COURSE SYLLABUS
for
Ph.D (Agril. Engg.)
in
Farm Machinery and Power Engineering

(Approved by Academic Council vide resolution No. 7644, dat. 07.12.2022)

ODISHA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY
BHUBANESWAR-751003

SEMESTER WISE COURSES TO BE TAKEN FOR THE Ph.D. (AG. ENGG.),
FARM MACHINERY AND POWER ENGINEERING (2022 onwards)

Course No.	Course Title	Credit hours		
		Major	Minor	Supporting
SEMESTER-I				
FMPE 601*	Advances in Farm Machinery and Power Engineering	2+1		
FMPE 602	Advances in Machinery for Precision Agriculture	2+1		
REE 602	Thermochemical Conversion of Biomass		2+1	
ASCE 601	Environmental Engineering for Plants and Animals			3+0
PGS-501	*Library and Information service*	*1+0 (NC)*		
PGS-504	*Basic concepts of laboratory techniques*	*0+1 (NC)*		
SEMESTER-II				
FMPE 603	Energy Conservation and Management in Production Agriculture	3+0		
FMPE 612*	Farm Machinery Management and Systems Engineering	2+1		
REE 609	Energy planning management & economics		3+0	
PFE 604	Agricultural Waste and Byproduct Utilization		2+1	
STAT 601	Theory of Designs and Analysis of Experiments			2+1
FMPE -699	Research for thesis		0+5	
PGS-502	*Technical writing and communication skills*	*0+1 (NC)*		
PGS-505	*Agricultural research, research ethics and rural development*	*1+0 (NC)*		
SEMESTER-III				
*CPE-RPE	Research and Publication Ethics			1+1
PFE -699	Research for thesis	0+10		
PGS-503	*Intellectual property and its management*	*1+0 (NC)*		
SEMESTER-IV				
PFE 699	Research for Thesis	0+20		
SEMESTER-V				
PFE 699	Research for Thesis	0+20		
PFE -691	Doctoral Seminar 1	0+1		
SEMESTER-VI				
PFE 699	Research for Thesis	0+20		
PFE 692	Doctoral Seminar 2	0+1		

- NC: Non-Credit courses are exempted if undergone during masters' programme.

Type of course	Minimum credit hours
A. Course Work	
i) Major course	12
ii) Minor course	06
iii) Supporting course	05
iv) Non-credit compulsory course	--
v) Seminar	02
Sub-Total	25
B. Thesis	75
Grand Total	100

Maximum course load is 18credit hours per semester

COURSE CONTENTS

Ph.D. (Agril.Engg.) in Farm Machinery and Power Engineering

ADVANCES IN FARM MACHINERY AND POWER ENGINEERING

1. Course Title : Advances in Farm Machinery and Power Engineering

2. Course Code : FMPE 601

3. Credit Hours : 2+1

4. Aim of the course

To familiarize the students about modern developments in construction, design and analysis of farm machinery systems as applied in different areas of agriculture.

5. Theory

Unit I

Advances in mechanization as applicable to Indian context. Outlook for improving agricultural productivity and reducing cost. Mechanization: Review of the applications of some of the advanced mechanization technologies and constraints in adaptability. Levels of mechanization and transition between levels.

Unit II

Sustainable mechanization management: Management of compaction of agricultural fields. Strategies to develop machinery and systems that reduce compaction. Concept of Controlled Traffic Farming (CTF) systems. Introduction of wide span mechanization to vegetable production systems to enhance productivity and sustainability.

Unit III

Optimization of production processes to minimize energy loss in agriculture. The rationale for the use of photovoltaic systems in farming. The Energy Returned on Energy Invested (EROEI) ratio as an indicator for evaluating the efficiency of renewable energy sources.

Unit IV

Board sensors, computing hardware, algorithms and software. Manipulator type ag-robots: Use in food processing, dairy, horticulture, and orchard industries.

Unit V

Precision Livestock Farming (PLF): Individual identification and monitoring of animals, tractability of livestock products. Developments in livestock and building

control: Radio telemetry systems to remotely monitor and record physiological parameters. Silage process and their variants. Coordination of machinery system to enhance quality of silage and forage conditioners.

6. Practical

Case studies and presentations on: Mechanization in India-analysis of machinery data-mechanization index and relation between productivity and mechanization. Levels of mechanization in different crops. Design of traffic lanes-field geometry and generating guideline lanes for operation of machinery. Planning use of multiple Machinery-sugarcane harvesting system. Measurement of soil compaction due to heavy machinery using cone penetrometer. Machine vision system design–case studies. Challenges in development of robotic machinery in agricultural operations-case studies.

7. Learning outcome

- The students will be able to design, develop, operate and manage advanced agricultural machinery and power systems.

8. Lecture schedule

S. No	Topic	No. of Lectures
1	Advances in mechanization as applicable to Indian context	**1**
2	Mechanization in large scale agricultural fields	**2**
3	Mechanization in small scale agricultural fields	**1**
4	Future outlook for improving agricultural productivity and reducing cost	**1**
5	Requirements of energy and fuels for machinery operations	**2**
6	Case studies of the applications of some of the advanced mechanization technologies and constraints in adaptability	**2**
7	Case studies of Technology transfer mechanisms in India	**1**
8	Levels of mechanization and transition between levels	**1**
9	Sustainable mechanization management	**1**
10	Management of compaction of agricultural fields	**1**
11	Strategies to develop machinery and systems that reduce compaction	**1**
12	Concept of Controlled Traffic Farming (CTF) systems	**1**
13	Introduction of wide span mechanization to vegetable production systems to enhance productivity and sustainability	**2**

