Unit I

Material and their characteristics, structure and properties of materials, wood, ferrous, Non-ferrous, alloys, plastic, elastomers, ceramics and composites. Material selection and metallurgy: Equilibrium diagram, time temperature transformation curves, heat treatments, surface treatment: Roughness and finishing.

Unit II

Measurement and quality assurance: Quality control, tolerance, limits and clearance. Automated 3-D coordinate measurements. Advance casting processes and powder metallurgy. Forming process: Fundamentals of metal forming, hot and cold rolling, forging processes, extrusion and drawing.

Unit III

Workshop practices applied in prototype production, jigs and fixtures. Traditional machining processes: Cutting tools, turning, boring, drilling, milling and related processes. Non traditional machining processes fuzzy c-mean (FCM), electric discharge machining (EDM), laser beam machining (LBM), Abrasive jet machining (AJM), and Wire-electro-discharge machining (EDM).

Unit IV

Joining processes: Gas flame processes, arc processes, brazing and soldering, adhesive and bonding.

Unit V

Numerical control: Command system codes, programme, cutter position X and Y, incremental movements, linear contouring, Z movements and commands. Manufacturing systems and automation. Robotics and robot arms. 3-D printing. Integrated manufacturing production system.

Practical

Identification of material and their application. Study of heat treatment processes and their suitability with respect to materials. Tool and equipments for measurements: Tolerance limits, clearance and surface finish. Site visits for study of advanced manufacturing techniques. Case studies.

VI. Learning outcome

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

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Material and their characteristics.	1
2.	Structure and properties of materials wood, ferrous, Non-ferrous, alloys, plastic, elastomers, ceramics and composites.	2
3.	Material selection and metallurgy: Equilibrium diagram, time temperature transformation curves.	1
4.	Heat treatments, surface treatment: Roughness and finishing.	2
5.	Measurement and quality assurance: Quality control, tolerance, limits and clearance.	1
6.	Automated 3-D coordinate measurements and practice.	2
7.	Advance casting processes and powder metallurgy.	1
8.	Forming process: Fundamentals of metal forming, hot and cold rolling, forging processes, extrusion and drawing.	2
9.	Forging processes, extrusion and drawing.	1
10.	Workshop practices applied in prototype production, jigs and fixtures.	1
11.	Traditional machining processes: Cutting tools, turning, boring, drilling, milling and related processes.	2
12.	Non traditional machining processes fuzzy c-mean (FCM), electric discharge machining (EDM), laser beam machining (LBM).	2
13.	Electric discharge machining (EDM), laser beam machining (LBM).	1
14.	Abrasive jet machining (AJM), and wire-electro-discharge machining (EDM).	2
15.	Joining processes: Gas flame processes, arc processes.	2
16.	Brazing and soldering processes.	1
17.	Adhesive and bonding processes.	1
18.	Numerical control: Command system codes.	1
19.	NC Programme, Robotics and robot arms.	2
20.	Cutter position X and Y, incremental movements, linear contouring, Z movements and commands.	1
21.	Manufacturing systems and automation.	1
22.	3-D printing and integrated manufacturing production system.	2
	Total	**32**

VIII. List of Practicals

S.No.	Topic	No. of Practicals
1.	Identification of material and their application.	2
2.	Study of heat treatment processes and their suitability with respect to materials.	5
3.	Tool and equipments for measurements: Tolerance limits, clearance and surface finish.	4
4.	Site visits for study of advanced manufacturing techniques.	2
5.	Case studies.	2
6.	Practical examination	1
	Total	**16**

IX. Suggested Reading

- Begeman ML, Ostwald PF and Amstead BH. 1979. *Manufacturing Processes: SI Version*. John Wiley and Sons. 7th Edition.
- Chapman PAJ. 1996. *Workshop Technology*, Part III. CBS Publisher and distributors Pvt

Ltd. 3rd Edition international Edition.
- Gupta RB. 2017. *Production Technology*, Vol I - Production Process. Satya Prakashan, New Delhi.
- Hoyos L. 2010. *Fundamentals of Tool Design*. American Society of Tool and Manufacturer Engineers. Sixth Edition.
- Jain RK. 1994. *Production Technology: A Textbook for Engineering Students*. Khanna Publishers, New Delhi.
- Polukin P, Gringerg B, Kantenik S, Zhadan V and Vasilye D. *Metal Process Engineering*, MIR Publishers Moscow.

I. Course Title : Machinery for Precision Agriculture

II. Course Code : FMPE 517

III. Credit Hours : 2+1

IV. Aim of the course

To learn the principles behind precision agriculture and the systems for implanting the same.

V. Theory

Unit I

Importance of precision agriculture. Mapping in farming for decision making. Geographical concepts of PA.Understanding and identifying variability

Unit II

Geographical Position System (GPS) Basics (Space Segment, Receiver Segment, Control Segment), Error and correction, Function and usage of GPS. Introduction to Geographic Information system (GIS), function of GIS, use of GIS for decisions. IDI devices usage in Precision Agriculture Yield monitor, variable rate applicator for fertilizers, seed, chemicals etc. Remote sensing Aerial and satellite imagery. Above ground (non-contact) sensors.

Unit III

Data analysis, concepts of data analysis, resolution, Surface analysis. Analysis application interpretive products (map, charts, application map etc).

Unit IV

Electronics and Control Systems for Variable rate applications, Precision Variable Equipment, Tractor-Implement interface technology, Environmental Implications of Precision Agriculture.

Unit V

Goals based on end results of Precision Agriculture, Recordkeeping, Spatial Analysis, Variable Rate Application, Reducing of negative environmental impact, Crop/ technology cost optimization. Economic of precision agriculture and determining equipment and software, review of Cost/Benefit of Precision Agriculture, System vs. Parcels. Making a selection.

VI. Practical

Calculation of the benefits of Data and Mapping, Determining Latitude/Longitude, UTM or State Plane Position Navigation with Waypoints, Configuring a GPS System. Defining area of field for prescriptive treatment. Making the Grid, The Grid Sampling Process, generation of yield maps, Thematic or Spatial Resolution, Yield

Map Example, Surface Analysis in Arc-View.

VII. Learning outcome

Knowledge about the principles guiding the concept of precision agriculture and Farm Machinery and equipment systems that make muse of this principle.

VIII. Lecture Schedule

S.No.	Topic	No of Lectures
1.	Introduction to precision agriculture, its importance and applications	1
2.	Mapping in farming for decision making and geographical concepts of PA.	2
3.	Understanding and identifying variability	1
4.	Introduction to Geographical Position System (GPS). Function and usage of GPS	2
5.	Basics of GPS (Space Segment, Receiver Segment, Control Segment), Error and correction	2
6.	Introduction to Geographic Information system (GIS), function of GIS, use of GIS for decisions.	2
7.	Remote sensing including aerial and satellite imagery	2
8.	IDI devices usage in Precision Agriculture Yield monitor, variable rate applicator for fertilizers, seed, chemicals etc. Above ground (non-contact) sensors	2
9.	Data analysis, concepts of data analysis	3
10.	Surface analysis. Analysis application interpretive products (map, charts, application map etc)	2
11.	Precision Variable Equipment	2
12.	Electronics and Control Systems for variable rate applications	2
13.	Tractor-Implement interface technology, Environmental Implications of Precision Agriculture	2
14.	Recordkeeping, Spatial Analysis	2
15.	Rate Application, reducing of negative environmental impact, Crop/technology cost optimization	2
16.	Economic of precision agriculture and determining equipment	2
17.	Review of Cost/Benefit of Precision Agriculture, Making a selection	2
	Total	**33**

IX. Practical Schedule

S.No.	Topic	No of Practicals
1.	Calculation of the benefits of data and mapping	1
2.	Determining Latitude/Longitude, UTM or State Plane Position Navigation with Waypoints	2
3.	Configuring a GPS System	1
4.	Defining area of field for prescriptive treatment	1
5.	Making the grid and grid sampling process	2
6.	Collection of tractor-implement interface data	1
7.	Generation of yield maps	2
8.	Example of spatial and temporal variability and resolution	1
9.	Surface Analysis using software like Arc-View	2
10.	Economic of precision agriculture and determining equipment	2
11.	Cost/Benefit of Precision Agriculture for making a optimized selection	2
	Total	**17**

X. Suggested Reading

- Clay SA, Clay DE and Bruggeman SA. 2017. *Practical Mathematics for Precision Farming* American Society of Agronomy, Crop Science Society and Soil Science Society of America, 5585 Gulford Rd, Madison, WI 53711
- Henten EJV, Goense D and Lokhorst C. 2009. *Precision Agriculture*. Wageningen Academic Publishers.
- Ram T, Lohan SK, Singh R and Singh P. 2014. *Precision Farming: A New Approach*. Astral International Pvt. Ltd., New Delhi, ISBN: ISBN 978-81-7035-827-5 (Hardbound) ISBN 978-93-5130-258-2 (International Edition).
- Shannon DK, Clay DE and Kitchen NR (editors). 2018. *Precision Agriculture Basics* American Society of Agronomy, Crop Science Society and Soil Science Society of America, 5585 Gulford Rd, Madison, WI 53711
- Singh AK and Chopra UK. 2007. Geoinformatics Applications in Agriculture. New India Publishing Agency, PritamPura, New Delhi.

I. Course Title : Machinery for Horticulture and Protected Agriculture

II. Course Code : FMPE 518

III. Credit Hours : 2+0

IV. Aim of the course

To learn about the different machinery used in cultivation of vegetable crops, orchard crops and also in protected agriculture.

V. Theory

Unit I

Vegetable cultivation, nursery machinery, tray seeders, grafting machines, vegetable trans-planters. Machinery for planting crops on raised beds, mulch laying and planting machines. Harvesting of vegetable crops: Harvesting platforms and pickers.

Unit II

Machinery for orchard crops: Pit diggers, inter-cultivators and basin forming equipment for orchards. Machinery for transplanting of trees. Harvesters for fruit crops: Shaker harvesters, types and principle of operation. Elevated platforms for orchard management and harvesting. Pruning machines.

Unit III

Machinery for orchards, vineyard machinery spraying machines, inter-cultivation machines. High clearance machines and special purpose machinery for crops on trellis. Machinery for special crops: Tea leaf harvesters, pruners and secateurs.

Unit IV

Machinery for lawn and garden: Grass cutters, special machinery for turf maintenance. Turf aerators and lime applicators.

Unit V

Protected agriculture: Principles, mechanical systems of greenhouse, ventilation systems, shading system, water fogging system, irrigation system, sensors, electrical and electronic system. Intelligent Control system for greenhouses. Machinery for processing of growth media, tray filling machines-tray sowing machines, transplanting machines. Robotic grafting machines. Weeding and thinning equipment. Crop protection and harvest under protected agriculture.

VI. Learning outcome

Knowledge about different principles of mechanizing cultivation of horticultural crops and in protected agriculture.

VII. Lecture Schedule

S.No.	Topic	No. of Lecture
1.	History of vegetable cultivation in India and scope of mechanization in Horticulture	1
2.	Methods of Nursery propagation techniques and machinery for nursery and tray seeders	1
3.	Machinery for field preparation for vegetables (Disc harrows, Disc plough, offset rotavator, sub soiler, bed makers)	1
4.	Principles of mulch laying and planting machines. Types of vegetable transplanters and their construction and working	1
5.	Working and construction of subsurface drip laying machine. Types of planters for vegetable crops and its working	1
6.	Principles of Pneumatic vegetable seeders and its working. Machinery for harvesting of vegetable crops like root crop harvester, its construction and working	1
7.	Types of vegetable extraction machine, its working and construction	1
8.	Types of pickers, their construction and working	1
9.	Construction and working of different types of post hole diggers	1
10.	Types of tractors and their uses in orchards	1
11.	Types of inter cultivators and its construction and working.	1
12.	Types of brush cutters and its working	1
13.	Types of basin forming equipment for orchards. Machinery for transplanting of trees and their construction and working	1
14.	Types of elevated platforms for orchard management. Types of Tree Pruners and principles and its working and construction	1
15.	Types of fruit pluckers and its working and construction	1
16.	Principles and working and construction of shaker harvesters	1
17.	Types of vineyard machinery and its working and construction	1
18.	Types of spraying machines and its working and construction. High clearance machines and special purpose machinery for crops on trellis.	1
19.	Types of orchard sprayers, its working and construction	1
20.	Types of Tea leaf harvesters, pruners and secateurs and its working and Construction	1
21.	Special purpose machinery for crops on trellis	1
22.	Types of lawn and garden mowers and its working.	1
23.	Studies on special machinery for turf maintenance working and construction of Turf aerators and lime applicators	1
24.	Introduction to protected agriculture. Principles of protected agriculture	1
25.	Greenhouses - Mechanical systems, ventilation systems, shading system, water fogging system and irrigation system.	2
26.	Sensors, electrical and electronic system. Intelligent Control system for greenhouses	1
27.	Machinery for processing of growth media, tray filling machines-tray sowing machines, transplanting machines	1
28.	Robotic grafting machines. Weeding and thinning equipment	1
29.	Crop protection and harvest under protected agriculture	1
	Total	**30**

VIII. Suggested Reading

- Bell B and Cousins S. 1997. *Machinery for Horticulture*. Old Pond Publishing Ltd ISBN-10: 0852363699,ISBN-13: 978-0852363690
- *Good Agricultural Practices for Greenhouse Vegetable Production in the South East European countries* FAO Rome 2017.
- Ponce P, Molina A, Cepeda P, Lugo E and MacCleery B. 2014. *Greenhouse Design and Control*. CRC Press, ISBN 9781138026292 - CAT K23481, 1st Edition.

Course Title with Credit Load
M.Tech. in Processing and Food Engineering

Major Courses (Requirement: 20 Credits)

Course Code	Course Title	Credit Hours
*PFE 501	Transport Phenomena in Food Processing	2+1
*PFE 502	Unit Operations in Food Process Engineering	2+1
*PFE 503	Field Crops Process Engineering	2+1
*PFE 504	Horticultural Crops Process Engineering	2+1
PFE 505	Storage Engineering and Handling of Agricultural Produce	2+1
PFE 506	Food Package Engineering	1+1
PFE 507	Instrumentation and Sensors in Food Processing	2+1
PFE 508	Application of Engineering Properties in Food Processing	2+1
PFE 509	Food Quality and Safety	2+1
PFE 510	Food Processing Technologies	2+1
PFE 511	Food Processing Equipment and Plant Design	1+1
PFE 512	Seed Process Engineering	1+1
PFE 513	Agri-Project Planning and Management	2+1
PFE 514	Farm Structures and Environmental Control	2+1
PFE 515	Dairy Product Processing	2+1
PFE 516	Processing of Meat, Poultry and Fish	2+1
PFE 517	Design of Aquacultural Structures	2+1
PFE 518	Thermal Environmental Engineering for Agricultural Processing	2+1
	Total	**33+18**

*Compulsory Courses

Minor Courses (Requirement: 08 Credits)

Course Code	Course Title	Credits
ME 501	Mechatronics and Robotics in Agriculture	2+0
ME 502	Refrigeration Systems	2+1
REE 513	Energy, Ecology and Environment	3+0
REE 518	Energy Management in Food Processing Industries	1+1
FMPE 502	Testing and Evaluation of Agricultural Equipment	1+1
FMPE 514	System Simulation and Computer Aided Problem Solving in Engineering	1+1

Course Code	Course Title	Credit Hours
FMPE 515	Computer Aided Design of Machinery	0+2
CSE 501	Big Data Analytics	2+0
CSE 502	Artificial Intelligence	2+0
MATHS 501	Finite Elements Method	1+1
MATHS 502	Numerical Methods for Engineers	2+1
CE 501	Dimensional Analysis and Similitude	1+1
	Any other course (s) of other department other than course(s) from major can be taken as per recommendations of the student's advisory committee.	

Supporting Courses (Requirement: 06 Credits)

Course Code	Course Title	Credit Hours
*STAT 501	Statistical Methods for Research Works	2+1
	Courses from subject matter fields (other than Major and Minor) relating to area of special interest and research problem can be taken as per recommendations of the student's advisory committee.	

*Compulsory Course

Common Courses (Requirement: 05 Credits)

Course Code	Course Title	Credit Hours
*PGS 501	Library and Information Services	0+1
*PGS 502	Technical Writing and Communications Skills	0+1
*PGS 503	Intellectual Property and its management in Agriculture	0+1
*PGS 504	Basic Concepts in Laboratory Techniques	0+1
*PGS 505	Agricultural Research, Research Ethics and Rural Development Programmes	0+1

*Detailed course outline to be developed by designated BSMA

List of Other Essential Requirements

Course Code	Course Title	Credit Hours
PFE 591	Seminar	0+1
PFE 599	Thesis Research	0+30

Course Contents
M.Tech. in Processing and Food Engineering

I. Course Title : Transport Phenomena in Food Processing
II. Course Code : PFE 501
III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with the principles of heat, mass and momentum transfer and its applications in food processing

V. Theory

Unit I

Introduction to heat and mass transfer and their analogy. Steady and unsteady state heat transfer. Analytical and numerical solutions of unsteady state heat conduction equations. Use of Gurnie-Lurie and Heisler Charts in solving heat conduction problems: Applications in food processing including freezing and thawing of foods.

