गोंय विद्यापीठ
ताळगांव पठार,
गोंय – ४०३ २०६
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(Accredited by NAAC)

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GU/Acad –PG/BoS -NEP Engg. /2024-25/767 Date: 22.01.2025

CIRCULAR

Ref. No.: GU/Acad –PG/BoS -NEP Engg. /2024/619 dated 30.10.2024

In supersession to the above referred Circular the Syllabus of Semester II of the **Master of Engineering (Industrial Engineering)** Programme approved by the Academic Council in its meeting held on 06th December 2024 is attached herewith. The Syllabus of Semester I approved earlier by the Academic Council in its meeting held on 22nd August 2024 is also attached

The Dean, Faculty of Engineering and Principals of affiliated Colleges offering the **Master of Engineering (Industrial Engineering)** Programme are requested to take note of the above and bring the contents of the Circular to the notice of all concerned.

ASHWIN VYAS LAWANDE
Digitally signed by ASHWIN VYAS LAWANDE
Date: 2025.01.22 17:16:55 +05'30'

(Ashwin V. Lawande)

Deputy Registrar – Academic

To,

1. The Dean, Faculty of Engineering, Goa University.
2. The Principals of affiliated Engineering Colleges.

Copy to,

1. The Director, Directorate of Technical Education, Govt. of Goa
2. The Chairperson, BoS in Mechanical Engineering.
3. The Controller of Examinations, Goa University.
4. The Assistant Registrar Examinations (Prof.), Goa University.
5. Directorate of Internal Quality Assurance, Goa University for uploading the Syllabus on the University website.

MASTER OF ENGINEERING (INDUSTRIAL ENGINEERING) RC 2024-25

TWO YEAR PROGRAMME STRUCTURE						
Semester I						
Sr. No.	**Course Code**	**Title of the Course**	**L**	**T**	**P**	**Credits**
Programme Specific Core (PSC) Courses						
1	MEC-500	Principles of Industrial Engineering & Management	3	1	0	4
2	MEC-501	Quality Engineering	3	0	0	3
3	MEC-502	Quality Engineering Lab	0	0	1	1
4	MEC-503	Optimization Techniques for Industrial Engineering	3	0	0	3
5	MEC-504	Optimization Techniques for Industrial Engineering Lab	0	0	1	1
Programme Specific Elective (PSE) Courses						
6	MEC-531	Materials Management	3	1	0	4
OR						
7	MEC-532	Energy Auditing	3	1	0	4
Research Specific Elective (RSE) Courses						
8	REC-561	Engineering Research & Publication	3	1	0	4
OR						
9	REC-562	Literature Review & Technical Writing for Engineers	3	1	0	4
		Total	**15**	**3**	**2**	**20**
Semester II						
Sr. No.	**Course Code**	**Title of the Course**	**L**	**T**	**P**	**Credits**
Programme Specific Core (PSC) Courses						
1	MEC-505	Data Analytics	3	0	0	3
2	MEC-506	Data Analytics Lab	0	0	1	1
3	MEC-507	Reliability Engineering	3	0	0	3
4	MEC-508	Reliability Engineering Lab	0	0	1	1
5	MEC-509	Operations and Project Management	3	0	0	3
6	MEC-510	Operations and Project Management Lab	0	0	1	1
Programme Specific Elective (PSE) Courses						
7	MEC-533	Supply Chain Management	3	0	0	3
8	MEC-534	Supply Chain Management Lab	0	0	1	1
OR						
9	MEC-535	Facility Design	3	0	0	3
10	MEC-536	Facility Design Lab	0	0	1	1
Research Specific Elective (RSE) Courses						
11	REC-563	Statistics and Data Analysis for Engineering Research	2	0	0	2
12	REC-564	Statistics and Data Analysis Lab	0	0	2	2
OR						
13	REC-565	Statistical Techniques for Engineering Research	2	0	0	2
14	REC-566	Probability and Statistical Analysis Lab	0	0	2	2
		Total	**14**	**0**	**6**	**20**