14	Optimization of production processes to minimize energy loss in agriculture	**2**
15	The rationale for the use of photovoltaic systems in farming	**1**
16	The Energy Returned on Energy Invested (EROEI) ratio as an indicator for evaluating the efficiency of renewable energy sources	**2**
17	Machine vision system-hardware and software technologies, and machine learning and image analysis techniques	**1**
18	Unmanned agricultural ground vehicles (UAGVs)	**1**
19	UAGVs instrumented mobile platform, on board sensors, Computing hardware, algorithms and software.	**1**
20	Manipulator type ag-robots: Use in food processing, dairy, Horticulture and orchard industries.	**2**
21	Precision Livestock Farming (PLF): Individual identification and monitoring of animals, tractability of livestock products	**1**
22	Developments in livestock and building control: Radio telemetry systems to remotely monitor and record physiological parameters	**2**
23	Silage process and their variants. Coordination of machinery system to enhance quality of silage and forage conditioners	**1**
24	Silage and forage conditioners	**1**
	Total	**32**

9. List of Practical

S. No	**Topic**	**No. of Practical**
1	Case studies of Mechanization in India	**1**
2	Case studies of Mechanization in SAARC countries	**1**
3	To find mechanization indeX	**1**
4	Relation between productivity and mechanization in India and Punjab	**1**
5	Relation between productivity and mechanization in developed countries	**1**
6	Levels of mechanization in cereal crops like paddy, Wheat etc.	**1**
7	Levels of mechanization in Horticulture crops	**1**
8	Levels of mechanization in cotton crop and pulses and oilseed crops	**1**
9	Design of traffic lanes-field geometry and generating guideline Lanes for operation of machinery.	**1**
10	Planning use of multiple machinery-sugarcane harvesting system	**1**
11	Measurement of soil compaction due to heavy machinery using Cone penetrometer.	**1**

12	Machine vision system design–case studies	**1**
13	Machine vision system design–case studies	**1**
14	Unmanned agricultural ground vehicles (UAGVs) for different applications like spraying, imaging etc.	**1**
15	Challenges in development of robotic machinery in agricultural Operations-case studies.	**1**
16	Developments in livestock and building control: Radio telemetry systems to remotely monitor and record physiological parameters.	**1**
	Total	**16**

10. Suggested Readings

- Chen G. (ed). 2018. Advances in Agricultural Machinery and Technologies. Boca Raton: CRC Press, https;//doi.org/10.1201/9781351132398
- Edwards GTC, Hinge G, Skou-Nielsen N and Villa-Henriksen A. 2017. Route Planning Evaluation of a Prototype Optimized in Field Route Planner for Neutral Material Flow Agricultural operations. Bio systems Engineering **153**:149-157.
- Seyyedhasani H. 2017. Using the Vehicle Routing Problem (VRP) to provide logistic Solutions in Agriculture. Ph.D. dissertation. University of Kentucky, Kentucky, USA
- Srivastava A K. 2006. Engineering Principles of Agricultural Machines, 2nd Edition American Society of Agricultural and Biological Engineers (ISBN) 1-892769-50-6 ASAE Publication 801M0206

ADVANCES IN MACHINERY FOR PRECISION AGRICULTURE

1. Course Title : Advances in Machinery for Precision Agriculture

2. Course Code : FMPE 602

3. Credit Hours : 2+1

4. Aim of the course

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

5. Theory

Unit I

Global navigation satellite system (GNNS). Satellite ranging: Accuracy, standards, Components of GIS, data layers, map component, attribute table component, function of a GIS, resolution. Data formats: Vector or raster. GIS for precision farming, data analysis, field calculator, convert to grid, interpolation, reclassification, image classification, band math, interpretation of analysis, farm management information systems, and crop intelligence.

Unit II

Yield Monitors: Components, Differential GPS Receiver, GNSS Receiver, mass flow sensors. Impact plates, measuring volume with a photoelectric sensor. Using microwave radiation, and Gamma rays to estimate volume, volumetric flow sensing and alternatives. Grain moisture sensor, fan speed sensor, elevator speed sensor, header position, yield monitor data, cotton yield monitors.

Unit III

Sources of soil variability, general soil sampling basics, systematic variability, selecting a soil sampling strategy. Parameters: Electrical conductivity, electromagnetic sensors, sensing mechanical impedance. Proximal plant sensing systems, crops canopy reflectance and fluorescence. Machine vision thermal sensors, mechanical sensors, acoustic sensors.

Unit IV

Remote sensing platforms: Aircraft or satellite. Sensors: Imaging or non-imaging, active or passive. Making use of reflected energy or emitted energy. The spectral signature of vegetation, vegetation indices, application to agriculture, nutrient management, weed management, disease and insect management, water management.

6. Practical

Simple programming for automotive precision farming calculations. Mathematics of longitude and latitude. Spatial statistics, soil sampling and understanding soil testing results for precision farming, calculations. Supporting management zones, understanding soil, water and yield variability in precision farming. Developing prescriptive soil nutrient maps, essential plant nutrients, fertilizer sources, and application rates calculations. Deriving and using an equation to calculate economic optimum fertilizer and seeding rates and cost of crop production.

7. Learning outcome

- Ability to understand design and operate PA systems.