Unit II

Convective heat transfer in food processing systems involving laminar and turbulent flow. Heat transfer in boiling liquids. Heat transfer between fluids and solid foods. Functional design of heat exchangers: shell and tube, plate and scraped surface heat exchangers. Radiation heat transfer: governing laws, shape factors, applications in food processing.

Unit III

Momentum transfer.Mass flow and balance. Steady and unsteady flow.Theory and equation of continuity.Bernoulli's theorem and application. Flow through immerged bodies, Measurement of flow, pressure and other parameters. Flow driving mechanism.

Unit IV

Molecular diffusion in gases, liquids and solids.Molecular diffusion in biological solutions and suspensions.Molecular diffusion in solids. Unsteady state mass transfer and mass transfer coefficients.Molecular diffusion with convection and chemical reaction.Diffusion of gases in porous solids and capillaries. Mass transfer applications in food processing.

VI. Practical

Solving problems on steady and unsteady state conduction with or without heat generation.Numerical analysis.Problems in natural and forced convection, radiation.Design of heat exchangers. Experiments on heat conduction, convection and radiation heat transfer.

VII. Learning outcome

The course will impart requisite knowledge about transport phenomenon with

respect to heat, mass and momentum transfer which is necessary to understand the food processing operations. After going through the course, students will be able to understand, analyse and solve numerically the food processing operations where heat/mass/momentum transfer is involved.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction to basic heat and mass transfer and their analogy	2
2.	Steady and unsteady state heat transfer.	2
3.	Use of Gurnie-Lurie and Heisler Charts in solving heat conduction problems	1
4.	Applications in food processing including freezing and thawing of foods.	1
5.	Convective heat transfer in food processing systems involving laminar and turbulent flow	2
6.	Heat transfer in boiling liquids, Heat transfer between fluids and solid foods.	2
7.	Functional design of heat exchangers; Shell and tube, plate and scraped surface heat exchangers.	2
8.	Radiation heat transfer: governing laws, shape factors, applications in food processing.	2
9.	Classification of Flow Phenomena, Momentum Flow and Momentum Equation for Laminar Flow, Momentum transfer. Mass flow and balance.	2
10.	Steady and unsteady flow, Fluid Element Trajectories, Stream Function and Velocity Potential	1
11.	Theory and equation of continuity. Bernoulli's theorem and application.	1
12.	Flow through immerged bodies, Measurement of flow; Measurement of flow pressure and other parameters. Flow driving mechanism.	2
13.	Mass Transfer (Diffusion),Diffusion: Phenomenological Description, Diffusion Coefficient and Fick's Law	2
14.	Driving Force for Diffusion, Microscopic Picture of Diffusion	1
15.	Molecular diffusion in biological solutions and suspensions.	1
16.	Unsteady state mass transfer and mass transfer coefficients.	2
17.	Molecular diffusion with convection and chemical reaction	1
18.	Diffusion of gases in porous solids and capillaries	1
19.	Mass transfer applications in food processing.	2
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Solving problems on steady conduction	1
2.	Solving problems on steady conductionwith or without heat generation	1
3.	Solving problems on steady and unsteady state conduction	2
4.	Steady and unsteady state conduction with or without heat generation	1
5.	Numerical analysis in heat transfer	1
6.	Problems in natural and forced convection	2
7.	Solving problems of heat transfer by radiation	2
8.	Design of heat exchangers.	2
9.	Experiments on heat conduction, convection	2
10.	Experiments on radiation heat transfer	1
	Total	**15**

X. Suggested Reading

- Bird, Stewart, Lightfoot 2002. *Transport Phenomena*, John Wiley & Sons.
- Bodh Raj 2012. *Introduction to Transport Phenomena*, PHI.
- Christie J. 1993. *Transport Process and Unit Operations*. Prentice-Hall of India Private Limited, New Delhi ISBN 0-13-045253-X.
- Coulson JM and Richardson JF. 1999. *Chemical Engineering*. Vol. II, IV.ThePergamon Press.
- Earle RL. 1985. *Unit Operations in Food Processing*. Pergamon Press.
- Holman JP 1992. Heat Transfer. McGraw Hill.
- Jorge Welti-Chanes, Jorge F and Velez-Ruiz 2002. *Transport Phenomena in Food Processing*. CRC Press ISBN: 9781566769938 Geankoplis.
- McCabe WL and Smith JC 1999. *Unit Operations of Chemical Engineering*. McGraw Hill.
- Plawsky, Joel L 2014. *Transport Phenomena Fundamentals*, CRC Press, ISBN: 978-1-4665-5535-8,1466555351.

I. Course Title : Unit Operations in Food Process Engineering

II. Course Code : PFE 502

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with different unit operations applicable in food industries.

V. Theory

Unit I

Review of basic engineering mathematics. Units and dimensions. Mass and energy balance. Principles of fluid flow. Heat transfer: Conduction, convection and radiation.Heat exchangers and their designs.

Unit II

Drying and dehydration: Psychrometry, theories of drying, EMC, equipment for drying of solid, pastes and liquid foods. Evaporation: Components, heat and mass balance in single and multiple effect evaporators, equipment and applications, steam economy. Thermal processing: Blanching, pasteurization and sterilization, death rate kinetics, process time calculations, sterilization equipment.

Unit III

Refrigeration and freezing: Principles, freezing curve, freezing time calculation, freezing equipment, cold chain.

Unit IV

Mechanical separation: Principle and equipment involved in sieving, filtration, sedimentation and centrifugation, cyclone separation. Material handling: Conveyors and elevators, components and design considerations for belt, chain, bucket and screw conveyors.

Unit V

Size reduction: Principles of size reduction, size reduction laws. Size reduction equipment: Jaw crusher, gyratory crusher, roller mill, hammer mill.

VI. Practical

Study of fluid flow properties. Study of heat exchangers, functional design of heat

exchangers.Application of psychometric chart.Determination of EMC.Study of driers. Solving problems on single and multiple effect evaporator. Elevating and conveying equipments. Size reduction equipments. Cleaning and sorting equipment. Sieve analysis. Kinetics of fruits and vegetables dehydration.Calculation of refrigeration load, solving of numerical problems. Visit to related food industry.

VII. Learning outcome

The students will get knowledge on various unit operations, backbone of all food processes. Knowledge on basic principles of thermal food processes, size reduction and separation operations involved in food processing and related equipment will prepare students to solve problems related with food processing. This will help students to solve problems of post-production processes and will also enhance employability in food industries.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Calculations of material balance related to various food processes	3
2.	Study of energy balance for processing operation and related parameters	3
3.	Study of fluid statics, fluid dynamics, flow characteristics	2
4.	Introduction to heat transfer, modes of heat transfer, heat conduction	2
5.	Introduction to Psychometrics basics	2
6.	Study of Dehydration, EMC, Mechanism of drying constant rate period, Falling rate period	2
7.	Study of drying equipments	2
8.	Evaporation, types of evaporators, Flow arrangements Mass and energy balance, Steam economy	2
9.	Thermal processing: Blanching, pasteurization and sterilization, death rate kinetics, process time calculations, sterilization equipment.	3
10.	Refrigeration and freezing: Principles, freezing curve, freezing time calculation, freezing equipment, cold chain.	2
11.	Mechanical separation: Principle and equipment involved in sieving, filtration, sedimentation and centrifugation, cyclone separation.	2
12.	Material handling: Conveyors and elevators, components and design considerations for belt, chain, bucket and screw conveyors.	2
13.	Study of principles involved in the size reduction and separation. Equipment used	3
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Use of units, dimensions and basic mathematical applications	1
2.	To judge the students ability for solving mass balance problems	2
3.	To judge the students ability for solving Energy balance problems	2
4.	To assess the flow rate of fluids through pipes and channels	1
5.	To verify the Bernoulli's Equation	1
6.	To Study heat exchangers and calculation of log mean temperature difference	1
7.	To solve the heat transfer problems	2
8.	To study different dryers used in drying of biological materials	1
9.	To study single effect and multi effect evaporators	1
10.	To calculate the thermal process time using trapezoidal/ Simpson's formulae	1

S.No.	Topic	No. of Practicals
11.	To find the graphical solution for calculation of thermal process time	1
12.	To study different separation equipments	1
13.	To study the size reduction equipments	1
	Total	**16**

X. Suggested Reading

- Berk. 2018. *Food Process Engineering and Technology*, Academic Press, ISBN: 978-0-12-812018-7
- Brennan JG, Butters JR, Cowell ND and Lilly AEI. 1990. *Food Engineering Operations*. Elsevier.
- Fellows P 1988. *Food Processing Technology: Principle and Practice*. VCH Publ.
- McCabe WL and Smith JC. 1999. *Unit Operations of Chemical Engineering*. McGraw Hill.
- Sahay KM and Singh KK. 1994. *Unit Operation of Agricultural Processing*. Vikas Publ. House.
- Singh RP and Heldman DR. 1993. *Introduction to Food Engineering*. Academic Press.
- Smith. 2011. *Introduction to Food Process Engineering*, Springer.
- Toledo. 2007. *Fundamentals of Food Process Engineering*, Springer.
- Varzakas. 2015. *Food Engineering Handbook*, CRC press.

I. Course Title : Field Crops Process Engineering

II. Course Code : PFE 503

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with the post harvest technology of cereals, pulses and oilseeds with special emphasis on equipment used in the milling and processing.

V. Theory

Unit I

Production and utilization of cereals and pulses, grain structure of major cereals, pulses and oilseeds and their milling fractions. Grain quality standards and physico-chemical methods for evaluation of quality of flours.

Unit II

Pre-milling treatments and their effects on milling quality. Parboiling and drying, conventional, modern and integrated rice milling operations. Wheat roller flour milling. Processes for milling of corn, oats, barley, gram, pulses, paddy and flour milling equipment.Layout of milling plants.

Unit III

Dal mills, handling and storage of by-products and their utilization. Storage of milled products.Expeller and solvent extraction processing.Assessment of processed product quality.

Unit IV

Packaging of processed products. Design characteristics of milling equipment, selection, installation and their performance. Quality standards for various processed products. Value added products of cereals, pulses and oilseeds.

VI. Practical

Physical properties of cereals and pulses, raw and milled products quality evaluations:Parboiling and drying, terminal velocities of grains and their fractions, study of paddy, wheat, pulses and oilseeds milling equipments, planning and layout of various milling plants. Development of value added products for cereals, pulses and oilseeds, visit to related agro processing industry.

VII. Learning outcome

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

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Production and utilization of cereals and pulses, grain structure of major cereals, pulses and oilseeds and their milling fractions.	2
2.	Conventional, modern and integrated rice milling process, pre-milling treatments, rice parboiling, rice milling equipment and layout of rice milling plant.	5
3.	Conventional and roller wheat flour milling process, pre-milling treatments, milling equipment and layout of wheat milling plant.	4
4.	Preparation of oilseeds and pre- treatments, conventional and modern oil extraction methods viz expeller, solvent extraction and super critical fluid extraction. Milling equipment and layout of oil milling plant.	4
5.	Processes for milling of pulses, pretreatments, milling equipment and layout of pulse milling plant.	4
6.	Processes for milling of corn, oats and barley, pretreatments and milling equipments. Layout of milling plant.	3
7.	Handling, packaging and storage of milled products, by-products and their utilization.	2
8.	Assessment of processed product quality. Quality standards for various grains, processed products. Physico-chemical methods for evaluation of quality Value added products of cereals, pulses and oilseeds.	3
9.	Design characteristics of milling equipment, selection, installation and their performance.	3
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Engineering properties of grains, raw and milled products	2
2.	Physical, milling and cooking quality of grains	2
3.	Study of paddy milling process and equipments.	1
4.	Study of wheat milling process and equipments,	1
5.	Study of oil extraction process and equipments,	1
6.	Study of pulse milling process and equipments,	1
7.	Planning and layout of various milling plants.	3
8.	Development of value added products for cereals, pulses and oilseeds	2
9.	Visit to various agro processing industry.	2
	Total	**15**

X. Suggested Reading

- Asiedu JJ. 1990. *Processing Tropical Crops*. ELBS/MacMillan.
- Chakraverty A. 1995. *Post-Harvest Technology of Cereals, Pulses and Oilseeds*. Oxford and IBH.
- Golob 2002. *Crop Post-Harvest: Science and Technology* Vol. 1, Wiley-Blackwell.
- Hodges 2004. *Crop post-harvest: science and technology* Vol. 2, Wiley-Blackwell.
- Morris Lieberman. 1983. *Post-Harvest Physiology and Crop Preservation*. Plenum Press.
- Pandey PH. 1994. *Principles of Agricultural Processing*. Kalyani.
- Pillaiyar P. 1988. *Rice - Post Production Manual*. Wiley Eastern.
- Sahay KM and Singh KK. 1994. *Unit Operations in Agricultural Processing*. Vikas Publ. House.

I. Course Title : Horticultural Crops Process Engineering

II. Course Code : PFE 504

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with processing of fruits and vegetables and the design features of the equipment used for their processing.

V. Theory

Unit I

Importance of postharvest technology of fruits and vegetables, structure, cellular components, composition and nutritive value of fruits and vegetables, fruit ripening, spoilage of fruits and vegetables.

Unit II

Harvesting and washing, pre-cooling, blanching, preservation of fruits and vegetables, commercial canning of fruits and vegetables, minimal processing of fruits and vegetables.

Unit III

Cold storage of fruits and vegetables, controlled atmosphere and modified atmosphere packaging of fruits and vegetables, quality deterioration and storage.

Unit IV

Dehydration of fruits and vegetables, methods, osmotic dehydration, foam mat drying, freeze drying, microwave heating, applications, radiation preservation of fruits and vegetables, irradiation sources.

Unit V

Intermediate moisture foods, ohmic heating principle, high pressure processing of fruits and vegetables, applications, sensory evaluation of fruit and vegetable products, packaging technology for fruits and vegetables, general principles of quality standards and control, FPO, quality attributes.

VI. Practical

Determination of size, shape, density, area-volume-mass relationship of fruits and vegetables, sugar-acid ratio of fruits, evaluation of washer, grader and packaging methods, experiments on drying of fruits and vegetables, controlled atmosphere storage and quality evaluation.

VII. Learning outcome

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

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Importance of postharvest technology of fruits and vegetables, structure, cellular components, composition and nutritive value of fruits and vegetables.	1
2.	Techniques for harvesting and washing of fruits and vegetables. Fruit ripening and spoilage.	2
3.	Pre-cooling of fruits and vegetables.	1
4.	Blanching: importance and objectives, blanching methods, effects on food (nutrition, colour, pigment, and texture).	1
5.	Different preservation techniques for fruits and vegetables.	1
6.	Commercial canning of fruits and vegetables.	1
7.	Minimal processing of fruits and vegetables.	1
8.	Modified and CA storage of fruits and vegetables, Cold storage, heat load calculations and design.	5
9.	Quality deterioration in fruits and vegetables.	1
10.	Different storage techniques for fruits and vegetables.	1
11.	Dehydration techniques of fruits and vegetables: osmotic dehydration, foam mat drying, freeze drying, microwave heating, applications, radiation preservation of fruits and vegetables, irradiation sources.	4
12.	Intermediate moisture foods.	1
13.	Ohmic heating and high pressure processing principle for fruits and vegetables.	2
14.	Applications of different processing techniques for fruits and vegetables.	1
15.	Sensory evaluation of fruit and vegetable products.	1
16.	Packaging technology for fruits and vegetables.	2
17.	General principles of quality standards and control.	2
18.	FPO, quality attributes for fruits and vegetables.	2
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Determination of size of fruits and vegetables	1
2.	Determination of shape of fruits and vegetables	1
3.	Determination of bulk density and true density of fruits and vegetables	1
4.	Determination of area-volume-mass relationship of fruits and vegetables	1
5.	Determination of sugar-acid ratio of fruits	1
6.	Evaluation of different types of washers for fruits and vegetables	1
7.	Evaluation of different types of graders for fruits and vegetables	1
8.	Different types of packaging methods for fruits and vegetables	1
9.	Determination of the water vapor permeability of packaging materials	1
10.	Different types of drying methods for fruits and vegetables	1
11.	Comparative evaluation of different dryers for fruits and vegetables	1

S.No.	Topic	No. of Practicals
12.	Determination of solid gain and moisture loss during osmotic dehydration in fruits	1
13.	Study of components and design of controlled atmosphere storage	1
14.	Study of quality evaluation of fruits and vegetables	2
	Total	**15**

X. Suggested Reading

- Bhatti S and Varma U. 1995. *Fruit and Vegetable Processing*. CBS.
- Cruesss WV. 2000. *Commercial Fruit and Vegetable Products*. Agrobios Publisher.
- Danthy ME. 1997. *Fruit and Vegetable Processing*. International Book Publisher.
- Simson. 2016. *Post-Harvest Technology of Horticultural crops*. AAP.
- Singh. 2018. *Advances in Post-Harvest Technologies of Vegetable Crops*. AAP.
- Srivastava RP and Kumar S. 1994. *Fruit and Vegetable Preservation*. Principles and Practices. International Book Distr.
- Thompson AK. 1996. *Post Harvest Technology of Fruits and Vegetables*. Blackwell.
- Verma LR and Joshi VK. 2000. *Post Harvest Technology of Fruits and Vegetables*. Vols. I-II. Indus Publisher.