Issued on: 22/01/2025

Semester III						
Sr. No.	**Course Code**	**Title of the Course**	**L**	**T**	**P**	**Credits**
Programme Specific Core (PSC) Courses						
1	**MEC-600**	Work System Design	3	0	0	3
2	**MEC-601**	Work System Design Lab	0	0	1	1
3	**MEC-602**	Lean Six Sigma	3	0	0	3
4	**MEC-603**	Lean Six Sigma Lab	0	0	1	1
Programme Specific Elective (PSE) Courses						
5	**MEC-631**	Industrial Safety and Occupational Health	3	0	0	3
6	**MEC-632**	Industrial Safety lab	0	0	1	1
OR						
7	**MEC-633**	Soft Computing	3	0	0	3
8	**MEC-634**	Soft Computing Lab	0	0	1	1
Research Specific Elective (RSE) Courses						
9	**REC-661**	System Modeling and Simulation	2	0	0	2
10	**REC-662**	System Modeling and Simulation Lab	0	0	2	2
OR						
11	**MEC-661**	Advanced Optimization	2	0	0	2
12	**MEC-662**	Advanced Optimization Lab	0	0	2	2
Generic Elective (GE) Courses						
13	**GEC-681**	Sustainability Principals & Practices	3	0	0	3
14	**GEC-682**	Sustainability Principals & Practices Lab	0	0	1	1
OR						
15	**GEC-687**	Marketing Management	3	0	0	3
16	**GEC-688**	Marketing Management Lab	0	0	1	1
		Total	**14**	**0**	**6**	**20**
Semester IV						
Sr. No.	**Course Code**	**Title of the Course**	**L**	**T**	**P**	**Credits**
Generic Elective (GE) Courses						
1	**GEC-685**	Financial Management	4	0	0	4
OR						
2	**GEC-686**	Entrepreneurship	4	0	0	4
Programme Specific Dissertation/Internship						
3	**MEC-698**	Dissertation	0	0	16	16
4	**MEC-699**	Internship	0	0	16	16
		Total	**4**	**0**	**16**	**20**

Issued on: 22/01/2025

THREE YEAR PROGRAMME STRUCTURE						
Semester I						
Sr. No.	**Course Code**	**Title of the Course**	**L**	**T**	**P**	**Credits**
Programme Specific Core (PSC) Courses						
1	MEC-500	Principles of Industrial Engineering & Management	3	1	0	4
Programme Specific Elective (PSE) Courses						
2	MEC-531	Materials Management	3	1	0	4
OR						
3	MEC-532	Energy Auditing	3	1	0	4
Research Specific Elective (RSE) Courses						
4	REC-561	Engineering Research & Publication	3	1	0	4
OR						
5	REC-562	Literature Review & Technical Writing for Engineers	3	1	0	4
		Total	**9**	**3**	**0**	**12**
Semester II						
Sr. No.	**Course Code**	**Title of the Course**	**L**	**T**	**P**	**Credits**
Programme Specific Core (PSC) Courses						
1	MEC-505	Data Analytics	3	0	0	3
2	MEC-506	Data Analytics Lab	0	0	1	1
Programme Specific Elective (PSE) Courses						
3	MEC-533	Supply Chain Management	3	0	0	3
4	MEC-534	Supply Chain Management Lab	0	0	1	1
OR						
5	MEC-535	Facility Design	3	0	0	3
6	MEC-536	Facility Design Lab	0	0	1	1
Research Specific Elective (RSE) Courses						
7	REC-563	Statistics and Data Analysis for Engineering Research	2	0	0	2
8	REC-564	Statistics and data Analysis Lab	0	0	2	2
OR						
9	REC-565	Statistical Techniques for Engineering Research	2	0	0	2
10	REC-566	Probability and Statistical Analysis Lab	0	0	2	2
		Total	**8**	**0**	**4**	**12**