8. Lecture schedule

S. No	Topic	No. of Lectures
1	Introduction about Global Navigation Satellite System (GNSS)	1
2	Satellite ranging including accuracy, standards etc.	1
3	Differential GNSS Receiver, RTK etc.	1
4	Components of GIS, data layers, map component,	**1**
5	Attribute table component, function of a GIS, resolution.	**1**
6	Data formats: Vector or raster	**1**
7	GIS for precision farming, data analysis, field calculator, convert to grid,	**1**
8	Interpolation, reclassification, image classification, band math and interpretation of analysis	**1**
9	Farm management information systems, and crop intelligence.	**1**
10	Introduction about Yield monitors and its components	**1**
11	Mass flow and impact plate sensors, measuring volume with a photoelectric sensor	**1**
12	Microwave radiation and Gamma rays to estimate volume, Different types of grain moisture sensors	**1**
13	Fan speed sensor, elevator speed sensor, header position, yield monitor data	**1**
14	Yield monitors for non-grain crops	**1**
15	Sources of soil variability, general soil sampling basics, systematic variability, selecting a soil sampling strategy	**1**
16	Proximal and remote sensing based soil sensors	**1**
17	Electromagnetic based sensors for soil electrical conductivity measurement	**1**
18	Sensing mechanical impedance based sensors for soil compaction	**1**
19	Spectroscopy for determination of soil properties	**1**

20	Introduction about proximal plant sensing systems	**1**
21	Remote sensing platforms: Aircraft or satellite.	**1**
22	Type of plant sensors: Imaging or non- imaging, active or passive	**1**
23	Use of reflected or emitted energy for vegetation detection	**1**
24	The spectral signature of vegetation, vegetation indices, application to agriculture	**1**
25	Sensing system for nutrient management,	**1**
26	Crops canopy reflectance and fluorescence	**1**
27	Machine vision thermal sensors, mechanical sensors, acoustic sensors	**1**
28	Sensors for weed detection and management	**1**
29	Sensing Techniques for disease and insect management,	**1**
30	Different type of sensors/devices for water management.	**1**
	Total	**30**

9. List of Practical

S. No	Topic	No. of Practical
1	Simple programming for automating precision farming calculations	**1**
2	Mathematics of longitude and latitude	**1**
3	Spatial and temporal statistics using GIS	**1**
4	Soil sampling strategies, understanding and results for precision farming	**1**
5	Creation of management zones	**1**
6	Measurement of yield variability in the field	**1**
7	Measurement of soil Compaction in the field	**1**
8	Measurement of soil EC in the field	**1**
9	Measurement of soil pH in the field	**1**
10	Developing and understanding prescriptive soil nutrient maps	**1**
11	Measurement of essential plant nutrients in the field	**1**
12	Fertilizer sources, and application rates calculations	**1**
13	Deriving and using an equation to calculate economic optimum fertilizer	**1**
14	Calculation of optimum seeding rates for optimized returns	**1**
15	Cost of crop production using precision technologies	**1**
	Total	**15**

10. Suggested Readings

- Clay DE, Clay SA and Bruggeman SA. 2017. Practical Mathematics for Precision Farming. American Society of Agronomy, Madison, WI, USA.
- Ram T, Lohan SK, Singh R and Singh P. 2014. Precision Farming: A New approach. Astral International Pvt. Ltd., New Delhi, India. ISBN: ISBN 978-81-7035-827-5 (Hardbound) ISBN 978-93-5130-258-2 (International Edition).
- Shannon DK, Clay DE and Kitchen NR Newell. 2018. Precision Agriculture Basics. American Society of Agronomy, Inc., Madison, WI, USA.
- Singh AK and Chopra UK. 2007. Geoinformatics Applications in Agriculture. New India Publishing Agency, New Delhi, India.
- Van-Henten EJ, Goense D and Lokhorst C. (ed). 2009. Precision Agriculture. Wageningen Academic Publishers, Wageningen, Netherlands.

ENERGY CONSERVATION AND MANAGEMENT IN PRODUCTION AGRICULTURE

1. Course Title : Energy Conservation and Management in Production Agriculture

2. Course Code : FMPE 603

3. Credit Hours : 3+0

4. Aim of the course

- To enable the student to calculate the energy requirements in different systems and different agricultural operations and to optimize

To enable the student to manage different agricultural systems and operations for energy conservation.

5. Theory

Unit I

Introduction**,** Classification of energy**,** Energy coefficients, Energy requirements for wheat production**,** Energy requirements for paddy production

Unit II

Energy requirements for maize production**,** Energy requirements for cotton production**,** Energy requirements for oil seeds production, Energy requirements for pulse production, Energy requirements for production of other crops

Unit III

Energy requirements for vegetable production, Energy requirements for fruit production, Energy requirements for fish production, Energy requirements for meat and milk production, Limits of energy conservation

Unit IV

Energy planning, management and forecasting in agriculture, Design of integrated energy supply system, Energy conservation and returns, Assessment of energy conservation technology, Case studies on application of various techniques of energy conservation and management

6. Learning outcome

- Ability to understand the energy inflow and outflow to a system
- Ability to calculate energy consumption in different farm operations

7. Lecture schedule

S. No	Topic	No. of Lectures
1	Introduction	**1**
2	Classification of energy	**2**
3	Energy coefficients	**2**
4	Energy requirements for wheat production	**2**
5	Energy requirements for paddy production	**2**
6	Energy requirements for maize production	**2**
7	Energy requirements for cotton production	**2**
8	Energy requirements for oil seeds production	**1**
9	Energy requirements for pulse production	**2**
10	Energy requirements for production of other crops	**2**
11	Energy requirements for vegetable production	**2**
12	Energy requirements for fruit production	**1**
13	Energy requirements for fish production	**1**
14	Energy requirements for meat and milk production	**2**
15	Limits of energy conservation	**1**
16	Energy planning, management and forecasting in agriculture	**3**
17	Design of integrated energy supply system	**2**
18	Energy conservation and returns	**2**
19	Assessment of energy conservation technology	**2**
20	Case studies on application of various techniques of energy conservation and management	**2**
	Total	**36**

9. Suggested Readings

- Mittal JP, Panesar BS, Singh S, Singh CP and Mannan KD. 1987. Energy in Production Agriculture and Food Processing. ISAE and School of Energy Studies for Agriculture, PAU Ludhiana, ISAE Publication.
- Pimental D. 1980. Handbook of Energy Utilization in Agriculture. CRC Press. Boca Rotan, USA.
- Singh S and Singh RS. 2014. Energy for Production Agriculture. DKMA, ICAR, New Delhi, India.