I. Course Title : Storage Engineering and Handling of Agricultural Produce

II. Course Code : PFE 505

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with the safe storage of food materials, design of storage structures and the design of different material handling equipment used in the industries.

V. Theory

Unit I

Storage of grains, biochemical changes during storage, production, distribution and storage capacity estimate models, storage capacity models, ecology, storage factors affecting losses, storage requirements.

Unit II

Bag and bulk storage, godowns, bins and silos, rat proof godowns and rodent control, method of stacking, preventive method, bio-engineering properties of stored products, function, structural and thermal design of structures, aeration system.

Unit III

Grain markets, cold storage, controlled and modified atmosphere storage, effects of nitrogen, oxygen, and carbon dioxide on storage of durable and perishable commodities, irradiation, storage of dehydrated products, food spoilage and preservation, BIS standards.

Unit IV

Physical factors influencing flow characteristics, mechanics of bulk solids, flow through hoppers, openings and ducts; design of belt, chain, screw, roller, pneumatic conveyors and bucket elevators,principles of fluidization, recent advances in handling of food materials.

VI. Practical

Physical factors influencing flow characteristics, mechanics of bulk solids, flow through hoppers, openings and ducts, design of belt, chain, screw, roller, pneumatic conveyors and bucket elevators; principles of fluidization; recent advances in handling of food materials.

VII. Learning outcome

Student's capability to understand and undertake mechanical handling of food as per requirement of food industries as well as storage devices and systems for safe storage of food for longer period of time.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Importance of storage, Types of losses, Principle of storage, Aeration of grains, Factors causing deterioration of grains, Sources of infestation	3
2.	Biochemical changes during storage, Grain storage capacity estimation models	2
3.	Factors affecting losses, Storage requirements	2
4.	Bag and bulk storage, godowns, bins and silos, Selection of storage type, Deep and shallow bins	3
5.	Rat proof godowns and rodent control, method of stacking, preventive method, bio-engineering properties of stored products	2
6.	Functional, structural and thermal design of structures, aeration system.	2
7.	Grain markets- Recent reforms, Continued constraints to grain market integration, Rice and wheat marketing channels in India, Import, export and food policy, Food grains management system	2
8.	Cold storage,Controlled and modified atmosphere storage, Effects of nitrogen, oxygen, and carbon dioxide on storage of durable and perishable commodities.	3
9.	Food irradiation, Storage of dehydrated products, Food spoilage and preservation, BIS standards.	2
10.	Physical factors influencing flow characteristics, Rolling resistance, Mechanics of bulk solids - Shear apparatus for determination of flow properties, Yield locus, Time yield locus and effective yield locus.	3
11.	Flow through hoppers, openings and ducts – Types of flow along bins or hopper wall, Flow function and Critical flow factor, Critical dimensions of hopper openings;	2
12.	Material handling equipment, Design of belt, chain, screw, roller, pneumatic conveyors and bucket elevators.	4
13.	Principles of fluidization, recent advances in handling of food materials.	2
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Determination of angle of repose	1
2.	Determination of coefficient of internal friction	1
3.	Determination of coefficient of external friction	1
4.	Physical factors influencing flow characteristics	1

S. No	Topic	No. of Practicals
5.	Determination of flow properties using Shear apparatus	1
6.	Determination of Yield locus, Time yield locus and effective yield locus from Mohr's circle	1
7.	Flow through hoppers, openings and ducts	1
8.	Design of belt conveyors	1
9.	Design of chain conveyors	1
10.	Design of screw conveyors	1
11.	Design of bucket elevators	1
12.	Design of roller conveyors	1
13.	Design of pneumatic conveyors	1
14.	Principles of fluidization	1
15.	Recent advances in handling of food materials	2
	Total	16

X. Suggested Reading

- Boumans. 1985. *Grain Handling and Storage.* Elsevier.
- FAO. 1984. *Design and Operation of Cold Stores in Developing Countries*. FAO.
- Golob. 2002. *Crop Post-Harvest: Science and Technology*. Vol 1 Wiley-blackwell.
- Hall CW. 1970. *Handling and Storage of Food Grains in Tropical and Sub-Tropical Areas*. FAO Publisher Oxford & IBH.
- Henderson S and Perry SM. 1976. *Agricultural Process Engineering*. 5th Ed. AVI Publisher.
- Hodges 2004. *Crop Post-Harvest: Science and Technology*. Vol 2, Wiley-blackwell.
- Ripp BE. 1984. *Controlled Atmosphere and Fumigation in Grain Storage*. Elsevier.
- Shefelt RL and Prussi SE. 1992. *Post Harvest Handling – A System Approach*. Academic Press.
- Vijayaraghavan S 1993. *Grain Storage Engineering and Technology*. Batra Book Service.

I. Course Title : Food Package Engineering

II. Course Code : PFE 506

III. Credit Hours : 1+1

IV. Aim of the course

To acquaint and equip the students with packaging methods, packaging materials, packaging machineries, modern packaging techniques etc.

V. Theory

Unit I

Introduction of packaging: Package, functions and design. Principle in the development of protective packaging. Deteriorative changes in foodstuff and packaging methods of prevention.

Unit II

Food containers: Rigid containers, glass, wooden boxes, crates, plywood and wire bound boxes, corrugated and fibre board boxes, textile and paper sacks, corrosion of containers (tin plate).Flexible packaging materials and their properties.Aluminum as packaging material.Evaluation of packaging material and package performance.

Unit III

Packaging equipment: Food packages, bags, types of pouches, wrappers, carton and other traditional package.Retortable pouches: Shelf life of packaged foodstuff.

Unit IV

Methods to extend shelf life.Packaging of perishables and processed foods. Special problems in packaging of food stuff.

Unit V

Package standards and regulation: Shrink packaging, aseptic packaging, CA and MAP. Biodegradable packaging: Recent advances in packaging, active packaging, smart packaging, antioxidant and antimicrobial packaging, edible films and biodegradable packaging, microencapsulation and nano encapsulation.

VI. Practical

Thickness, substance weight, water absorption capability of flexible packaging materials,strength properties of packaging materials,water vapour and gas transmission rate of flexible packaging materials,identification and chemical resistance of plastic films. Packaging of fruits/vegetables: Estimation of shelf-life of packaged food stuff, familiarization of types of packaging material.

VII. Learning outcome

Student's capability to develop packages for all kinds of food products as per requirement of food industries and thereby adding value to the food products.

VIII. Lectures Schedule

S.No.	Topic	No. of Lectures
1.	Introduction to food packaging, Definition, importance, package, functions of packaging, design.	1
2.	Principle in the development of protective packaging	1
3.	Deteriorative changes in foodstuff, Factors affecting shelf life of foods during storage, interactions of spoilage agents with environmental factors (water, oxygen, light and pH), packaging methods of prevention	1
4.	Food containers: Rigid containers, glass, wooden boxes, crates, plywood and wire bound boxes, corrugated and fibre board boxes, textile and paper sacks, corrosion of containers (tin plate).	1
5.	Flexible packaging materials and their properties. Aluminum as packaging material.	1
6.	Evaluation of packaging material and package performance: Testing methods for flexible, rigid and semi rigid materials. Paper and paper board:thickness, bursting strength, breaking length, stiffness, tear resistance, folding endurance, ply bond and surface oil absorption, Plastic film and laminates: thickness, tensile strength, gloss, haze and burning test to identify polymer, aluminium foil: thickness and pin holes, Glass containers: visual defects, colour, dimensions and impact strength and metal containers: pressure test and product compatibility	3
7.	Packaging equipment for food packages, bags, types of pouches, wrappers, carton and other traditional packages	1
8.	Retortable pouches: Shelf life of packaged foodstuff.	1
9.	Methods to extend shelf life. Packaging of perishables and processed foods	1
10.	Special problems in packaging of food stuff	1
11.	Package standards and regulation: Shrink packaging, aseptic packaging, CA and MAP	2

S.No.	Topic	No. of Lectures
12.	Recent advances in packaging, active packaging, smart packaging, antioxidant and antimicrobial packaging, edible films and biodegradable packaging, microencapsulation and nano encapsulation	2
	Total	**16**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Familiarization of types of packaging material	1
2.	Determination of thickness of different types of packaging materials	1
3.	To determinewater absorption capability of flexible packaging materials	1
4.	Determination of tensile strength of packaging material	1
5.	Determination of compressive strength of packaging material	1
6.	Determination of water vapour transmission rate of packaging material	1
7.	Determination of gas transmission rate of packaging material	1
8.	Identification of different types of plastic films	1
9.	Testing of chemical and grease resistance of packaging materials	1
10.	Determination of bursting strength of packages	1
11.	Drop test for food package strength	1
12.	Vacuum packaging of various food products	1
13.	Nitrogen packaging of food products	1
14.	To study the effect of shrink wrapping onshelf life of fruits and vegetables	1
15.	To study the effect of active modified atmosphere packaging onshelf life of fruits and vegetables	1
16.	Visit to relevant industries	1
	Total	**16**

X. Suggested Reading

- Crosby NT. 1981. *Food Packaging Materials*. Applied Science Publisher.
- Frank A. 1992. *A Handbook of Food Packaging*. Springer.
- Mahadeviah M and Gowramma RV. 1996. *Food Packaging Materials*. Tata McGraw
- Hill.Palling SJ. 1980. *Developments in Food Packaging*. Applied Science Publisher.
- Robertson GL. 2013. *Food Packaging - Principles and Practice*. 3rd Ed Taylor & Francis.
- Sacharow S and Grittin RC. 1980. *Principles of Food Packaging*. AVI Publisher.

I. Course Title : Instrumentation and Sensors in Food Processing

II. Course Code : PFE 507

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with instrumentation and use of sensors in food processing operations.

V. Theory

Unit I

Basic instrumentation systems and transducer principles. Displacement transducers, Potential meters, LDVT, Piezoelectric and capacitive transducers, Digital transducers, velocity transducers.

Unit II

Acceleration and absolute motion measurement, Force transducer, Strain gauge, Hydraulic load cell, Cantilever type and probing ring. Method of separation of force: Torque, power and energy measuring technique.

Unit III

Temperature measurement using bi-metals, thermisters, thermocouples, humidity measurement, manometers. Flow transducer, positive displacement, venturimeter, Rotameter, Drag force, hot wire anemometer.

Unit IV

Theory and classifications of chemical sensors, biosensors, fibre optic sensors, gas sensors etc. Biosensor: Concepts, types of biosensors, methods of immobilizing biosensors, application. Imaging methods: X-ray imaging, Computed tomography, MRI, Ultrasound, Hyperspectral imaging. Spectroscopy and chemometrics: UV and visual spectroscopy, NIR spectroscopy, FTIR spectroscopy.

VI. Practical

Identification of components of generalized measuring system: Calibration of instruments, experiment on LVDT, strain gauge transducer, force, torque, power and pressure, fluid flow rates, temperature, calorific value, vibration measurement.Use of data loggers and data storage devices, spectroscopy, imaging systems.

VII. Learning outcome

Student's capability to control the process operations through precise instrumentation and knowledge of sensors for precision analysis of food quality in food industries.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Basic instrumentation systems	1
2.	Transducer principles	1
3.	Displacement transducers, Potential meters, LDVT, Piezoelectric and capacitive transducers, Digital transducers, velocity transducers.	3
4.	Acceleration and absolute motion measurement, Force transducer, Strain gauge, Hydraulic load cell, Cantilever type and probing ring.	3
5.	Different methods of separation of force: Torque, power and energy measuring technique	3
6.	Temperature measurement using bi-metals, thermistors, thermocouples, humidity measurement, manometers.	3
7.	Flow transducer, positive displacement, venturi meter, Rotameter, Drag force, hot wire anemometer.	2
8.	Theory and classification of chemical sensors, biosensors, fibre optic sensors, gas sensors etc.	4
9.	Biosensor: Concepts, types of biosensors, methods of immobilizing biosensors, application.	3
10.	Imaging methods for foods, Principles, equipment, food applications- X-ray imaging, Computed tomography, MRI, Ultrasound, Hyperspectral imaging.	4
11.	Various methods of spectroscopy and chemometrics, principles, equipment, food applications- UV and visual spectroscopy, NIR spectroscopy, FTIR spectroscopy.	3
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Identification of components of generalized measuring system for temperature, pressure, relative humidity, moisture etc.	1
2.	Calibration of moisture measuring equipment	1
3.	Calibration of temperature control and measuring devices	1
4.	To study the working of Bourdon Pressure Gauge and to check the calibration of the gauge in a deadweight pressure gauge calibration set up.	1
5.	To study various temperature measuring instruments e.g. Mercury-in-glass thermometer, Thermocouple, Electrical resistance thermometer, laser thermometer and to estimate their response times	1
6.	To determine the calorific value of different food products using a bomb calorimeter having temperature sensing device	1
7.	To study a Linear Variable Differential Transformer (LVDT) and use it in a simple experimental set up to measure a small displacement	1
8.	To measure torque of a rotating shaft using torsion meter/strain gauge torque transducer	1
9.	To measure the speed of a motor shaft with the help of non-contact type pick-ups (magnetic or photoelectric)	1
10.	To measure static/dynamic pressure of fluid in pipe/tube using pressure transducer/pressure cell	1
11.	To determine the hardness/firmness of food samples using a texture analyzer	1
12.	To study the effect of vibrations during transportation on the quality of food (damage/ bruising/ texture etc) using a simulated vibration test	1
13.	To study and use the data logging and data storage devices	1
14.	To study and understand the working principle of UV and visual spectroscopy for measurement of food properties	1
15.	To study and understand the working principle of NIR and FTIR spectroscopy for measurement of food properties	1
16.	To study the working principle of X-ray imaging, Computed tomography, MRI, Ultrasound and Hyperspectral imaging for measurement of food quality	1
	Total	**16**

X. Suggested Reading

- Doebelin EO. 1990. *Measurement Systems Applications and Design*. Tata McGraw Hill.
- Erika KR and Brimelow JB. 2001. *Instrumentation and Sensors for the Food Industry*. CRC Woodhead.
- Nakra BC and Chaudhary KK. 2004. *Instrumentation Measurement and Analysis*. Tata McGraw Hill.
- Mukhopadhyay. 2014. *Novel Sensors for Food Inspection: Modelling, Fabrication and Experimentation.* Springer.
- Mukhopadhyay SC. 2017. *Sensors for Everyday Life*. Springer.
- Paré JRJ and Bélanger JMR. 1997. *Instrumental Methods in Food Analysis*. Elsevier Academic Press.

I. Course Title : Application of Engineering Properties in Food Processing

II. Course Code : PFE 508

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint the students with different techniques of measurement of engineering properties and their application in the design of processing equipment.

V. Theory

Unit I

Physical characteristics of different food grains, fruits and vegetables: Shape and size, description of shape and size, volume and density, porosity, surface area. Rheology: ASTM standard, terms, physical states of materials, classical ideal material, rheological models and equations, viscoelasticity, creep-stress relaxation, non-Newtonian fluid and viscometry, rheological properties, force, deformation, stress, strain, elastic, plastic behaviour.

Unit II

Contact stresses between bodies, Hertz problems, firmness and hardness, mechanical damage, dead load and impact damage, vibration damage, friction, effect of load, sliding velocity, temperature, water film and surface roughness. Friction in agricultural materials, rolling resistance, angle of internal friction, angle of repose, flow of bulk granular materials, aero dynamics of agricultural products, drag coefficients, terminal velocity.

Unit III

Thermal properties: Specific heat, thermal conductivity, thermal diffusivity, methods of determination, steady state and transient heat flow. Electrical properties: Dielectric loss factor, loss tangent, A.C. conductivity and dielectric constant, method of determination, energy absorption from high frequency electric field.

Unit IV

Application of engineering properties in design and operation of agricultural equipment and structures.

VI. Practical

Experiments for the determination of physical properties like length, breadth, thickness, surface area, bulk density, porosity, true density, coefficient of friction, angle of repose and colour for various food grains, fruits, vegetables, spices and processed foods, aerodynamic properties like terminal velocity, lift and drag force for food grains, thermal properties like thermal conductivity, thermal diffusivity and specific heat. Rheological properties: firmness and hardness of grain, fruits and stalk, electrical properties like dielectric constant, dielectric loss factor, loss tangent and A.C. conductivity of various food materials.