Issued on: 22/01/2025

Semester III						
Sr. No.	**Course Code**	**Title of the Course**	**L**	**T**	**P**	**Credits**
Programme Specific Core (PSC) Courses						
1	MEC-501	Quality Engineering	3	0	0	3
2	MEC-502	Quality Engineering Lab	0	0	0	1
3	MEC-503	Optimization Techniques for Industrial Engineering	3	0	0	3
4	MEC-504	Optimization Techniques for Industrial Engineering Lab	0	0	1	1
Programme Specific Elective (PSE) Courses						
5	**MEC-631**	Industrial Safety and Occupational Health	3	0	0	3
6	**MEC-632**	Industrial Safety lab	0	0	1	1
OR						
7	**MEC-633**	Soft Computing	3	0	0	3
8	**MEC-634**	Soft Computing Lab	0	0	1	1
		Total	**9**	**0**	**3**	**12**
Semester IV						
Sr. No.	**Course Code**	**Title of the Course**	**L**	**T**	**P**	**Credits**
Programme Specific Core (PSC) Courses						
1	MEC-507	Reliability Engineering	3	0	0	3
2	MEC-508	Reliability Engineering Lab	0	0	1	1
3	MEC-509	Operations and Project Management	3	0	0	3
4	MEC-510	Operations and Project Management Lab	0	0	1	1
Generic Elective (GE) Courses						
5	**GEC-681**	Sustainability Principals & Practices	3	0	0	3
6	**GEC-682**	Sustainability Principals & Practices Lab	0	0	1	1
OR						
7	**GEC-687**	Marketing Management	3	0	0	3
8	**GEC-688**	Marketing Management Lab	0	0	1	1
		Total	**9**	**0**	**3**	**12**

Semester V						
Sr. No.	**Course Code**	**Title of the Course**	**L**	**T**	**P**	**Credits**
Programme Specific Core (PSC) Courses						
1	**MEC-600**	Work System Design	3	0	0	3
2	**MEC-601**	Work System Design Lab	0	0	1	1
3	**MEC-602**	Lean Six Sigma	3	0	0	3
4	**MEC-603**	Lean Six Sigma Lab	0	0	1	1
Research Specific Elective (RSE) Courses						
5	**REC-661**	System Modeling and Simulation	2	0	0	2
6	**REC-662**	System Modeling and Simulation Lab	0	0	2	2
OR						
7	**MEC-661**	Advanced Optimization	2	0	0	2
8	**MEC-662**	Advanced Optimization Lab	0	0	2	2
		Total	**8**	**0**	**4**	**12**
Semester VI						
Sr. No.	**Course Code**	**Title of the Course**	**L**	**T**	**P**	**Credits**
Generic Elective (GE) Courses						
1	**GEC-685**	**Financial Management**	4	0	0	4
OR						
2	**GEC-686**	**Entrepreneurship**	4	0	0	4
Programme Specific Dissertation/Internship						
3	**MEC-698**	**Dissertation**	0	0	0	16
OR						
4	**MEC-699**	**Internship**	0	0	0	16
		Total	**4**	**0**	**0**	**20**

Semester – I
Programme Specific Core (PSC) Courses
Name of the Programme : Master of Engineering (Industrial Engineering)
Course Code : MEC-500
Title of the Course : Principles of Industrial Engineering & Management
Number of Credits : 4
Effective from AY : 2024-25

Pre-requisites for the Course:	Nil	
Course Objectives:	1. The course employs a strategic structure that identifies and illustrates the concepts of industrial engineering in order to help students understand industrial engineering. 2. The course provides insights to the students for implementing productivity improvement procedures at their workplace. 3. The course will help students, in revisiting the management theories being practiced in the industry at their workplace. 4. The course conforms to the immediate requirements of aspirants for post graduate studies in Industrial Engineering and Management Colleges.	
Content:		**No of hours**
Unit - I	Need of optimization of resources. Evolution of industrial Engineering Concept of Production, Types of Production, Concept of Productivity, Types of Productivity, Production vs Productivity, Factors influencing Productivity, Productivity Measures Work Study, Work content, Method Study, Procedure of Method Study, Advantages and Limitations, Work Measurement, Techniques of Work Measurement (Work Sampling, Time Study, PMTS	**12**
Unit - 2	Value Engineering and Value Analysis, Value Engineering Phases, FAST diagram Job Evaluation, Qualitative and Quantitative Methods of Job Evaluation (Ranking by paired comparison, Grade description, Point system, Factor Comparison)	**12**
Unit - 3	Management, Management theories, Manager V/S Leader Organisation, Organisational structure, Span of control, Authority Responsibility and Delegation Leadership, theories of leadership, Leadership styles, Blake Mouton grid, Case studies on Leadership	**12**
Unit - 4	Motivation, Theories of Motivation (Maslow's Theory, Herzberg Theory, McGregor's Theory, Vroom's Expectancy theory) Communication, Communication process model, Barriers, Case studies on Communication	**9**
Pedagogy:	Constructivist, Collaborative, Integrative	