MECHANICS OF TILLAGE IN RELATION TO SOIL AND CROP

1. Course Title : Mechanics of Tillage in Relation to Soil and Crop

2. Course Code : FMPE 604

3. Credit Hours : 2+1

4. Aim of the course

- To have deeper understanding of the tillage process in terms of crop requirement, soil characteristics and machinery function

5. Theory

Unit I

Soil condition and soil strength determining factors. General aspects of mechanical behavior of soil elements. Soil compaction, conditions for its occurrence. Methods of estimation of soil compaction by experimental stress distribution. Concept of soil distortion, deformation at constant volume. Expansion of soil at breaking.

Unit II

Occurrence of soil breaking fundamentals. Measures of resistance against breaking. Shear failure and Coulomb's law. Compaction v/s shear failure. Tensile failure of soil, idealized brittle failure, Griffith's Model. Loading rate and repeated loading effects. Draft calculation-using mechanism of rigid soil bodies.

Unit III

Crop requirements: Root structure, Soil conditions and purpose of tillage, looseness of soil and depth of loosening. Structure of seedbed. Soil properties, properties affected by tillage and those not affected by tillage. Soil compaction, formation of clods and dust. Effect of tillage on erosion and water logging. Impact of climate factors on soil. Tillage requirement for various types of soils.

Unit IV

Tillage operations for special tasks. Preparation of soil for cropping and stubble management. Primary and secondary tillage. Ploughing and its effect on soil. Disc tillage: Appropriate conditions and effect. Requirement of seedbed and techniques of creating proper seedbed. Quality of sowing and sowing methods. Modern trends and objectives of soil tillage.

Unit V

Plough bodies: Generalized representation, intake main flow and output process. Main flow under different surface curvatures. Kinetic aspects of plough bodies with

different shapes. Draft of plough bodies as affected by moisture, speed and attachments.

6. Practical

Characterization of soil condition before and after tillage. Cone penetrometer resistance, bulk density, moisture content. Measurement of forces on tillage tools under soil bin condition/ field condition. Measurement of soil manipulation by different tillage tools: Pulverization, furrow profile, inversion and mixing. Measurement of energy required for soil breakup by different methods. Field study of crop root development in relation to soil compaction and hard pan. Measurement of moisture movement in different surface configuration: Ridges, furrows, raised bed and flat bed. Field evaluation of plant establishment in relation to planting parameters.

7. Learning outcome

- Ability to design tillage machinery based on engineering principles as applied tom tillage science.

8. Lecture schedule

S. No	Topic	No. of Lectures
Unit I		
1	Soil condition and soil strength determining factors	**1**
2	General aspects of mechanical behavior of soil elements.	**1**
3	Soil compaction, conditions for its occurrence	**2**
4	Methods of estimation of soil compaction by experimental stress distribution.	**1**
5	Concept of soil distortion, deformation at constant volume.	**1**
6	Expansion of soil at breaking	**1**
Unit II		
7	Occurrence of soil breaking fundamentals	**1**
8	Measures of resistance against breaking	**1**
9	Shear failure and Coulomb's law	**1**
10	Compaction v/s shear failure	**1**
11	Tensile failure of soil, idealized brittle failure, Griffith's Model.	**1**
12	Loading rate and repeated loading effects	**1**
13	Draft calculation-using mechanism of rigid soil bodies.	**1**
Unit III		
14	Crop requirements: Root structure, Soil conditions and purpose of tillage, looseness of soil and depth of loosening	**1**
15	Structure of seedbed. Soil properties, properties affected by tillage and those not affected by tillage	**2**
16	Soil compaction, formation of clods and dust	**1**

17	Effect of tillage on erosion and water logging	**1**
18	Impact of climate factors on soil	**1**
19	Tillage requirement for various types of soils	**1**
Unit IV		
20	Tillage operations for special tasks	**1**
21	Preparation of soil for cropping and stubble management.	**1**
22	Primary and secondary tillage. Ploughing and its effect on soil.	**1**
23	Disc tillage: Appropriate conditions and effect	**1**
24	Requirement of seed bed and techniques of creating proper seed bed	**1**
25	Quality of sowing and sowing methods	**1**
26	Modern trends and objectives of soil tillage	**1**
Unit V		
27	Plough bodies: Generalized representation, intake main flow and output process	**1**
28	Main flow under different surface curvatures	**1**
29	Kinetic aspects of plough bodies with different shapes.	**1**
30	Draft of plough bodies as affected by moisture	**1**
	Total	**32**

9. List of Practical

S. No	**Topic**	No. of Practical
1	Characterization of soil condition before and after tillage.	**2**
2	Cone penetrometer resistance, bulk density, moisture content.	**1**
3	Measurement of forces on tillage tools under soil bin condition/field condition	**2**
4	Measurement of soil manipulation by different tillage tools: Pulverization, furrow profile, inversion and mixing	**2**
5	Measurement of energy required for soil breakup by Different methods.	**2**
6	Field study of crop root development in relation to soil Compaction and hardpan.	**2**
7	Measurement of moisture movement in different surface configuration: Ridges, furrows, raised bed and flat bed.	**2**
8	Field evaluation of plant establishment in relation to planting parameters	**1**
	Total	**14**

9. Suggested Reading

- Birkas M. 2014. Book of Soil Tillage. Szent Istvan University Press, Godollo, Hungary. ISBN-978-963-269-447-4 (Unit III & IV).
- Koolen AJ and Kuipers H. 1983. Agricultural Soil Mechanics. Springer-Verlag. New York,USA. ISBN 13:978-3-642-69012-9 (Unit I, II, V).