VII. Learning outcome

Student's capability to apply properties of food for design of equipment and structures.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Physical characteristics of different food grains, fruits and vegetables: Shape and size, description of shape and size.	3
2.	Volume and density, porosity, surface area.	1
3.	Rheology: ASTM standard, terms, physical states of materials, classical ideal material.	2
4.	Rheological models and equations, visco elasticity.	2
5.	Creep-stress relaxation, non-Newtonian fluid and viscometry.	1
6.	Rheological properties, force, deformation, stress, strain, elastic, plastic behavior.	1
7.	Contact stresses between bodies, Hertz problems, firmness and hardness	1
8.	Mechanical damage, dead load and impact damage.	2
9.	Vibration damage, friction, effect of load, sliding velocity.	1
10.	Temperature, water film and surface roughness.	1
11.	Friction in agricultural materials, rolling resistance, angle of internal friction, angle of repose.	2
12.	Flow of bulk granular materials.	1
13.	Aero dynamics of agricultural products, drag coefficients, terminal velocity.	3
14.	Thermal properties: Specific heat, thermal conductivity, thermal diffusivity.	1
15.	Methods of determination, steady state and transient heat flow	1
16.	Electrical properties: Dielectric loss factor, loss tangent.	1
17.	A.C. conductivity and dielectric constant, method of determination.	2
18.	Energy absorption from high frequency electric field.	1
19.	Application of engineering properties in design and operation of agricultural equipment and structures.	3
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	To determine the size of grains, pulses, oil seeds, spices, fruits and vegetables.	1
2.	To determine the shape of various food grains and fruits and vegetables.	1
3.	To determine the bulk density of food grains and fruits and vegetables.	1
4.	To determine the particle density/true density and porosity of solid grains.	1
5.	To study the comparison pycnometer for finding the particle density of food grains.	1
6.	To determine the angle of repose of grains, oilseeds etc.	1
7.	To find the coefficient of external friction for different food grains.	1
8.	To determine the coefficient of internal friction of different food grains.	1
9.	To plot the normal stress vs. sheet stress curves for different food grains.	1
10.	To study the separating behaviour of a grain sample in a vertical wind tunnel (Aspirator column).	1
11.	To study the thermal properties (thermal conductivity, thermal diffusivity and specific heat) of food grains.	2

S.No.	Topic	No. of Practicals
12.	To determine the Rheological properties: firmness and hardness of grain, fruits, stalk and vegetables.	1
13.	To study the electrical properties (dielectric constant, dielectric loss factor) of various food materials.	1
14.	To study the electrical properties (loss tangent and A.C. conductivity) of various food materials.	1
	Total	**15**

X. Suggested Reading

- Ludger F and Teixeira AA. 2007. *Food Physics Physical Properties - Measurement and Application*. Springer.
- Mohesenin NN. 1980. *Thermal Properties of Foods and Agricultural Materials*. Gordon and Breach Science Publisher.
- Mohesenin NN. 1980. *Physical Properties of Plant and Animal Materials*. Gordon & Breach Science Publisher.
- Peleg M and Bagelay EB. 1983. *Physical Properties of Foods*. AVI Publisher.
- Peter B. 2007. *The Chemical Physics of Food*. Wiley-Blackwell.
- Rao MA and Rizvi SSH. 1986. *Engineering Properties of Foods*. Marcel Dekker.
- Singhal OP and Samuel DVK. 2003. *Engineering Properties of Biological Materials*. Saroj Prakasan.
- Sitkei. 1986. *Mechanics of Agricultural Materials*. Elsevier.

I. Course Title : Food Quality and Safety

II. Course Code : PFE 509

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with the latest standards to maintain food quality and safety.

V. Theory

Unit I

Food safety:Need for quality control and safety, strategy and criteria, microbiological criteria for safety and quality, scope of food toxicology, toxic potential and food toxicants, biological and chemical contaminants.

Unit II

Food additives and derived substances, factors affecting toxicity, designing safety in products and processes, intrinsic factors, establishing a safe raw material supply, safe and achievable shelf life.

Unit III

Process equipment and machinery auditing, consideration of risk, environmental consideration, mechanical quality control.

Unit IV

Personnel hygienic standards, preventative pest control, cleaning and disinfesting system, biological factors underlying food safety.

Unit V

Preservation and stability, contaminants of processed foods, adulteration, prevention and control, FSSAI, ISO, Codex, GMP, BIS and HACCP.Practices, principles, standards, specifications, application establishment and implementation, HACCP and quality management system.Food Safety Management Systems (FSMS), Traceability.

VI. Practical

Microbiological examination of food, hazard analysis, premises design, HACCP project plan, CCP, CCP Decision tree, HACCP control chart. HACCP case studies: Survey, BIS, FPO, Codex standards and specifications. Visits to food industries to study the various quality and safety aspects adopted.

VII. Learning outcome:

Student's capability to measure food quality as well as ensure food safety in food supply chain.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Food safety: Need for quality control and safety, strategy and criteria.	2
2.	Microbiological criteria for safety and quality.	1
3.	Scope of food toxicology, toxic potential and food toxicants.	2
4.	Biological and chemical contaminants.	1
5.	Food additives and derived substances, factors affecting toxicity.	2
6.	Designing safety in products and processes, intrinsic factors.	2
7.	Establishing a safe raw material supply, safe and achievable shelf life.	2
8.	Process equipment and machinery auditing.	1
9.	Consideration of risk, environmental consideration. Biological factors underlying food safety.	2
10.	Personnel hygienic standards, preventative pest control. Cleaning and disinfesting system.	2
11.	Preservation and stability, contaminants of processed foods, adulteration, prevention and control	3
12.	FSSAI-Practices, principles, standards, specifications, application establishment and implementation	2
13.	ISO-Practices, principles, standards, specifications, application establishment and implementation.	2
14.	Codex, GMP and BIS - Practices, principles, standards, specifications, application establishment and implementation.	3
15.	HACCP and quality management system.	1
16.	Food Safety Management Systems (FSMS), Traceability.	2
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	To test microbiological contamination of food.	1
2.	To conduct hazard analysis.	2
3.	To study the premises design for food safety and quality.	2
4.	To study the HACCP project plan.	1
5.	To prepare CCP and CCP Decision tree.	2

S.No.	Topic	No. of Lectures
6.	To prepare HACCP control chart.	2
7.	To conduct the Survey and study BIS- standards and specifications.	2
8.	To study the FPO standards and specifications.	1
9.	To study the codex standards and specifications.	1
10.	Visits to food industries to study the various quality and safety aspects adopted.	2
	Total	**15**

X. Suggested Reading

- Herschdoerfer, SM. 1984. *Quality Control in the Food Industry*. Vol. 1 Academic Press.
- Herschdoerfer SM. 2012. *Quality Control in the Food Industry*. Vol. 2 Elsevier Science.
- Hubbard MR. 2003. *Statistical Quality Control for the Food Iindustry*. Springer.
- Mahadeviah M and Gowramma R V. 1996. *Food Packaging Materials*. Tata McGraw Hill.
- Mehmet M. 2011. *Biosensors in Food Processing, Safety, and Quality Control*. CRC Press.
- Palling SJ. 1980. *Developments in Food Packaging*. Applied Science Publisher.
- Sacharow S and Grittin RC. 1980. *Principles of Food Packaging*. AVI Publisher.
- Yanbo H, Whittaker AD and Lacey RE. 2001. *Automation for Food Engineering*. Food Quality Quantization and Process Control-CRC Press.

I. Course Title : Food Processing Technologies

II. Course Code : PFE 510

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with different unit operations to be performed in food industries and related equipment.

V. Theory

Unit I

Mixing and homogenization; Principles of solid and liquid mixing, types of mixers for solids, liquid and pastes homogenization. Emulsification: Principles and equipments.

Unit II

Novel dehydration technologies; Osmotic dehydration, foam mat drying, puff drying, freeze drying, microwave drying, dehumidified air drying. Extrusion: Theory, equipment, applications.

Unit III

Non-thermal processing; Principles and equipment involved in ohmic heating, pulsed electric field preservation, hydrostatic pressure technique (vacuum processing, high pressure processing of Foods), ultrasonic technology, irradiation, quality changes and effects on microorganisms, nanotechnology in food processing.

Unit IV

Distillation, leaching and extraction: Principles and equipment for distillation, crystallization, phase equilibria, multistage calculations, leaching principles and equipment, solvent extraction, super-critical fluid extraction, near critical fluid extraction: Equipment and experimental techniques used in NCF extraction and

industrial application, advanced methods for extraction of food components and aroma recovery.

Unit V

Food plant hygiene; Cleaning, sterilizing, waste disposal methods, Food processing plant utilities, steam requirements in food processing, HACCP in food processing industries.

VI. Practical

Conducting experiments and solving problems on mixing and mixing indices, homogenization, distillation, crystallisation, extraction, leaching, membrane separation, reverse osmosis and ultrafiltration, design of plate and packed tower, visit to related food industry.

VII. Learning outcome

Student's capability to develop food products using recent techniques as per requirement of food industries.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Mixing and homogenization: Principles of solid and liquid mixing.	1
2.	Types of mixers for solids, liquid and pastes homogenization.	2
3.	Emulsification: Principles and equipments.	1
4.	Novel dehydration technologies: Osmotic dehydration, foam mat drying, puff drying.	2
5.	Freeze drying, microwave drying, and dehumidified air drying.	2
6.	Extrusion: Theory, equipment, applications.	2
7.	Non-thermal processing: Principles and equipment involved in ohmic heating, pulsed electric field preservation.	2
8.	Hydrostatic pressure technique (vacuum processing, high pressure processing of Foods), ultrasonic technology.	2
9.	Irradiation, quality changes and effects on microorganisms, nanotechnology in food processing.	2
10.	Distillation; Principles and equipment for distillation.	2
11.	Leaching; Principles and equipment.	2
12.	Extraction; Solvent extraction, crystallization, phase equilibria, multistage calculations.	3
13.	Super-critical fluid extraction, near critical fluid extraction: Equipment and experimental techniques used in NCF extraction and industrial application.	3
14.	Advanced methods for extraction of food components and aroma recovery.	1
15.	Food plant hygiene; Cleaning, sterilizing, waste disposal methods. Food processing plant utilities, steam requirements in food processing.	2
16.	HACCP in food processing industries.	1
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Conducting experiments and solving problems on mixing and mixing indices.	2
2.	To conduct the experiment on homogenization.	2
3.	To study the process of crystallization.	1
4.	To conduct the experiment on extraction.	2
5.	Experimentation on leaching process.	1
6.	To study the membrane separation process.	1
7.	To conduct the experiment on reverse osmosis technique.	1
8.	To conduct the experiment on ultrafilteraion process.	1
9.	Design of plate and packed tower.	2
10.	Visit to related food industry.	2
	Total	**15**

X. Suggested Reading

- Brennan JG, Butters JR, Cowell ND and Lilly AEI 1990. *Food Engineering Operations*. Elsevier.
- Earle RL. 1985. *Unit Operations in Food Processing*. Pergamon Press.
- Fellows P. 1988. *Food Processing Technology: Principle and Practice*. VCH Publisher.
- Geankoplis JC. 1999. *Transport Process and Unit Operations*. Allyn & Bacon.
- Gould GW. 1996. *New Methods of Food Preservation*. Blackie Academic & Professional.
- Heldman DR and Lund BD. 1992. *Hand Book of Food Engineering*. Marcel Dekker.
- McCabe WL and Smith JC. 1999. *Unit Operations of Chemical Engineering*. McGraw Hill.
- Sahay KM and Singh KK. 1994. *Unit Operation of Agricultural Processing*. Vikas Publ. House.
- Singh RP 1991. *Fundamentals of Food Process Engineering*. AVI Publisher.
- Singh RP and Heldman DR 1993. *Introduction to Food Engineering*. Academic Press.

I. Course Title : Food Processing Equipment and Plant Design

II. Course Code : PFE 511

III. Credit Hours : 1+1

IV. Aim of the course

To acquaint and equip the students with the design features of different food processing equipment being used in the industries along with the layout, planning of different food processing plants.

V. Theory

Unit I

Design considerations of processing agricultural and food products.

Unit II

Design of machinery for drying, milling, separation, grinding, mixing, evaporation, condensation, membrane separation.

Unit III

Human factors in design, selection of materials of construction and standard component, design standards and testing standards. Plant design concepts and general design considerations: Plant location, location factors and their interaction with plant location, location theory models, and computer aided selection of the location.

Unit IV

Feasibility analysis and preparation of feasibility report; Plant size, factors affecting plant size and their interactions, estimation of break-even and economic plant size. Product and process design, process selection, process flow charts, computer aided development of flow charts.

Unit V

Hygienic design aspects and worker's safety, functional design of plant building and selection of building materials, estimation of capital investment, analysis of plant costs and profitability's, management techniques in plant design including applications of network analysis, preparation of project report and its appraisal.

VI. Practical

Detailed design and drawing of mechanical dryers, milling equipment, separators, evaporators, mixers and separators. Each individual student will be asked to select a food processing plant system and develop a plant design report which shall include product identification and selection, site selection, estimation of plant size, process and equipment selection, process flow-sheeting, plant layout, and its evaluation and profitability analysis.

VII. Learning outcome

Student's capability to deal with food processing equipment and plant, techno-economic feasibility analysis of the project as needed in food industries.

VIII. Lecture Schedule

S.No.	Toic	No. of Lectures
1.	Design considerations of processing agricultural and food products. Plant design concepts - situations giving rise to plant design problems.	2
2.	General design considerations, Food Processing Unit Operations, Design of machinery for drying, milling and grinding	2
3.	Design principles of separation, mixing machines	1
4.	Design of evaporation, condensation, membrane separation machines	2
5.	Human factors in design, selection of materials of construction and standard component	1
6.	Design standards and testing standards	1
7.	Plant location, location factors and their interaction with plant location, location theory models, and computer aided selection of the location.	2
8.	Pre Selection/ Pre feasibility stage, Analysis Stage: Market Analysis, Situational analysis related to market	1
9.	Technical analysis, Financial Analysis, Sensitivity and risk analysis, Feasibility cost estimates	1
10.	Break Even Analysis: Introduction, Break-Even Chart, Fixed Costs, Variable costs, Breakeven point calculation	1
11.	Product and process design, process selection, process flow charts, computer aided development of flow charts.	1
12.	Hygienic design aspects and worker's safety, functional design of plant building and selection of building materials	1
13.	Estimation of capital investment, analysis of plant costs and profitability's. Management techniques in plant design including applications of network analysis. Project report and its appraisal.	2
	Total	**18**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Detailed design and drawing of mechanical dryers	2
2.	Detailed design and drawing of milling equipment	2
3.	Design of separators	2
4.	Design of evaporators	2
5.	Design of mixers and separators	2
6.	Project report preparation by students. (Individual student will select a processing plant, develop design report include product identification, site selection, estimation of plant size, process and equipment, process flow-sheeting, plant layout, its evaluation and profitability analysis	5
	Total	**15**

X. Suggested Reading

- Antonio LG and Gustavo VBC. 2005. *Food Plant Design*. CRC Press.
- Couper. 2012. *Chemical Process Equipment*. Selection and Design Elsevier.
- George S and Athanasios EK. 2015. *Handbook of Food Processing Equipment*. Springer.
- Lloyd EB and Edwin HY. 1959. *Process Equipment Design*. Wiley-Interscience.
- Michael MC. 2013. *Food Plant Sanitation: Design, Maintenance, and Good Manufacturing Practices*. CRC Press.

I. Course Title : Seed Process Engineering

II. Course Code : PFE 512

III. Credit Hours : 1+1

IV. Aim of the course

To acquaint and equip the students with seed processing along with the design features of the equipment used in their processing.

V. Theory

Unit I

Processing of different seeds and their engineering properties, principles and importance of seed processing.

Unit II

Performance characteristics of different unit operations such as precleaning, grading, conveying, elevating, drying, treating, blending, packaging and storage, seed processing machines like scalper, debreader, huller, velvet separator, spiral separator, cleaner-cum-grader, specific gravity separator, indent cylinder, disc separator, and colour sorter, seed treater, weighing and bagging machines, their operation and maintenance, installation and determination of their capacity, seed quality maintenance during processing, plant design and layout, economy and safety consideration in plant design.

Unit III

Seed drying principles and methods, theory of seed drying, introduction to different types of heated air dryers, significance of moisture equilibrium, method of maintaining safe seed moisture, thumb rule and its relevance.

Unit IV

Importance of scientific seed storage, types of storage structures to reduce temperature and humidity, management and operation/cleanliness of seed stores, packaging-principles, practices, materials and hermetic packaging, seed treatment methods and machines used, method of stacking and their impact, design features of medium and long term seed storage building.

VI. Practical

Study of various seed processing equipments such as pre-cleaners, scalpers, air screen cleaners, graders, spiral and pneumatic separators, seed treating equipment, bag closures, scale etc. and their performance evaluation, design and layout of seed processing plant and its economics, analysis of cost of operation and unit cost of processed product, effect of drying temperature and duration of seed germination and storability.