References/ Readings:	Textbooks 1. Introduction to Work study by ILO, Universal Book Corporation, 3rd edition, 1988 2. Mundel Marvin E., Measuring and enhancing productivity of service and government organization, Asian Productivity Organization, 1975 3. Harold G. Tuffy, Compendium on Value Engineering, The Indo American Society, Bombay, 1983 4. Koontz, Harold and Weihrich Heinz, Essentials of Management, Tata McGraw Hill, New Delhi, 1998 5. Management, Stoner James Freeman, Edward R and Gilbert R Daniel, Prentice Hall, New Delhi, 1999 6. Rasberry R W and Lemoine L F, Kent, Effective Managerial Communication, Publishing Company, 198 7. M. Telsang; Industrial Engineering and Production Management; S. Chand, New Delhi; 2015 References 1. R. M. Barnes; Motion and Time study - Design and Measurement of Work; Wiley and Sons; New York; 1980 2. Mundel Marvin E., Improving productivity and effectiveness, Prentice Hall, NY, 1983 3. A. P. Verma; Industrial Engineering & Management; S. K. Kataria& Sons; 2012. 4. M. Mahajan; Industrial Engineering and Production Management; Dhanpat Rai & Co.; 2014
Course Outcomes:	On completing this course students will be able to: CO 1. Understand the basic concepts of industrial engineering and management CO 2. Apply the productivity improvement techniques learnt in real life situations. CO 3. Analyze case studies on management theories. CO 4. Evaluate improvement potential of existing ways of doing work and propose improved solutions.

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Name of the Programme : **Master of Engineering (Industrial Engineering)**
Course Code : **MEC-501**
Title of the Course : **Quality Engineering**
Number of Credits : **3**
Effective from AY : **2024-25**

Pre-requisites for the Course:	Nil	
Course Objectives:	The course will enable students to: 1. Understand quality with relation to statistical process control and acceptance sampling, 2. Apply the knowledge to cases in industrial applications on statistical process control and acceptance sampling. 3. Analyze the metrics in control charts and sampling plans. 4. Evaluate quality in industry-based applications.	
Content:		**No of hours**
Unit - 1	**Introduction:** Basic concepts of Quality: Definitions, philosophy and costs. Total Quality Management, KAIZEN, Quality circles, Quality Function Deployment, Six Sigma, Zero Effect Zero Defect, ISO standards, Preliminary discussions on Design of Experiments and Taguchi Methods. **Quality tools:** Introduction and Case studies: Frequency distribution and Histogram, Run chart, Stem-and-leaf plot, Pareto diagram, Cause and Effect Diagram, Scatter diagram, Check sheet, Control chart.	**12**
Unit - 2	**Variable Control Charts:** Introduction, Statistical basis of the Charts, Development, use and interpretation of Sample Mean, Range Chart and Standard Deviation Chart, Type-I and Type-II errors, Average Run Length (ARL), Average Time to Signal (ATS), Operating-Characteristic (O.C.) Curve, Process Capability studies. **Industrial case-studies:** On defect reduction and process control.	**11**
Unit - 3	**Control Charts for Attributes:** Introduction, Control charts for non-conforming items (p-chart, np-chart)- Statistical Basis, Development and Operation, Fixed sample size and Variable sample size, Type I and II errors, O.C. curve and ARL. Control charts for nonconformities (c-chart, u-chart)- Statistical Basis, Development and Operation, Fixed sample size and Variable sample size, Type I and II errors, O. C. curve and ARL. Industrial case-studies on process control.	**11**
Unit - 4	**Acceptance Sampling by Attributes:** Introduction, Advantages and Disadvantages of sampling, single, double and multiple sampling plans - Calculation of probability of acceptance, O. C. curve concept; Military Standard System- Concept and use, Designing single, double and multiple sampling plans; Dodge-Romig system- Concept and use, Designing single and double sampling plans; Sequential Sampling Plan- design and application. Industrial case-studies on setting up and use of above sampling	**11**