MECHANICS OF TRACTION AND ITS APPLICATION

1. Course Title : Mechanics of Traction and its Application

2. Course Code : FMPE 611

3. Credit Hours : 2+1

4. Aim of the course

Learning techniques of modelling soil traction device interaction under different states of wheel and under different soil conditions by analytical and empirical method.

5. Theory

Unit I

Tractor performance in soft soils, operational states of wheel: Wismer and Luth. Path traced by point on tyre periphery. Rolling resistance, conditions of wheel soil interaction, theoretical prediction, work on soil deformation, Bekker's model, derivation of resistance offered by flat rigid plate on soft soil. Measurement of sinkage parameters. Soft wheel on soft surface and rigid wheel on soft surface. Empirical prediction of tractive force: Bekker's model, stress deformation relation in soil, analysis of tractive performance of tracks.

Unit II

Empirical modelling of tractor performance, tractive performance modelling and mobility number. Empirical models for rolling resistance and traction by Gee-Clough. Derivation of equations for drawbar pull and drawbar power.

Unit III

Rigid wheel systems. Rigid wheel at rest: Soil bearing capacity, contact pressure and sinkage. Rigid wheel at driving state: Ground reaction on rigid wheel during driving action, force balance in soil reaction to driving wheel, determination of driving force, compaction resistance and effective driving force. Energy equilibrium under driving wheel.

Unit IV

Wheel under braking state: Slip velocity and amount of slippage under braked wheel. Soil deformation under braked wheel. Distribution of shear stresses and normal stress under driving wheel.

Unit V

Tyre wheel system-deformation of tyre and area of contact. Deformation of tyre and its measurement. Tyre deformation as function of inflation pressure. Ground reaction

during pure rolling of tyre on hard surface. Trafficability in soft terrain, concept of wheel mobility number-cornering characteristic of wheel forces on a steered wheel under driving and braking conditions. Relation between cornering force and self-aligning torque.

6. Practical

Measurement of soil parameters for modelling traction-simulation of the different traction models to obtain the tractive performance. Calculating the performance of tractor drive wheels, Braking performance of trailer wheels on road, Planter metering drive wheels, Tractor front wheel. Measurement of performance of tyres under soil bin condition/field condition for driving and braking. Measurement of variation in contact patch of tractor tyres under different inflation pressures. Design of lugged wheels for wet puddle soil condition. Field experiment with tractive performance of tractor

7. Learning outcome

- Ability to model vehicle traction mechanics and provide insight into behavior of vehicles under different soil conditions.
- Ability to model vehicle traction mechanics and provide insight into behavior of vehicles under different soil conditions.

8. Lecturer Schedule

S. No	Topic	No. of Lectures
1	Tractor performance in soft soils, operational states of wheel: Wismer and Luth	**2**
2	Path traced by point on tyre periphery	**1**
3	Rolling resistance, conditions of wheel soil interaction, theoretical prediction, work on soil deformation. Bekker's model, derivation of resistance offered by flat rigid plate on soft soil	**4**
4	Measurement of sinkage parameters	**1**
5	Soft wheel on soft surface and rigid wheel on soft surface	**1**
6	Empirical prediction of tractive force : Bekker's model, stress deformation relation in soil, analysis of tractive performance of tracks	**2**
7	Empirical modelling of tractor performance, tractive performance modelling and mobility number	**2**
8	Empirical models for rolling resistance and traction by Gee-Clough	**1**

9	Derivation of equations for drawbar pull and drawbar power	**1**
10	Rigid wheel systems. Rigid wheel at rest: soil bearing capacity, contact pressure and sinkage	**2**
11	Rigid wheel at driving state: Ground reaction on rigid wheel during driving action	**2**
12	Force balance in soil reaction to driving wheel, determination of driving force, compaction resistance and effective driving force	**2**
13	Energy equilibrium under driving wheel	**1**
14	Wheel under braking state: slip velocity and amount of slippage under braked wheel	**2**
15	Soil determination under braked wheel	**1**
16	Distribution of shear stresses and normal stress under driving wheel	**1**
17	Tyre wheel system-deformation of tyre and area of contact	**1**
18	Deformation of tyre and its measurement. Tyre deformation as function of inflation pressure	**1**
19	Ground reaction during pure rolling of tyre on hard surface	**1**
20	Trafficability in soft terrain, concept of wheel mobility number-cornering characteristics of wheel forces on a steered wheel under driving and braking conditions.	**2**
21	Relation between cornering force and self-aligning torque	**1**
	Total	**32**

9. List of Practical

S. No	**Topic**	**No. of Practical**
1	Measurement of soil parameters for modelling traction-simulation of the different traction models to obtain the tractive performance	**3**
2	Calculating the performance of tractor drive wheels, Braking performance of trailer wheels on road, Planter metering drive wheels. Tractor front wheel.	**4**
3	Measurement of performance of tyres under soil bin condition/field condition for driving and braking.	**2**
4	Measurement of variation in contact patch of tractor tyre under different inflation pressures.	**1**
5	Design of lugged wheels for wet puddle soil condition	**2**
6	Field experiment with tractive performance of tractor	**2**
7	Revision	**1**
8	Revision	**1**
	Total	**16**

10. Suggested Readings

- Muro T and O'Brien J. 2004. Terramechanics: Land Locomotion Mechanics. Lisse, Netherlands. ISBN 90 5809 572 X (Unit III, IV, V).
- Macmillan RH. 2010. The Mechanics of Tractor-Implement Performance: Theory and Worked Examples: A Textbook for Students and Engineers. Custom Book Centre, University of Melbourne, Australia. http://hdl.handle.net/11343/33718 (Unit I, II).