VII. Learning outcome

Student's capability to understand processing and storage requirement of seed maintaining its vigor and viability, suitable equipment for seed processing as per requirement of seed industries.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Processing of different seeds and their engineering properties.	1
2.	Principles and importance of seed processing.	1
3.	Performance characteristics of different unit operations such as pre-cleaning, grading, conveying, elevating, drying.	1
4.	Treating, blending, packaging and storage, seed processing machines like scalper, de-breeder, huller.	1
5.	Velvet separator, spiral separator, cleaner-cum-grader, specific gravity separator, indent cylinder, disc separator, and colour sorter.	1
6.	Seed treater, weighing and bagging machines, their operation and maintenance, installation and determination of their capacity.	1
7.	Seed quality maintenance during processing.	1
8.	Plant design and layout, economy and safety consideration in plant design.	2
9.	Seed drying principles and methods, theory of seed drying.	1
10.	Introduction to different types of heated air dryers.	1
11.	Significance of moisture equilibrium, method of maintaining safe seed moisture, thumb rule and its relevance.	1
12.	Importance of scientific seed storage, types of storage structures to reduce temperature and humidity.	1
13.	Management and operation/cleanliness of seed stores, packaging-principles, practices, materials and hermetic packaging.	1
14.	Seed treatment methods and machines used, method of stacking and their impact.	1
15.	Design features of medium and long term seed storage building.	1
	Total	**16**

IX. List of Practical

S.No.	Topic	No. of Practicals
1.	To study seed processing equipment such as pre-cleaners, scalpers and their performance evaluation.	2
2.	To study graders and their performance evaluation.	2
3.	To study air screen cleaners and their performance evaluation.	1
4.	To study spiral and pneumatic separators and their performance evaluation.	2
5.	To study seed treating equipment, bag closures, scale and their performance evaluation.	2
6.	To study design and layout of seed processing plant and its economics.	2
7.	To analyze the cost of operation and unit cost of processed product.	2
8.	To study the effect of drying temperature and duration of seed germination and storability.	2
	Total	**15**

X. Suggested Reading

- Babasaheb. 2004. *Seeds Handbook: Processing and Storage.* CRC.
- Gregg *et al.* 1970. *Seed Processing*. NSC.
- Guar. 2012. *A Handbook of Seed Processing and Marketing* Agrobios.
- Henderson S and Perry S M. 1976. *Agricultural Process Engineering*. 5th Ed. AVI Publisher.
- Mathad. 2017. *Seed Processing: A Practical Approach.* NIPA.
- Sahay KM and Singh KK. 1994. *Unit Operation of Agricultural Processing*. Vikas Publisher House.
- Vaugha. 1968. *Seed Processing and Handling*.https://www.mcia.msstate.edu/pdf/seed-processing-and-handling_1.pdf.

I. Course Title : Agri-Project Planning and Management

II. Course Code : PFE 513

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with the techniques of project development and evaluation along with different standards.

V. Theory

Unit I

Project development, market survey and time motion analysis.

Unit II

Selection of equipment, technology option, techno-economic feasibility and processing in production catchment.

Unit III

Product and process design, PERT, CPM, transport model, simplex, linear and dynamic programming, operation log book. Material balance and efficiency analysis, performance testing, performance indices, energy requirement and consumption. Marketing of agricultural products, market positioning.

Unit IV

BIS/FSSAI/ISO standards/ guidelines on best practices, equipment and their design and operation for handling, processing and storage of food/feed.

VI. Practical

Preparation of project and feasibility report. Salient features, design and layout of different food processing units; MSME, large processing unit. Record keeping related to production, finance and marketing. Techno-economic feasibility and SWOT analysis for Start-ups.

VII. Learning outcome

Student's capability to plan, scheduling of activities and manage a food related project as per requirement of food industries.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Project development.	2
2.	Market survey and time motion analysis.	2
3.	Selection of equipment for agro project planning.	2
4.	Technology option.	2
5.	Techno-economic feasibility and processing in production catchment.	2
6.	Product and process design.	2
7.	PERT, CPM.	2
8.	Transport model, simplex, linear and dynamic programming, operation log book.	3
9.	Material balance and efficiency analysis.	3
10.	Performance testing, performance indices, energy requirement and consumption.	3
11.	Marketing of agricultural products, market positioning.	2
12.	BIS/FSSAI/ISO standards/ guidelines on best practices.	2
13.	Equipment and their design and operation for handling, processing and storage of food/feed.	3
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	To study the preparation of project and feasibility report.	2
2.	To design salient features, design and layout of MSME.	2
3.	Design and layout of different food processing units: MSME, large processing unit.	2
4.	To study record keeping related to production.	2
5.	To study record keeping related to finance and marketing.	2
6.	To conduct experiment on agro project management and design techno-economic feasibility.	2
7.	To conduct SWOT analysis for different Start-ups.	3
	Total	**15**

X. Suggested Reading

- Ahmed T. 1997. *Dairy Plant Engineering and Management*. 4th Ed. Kitab Mahal.
- Albert L. 2017. *Project Management, Planning and Control*.
- Anandajayasekeram P. 2004. *Agricultural Project Planning and Analysis*.

I. Course Title : Farm Structures and Environmental Control

II. Course Code : PFE 514

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with the different types of farm structures and techniques, to control atmospheric parameters and to create favourable environment in the agricultural structures.

V. Theory

Unit I

Farmstead planning, survey and data collection for information bank. Analysis of data, Lay outs. Cost estimation and appraisal. Project development; Time, motion and input analysis, flow charts and drawings andcase studies.

Unit II

Farm structures (farmstead, livestock, poultry, storage godowns, farm machinery storage, biogas, green house, net house etc), their design, constructional details and design of low cost structures. Heating, ventilating and exhaust systems, air distribution and air cleaning, combustion of fuels and equipment.

Unit III

Drying and dehumidification system, air-water contact operations and evaporation, process and product air conditioning, energy efficient environmental control practices. Rural electrification, households electric wiring, rural water supply and sanitation.

Unit IV

Instruments and measurements:Codes and standards.

VI. Practical

Calculation of heating and cooling load,design calculation of moisture condensation in agricultural buildings, study of moisture migration behaviour in storage bins, design aspect of green house, net house, septic tank, grain storage structures, cold storage.

VII. Learning outcome

Student's capability to design new farm structures and create suitable atmosphere within it.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Farmstead Planning, types and objectives. Planning principles and layout, design and construction of farmstead.	2
2.	Survey and data collection for information bank. Analysis of data, Lay outs. Cost estimation and appraisal.	2
3.	Project development: Time, motion and input analysis, flow charts and drawings and case studies.	2
4.	Farm structure, layout and structural design of shelters for dairy animals (cow, buffaloes, calves, bulls etc).	3
5.	Layout and structure design of modern poultry houses (cage type) along with other associated structures.	2

S.No.	Topic	No. of Lectures
6.	Familiarization with various rural grain storage structures. Layout, design and constructional detail of grain and feed storage structures like bins and silos.	3
7.	Layout and structural design of storage structures for farm inputs like farm machinery, seeds, weedicides, insecticides and fertilizers.	1
8.	Ventilation utility in farm buildings; principles of natural ventilation; psychometric processes; heat and mass balance equation for ventilation; ventilation rates for temperature moisture and odour control.	3
9.	Rural electrification, households electric wiring, rural water supply and sanitation.	2
10.	General design considerations, operational and maintenance of biogas plant.	2
11.	Drying and dehumidification system, air-water contact operations and evaporation, process and product air conditioning, energy efficient environmental control practices.	3
12.	Environmental indices like THI; wet bulb depression, daily range, degree days, effective temperature, black globe temperature; mean radiant temperature, etc. Basic solar-earth angles and sol-air temperature.	3
13.	Instruments and measurements; Codes and standards.	2
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Planning and layout of a farmstead.	1
2.	Instruments for measurements of environmental parameters.	1
3.	Design of a farm fencing system.	1
4.	Study of moisture migration behaviour in storage bins.	1
5.	Design aspect of Septic tank.	1
6.	Design aspect of Net house.	1
7.	Design aspect of Grain storage structures.	1
8.	Design aspect of Green house.	1
9.	Design aspect of Cold storage.	1
10.	Design of a feed/fodder storage structures.	1
11.	Design of a biogas plant.	1
12.	Calculation of heating and cooling load.	1
13.	Design calculation of moisture condensation in agricultural buildings.	1
14.	Design of ventilation system for dairy and poultry house.	1
15.	Visit to Green/ Net house and cold storage.	2
	Total	**16**

X. Suggested Reading

- Albright LD. 1990. *Environmental Control for Animals and Plants*. ASAE Textbooks.
- Esmay ML and Dixon JE. 1986. *Environmental Control for Agricultural Buildings*. The AVI Corp.
- Gaudy AF and Gaudy ET. 1988. *Elements of Bioenvironmental Engineering*. Engineering Press.
- Moore FF. 1994. *Environmental Control Systems: Heating, Cooling, Lighting*. Chapman and Hall.
- Threlkeld JL. 1970. *Thermal Environmental Engineering*. Prentice Hall.

I. Course Title : Dairy Product Processing

II. Course Code : PFE 515

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with the various dairy products, processing methods and related equipment.

V. Theory

Unit I

Procurement, transportation and processing of market milk, cleaning and sanitization of dairy equipment. Special milks such as flavoured, sterilized, recombined and reconstituted toned and double toned.

Unit II

Condensed milk: Methods of manufacture and related equipment, evaluation of condensed and evaporated milk. Dried milk: Definition, methods of manufacture of skim and whole milk powder, instantiation, physiochemical properties, evaluation, defects in dried milk powder. Cream: Cream separation, neutralization, sterilization, pasteurization and cooling of cream, defects in cream, Butter: methods of manufacture, defects in butter.

Unit III

Ice cream: Methods of manufacture and related equipment, defects in ice cream, technology of softy manufacture. Cheese: Methods of manufacture, cheddar, Gouda, cottage and processed cheese, defects in cheese.

Unit IV

Indigenous milk products: Method of manufacture of *yoghurt, dahi, khoa, burfi, kalakand, gulabjamun, rosogolla, srikhand, chhana, paneer, ghee, lassi*etc.Probiotic milk product.

VI. Practical

Estimation and fat and SNF in milk.Operation of LTLT and HTST Pasteurization. Preparation of special milks.Cream separation and standardization of milk. Preparation and evaluation of table butter, ice-cream, cheese and indigenous milk product such as *khoa, chhana, paneer, ghee, rosogolla, gulabjamun, shrikhand, lassi, burfi,* etc. Visit to dairy plants.

VII. Learning outcome

Student's capability to mechanize processing operations in dairy industries for manufacturing of dairy products.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Collection and transportation of milk; Practices for collection of milk, preservation at farm, refrigeration, natural microbial inhibitors, lactoperoxidase system.	1
2.	Reception and treatment of milk: Reception, chilling, clarification and storage. General practices. Homogenization: pretreatments, theories, synchronization of homogenizer with operation of pasteurizer (HTST),	

S.No.	Topic	No. of Practicals
	effect of homogenization on physical properties of milk. Bactofugation: Theory and microbiology.	**3**
3.	Principles of thermal processing; kinetics of microbial destruction, thermal death curve, arrhenius equation, D value, Z value, F0 value, Q10 value. Factors affecting thermal destruction of micro organisms. Definition and description of processes; Pasteurization, thermisation, sterilization, UHT Processing.	**2**
4.	Cleaning and sanitization of dairy equipment	**1**
5.	Manufacture of special milks: flavoured, sterilized milk, recombined and reconstituted toned and doubled toned.	**2**
6.	Condensed milk, sweetened condensed milk and evaporated milk. Manufacture of evaporated milk, sweetened condensed milk and Recombined sweetened condensed milk and related equipment	**2**
7.	Physico chemical changes taking place during manufacture of condensed milk, Heat stability of milk and condensed milk, Physico chemical properties of condensed milk, Chemical defects in condensed milk, their causes and prevention.	**2**
8.	Dried Milks; Definition, grading and quality of raw milk for dried milks, Manufacture of skim milk powder (SMP), whole milk powders and heat classified powders,	**2**
9.	Physico chemical changes taking place during manufacture of dried milks, Physical properties of dried milks, Defects in dried milk during manufacture and storage, their causes and prevention.	**2**
10.	Cream: Definition, Efficiency of cream separation and factors affecting it; Neutralization, standardization, pasteurization and cooling of cream; Defects in cream	**2**
11.	Butter; Definition, Introduction to the butter making process; theory of churning, Technology of Butter manufacture, Batch and continuous methods, Defects in butter.	**2**
12.	History of ice cream industry, composition of ice cream, stabilizers and emulsifiers, properties and role in quality of ice cream Ice cream:	**1**
13.	Manufacturing, Ice cream plant components, Types of freezers, refrigeration control/ instrumentation, Technology of softy manufacture.	**2**
14.	Defects in ice cream, their causes and prevention	**1**
15.	Cheese; Manufacture of different varieties of cheese; Cheddar, Gouda, Cottage and processed cheese. Microbiological defects in cheese; their causes and prevention.	**3**
17.	Indigenous milk products: Product description, methods of manufacture of *yoghurt, dahi, khoa, burfi, kalakand, gulabjamun, rosogolla, srikhand, chhana, paneer, ghee, lassi*etc. Probiotic milk product.	**2**
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Estimation of fat and SNF in milk.	1
2.	Operation of LTLT and HTST Pasteurizer.	1
3.	Standardization of milk.	1
4.	Preparation of special milks.	1
5.	Cream separation: parts of separator and the process.	1
6.	Preparation of table butter using the power driven churn.	1
7.	Preparation of plain and fruit flavoured ice cream.	1

S.No.	Topic	No. of Practicals
8.	Preparation and analysis of *khoa* from cow and buffalo milk.	1
9.	Preparation and analysis of *chhana* from cow and buffalo milk.	1
10.	Preparation and analysis of *paneer* from cow and buffalo milk.	1
11.	Preparation and analysis of*lassi*from cow and buffalo milk.	1
12.	Preparation of *ghee* from cream and butter.	1
13.	Preparation of *rosogolla* and *gulabjamun.*	1
14.	Preparation of srikhand and burfi.	1
15.	Visit to dairy plant.	1
	Total	**15**

X. Suggested Reading

- Adnan T. 2009. *Dairy Powders and Concentrated Products* (*Society of Dairy Technology*). Wiley-Blackwell.
- Adnan T. 2006. *Probiotic Dairy Products* (*Society of Dairy Technology series*). Wiley-Blackwell.
- Britz. 2008. *Advanced Dairy Science and Technology*. Blackwell Publisher: Blackwell Publisher Professional.
- De. 2001. *Outlines of Diary Technology*. Oxford.
- Hui YH. 1992. *Dairy Science and Technology Handbook*. Vol. I, II and III Wiley.
- Spreer E. 2017. *Milk and Dairy Product Technology*. Taylor and Francis.
- Walstra P, Jan TM, Wouters and Geurts TJ. 2006. *Dairy Science and Technology*. CRC, Taylor and Francis.

I. Course Title : Processing of Meat, Poultry and Fish

II. Course Code : PFE 516

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with processing of meat, fish and poultry and the design features of the equipment used for their processing.

V. Theory

Unit I

Meat: Genetic engineering of farm animals for better meat quality, automation for the modern slaughterhouse, hot-boning of meat, new spectroscopic techniques for online monitoring of meat quality, real-time PCR for the detection of pathogens in meat, new developments in decontaminating raw meat, automated meat processing, developments in chilling and freezing of meat, high pressure processing of meat, approaches for the development of functional meat products, new techniques for analyzing raw meat, modified atmosphere packaging, perspectives for the active packaging of meat products.

Unit II

Poultry: Breeding and quality of poultry, stunning and slaughter of poultry, processing and packaging of poultry, new techniques of preservation of poultry, production of turkeys, geese, ducks and game birds, microbial hazards in poultry production and processing, latest trends in measuring quality of poultry and poultry products, treatment and disposal of poultry processing waste.

Unit III

Fish and seafood: Fresh fish handling and chill storage, modified atmospheric packaging of seafoods, fish odours and flavours, assessment of freshness of fish and seafoods, traditional dried and salted fish products, proteolysed fish products, minced fish technology, retort pouch processing technology, irradiation and microwave in fish handling and processing, advanced freezing technology for fish storage, high pressure processing of seafoods, value addition of freshwater and aqua cultured fish products, application of enzymes in fish processing and quality control, toxins, pollutants and contaminants in fish and seafoods.

Unit IV

Milk: Physical, chemical and nutritional properties of milk components, improvements in the pasteurization and sterilization of milk. Flavour generation in dairy products, controlling texture of fermented dairy products, functional dairy products, on-line measurement of product quality in dairy processing, high pressure processing of milk products, novel separation technologies to produce dairy ingredients, new technologies to increase shelf-life of dairy products, genetic engineering of milk proteins, production and utilization of functional milk proteins, methods of improving nutritional quality of milk, significance of milk fat in dairy products, chromatographic, spectrometric, ultrasound and other techniques for analysis of milk lipids.

VI. Practical

Analysis of fresh and processed meat, fish, poultry and milk products, preservation of fresh meat and fish, processing and production of different products from fresh meat, fish and milk, shelflife studies on different meat, fish and milk products. Visit to processing plants.