	plans.	
Pedagogy:	Constructivist, Integrative, Reflective and Enquiry based	
References/ Readings:	Text Books 1. A. Mitra; Fundamentals of Quality Control and Improvement; Third Edition; Wiley India; 2008. 2. D. C. Montgomery; Statistical Quality Control: A Modern Introduction; Sixth Edition, Wiley India; 2009. Reference Books 1. E. L. Grant, R. S. Leavenworth; Statistical Quality Control; Seventh Edition; McGraw Hill India; 2000. 2. R. K. Jain, H. M. Trivedi; Quality Management for Zero Defect and Zero Effect: A Compendium of Case Studies and Best Practices; American Society for Quality India; 2016.	
Course Outcomes:	After going through this course, the students will be able to: CO 1. Understand the concepts of quality, statistical process control, acceptance sampling, CO 2. Apply the knowledge gained from statistical process control, acceptance sampling, CO 3. Analyze quality tools, control charts, sampling plans CO 4. Evaluate quality tools, performance of control charts and sampling plans.	

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Name of the Programme : Master of Engineering (Industrial Engineering)
Course Code : MEC-502
Title of the Course : Quality Engineering Lab
Number of Credits : 1
Effective from AY : 2024-25

Pre-requisites for the Course:	Nil	
Course Objectives:	The course will enable students to: 1. Understand quality tools, control charts and acceptance sampling plan and the methodology of solving using software. 2. Apply the knowledge of quality tools, control charts and acceptance sampling on industrial cases as well as software-based solutions. 3. Interpret the solutions obtained by using quality tools, control charts and acceptance sampling. 4. Recommend course of action based on the output obtained from the use of quality tools, control charts and acceptance sampling.	
Content:		**No of hours**
Unit - 1	1. Assignment on Quality tools, 2. Using software like MS Excel, MINITAB etc., solve industrial problem involving the following: A. Pareto Chart B. Cause and Effect Diagram C. Histogram	**8**
Unit - 2	1. Assignment on Variable Control Charts 2. Using software like MS Excel, MINITAB etc., solve industrial case solve industrial problem on Variable Control Charts.	**8**
Unit - 3	1. Assignment on Attribute Control Chart 2. Using software like MS Excel, MINITAB etc., solve industrial case solve industrial problem on Attribute Control Chart.	**8**
Unit - 4	1. Assignment on Acceptance Sampling Plan. 2. Using software like MS Excel, MINITAB etc., solve industrial case solve industrial problem on Acceptance Sampling Plan.	**6**
Pedagogy:	Constructivist, Integrative, Reflective and Enquiry based	
References/ Readings:	Text Books 1. C. Montgomery; Statistical Quality Control: A Modern Introduction; Sixth Edition, Wiley India; 2009. 2. A. Mitra; Fundamentals of Quality Control and Improvement; Third Edition; Wiley India; 2008.	
Course Outcomes:	After going through this course, the students will be able to: CO 1. Understand quality tools, control charts and acceptance sampling plan. CO 2. Apply the knowledge to cases in industrial applications on quality tools, control charts and acceptance sampling. CO 3. Analyze the metrics/output of quality tools, control charts and acceptance sampling. CO 4. Evaluate quality tools, control charts and acceptance sampling.	