FARM MACHINERY MANAGEMENT AND SYSTEMS ENGINEERING

1. Course Title : Farm Machinery Management and Systems Engineering

2. Course Code : FMPE 612

3. Credit Hours : 2+1

4. Aim of the course

- Understanding Farm Machinery from systems approach and ability to model the Farm machinery system.

5. Theory

Unit I

Mathematical models of field machinery systems: Operational constrains, power constrains, weather constrains. Systems approach to field operations and models of: Tillage, seeding, chemical application, harvesting, and storage and irrigation systems.

Unit II

Engineering economics: Concept of incremental and differential cost, economic efficiency, time value of money. Equipment investment cost: Operational cost, production cost, income cost and uncertainty cost. B.C. ratio, payback period, IRR machinery replacement policies.

Unit III

Uncertainty: Concepts of probability, probability functions, distributions, sampling. Statistics, confidence limits, significance, contingency tables, analysis of variance. Regression and correlation. Monte Carlo methods and applications to farm machinery.

Unit IV

System modeling in farm machinery: Numerical methods, analogs, models with uncertainty stochastic service system. Feasibility system design-stability. Deterministic systems and stochastic systems.

Unit V

Optimum Design: Trial and error, differential calculus, calculus of variations. Allocations: Linear programming, simplex technique. Transportation and assignment technique. Critical path scheduling, dynamic programming, game and its applications to farm machinery management.

6. Practical

Solving problems of mathematical models of field machinery, constraints, power constraints, weather constraints. Problems relates to tillage seeding chemical

application harvesting and storage and irrigation systems. Problem solving in Economics of Engineering, calculation of investment cost, operational cost, and uncertainty cost. Case studies in machine performance modelling, Economics of machine selection, Analog components, Analog modelling stochastic system modelling and critical path scheduling.

7. Learning outcome

Ability to understand and develop model of any farm machinery system to help in selection, management and optimization.

8. **Lecturer Schedule**

S. No	Topic	No. of Lectures
1	Understanding Farm Machinery from systems approach and ability to model the Farm machinery system	**2**
2	Mathematical models of field machinery systems: Operational constrains, power constrains, weather constrains.	**2**
3	Systems approach to field operations and models of: Tillage, seeding, chemical application, harvesting, storage and irrigation systems	**3**
4	Engineering economics: Concept of incremental and differential cost, economic efficiency, time value of money	**1**
5	Equipment investment cost: Operational cost, production cost, income cost and uncertainty cost. B.C. ratio, payback period, IRR machinery replacement policies	**2**
6	Uncertainty: Concepts of probability, probability functions, distributions, sampling	**2**
7	Statistics, confidence limits, significance, contingency tables, Analysis of variance.	**1**
8	Regression and correlation. Monte Carlo methods and applications to farm machinery	**3**
9	System modeling in farm machinery: Numerical methods, analogs, models with uncertainty stochastic service system.	**3**
10	Feasibility system design-stability	**1**
11	Deterministic systems and stochastic systems.	**2**
12	Optimum Design: Trial and error, differential calculus, calculus of variations	**2**
13	Allocations: Linear programming, simplex technique Transportation and assignment technique	**4**
14	Critical path scheduling, dynamic programming, game and its applications to farm machinery management	**4**
	Total	**32**

9. List of Practical

S. No	Topic	No. of Practical
1	Problems solving of mathematical models of field machinery, constraints, power constraints, weather constraints	**3**
2	Mathematical problems relates to tillage, seeding, chemical application harvesting and storage and irrigation systems	**3**
3	Problem solving in Economics of Engineering, calculation of investment cost, operational cost, and uncertainty cost	**3**
4	Case studies in machine performance modelling, Economics of machine selection	**2**
5	Case studies in machine performance modelling	**2**
6	Economics of Power and machine selection	**2**
	Total	**15**

10. Suggested Reading

- Hunt DR. 1986. Engineering Models for Agricultural Production. AVI Pub. Co., Westport, CT, USA.
- Hunt D and Wilson D. 2015. Farm Power and Machinery Management. Waveland Press, Illinois, USA.
- Singh S and Verma SR. 2009. Farm Machinery Maintenance and Management. DIPA, ICAR, New Delhi.

MACHINERY FOR SPECIAL FARM OPERATIONS

1. Course Title : Machinery for Special Farm Operations

2. Course Code : FMPE 613

3. Credit Hours : 2+0

4. Aim of the course

- To bring to focus special farm operations that are not covered under conventional operations and the machinery used for such operations.

5. Theory

Unit I

Machinery for land development. Tractor operated and self-propelled machines for laying drainage system, sub surface drip laying machines, subsoiler, trenchers, laser levelers.

Unit II

Machines for plant protection, pneumatic, thermal type sprayers, aero/drone spraying and other methods of spraying, electrostatic charging, air sleeve boom sprayer, disinfection of seedbeds by microwaves and other methods. Safety aids for operator and advances in plant protection method.

Unit III

Field plot machinery and its importance. Fertilizer and manure spreader.

Unit IV

Machines for residue management. Silage and hay making machines.

Unit V

Machinery for horticultural crops. Crop specific machines for cotton, sugarcane, forage/fodder. Machines for processing and handling of agricultural products.

6. Learning outcome

Understanding of the broad horizon of agricultural machinery used for specialized agricultural operations.