VII. Learning outcome

Student's capability to process meat, fish and poultry and manufacture value added products as per requirement of food industries.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Genetic engineering of farm animals for better meat quality.	1
2.	Developments in automation of the modern slaughterhouse, hot-boning process of meat, benefits of hot boning.	1
3.	New spectroscopic techniques for online monitoring of meat quality, Real-time PCR for the detection of pathogens in meat.	2
4.	Automated meat processing, developments in chilling and freezing of meat, High pressure processing of meat, approaches for the development of functional meat products.	3
5.	New techniques for analyzing raw meat, modified atmosphere and active packaging of meat products.	2
6.	Breeding and quality of poultry, Stunning and slaughter of poultry, Processing and packaging and new techniques of preservation of poultry.	2
7.	Production of turkeys, geese, ducks and game birds.	1
8.	Microbial hazards in poultry production and processing, treatment and disposal of poultry processing waste, Latest trends in measuring quality of poultry and poultry products. Treatment and disposal of poultry processing waste.	3

S No	Topic	No. of Lectures
9.	Fish and seafood: Fresh fish handling and chill storage, modified atmospheric packaging, Assessment of freshness of fish and seafoods, different traditional and proteolysed fish products, minced fish technology.	3
10.	Retort pouch processing technology, irradiation and microwave in fish processing, Advanced freezing technology for fish storage, Value addition of freshwater and aqua cultured fish products, application of enzymes in fish processing.	3
11.	Quality control: toxins, pollutants and contaminants in fish and sea foods.	1
12.	Physical, chemical and nutritional properties of milk components, improvements in the pasteurization and sterilization of milk.	2
13.	Flavour generation in dairy products, controlling of texture in fermented dairy products.	1
14.	Functional dairy products, on-line measurement of product quality, high pressure processing, Novel separation technologies to produce dairy ingredients, new technologies to increase shelf-life of dairy products.	2
15.	Genetic engineering of milk proteins, production and utilization of functional milk proteins.	1
16.	Methods of improving nutritional quality of milk, significance of milk fat in dairy products and different techniques for analysis of milk lipids.	2
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Analysis of fresh and processed meat products	1
2.	Analysis of fresh and processed fish products	1
3.	Analysis of fresh and processed poultry products	1
4.	Analysis of fresh and processed milk products	1
5.	Preservation of fresh meat and fish	1
6.	Processing and production of different products from fresh meat	2
7.	Processing and production of different products from fresh fish	2
8.	Processing and production of different products from fresh poultry	2
9.	Processing and production of different products from fresh milk	1
10.	Shelf life studies on different meat, fish and milk products	2
11.	Visit to processing plants	1
	Total	**15**

X. Suggested Reading

- Chooksey MK. 2003. *Fish Processing and Product Development*. CIFE, Kochi.
- Chooksey MK and Basu S. 2003. *Practical Manual on Fish Processing and Quality Control*. CIFE, Kochi.
- Hall GM. 1997. *Fish Processing Technology*. Blabie Academic and Professional.
- Lawrie RS. 1985. *Developments in Meat Sciences*. Vol III Applied Science Publishers.
- Mead GC. 1989. *Processing of Poultry*. Elsevier.
- Pearson AM and Tauber FW. 1984. *Processed Meats*. AVI Publishers.
- Stadelman WJ and Cotterill OJ. 1980. *Egg Science and Technology*. AVI Publishers.

I. Course Title : Design of Aquacultural Structures

II. Course Code : PFE 517

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with aquaculture structures and their design features.

V. Theory

Unit I

Inland fish farming and associated considerations.

Unit II

Fish physiology and micro-climatic considerations.Site selection for aquaculture structures.

Unit III

Design of dykes, sluice, channels etc. Aeration and feeding systems: Design of fish rearing structures, hatcheries, containers for live fish, fingerlings, fish seeds.

Unit IV

Aquaculture in recirculatory systems, oxygen and aeration, sterilization and disinfection. Recirculation of water:Reuse systems, water exchange, design of re-use systems, Inlet and outlet structures and water treatment plants.

VI. Practical

Aeration and feeding systems of fish ponds, fish farming structures, water treatment plants, containers for live fish.Design of re-use systems.Inlet and outlet structures.

VII. Learning outcome

Student's capability to design suitable aquaculture structures.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Inland fish farming.	1
2.	Considerations in site selection for designing inland fish farms.	2
3.	Preparatory work for designing inland fish farms: technological requirements, general technical, hydrological and meteorological data.	3
4.	Fish physiology.	2
5.	Micro-climatic considerations for fish farms.	1
6.	Design of dykes, sluice, channels etc.	3
7.	Aeration and feeding systems.	1
8.	Design of fish rearing structures.	1
9.	Hatcheries.	2
10.	Containers for live fish, fingerlings, fish seeds.	1
11.	Fish pond arrangements: Barrage Ponds, Contour Ponds, Paddy Ponds.	2
12.	Earth structures in fish farms: Dams and Dikes, Feeder Canals, Drainage canals, Drain Ditch, Internal Pond Drains, Borrow Pits and Internal Harvesting Pits.	3
13.	Aquaculture in recirculatory systems.	2
14.	Oxygen and aeration in fish farms. Sterilization and disinfection in fish farms.	2

S.No.	Topic	No. of Lectures
15.	Recirculation of water; Reuse systems, water exchange, design of re-use systems, Inlet and outlet structures.	3
16.	Water treatment plants in fish farms.	1
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Study of aeration systems of fish ponds.	1
2.	Study of feeding systems of fish ponds.	1
3.	Design of dykes in fish farming structures.	1
4.	Design of feeder canals in fish farming structures.	2
5.	Design of drainage canals in fish farming structures.	1
6.	Design of drain ditch in fish farming structures.	1
7.	Design of internal pond drains in fish farming structures.	1
8.	Design of borrow pits in fish farming structures.	1
9.	Design of internal harvesting pits in fish farming structures.	1
10.	Study of waste water management through aquaculture.	1
11.	Design of recirculatory ponds for waste water treatment in fish farms.	1
12.	Different types of containers for live fish.	1
13.	Design of re-use systems in fish farms.	1
14.	Different types of inlet and outlet structures in fish farms.	1
	Total	**15**

X. Suggested Reading

- FAO. 1983. *Inland Aquaculture Engineering*. ISBN 92-5-102168-6.

I. Course Title : Thermal Environmental Engineering for Agricultural Processing

II. Course Code : PFE 518

III. Credit Hours : 3+0

IV. Aim of the course

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

V. Theory

Unit I

Requirements of temperature and moisture in food preservation, processing, storage, animal and plant production systems, human comfort etc.

Unit II

Thermodynamic properties of moist air, psychrometric chart, psychrometric processes and applications. Mass transfer and evaporation of water from free surfaces, theory of psychrometer, direct contact transfer processes between moist air and water-air washer, cooling tower, heating and cooling of moist air by extended surface coils, dehumidification using moisture absorbing materials. Solar irradiations on structures, calculation of heating and cooling loads in buildings/ storage structures.

Unit III

Design of air conditioning systems, air distribution and duct design, air flow pattern and control, equipment, components and controls.Instruments for measurement and control of temperature and moisture.

Unit IV

Thermal insulation materials for environmental control systems, applications of environmental control in green house, dairy industry, potato storage etc.

VI. Learning outcome

Student's capability to design environmental control systems related to different unit operation in food processing industry.

VII. Schedule of Lectures

S.No.	Topic	No. of Lectures
1.	Requirements of temperature and moisture in food preservation, processing, storage, animal and plant production systems, human comfort etc. Various thermal indices.	5
2.	To study the different temperature, moisture and relative humidity measuring instruments.	3
3.	Thermodynamic properties of moist air.	3
4.	Psychrometric chart, psychrometric processes and applications. Mass transfer and evaporation of water from free surfaces, theory of psychrometer.	5
5.	Direct contact transfer processes between moist air and water-air washer, cooling tower, heating and cooling of moist air by extended surface coils, dehumidification using moisture absorbing materials.	4
6.	Solar irradiations on structures, calculation of heating and cooling loads in buildings/ storage structures.	5
7.	Introduction to air conditioning systems and design considerations.	4
8.	air distribution and duct design, air flow pattern and control, equipment, components and controls. Instruments for measurement and control of temperature and moisture.	4
9.	Thermal insulation materials for environmental control systems. Comparative performance of these materials.	4
10.	Applications of environmental control in farm buildings, farmstead, green house, dairy industry, poultry shed, potato storage etc.	5
	Total	**42**

VIII. Suggested Reading

- *Perry's Chemical Engineers' Handbook*, Section 12. (2007).
- Threlkald JL. *Thermal Environmental Engineering*, Pearson.

Course Title with Credit Load
M.Tech. in Soil and Water Conservation Engineering

Major Courses (Requirement: 20 Credits)

Course Code	Course Title	Credit Hours
*SWCE 501	Advanced Soil and Water Conservation Engineering	2+1
*SWCE 502	Applied Watershed Hydrology	2+1
SWCE 503	Soil and Water Conservation Structures	2+1
SWCE 504	Stochastic Hydrology	2+1
*SWCE 505	Watershed Management and Modeling	2+1
SWCE 506	Flow Through Porous Media	2+0
SWCE 507/IDE 507	Remote Sensing and GIS for Land and Water Resource Management	2+1
SWCE 508	Climate Change and Water Resources	3+0
SWCE 509	Numerical Methods in Hydrology	2+0
SWCE 510	Dryland Water Management Technologies	2+0
	Total	**19+6**

*Compulsory course

Minor Courses (Requirement: 08 Credits)

Course Code	Course Title	Credit Hours
IDE 505	Design of Drip and Sprinkler Irrigation Systems	2+1
IDE 506	Groundwater Engineering	2+1
IDE 510	Minor Irrigation	2+1
IDE 513	Water Resources Systems Engineering	2+1
CE 501	Dimensional Analysis and Similitude	2+0
CE 502	Water Quality and Pollution Control	2+1
FMPE 517	Machinery for Precision Agriculture	2+1
REE 513	Energy, Ecology and Environment	3+0
CSE 501	Big Data Analytics	2+0
CSE 502	Artificial Intelligence	2+0
CSE 504	Soft Computing Techniques in Engineering	2+1
MATH 501	Finite Element Methods	2+0
MATH 502	Numerical Methods for Engineers	2+0
ME 501	Mechatronics and Robotics in Agriculture	2+0
	Any other course(s) of other department can be taken as per recommendations of the student's advisory committee.	

Supporting Courses (Requirement: 06 Credits)

Course Code	Course Title	Credit Hours
*STAT 501	Statistical Methods for Research Works	2+1
	Courses from subject matter fields (other than Major and Minor) relating to area of special interest and research problem can be taken as per recommendations of the student's advisory committee.	

*Compulsory Course

Common Courses (Requirement: 05 Credits)

Course Code	Course Title	Credit Hours
*PGS 501	Library and Information Services	1+0
*PGS 502	Technical Writing and Communication Skills	1+0
*PGS 503	Intellectual Property and its management in Agriculture	1+0
*PGS 504	Basic Concepts in Laboratory Techniques	1+0
*PGS 505	Agricultural Research, Research Ethics and Rural Development Programmes	1+0

*Detailed course outline to be developed by designated BSMA

List of other Essential Requirements

Course Code	Course Title	Credit Hours
SWCE 591	Seminar	0+1
SWCE 599	Thesis Research	0+30

Course Contents
M.Tech. in Soil and Water Conservation Engineering

I. Course Title : Advanced Soil and Water Conservation Engineering

II. Course Code : SWCE 501

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip students with the advances in soil and water conservation measures, use of RS and GIS and Software's for design of soil and water conservation structures.

V. Theory

Unit I

Concept of probability in design of soil and water conservation structures. Probability and continuous frequency distribution. Fitting empirical distributions.

Unit II

Relevance of soil and water conservation in agriculture and in the river valley projects. Layout and planning of soil and water conservation measures. Software's for design of conservation structures.

Unit III

Productivity loss due to soil erosion. Water stress and water excess. Types and mechanics of soil erosion. Software's for soil loss estimation, WEAP, EPIC

Unit IV

Theories of sediment transport. Control of runoff and sediment loss. Sediment deposition process. Estimation of sediment load.

Unit V

Design of soil and water conservation structures: Check dams, gully plugs, gabion structures, earth dams, silt detention dams, farm ponds, etc., and the alternate use of the stored water for agriculture. Application of Remote Sensing and GIS in Soil and Water Conservation.

VI. Practical

Assessment of erosive status of a watershed through field measurement or analysis of morphometric properties. Estimation of erosivity index of rainfall. Determination of soil physical properties: Texture, grain size distribution, Atterberg's limits, various moisture percentages. Locating best possible sites of soil and water conservation structures on the basis of map features and erosivity status. Estimation of costs of soil and water conservation measures.

VII. Learning outcome

The students will able to plan and design soil and water conservation measures in particular watershed using RS and GIS techniques. They can estimate the

sedimentation and capacity losses, design of gully control structures and earthen dams usingsoftware's.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Concept of probability in design of soil and water conservation structures	2
2.	Probability and continuous frequency distribution	2
	Fitting empirical distributions	2
3.	Relevance of soil and water conservation in agriculture and in the river valley projects	2
4.	Layout and planning of soil and water conservation measures	2
5.	Software's for design of conservation structures	1
6.	Productivity loss due to soil erosion	1
7.	Water stress and water excess	1
8.	Types and mechanics of soil erosion	1
9.	Software's for soil loss estimation, WEAP, EPIC	3
10.	Theories of sediment transport	2
11.	Control of runoff and sediment loss	1
12.	Sediment deposition process and estimation of sediment load	2
13.	Design of soil and water conservation structures: Check dams, gully plugs, gabion structures, earth dams, silt detention dams, farm ponds, etc., and the alternate use of the stored water for agriculture	6
14.	Application of Remote Sensing and GIS in Soil and Water Conservation	3
	Total	**31**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Assessment of erosive status of a watershed through field measurement	2
2.	Morphometric analysis of a watershed	2
3.	Estimation of erosivity index of rainfall	1
4.	Determination of soil texture	1
5.	Determination of soil grain size distribution	1
6.	Determination of Atterberg's limits of soil	1
7.	Determination of various soilmoisture percentages	1
8.	Locating best possible sites of soil and water conservation structures on the basis of map features and erosivity status	2
9.	Design of Check dams, gully plugs, gabion structures, earth dams, silt detention dams and farm ponds	4
10.	Estimation of costs of soil and water conservation measures	2
	Total	**17**

X. Suggested Reading

- Garg SK. 1987. *Irrigation Engineering and Hydraulic Structures*. Khanna Publishers, New Delhi.
- Kirkby MJ and Morgan PPC (eds). 1980. *Soil Erosion*. John Wiley and Sons. New York, USA.
- Suresh R. 2016. *Soil and Water Conservation Engineering*. Standard Publishers and Distributors, Delhi.

I. Course Title : Applied Watershed Hydrology

II. Course Code : SWCE 502

III. Credit Hours : 2+1

IV. Aim of the course

To provide in depth knowledge of surface and sub-surface hydrology of watershed including stream flow measurement and computer simulation of hydrological processes in small watersheds.

V. Theory

Unit I

Hydrology in water resources planning, rainfall, surface runoff and sub-surface runoff as components of hydrologic cycle. Runoff phenomena, relationship between precipitation and runoff. Stream flow measurement and analysis of data in detail.

Unit II

Synthetic unit hydrograph. Recent advances in analysis of hydrologic data and flow from small watersheds. Methods of runoff estimation from small watersheds. Use of IUH and various methods of estimation. Runoff estimation models: SCS, CN software.

Unit III

Micro climate, estimation methods of evaporation. Advances and improvements in rational approach. SCS approach criticism and improvements.

Unit IV

Hydrological hazard functions. Methods of estimation of hydrologic parameters. Data transformation.

Unit V

Calibration and evaluation of hydrologic models. Computer simulation of hydrological process in small watersheds.

VI. Practical

Delineation of watershed and study of watershed characteristics. Measurement of rainfall and runoff in a watershed and data analysis. Estimation of infiltration and runoff from a watershed. Analysis and derivation of various types of hydrographs. Flood routing. Reservoir sedimentation. Watershed model components. Visit to a watershed.

VII. Learning outcome

The students will be able to understand and analyze the process and the effect of various climatic parameters on rainfall-runoff relationship. They can also be able to develop the competency for calibration and evaluation of hydrologic models and computer simulation.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Hydrology in water resources planning, rainfall, surface runoff and sub-surface runoff as components of hydrologic cycle	2
2.	Basics of watershed hydrology and processes, global and watershed perspectives	2

S.No.	Topic	No. of Lectures
3.	Runoff phenomena, relationship between precipitation and runoff	1
4.	Synthetic unit hydrograph, Unit hydrograph and its derivation including for complex storm,	3
5.	S-hydrograph and derivation, Use of IUH and various methods of estimation.	3
6.	Runoff estimation models: SCS, CN software	3
7.	Flood routing principles	2
8.	Recent advances in analysis of hydrologic data and flow from small watersheds. Methods of runoff estimation from small watersheds.	3
9.	Micro climate, estimation methods of evaporation. Advances and improvements in rational approach. SCS approach criticism and improvements	3
10.	Process of sedimentation of reservoirs	2
11.	Hydrological hazard functions, Methods of estimation of hydrologic parameters, Data transformation,	3
12.	Hydrologic modeling approaches, component conceptualization, types of watershed hydrologic models and choice of model.	3
13.	Calibration and evaluation of hydrologic models. Computer simulation of hydrological process in small watersheds	2
	Total	**32**

VIII. List of Practicals

S.No.	Topic	No. of Practicals
1.	Delineation of watershed and study of watershed characteristics	1
2.	Measurement of rainfall and runoff in a watershed	1
3.	Analysis of hydrologic data and flow from small watersheds	1
4.	Estimation of infiltration and runoff from a watershed	1
5.	Measurement and analysis of stream flow data	1
6.	Analysis of synthetic unit hydrograph for complex storm	1
7.	Analysis of S-hydrograph for complex storm	1
8.	Use of runoff estimation models: SCS, CN software	2
9.	Study of different types of flood routing methods	2
10.	Computer simulation of hydrological process in small watersheds	1
11.	Study of reservoir sedimentation	1
12.	Study of watershed model components	1
13.	Visit to a watershed	1
	Total	**16**

IX. Suggested Reading

- Haan CT. *Hydrologic Modeling of Small Watershed.*
- Singh VP. 2010. *Rainfall-Runoff Modeling* (Vol. I)—Prentice Hall, New York.
- Singh VP. 2010. *Environmental Hydrology*. Springer, New York.