Name of the Programme : Master of Engineering (Industrial Engineering)
Course Code : MEC-503
Title of the Course : Optimisation Techniques for Industrial Engineering
Number of Credits : 3
Effective from AY : 2024-25

Pre-requisites for the Course	Basics mathematical concepts	
Course Objectives:	The course will enable students to: 1. To analyze real-life decision-making situations and develop the art of converting these situations into mathematical models 2. To understand the working principles of techniques to solve LPP models and solve differently styled LP problems 3. To study standard network analysis problems and apply solution techniques. 4. To solve problems wherein the dynamic decisions are made in stages and consolidated to arrive at final decision 5. To understand the concept of queuing theory and solve real life queuing problems	
Content		**No of hours**
Unit - 1	**Introduction:** Management and decision making, historical development of operations research, models and principles of modeling, techniques in operations research. **Linear Programming:** Introduction, Formulation of linear programming problems (LPP), Assumptions and guidelines in formulation of LPPs. **Techniques to solve LPP:** Graphical method, Analysis of special cases through graphical method. Simplex method, Big-M method, Analysis of special cases through simplex method	**10**
Unit - 2	**Modified Simplex method:** Working principle, advantages. **Transportation model:** Introduction, Formulation, Transportation algorithm – finding initial basic feasible solution using Northwest corner rule, Least cost cell and Vogel's approximation method. Optimizing a transportation model.	**11**
Unit - 3	**Assignment model:** Introduction, Formulation, Hungarian algorithm **Network Analysis:** Introduction, scope, definitions, Minimal spanning tree problem, Maximal-flow problems. **Game Theory:** Introduction, Two-person zero-sum game, saddle point, pure and mixed strategy, dominance rule.	**12**
Unit - 4	**Dynamic Programming:** Introduction, characteristics of dynamic programming, dynamic programming approach to Capital allocation problem, Knap Sack and Travelling Salesman problem. **Queuing Theory:** Introduction, general structure and performance measures of queuing system, cost analysis, Markovian Poisson-exponential	**12**

	single server infinite population model.	
Pedagogy:	Inquiry-Based Learning, Reflective, Integrative Learning	
References/ Readings:	Text Books 1. R. Paneerselvam; Operations Research; Prentice Hall of India Private Ltd.; 2e; 2016 2. P. K. Gupta, D. S. Hira; Operations Research; S Chand; 5e; 2015 3. Ravindran, D. Philips, J. J. Solberg; Operations Research: Principles and Practice; John Wiley & Sons Inc.; 2e; 2012 4. N. D. Vohra; Quantitative Techniques in Management; Tata McGraw-Hill Publishing Co. Ltd.; 5e; 2017 Reference Books 1. S. D. Sharma; Operations Research: Theory; Methods and Applications; Kedar Nath; 2014 2. J. K. Sharma; Operations Research; Laxmi Publications; 4e; 2012 3. S. R. Yadav, A. K. Malik; Operations Research; Oxford University Press; 1e; 2014 4. H. A. Taha; Operations Research: An Introduction; Pearson Education, Inc.; 9e; 2014 5. F. S. Hillier, G. J. Lieberman; Introduction to Operations Research; Tata McGraw Hill; 8e; 2005	
Course Outcomes:	After going through this course, the students will be able to: CO 1. Understand the applied concept of real life models, problem formulations and tools to solve various linear programming models CO 2. Apply the appropriate technique to solve any given real-life linear programming model CO 3. Analyze the formulation strategies of linear programming models and the complexity of solution procedures to solve linear programming problems CO 4. Evaluate the performance of various solution techniques used to solve the linear programming problems	

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Name of the Programme : Master of Engineering (Industrial Engineering)
Course Code : MEC-504
Title of the Course : Optimisation Techniques for Industrial Engineering Lab
Number of Credits : 1
Effective from AY : 2024-25