7. Lecture Schedule

S. No	Topic	No. of Lectures
1	Machinery for land development	1
2	Tractor operated and self-propelled machines for laying drainage system, sub surface drip laying machines, subsoiler, trenchers	2

3	Laser levelers	2
4	Machines for plant protection	1
5	Pneumatic, thermal type sprayers	2
6	Aero/drone spraying and other methods of spraying	2
7	Electrostatic charging, air sleeve boom sprayer	2
8	Disinfection of seed beds by micro waves and other methods	1
9	Safety aids for operator and advances in plant protection method	2
10	Field plot machinery and its importance	1
11	Fertilizer and manure spreader	2
12	Machines for residue management (in situ)	4
13	Machines for residue management (ex situ)	2
14	Silage and hay making machines	3
15	Machinery for horticultural crops	2
16	Crop specific machines for cotton, sugarcane, forage/fodder	2
17	Machines for processing and handling of agricultural products	1
	Total	32

8. Suggested Reading

- Boson ES, Sultan-Shakh EG, Smirnov II and Verniaev OV. 2016. Theory, Construction and Calculation of Agricultural Machines. Scientific Publishers.
- Kanafozski C and Karwowiki T. 1976. Agricultural Machines: and Construction. Vol. I & II, Translated and published by US Dept. of Agriculture and National Science Foundation, Washington, DC, USA.
- Kepner RA, Bainer R and Barger EL. 2017. Principles of Farm Machinery. CBS publishers and Distributors Pvt. Ltd, New Delhi, India.

ERGONOMICS IN WORKING ENVIRONMENT

1. Course Title : Ergonomics in Working Environment

2. Course Code : FMPE 614

3. Credit Hours : 2+1

4. Aim of the course

- To enable the student to understand the concept of designing the working environment and designing farm machinery and equipment to ensure operators comfort and safety.

5. Theory

Unit I

Musculoskeletal problems in sitting and standing postures-behavioral aspects of posture, body mechanics. Workspace design for standing and seated workers. Display units, controls and human-machine interaction, design of static work.

Unit II

Noise and noise control. Measurement of noise and safe limits. Protection from noise. Vibration and health. Vibrations generated by agricultural machines. Types of vibrations: Whole body vibrations and hand transmitted vibrations. Methods of measurements of vibrations, hazards of vibrations. Vibration White Fingers (VWF). Vibration reductions in agricultural machines.

Unit III

Working environment-heat and cold stress conditions. Thermal balance of human body. Measurement of thermal environment. Heat and cold stress condition. Thermoregulatory system of human body. Heat and cold acclimatization. Effect of climate on human performance. Environmental dust and its measurement: Organic and inorganic dust. Types of dust and their hazards: Respirable, thoracic and inhalable dust. Personal protection from dust.

Unit IV

Time motion study and its purpose. Application of Time motion study in agricultural and processing operations. Recent research works related to ergonomics in agriculture.

6. Practical

Design of workspace for static work in standing and sitting positions. Study of body mechanics and postures in design of agricultural machinery. Human energy expenditure, calibration of subjects, Human workload and its assessment. Study of work and rest schedule. Measurement of visibility of tractors. Measurement and control of noise in tractors and self-propelled machines. Measurement of human vibrations in farm tractors and agricultural machines. Study of dust generated in agricultural operations.

7. Learning outcome

- Ability to design working environment of different agricultural machinery for efficient and safe operations.

8. Lecture Schedule

S. No	Topic	No. of Lectures
1	Basics of body mechanics, stability and support	**1**
2	Control of muscle function, fatigue and discomfort	**1**
3	Musculoskeletal problems in sitting and standing posture	**2**
4	Behavioral aspects of posture, risk factors for musculoskeletal disorders	**1**
5	Importance of ergonomics in workspace design	**1**
6	Workspace design for standing workers	**1**
7	Workspace design for seated workers	**1**
8	First hourly examination	**1**
9	Visual display units, controls and human- machine interaction	**1**
10	Design of static work	**1**
11	Importance of noise control and safe limits for human	**1**
12	Measurement of noise, reduction and protection	**1**
13	Machine vibrations, human vibrations and health hazards	**1**
14	Whole body vibrations and hand transmitted vibrations	**1**
15	Methods of measurements of vibrations and health hazards	**1**
16	Vibration reduction techniques for agricultural machines	**1**
17	Mid-semester examination	**1**
18	Working environment- heat and cold stress conditions, thermal balance of human body	**1**
19	Measurement of thermal environment	**1**
20	Thermo-regulatory system of human body, heat and cold acclimatization, effect of climate on human performance	**2**
21	Environmental dust and its measurement, type of dust organic and inorganic dust, dust health hazard	**1**
22	Respirable, thoracic and inhalable dust, protection from dust	**1**
23	Time motion study and its purpose	**1**
24	Application of time motion study in agricultural and processing operations	**1**
25	Recent research work related to physiological parameters of ergonomics in agriculture	**1**
26	Recent research work related to tractor space layout and design of controls	**1**
27	Recent research work related to noise studies on farm machines	**1**
28	Recent research work related to vibrations studies on farm machines	**1**
29	Recent research work related to accidents and safety studies on farm machines	**1**
30	Revision and discussion	**1**

	Total	**32**

List of Practical:

S. No	Topic	No. of Practical
1	Design of workspace for static work in standing or sitting posture	1
2	Study of body mechanics and posture in design of agricultural machinery	2
3	Study of displays and controls in tractors	1
4	Calibration of subjects on ergometer and treadmill	2
5	Human workload and its assessment	1
6	Study of work and rest schedule	1
7	Measurement of visibility to tractor operators	1
8	Measurement of noise in tractors and self-propelled machines	1
9	Measurement of machine component vibration	1
10	Measurement of hand arm vibrations	1
11	Measurement of whole-body vibrations	1
12	Study of dust generated in agricultural operations	1
13	Case study of design improvement in agricultural machine/tool through ergonomic concept	1
14	Practical examination	1
	Total	16