I. Course Title : Soil and Water Conservation Structures

II. Course Code : SWCE 503

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint students with the planning and design of soil and water conservation

structures, their stability checks and mechanized soil conservation techniques.

V. Theory

Unit I

Design, planning and layout of soil and water conservation structures. Criteria of selection of appropriate structures as per soil, land use and climatic conditions.

Unit II

Design and construction of earthen dam, stability analysis of land slopes and soil mass including landslides.

Unit III

Hydrological and structural design including stress analysis. Hydraulic jump and energy dissipaters for soil conservation structures.

Unit IV

Seepage through dams, flow net and determination of uplift pressure in drop structures, design of energy dissipaters.

Unit V

Design of water harvesting structures, construction, maintenance and utilization of stored water. Mechanized construction techniques for soil and water conservation structures.

VI. Practical

Numerical approach on probability distribution functions. Stability analysis and structural design of masonry water harvesting structures. Design of earthen dams and other energy dissipating structures. Cost analysis of water harvesting structures. Field visit to already constructed water harvesting structures in the nearby area/ watershed.

VII. Learning outcome

The student will be able to design the soil and water conservation structures as well as permanent gully control structures and water harvesting structures. They can have understanding of mechanized construction of soil and water conservation structures.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1	Introduction and need of Soil and Water Conservation in agricultural watershed	1
2	Runoff process and factors affecting it and estimation of runoff using various methods	3
3	Analysis of rainfall data, Probability concepts in the design of structures	3
4	Introduction, classification and functional requirement of soil and water conservation structures-Straight Drop spillway, chute spillway and drop inlet spillway	1
5	Specific energy and specific force	2
6	Hydraulic jump and its application, type of hydraulic jump, energy dissipation due to jump, jump efficiency, relative loss of energy	2
7	Straight drop spillway- Components and their functions, hydrologic, hydraulic and structural design	4

S.No.	Topic	No. of Lectures
8	Drop inlet spillway- Components and their functions, hydrologic, hydraulic and structural design	2
9	Chute Spillway- Components and their functions, hydrologic, hydraulic and structural design	3
10	Criteria of selection of appropriate structures as per soil, land use and climatic conditions	1
11	Design of energy dissipaters in soil and water conservation structures	1
12	Introduction, types, design, criteria and construction of earthen dam, causes of failure of earthen dam, retaining wall and its design	3
13	Stability analysis of land slopes and soil mass including landslides, seepage control in earthen dams, flow net in earthen dams	2
14	Water harvesting: principles, importance and issues. Water harvesting techniques: classification based on source, storage and use. Runoff harvesting: short-term and long-term harvesting techniques, purpose and design criteria.	3
15	Mechanized construction techniques for soil and water conservation structures	1
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Study of various probability distribution function for rainfall analysis	1
2.	Construction of specific energy and specific force diagram	2
3.	Measurement of hydraulic jump parameters and amount of energy dissipation	1
4.	Hydrologic and hydraulic design of a straight drop spillway	1
5.	Determination of uplift force and construction of uplift pressure diagram	1
6.	Determination of loads on headwall and construction of triangular load diagram	1
7.	Stability analysis of a straight drop spillway	1
8.	Hydraulic design of a chute spillway	1
9.	Design of drop inlet spillway	1
10.	Design of energy dissipating structures	1
11.	Design of earthen dam	1
12.	Seepage analysis in earthen embankment	1
13.	Design of water harvesting structures	1
14.	Economic analysis of water harvesting structures	1
15.	Field visit to already constructed water harvesting structures in the nearby area/watershed.	1
	Total	**16**

X. Suggested Reading

- Mahnot SC, Singh PK and Chaplot PC. 2011. *Soil and Water Conservation and Watershed Management*. Apex Publishing House, Udaipur.
- Murty VVN. 1988. *Land and Water Management Engineering.* Second Edition Kalyani Publishers, New Delhi.
- Singh Gurmel C, Venkataraman G, Sastri and Joshi BP. 1991. *Manual of Soil and Water conservation Practices*. Oxford and IBH Publishing Co. Pvt. Ltd, New Delhi.

- Singh PK. 2000. *Watershed Management* (*Design and Practice*). e-media publications, Udaipur.
- Suresh R. 2006. *Soil and Water Conservation Engineering*. Fourth Edition Standard Publishers and Distributors, Delhi.
- Singh Raj Vir. 2003. *Watershed Management*. Second Edition, Yash Publishing, Bikaner.

I. Course Title : Stochastic Hydrology

II. Course Code : SWCE 504

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint students about the stochastic processes in hydrology including statistical characteristics of hydrological time series data, modeling hydrologic uncertainty and analysis of multivariate hydrologic series,

V. Theory

Unit I

Hydrologic cycle, Systems concept, Hydrologic systems model. Classification of hydrologic models, Statistical, stochastic and deterministic approaches. Statistical characteristics of hydrological data, probability distribution of hydrologic variables. Deterministic and stochastic hydrology, Cause and effect analysis. Hydrologic time series analysis – nature, stationarity and ergodicity, components of time series, trend, periodicity and stochastic parts, parameter estimation of probability distributions. Analysis of hydrologic extremes.

Unit II

Multivariate regression analysis, correlation analysis, correlation coefficient and its significance in regional analysis. Developing prediction equation by simple and multiple linear regression. Reliability of the Model.

Unit III

Stochastic Process: Classification, stationary process. Time series: Classification, component of time series. Methods of investigation: Auto correlation coefficient, moving average process, auto regressive process, auto regressive moving average process, auto regressive integrated moving average process. Spectral analysis, analysis of multivariate hydrologic series.

Unit IV

Thomas Fiering model, Box Jenkins model. Model formulation: Parameter estimation, calibration and validation. Application to hydrologic data. Generation and forecasting. Regional flood frequency analysis. Transformations, Hypothesis testing.

Unit V

Modeling hydrologic uncertainty. First order Markov process, Markov chain, Data generation, Hydrologic time series analysis, Modelling of hydrologic time series.

VI. Practical

To estimate various statistical parameters of the hydrologic variables, estimating missing data in historical series, various parameter estimation methods like method of moments, method of maximum likelihood, method of mixed moments, probability of weighted moments fitting discrete and continuous distribution functions to

variables, application of transformation techniques to historical data for estimating variables at different return periods, determining correlation and regression coefficients, analyzing multivariate regression, autocorrelation coefficient for independent and correlated events, fitting ARMA models, fitting Markov models of first and second order, regional frequency analysis, time series analysis of the historical data, estimating and fitting Thomas Fiering Model.

VII. Learning outcome

The students are enabled to understand the stochastic process of hydrology including statistical based analysis of hydrological time series data. They are exposed to stochastic and deterministic modeling of small watersheds.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Hydrologic cycle, Systems concept, Hydrologic systems model	1
2.	Hydrological models, processes and systems - Physical Characterization of watersheds; Rainfall measurements	1
3.	Classification of hydrologic models, Statistical, stochastic and deterministic approaches	1
4.	Statistics and probabilities in hydrology – Basic concepts – Experiment, Sample space, element, event, complement, intersection, disjoint, union, statistical parameters; Uncertainty in hydrological event; Statistical homogeneity, Permutation, combination, probability, conditional probability; Independent events, random variables, discrete and continuous sample space, Probability and Return period	3
5.	Statistics and probabilities in hydrology- Frequency Analysis – Mean, Median, Mode, Variance, Frequency Analysis - Standard deviation, Coefficient of Variance, Skewness, Kurtosis Theorems on Probability; Total probability theorem and Baye's theorem	3
5.	Statistics and probabilities in hydrology- Discrete and Continuous probability - Random Variable and Variate; Probability Distribution of hydrological variables; Co-relation and regression analysis.	3
6.	Introduction and examples of stochastic processes; Specification of stochastic process- nature, stationarity and ergodicity, components of time series,	2
7.	Hydrologic time series analysis –trend, periodicity	1
8.	Stochastic time series analysis- Methods of analysis -Auto correlation coefficient,	1
9.	Stochastic time series analysis- moving average process, auto regressive process,	2
10.	Stochastic time series analysis- auto regressive moving average process,	2
10.	Stochastic time series analysis- auto regressive integrated moving average process.	2
11.	Spectral analysis, analysis of multivariate hydrologic series	2
12.	Thomas Fiering model, Box Jenkins model	2
13.	Model formulation: Parameter estimation, calibration and validation.	2
14.	Application to hydrologic data	2
15.	Generation and forecasting- Regional flood frequency analysis Transformations,	1
16.	Hypothesis testing	1
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Development of regression models	1
2.	Estimation of missing data in historical series	1
3.	Parameter estimation-Method of Moments	1
4.	Parameter estimation-method of maximum likelihood	1
5.	Parameter estimation- method of mixed moments, Probability of weighted moments	1
6.	Fitting discrete and continuous distribution functions to variables	1
7.	Transformation techniques to historical data for estimating variables at different return periods	1
8.	Regression analysis, Correlation analysis,	1
9.	Analyzing multivariate regression,	1
10.	Autocorrelation coefficient for independent and correlated events,	1
11.	Fitting ARMA models to rainfall runoff data	1
12.	Fitting Markov models of first and second order,	1
13.	Regional frequency analysis,	1
14.	Estimating parameters of Thomas Fiering Model	1
15.	Fitting of Thomas Fiering Model	1
	Total	**15**

X. Suggested Reading

- Clarke RT. *Mathematical Models in Hydrology*. FAO Publication.
- Haan CT. 2002. *Statistical Methods in Hydrology*. Iowa State Press.
- Kotteguda NT. 1982. *Stochastic Water Resources Technology*. The Macmillan Press, New York.
- McCuen RH and Snyder WM. *Hydrological Modelling–Statistical Methods and Applications*. Prentice Hall Inc., New York.
- Yevjevich V *Stochastic Processes in Hydrology*. Water Resources Publications, Colorado.

I. Course Title : Watershed Management and Modeling

II. Course Code : SWCE 505

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint students with watershed management concept and its benefit for sustainable rural development through participatory approach, including environmental impact as well as policy frame work.

V. Theory

Unit I

Concept of watershed, its hydrological and geomorphological characteristics. Status of watershed management programs in India. Problems of desertification and degradation.

Unit II

Concept of watershed management and sustainability, participatory approach and operational watershed. Surveys, monitoring, reclamation and conservation of agricultural and forest watersheds, hill slopes and ravines.

Unit III

Watershed management research instrumentation and measurement, problem identification, simulation and synthesis. Rainfed farming and drought management. Modeling of flood and drought phenomenon.

Unit IV

Use of Remote Sensing and GIS in watershed management and modeling. Watershed modeling approaches, mathematical bases and structure of existing watershed models.

Unit V

Environmental impact assessment of watersheds. Quantitative evaluation of management techniques. National land use policy, legal and social aspects. Case studies of watershed management.

VI. Practical

Selection and delineation of a watershed. Benchmark surveys. Preparation of watershed land use map. Preparation of watershed development proposal. Preparation of watershed evaluation and impact assessment report. Application of watershed models for evaluation of conservation treatments. Use of Remote Sensing and GIS in watershed management and modeling.

VII. Learning outcome

The students will be able to understand different conservation practices and their effect on watershed behavior. They can also estimate the geomorphologic parameters of particular watershed which is quite useful for watershed planning and development of watershed models.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1	Concept of watershed, its hydrological and geomorphological characteristics	2
2	Status of watershed management programs in India	2
3	Problems of desertification and degradation	2
4	Concept of watershed management and sustainability, participatory approach and operational watershed	3
5	Surveys, monitoring, reclamation and conservation of agricultural and forest watersheds, hill slopes and ravines	3
6	Watershed management research instrumentation and measurement, problem identification, simulation and synthesis	2
7	Rainfed farming and drought management	2
8	Modeling of flood and drought phenomenon	2
9	Use of Remote Sensing and GIS in watershed management and modeling	2
10	Watershed modeling approaches, mathematical bases and structure of existing watershed models	3
11	Environmental impact assessment of watersheds	2
12	Quantitative evaluation of management techniques	2
13	National land use policy, legal and social aspects	2
14	Case studies of watershed management	3
	Total	**32**

IX. List of Practicals

S.No.	Topic	No of Practicals
1	Selection and delineation of a watershed	3
2	Benchmark surveys	2
3	Preparation of watershed land use map	2
4	Preparation of watershed development proposal	3
5	Preparation of watershed evaluation and impact assessment report	2
6	Application of watershed models for evaluation of conservation treatments	2
7	Use of Remote Sensing and GIS in watershed management and modelling	2
	Total	**16**

X. Suggested Reading

- Dhaliwal GS Hansra BS and Ladhar SS. 1993. *Wetlands, their Conservation and Management*. Punjab Agricultural University, Ludhiana.
- Dhruvanarayana VV, Sastry G and Patnaik US. *Watershed Management*. Publ. and Inf. Dv., ICAR, Krishi Anusandhan Bhavan, New Delhi.
- Singh RV. 2000. *Watershed Planning and Management*. Second Edition Yash Publishing House, Bikaner.
- Suresh R. 2017. *Watershed Planning and Management*. Standard Publication and Distribution, Delhi.
- Tideman EM. 1999. *Watershed Management* (*Guidelines for Indian Conditions*). Omega Scientific Publishers, New Delhi.

I. Course Title : Flow Through Porous Media

II. Course Code : SWCE 506

III. Credit Hours : 2+0

IV. Aim of the course

To provide comprehensive knowledge to the students in aquifer and fluid properties, unsaturated flow theory and movement of groundwater in fractured and swelling porous media.

V. Theory

Unit I

Aquifer and fluid properties, forces holding water in soils, hydrodynamics in porous media and limitations of governing laws.

Unit II

Differential equations of saturated flow, initial and boundary conditions. Dupuit and Business approximations and linearization techniques.

Unit III

Stream functions, potential functions and flow net theory. Analysis of seepage from canals and ditches.

Unit IV

Unsaturated flow theory, Infiltration and capillary rise flux dynamics. Movement of groundwater in fractured and swelling porous media.

Unit V

Hydro-dynamic dispersion in soil-aquifer system. Velocity hydrograph, flow characteristics at singular points, examples of velocity hydrograph, solution by complex velocity, solution of triangular dam, drainage in retaining structures, influence of seepage on stability of slopes, drainage methods for stability of slopes.

VI. Learning outcome

The students will be able to understand physical properties of flow through porous media. Competence on various laws governing dynamics of flow through porous media. Understanding of hydrodynamics in porous media, governing laws and boundary conditions.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Aquifer and its classification, properties of aquifers and fluids	1
2.	Forces responsible for holding water in soil and movement, hydrostatic pressure distribution	1
3.	Porosity, permeability and hydraulic conductivity: its importance in fluids flow	1
4.	Hydrodynamics in porous media: Continuum approach to porous media, Representative Elementary Volume (REV), linear and aerial porosity, velocity and specific discharge relationship in porous medium	3
5.	Generalization of Darcy Law in isotropic and anisotropic layered porous medium, deviation from Darcy Law and limitations of governing laws in flow through porous media	3
6.	Saturated flow: Differential equations for flow through saturated medium, initial and boundary conditions, types of boundary conditions, boundary and initial value problems	3
7.	Dupuit and Boussinesq approximations and linearization: Dupuit assumption and equation, Boussinesq linearization Techniques and solutions	3
8.	Unsaturated flow theory: Continuity and conservation equations for a homogeneous fluid in non-deforming medium and deforming medium, continuity equation for compressible fluid and moveable solid matrix	6
9.	Infiltration and capillary rise flux dynamics, movement of groundwater in fractured and swelling porous media	2
10.	Stream and potential functions: Stream functions in two and three dimensional flow, potential functions and flow net theory	3
11.	Analysis of seepage from canals and ditches	2
12.	Hydro-dynamic dispersion in soil-aquifer system: Hydro-dynamic dispersion, derivation of dispersion and diffusion equation	3
13.	Velocity hydrograph: Flow characteristics at singular points, examples of velocity hydrograph, solution by complex velocity, solution of triangular dam, drainage in retaining structures, influence of seepage on stability of slopes, drainage methods for stability of slopes	3
	Total	**34**

X. Suggested Reading

- Bears J. 1972. *Dynamics of Fluids in Porous Media.* American Elsevier Publishing Co. Inc. New York.

- Bear J and Arnold V. *Modeling Groundwater Flow and Pollution.* D. Reidel Publishing Company.
- Collins RE. 1961. *Flow of Fluids through Porous Materials.* Reinhold publishing cooperation, New York.
- Core AT *Flow in Porous Media.*
- De Wiest Roger JM. 1969. *Flow through Porous Media*. Academic press, New York.
- Helmut K *Soil Physics*. pp. 7-79.
- Verruijt A. 1982. *Theory of Groundwater Flow*. 2nd Edn., Macmillan, London

I. Course Title : GIS and Remote Sensing for Land and Water Resource Management

II. Course Code : SWCE 507/IDE 507

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint students with recent technology of RS and GIS including satellite data analysis, digital image processing and thematic mapping of land use, surface and ground water.

V. Theory

Unit I

Physics of remote sensing, electromagnetic radiation (EMR), interaction of EMR with atmosphere, earth surface, soil, water and vegetation. Remote sensing platform, monitoring atmosphere, land and water resources: LANDSAT, SPOT, ERS, IKONOS and others, Indian Space Programme.

Unit II

Satellite Data analysis: Visual interpretation, digital image processing, image pre-processing, image enhancement, image classification and data merging.

Unit III

Definition: Basic components of GIS, map projections and co-ordinate system, spatial data structure-raster, vector, spatial relationship, topology, geodatabase models, hierarchical network, relational, object-oriented models, integrated GIS database-common sources of error–data quality: Macro, micro and usage level components, meta data, Spatial data transfer standards.

Unit IV

Thematic mapping, measurements in GIS: Length, perimeter and areas. Query analysis, reclassification: Buffering, neighbourhood functions, map overlay: Vector and raster overlay: Interpolation, network analysis, digital elevation modelling. Analytical Hierarchy Process, Object oriented GIS–AM/FM/GIS, Web Based GIS.

Unit V

Spatial data sources: 4M GIS approach water resources system, Thematic maps, rainfall runoff modelling, groundwater modelling, water quality modelling and flood inundation mapping and modelling. Drought monitoring, cropping pattern change analysis, performance evaluation of irrigation commands. Site selection for artificial recharge, reservoir sedimentation.

VI. Practical

Familiarization with the Remote sensing instruments and satellite imagery. Aerial

Photograph and scale determination with stereoscope. Interpretation of satellite imageries and aerial photographs. Determination of Parallaxes in images. Introduction to digital image processing software and GIS software and their working principles. Generation of digital elevation model (DEM) for land and water resource management. Case studies on mapping, monitoring and management of natural resources using remote sensing and GIS.

VII. Learning outcome

Students will be able to use satellite remote sensing to perform image analysis and classification for developing thematic maps. Able to integrate satellite data with GIS to undertake recourse mapping and planning studies.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction and brief history of RS and GIS, applications of RS and GIS	1
2.	Physics of remote sensing. Electromagnetic radiation (EMR), interaction of EMR with atmosphere, earth surface, soil, water and vegetation	1
3.	Remote sensing platforms: Monitoring atmosphere, land and water resources: LANDSAT, SPOT, ERS, IKONOS and others. Indian Space Programme	2
4.	Satellite data analysis. Visual interpretation.	1
5.	Digital image processing- Image pre-processing, Image enhancement, Image classification, data merging.	3
6.	Basic components of GIS- Map projections and co-ordinate system.	2
7.	Spatial data sources,Thematic maps	1
7.	Spatial data structure: Raster, vector data, Spatial relationship-Topology	1
8.	Geodatabase models: Hierarchical, network, relational, object-oriented models. Integrated GIS database	3
9.	Data quality, Common sources of error, Macro, micro and Usage level components, Meta data and Spatial data transfer standards	2
10.	Measurement in GIS- Length, perimeter and areas	1
10.	Query analysis. Reclassification, Buffering and Neighbourhood functions	1
11.	Map overlay: Vector and raster overlay	1
12.	Interpolation and network analysis	1
13.	Digital elevation modelling. Analytical Hierarchy Process. Object oriented GIS, AM/FM/GIS and Web Based GIS	3
14.	GIS approach to Rainfall runoff modelling, Flood inundation mapping and modelling	2
15.	GIS approach to Groundwater modelling and water quality modelling	2
16.	Site selection for artificial recharge. Reservoir sedimentation	1
17.	Drought monitoring	1
18.	Performance evaluation of irrigation commands	1
19.	Cropping pattern change analysis	1
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Familiarization with the remote sensing instruments and satellite imagery	1
2.	Methods of establishing ground truth survey and Comparison between ground truth and remotely sensed data	2
3.	Aerial Photograph and scale determination with stereoscope	1
4.	Interpretation of satellite imagery and aerial photograph	1
5.	Determination of Parallaxes in images	1
6.	Demonstration on GPS; Provision of Ground Control by GPS in different mode	1
7.	Introduction to digital image processing software	1
8.	Introduction to GIS software	1
9.	Data input; Data editing and Topology creation -Digitization of point, line & polygon features	
10.	SRTM & CARTO DEM download from web and Georeferencing of an image	1
11.	Delineation of Watershed, DEM generation: slope, Aspect, flow direction, Flow accumulation, Drainage, network and morphometric analysis	2
12.	LULC by supervised classification and LULC by unsupervised classification	1
13.	Application of Remote Sensing data and GIS for water quality parameters	
14.	Temporal satellite data analysis for vegetation condition, crop water requirement calculation	1
15.	Erosion mapping using aerial and satellite Data	1
	Total	**17**

X. Suggested Reading

- Ian HS, Cornelius and Steve C. 2002. *An Introduction to Geographical Information Systems*. Pearson Education, New Delhi.
- James BC and Randolph HW. 2011. *Introduction to Remote Sensing*. The Guilford Press.
- Lilles TM and Kiefer RW. 2008. *Remote Sensing and Image Interpretation*. John Wiley and Sons.
- Paul Curran PJ. 1985. *Principles of Remote Sensing*. ELBS Publications.
- Rees WG. 2001. *Physical Principles of Remote Sensing*. Cambridge University Press.

I. Course Title : Climate Change and Water Resources

II. Course Code : SWCE 508

III. Credit Hours : 3+0

IV. Aim of the course

To acquaint students about the concept of climate change and its impact on surface and ground water resources. To understand adaptation and mitigation strategy under climate change scenario.

V. Theory

Unit I

The climate system: Definitions, climate, climate system, climate change. Drivers of climate change, characteristics of climate system components: Greenhouse effect,

carbon cycle, wind systems. Trade winds and the Hadley Cell, ozone hole in the stratosphere, El Nino, La Nina– ENSO, teleconnections.

Unit II

Impacts of climate change: Observed and projected**,** global and Indian scenario, observed changes and projected changes of IPCC: Impacts on water resources, NATCOM Report, impacts on sectoral vulnerabilities, SRES, different scenarios, climate change impacts on ET and irrigation demand.

Unit III

Tools for vulnerability assessment: Need for vulnerability assessment, steps for assessment, approaches for assessment. Models: Quantitative models, Economic models, impact matrix approach, Box models, Zero-dimensional models, Radioactive-convective models, Higher-dimension models, EMICs (Earth-system models of intermediate complexity), GCMs (global climate models or general circulation models), Sectoral models.

Unit IV

Adaptation and mitigation water: Related adaptation to climate change in the fields of ecosystems and biodiversity, agriculture and food security, land use and forestry, human health, water supply and sanitation, infrastructure and economy (insurance, tourism, industry and transportation), Adaptation, vulnerability and sustainable development.

Unit V

Sector specific mitigation: Carbon dioxide capture and storage (CCS), bio-energy crops, biomass electricity, hydropower, geothermal energy, energy use in buildings, land-use change and management, cropland management, afforestation and reforestation. Potential water resource conflicts between adaptation and mitigation. Implications for policy and sustainable development.

Case studies: Water resources assessment case studies: Ganga Damodar Project, Himalayan glacier studies, Ganga valley project. Adaptation strategies in assessment of water resources. Hydrological design practices and dam safety, operation policies for water resources projects. Flood management strategies, drought management strategies, temporal and spatial assessment of water for irrigation, land use and cropping pattern, coastal zone management strategies.

VI. Learning outcome

The students will be able to understand climate change concept particularly on surface and ground water. Students can have in depth knowledge about adaptation and mitigation strategies in respect of climate change.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Definitions- climate, climate system, climate change; Drivers of climate change	3
2.	Climate system and its components; wind systems, carbon cycle, Greenhouse effect, Trade winds and the Hadley Cell, ozone hole in the stratosphere, El Nino, La Nina– ENSO, teleconnections	3
3.	Climate scenarios- SRES, RCP, Scenario based observed and projected climate changes in Indian and global context	3

S.No.	Topic	No. of Lectures
4.	IPCC projected climate change impacts on water resources, NATCOM Report-impacts on ET and irrigation demand	3
5.	Vulnerability assessment: Need, steps for assessment, approaches for assessment	2
6.	Models: Quantitative models, Economic models, impact matrix approach, Box models, Zero-dimensional models, Radioactive-convective models, Higher-dimension models, EMICs (Earth-system models of intermediate complexity), GCMs (global climate models or general circulation models), Sectoral models	4
7.	Adaptation to climate change in the fields of ecosystems and biodiversity, agriculture and food security, land use and forestry, human health, water supply and sanitation, infrastructure and economy (insurance, tourism, industry and transportation)	4
8.	Sector specific mitigation: Carbon dioxide capture and storage (CCS)	2
9.	Sector specific mitigation: bio-energy crops, biomass electricity, hydropower, geothermal energy, energy use in buildings	2
10.	Sector specific mitigation: land-use change and management, cropland management, afforestation and reforestation	2
11.	Potential water resource conflicts between adaptation and mitigation	2
12.	Implications for policy and sustainable development.	2
13.	Case studies- Ganga Damodar Project, Himalayan glacier studies, Ganga valley project	5
14.	Adaptation strategies in assessment of water resources- Temporal and spatial assessment of water for irrigation, land use and cropping pattern	2
15.	Adaptation strategies in assessment of water resources- Hydrological design practices and dam safety, operation policies for water resources projects	3
16.	Flood management strategies, coastal zone management strategies.	3
	Total	**45**

VIII. Suggested Reading

- Majumdar PP and Nagesh KD. *Floods in a Changing Climate: Hydrological Modelling*. Cambride University Press, New York.
- Pathak H, Agarwal PK and Singh SD. *Mitigation in Agriculture: Methodology for Assessment and Application*. Division of Environmental Sciences, IARI New Delhi.
- Rao YS, Zhang TC Ojha, Gurjar BR, Tyagi RD, Kao CM (eds). *Climate Change Modelling, Mitigation, and Adaptation*. American Society of Civil Engineers.
- Srinivasa RK and Nagesh KD. *Impact of Climate Change on Water Resources with Modelling Techniques and Case Studies*. Springer publications, New York.
- Tamim Y and Caitlin AG. *Climate Change and Water Resources*. Springer Publication.

I. Course Title : Numerical Methods in Hydrology

II. Course Code : SWCE 509

III. Credit Hours : 2+0

IV. Aim of the course

To acquaint students about the concept of linear space, triangular and quadrilateral shape functions, isoparametric elements and transformation of coordinates.

V. Theory

Unit I

Review of finite difference operators. Concept of linear space and basis functions. Approximating from finite dimensional sub spaces.

Unit II

Variational and weighted residual methods. Langrange polynomials. Triangular and quadrilateral shape functions.

Unit III

Isoparametric elements and transformation of coordinates. Basis functions in three dimensions.

Unit IV

Galerkin finite element solution of Laplace, diffusion and dispersion-convection equations.

Unit V

Method of collocation, application in surface and sub surface hydrology.

VI. Learning outcome

The students are able to understand numerical methods in hydrology by having in-depth knowledge of linear space and finite element solution in surface and sub-surface hydrology.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1	Review of finite difference operators	2
2	Concept of linear space and basis functions	3
3	Approximating from finite dimensional sub spaces	3
4	Variational and weighted residual methods	2
5	Langrange polynomials	2
6	Triangular and quadrilateral shape functions	3
7	Isoparametric elements and transformation of coordinates.	3
8	Basis functions in three dimensions	3
9	Galerkin finite element solution of Laplace	3
10	Diffusion and dispersion-convection equations	3
11	Method of collocation	2
12	Application in surface and sub surface hydrology	3
	Total	**32**

VIII. Suggested Reading

- Bear J and Verruijt A. 1987. *Modeling Groundwater Flow and Pollution*. 414 pp. Dordrecht, Boston.
- Carr JR. 1995. *Numerical Analysis for the Geological Sciences*. 592 pp. Prentice-Hall, Englewood Cliffs NJ.
- George H and Patricia W. 2000. *Numerical Methods in the Hydrological Sciences*. American Geophysical Union, Florida Avenue, NW.
- Gerald CF and Wheatley PO. 1999. *Applied Numerical Analysis*. 6th ed., 768 pp, Addison-Wesley, Reading, MA.
- Middleton GV. 2000. *Data Analysis in the Earth Sciences using MATLAB* 260 pp., Prentice Hall, Saddle River NJ.

• Wang HF and Anderson MP. 1982. *Introduction to Groundwater Modeling: Finite Difference and Finite Element Methods*. 237 pp, W.H. Freeman and Co., San Francisco.

I. Course Title : Dryland Water Management Technologies

II. Course Code : SWCE 510

III. Credit Hours : 2+0

IV. Aim of the course

To provide detail knowledge about analysis of severity of drought assessment and various dry land water management technologies suitable for conservation, harvesting and enhancing productivity of rainfed areas.

V. Theory

Unit I

Drought severity assessment: Meteorological, hydrological and agricultural methods. Drought indices. GIS based drought information system, drought vulnerability assessment and mapping using GIS. DPAP programme, drought monitoring constraints, limiting crop production in dry land areas. Types of drought, characterization of environment for water availability, crop planning for erratic and aberrant weather conditions.

Unit II

Stress physiology and crop resistance to drought, adaptation of crop plants to drought, drought management strategies. Preparation of appropriate crop plans for dry land areas. Mid contingent plan for aberrant weather conditions.

Unit III

Land shaping and land development for soil moisture conservation. Improvement of tillage and soil management by implements and engineering practices. Soil and moisture conservation for rainfed lands through improved implements and engineering practices. Gel technology.

Ex-situ measures: Water harvesting-micro catchments. Design of small water harvesting structures: Farm Ponds, percolation tanks their types and design, recycling of runoff water for crop productivity.

Unit IV

Crops and cropping practices related to soil and moisture conservation. Fertility management in dryland farming. Planning and development of watersheds from engineering view point. Case studies.

Unit V

Application of aerial photography in surveys and planning of watersheds for rainfed agriculture.

Use of Remote Sensing in soil moisture estimation.

VI. Learning outcome

The students will be able to understand drought severity assessment techniques alongwith new and appropriate methods of rainwater conservation and harvesting technologies for rainfed areas.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Drought severity assessment: Meteorological, hydrological and agricultural methods	2
2.	Drought indices	1
3.	GIS based drought information system, drought vulnerability assessment and mapping using GIS	2
4.	DPAP programme, drought monitoring constraints, limiting crop production in dry land areas	2
5.	Types of drought: characterization of environment for water availability	1
6.	Types of drought: crop planning for erratic and aberrant weather conditions	1
7.	Stress physiology and crop resistance to drought	1
8.	Adaptation of crop plants to drought and drought management strategies	1
9.	Preparation of appropriate crop plans for dry land areas	2
10.	Mid contingent plan for aberrant weather conditions	1
11.	Land shaping and land development for soil moisture conservation	1
12.	Improvement of tillage and soil management by implements and engineering practices	2
13.	Soil and moisture conservation for rainfed lands through improved implements and engineering practices	2
14.	Introduction of Gel technology for conservation measures	1
15.	*Ex-situ* measures: Water harvesting-micro catchments	1
16.	Design of small water harvesting structures: Farm Ponds	1
17.	Design of small water harvesting structures: percolation tanks their types and design	2
18.	Recycling of runoff water for crop productivity	1
19.	Crops and cropping practices related to soil and moisture conservation	1
20.	Fertility management in dryland farming	1
21.	Planning and development of watersheds from engineering view point	2
22.	Planning and development of watersheds - Case studies	1
23.	Application of aerial photography in surveys and planning of watersheds for rainfed agriculture	1
24.	Use of Remote Sensing in soil moisture estimation	1
	Total	**32**

VIII. Suggested Reading

- Das NR. 2007. *Tillage and Crop Production*. Scientific Publishers.
- Dhopte AM. 2002. *Agro Technology for Dryland Farming*. Scientific Publ.
- Gupta US. 1995. *Production and Improvements of Crops for Drylands.* Oxford & IBH
- Singh RP. 1988. *Improved Agronomic Practices for Dryland Crops*. CRIDA.
- Singh RP. 2005. *Sustainable Development of Dryland Agriculture in India.* Scientific Publ.
- Singh RV. 2003. *Watershed Planning and Management*. Second Edition. Yash Publishing House, Bikaner.
- Singh SD. 1998. *Arid Land Irrigation and Ecological Management*. Scientific Publishers.