10. Suggested Reading

- Astrand PO, Rodahl K, Dahl HA and Stromme SB. 2003. Textbook of Work Physiology: Physiological Bases of Exercise. Champaign IL: Human Kinetics.
- Bridger RS. 2009. Introduction to Ergonomics. 3rd edition CRC Press, Boca Raton, USA.
- Gite LP, Majmudar J, Mehta CR and Khadatkar A. 2009. Anthropometric and Strength Data of Indian Agricultural Workers for Farm Equipment Design. Central Institute of Agricultural Engineering, Bhopal, India.
- Gite LP, Agrawal KN, Mehta CR, Potdar RR and Narwariya BS. 2019. Handbook of Ergonomical Design of Agricultural Tools, Equipment and work Places. Jain Brothers, New Delhi.
- Kroemer KHE and Grandjean E. 1997. Fitting the Task to the Human: A Textbook of Occupational Ergonomics. Taylor & Francis, Philadelphia, USA.
- Pearsons K. 2003, Human Thermal environments: The Effects of Hot, Moderate and Cold Environment on Human Health, Comfort and Performance. Taylor and Francis, New York, USA.
- Sanders MS and McCormick EJ. 1993. Human Factors in Engineering and Design. McGraw Hill, New York, USA.

THEORY OF DESIGN AND ANALYSIS OF EXPERIMENT

1. Course Title : Theory of design and analysis of experiment

2. Course Code : STAT 601

3. Credit Hours : 2+1

4. Aim of the course

- To enable the student to understand the concept of designing experiments statistically and analyzing the observed data to arrive at conclusions

5. Theory

Unit I

Introduction, terminology in experimental design, experimental error, uniformity of trials, principles of experimental design, size of plot, completely randomized design, Advantages and disadvantages of CRD, Analysis of CRD, Least square estimates of effects, Expectations of Sum of Squares

Unit II

Randomized block design. (RBD), Layout of RBD, Advantages and disadvantages of RBD, Statistical analysis procedure of RBD, Least Squares Estimates and Expectations of Mean Sum of Squares, Estimation of Missing value in RBD

Unit III

Latin Square Design, Layout of Latin Square Design, Advantages and Disadvantages of Latin Square Design, Least Squares Estimates and Expectations of Mean Sum of Squares, Expectations of Sum of Squares, Efficiency of LSD, and Estimation of Missing value in LSD.

Unit IV

Factorial Experiment, Basic ideas and notations. Main effects and Interactions. Statistical analysis of 2^2 design. Yates method of computing Factorial Effect. 2^3 Factorial Experiments, Compounding in Factorial Design. Latin Square Design (LSD), Layout of Latin Square Design, Advantages and Disadvantages of LSD. Statistical analysis of LSD. Confounding in Factorial Design.

6. Practical

Analysis of CRD experiments, Analysis of RBD experiments, Analysis of LSD experiments, Analysis of experimental data for 2^2 and 2^3 factorial designs. Analysis of split plot Design experiments, Missing plot technique in RBD, Missing plot technique in LSD. Statistical Analysis of data using computer software

7. Learning outcome

- To enable the students statistically design Experiments and analyze the data to arrive at conclusions.

8. Lecture Schedule

S. No	Topic	No. of Lectures
1	Introduction, terminology in experimental design	**1**
2	Experimental errors, uniformity of trials, principles of experimental design, size of plot,	**2**
3	Completely Randomized Design, Advantages and Disadvantages of CRD	**2**
4	Analysis of CRD experiments	**1**
5	Least square estimates of effects ,Expectations of Sum of Squares	**1**
6	Randomized block design. (RBD), Layout of RBD, Advantages and disadvantages of RBD	**2**
7	Statistical analysis procedure of RBD	**2**
8	Least Squares Estimates and Expectations of Mean Sum of Squares	**2**
9	Estimation of Missing value in RBD	**2**
10	Latin Square Design, Layout of Latin Square Design	**2**
11	Analysis of LSD problems, Advantages and Disadvantages of Latin Square Design	**2**
12	Least Squares Estimates and Expectations of Mean Sum of Squares, Expectations of Sum of Squares, Efficiency of LSD	**2**
13	Estimation of Missing value in LSD	**2**
14	Factorial Experiment, Basic ideas and notations	**2**
15	Main effects and Interactions	**1**
16	Statistical analysis of 2^2 design	**2**
17	Yates method of computing Factorial Effect Totals.	**2**
18	2^3 Factorial Experiments	**2**
19	Compounding in Factorial Design	**1**
20	Latin Square Design (LSD), Layout of Latin Square Design, Advantages and Disadvantages of LSD	**1**
21	Statistical analysis of LSD. Confounding in Factorial Design	**2**
	Total	**36**

List of Practical:

S. No	Topic	No. of Practical
1	Analysis of CRD Experiments	2
2	Analysis of RBD Experiments	2
3	Analysis of LSD Experiments	2
4	Analysis of Factorial Design Experiments (2^3, 3^3)	2
5	Analysis of Split plot Design	2
6	Analysis of Missing plot Problem in RBD	2
7	Analysis of Missing plot Problem in LSD	2
8	Statistical Analysis of data using computer software	2
	Total	16

10. Suggested Readings

- Statistical Procedures for Agricultural Research, 2nd Edition, Kwanchai A. Gomez, Arturo A. Gomez, John Wiley & Sons Inc
- Statistical Methods for Agricultural Workers: By V. G. Panse and P. V. Sukhatme, Indian Council of Agricultural Research, 1961
- Fundamentals of Applied Statistics, S. C. Gupta, V. K. Kapoor, Sultan Chand & Sons