Pre-requisites for the Course	Basics knowledge of using Microsoft Excel/VBA/ MATLAB or any other mathematical software	
Course Objectives:	The course will enable students to use software: 1. To solve linear programming problems using simplex or modified simplex method and perform sensitivity analysis 2. To solve a transportation and assignment model 3. To solve problems wherein the dynamic decisions are made in stages and consolidated to arrive at final decision 4. To solve game theory and queuing theory problems	
Content		**No. of Hours**
List of Experiments	Perform any 5 experiments from the list given below using Microsoft Excel/VBA/ / MATLAB or any other relevant mathematical software: 1. Solve linear programming problem using simplex or modified simplex method 2. Perform sensitivity analysis to understand the effect of changes in the input data on the optimal solution 3. Solve the transportation model using northwest corner rule to find a feasible solution 4. Solve the transportation model using Least cost rule to find a feasible solution 5. Solve the transportation model using Vogel's approximation method to find a feasible solution 6. Solve the assignment model using Hungarian algorithm 7. Solve a mixed strategy game theory problem using dominance rule 8. Use dynamic programming approach to solve the capital allocation model 9. Use dynamic programming approach to solve the knap sack model 10. Analyse the output of a M/M/1/∞ queuing model	**30**
Pedagogy:	Constructivist, Integrative, Reflective and Enquiry based	
References/ Readings:	Text Books 1. Ken Bluttman, Microsoft Excel Formulas and Functions for dummies, 5th edition, Wiley, 2020 2. Manisha Nigam, Data Analysis with Excel, 1st edition, Bpb, 2019 3. Rudra Pratap, Getting Started with MATLAB, 7th edition, Oxford University Press, 2019 4. R. Paneerselvam; Operations Research; Prentice Hall of India Private Ltd.; 2e; 2016	

	5. P. K. Gupta, D. S. Hira; Operations Research; S Chand; 5e; 2015 6. N. D. Vohra; Quantitative Techniques in Management; Tata McGraw-Hill Publishing Co. Ltd.; 5e; 2017 Reference Books 1. Mike Mcgrath, Excel VBA in easy steps, 4th edition, Bpb, 2017 2. Amos Gilet, MATLAB: An introduction with Applications, 4th edition, Wiley, 2012 3. S. D. Sharma; Operations Research: Theory; Methods and Applications; Kedar Nath; 2014 4. J. K. Sharma; Operations Research; Laxmi Publications; 4e; 2012 5. H. A. Taha; Operations Research: An Introduction; Pearson Education, Inc.; 9e; 2014 6. F. S. Hillier, G. J. Lieberman; Introduction to Operations Research; Tata McGraw Hill; 8e; 2005
Course Outcomes:	After going through this course, the students will be able to perform software-based analysis to: CO 1. Understand the applied concept of real life models, problem formulations and tools to solve various linear programming models CO 2. Apply the appropriate technique to solve any given real-life linear programming model CO 3. Analyze the formulation strategies of linear programming models and the complexity of solution procedures to solve linear programming problems CO 4. Evaluate the performance of various solution techniques used to solve the linear programming problems

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Programme Specific Elective (PSE) Courses
Name of the Programme : Master of Engineering (Industrial Engineering)
Course Code : MEC-531
Title of the Course : Materials Management
Number of Credits : 4
Effective from AY : 2024-25

Pre-requisites for the Course:	Nil	
Course Objectives:	The course will enable students to: 1. Understand the fundamental aspects of basics of materials management 2. Illustrate competency in analysis for material planning 3. Apply inventory management models 4. Develop Skills for purchasing practices and storage in warehouse	
Content:		**No of hours**
Unit - 1	**Introduction**: Operating environment-aggregate planning-role, need, strategies, costs techniques, approaches-master scheduling-manufacturing planning and control system-manufacturing resource planning enterprise resource planning-making the production plan **Materials Planning** Materials requirements planning-bill of materials-resource requirement planning manufacturing resource planning-capacity management-scheduling orders-production activity control-codification.	**13**
Unit - 2	**Inventory Management** Policy Decisions–objectives-control -Retail Discounting Model, Newsvendor Model; EOQ and EBQ models for uniform and variable demand With and without shortages –Quantity discount models. Probabilistic inventory model	**11**
Unit - 3	**Purchasing Management** Establishing specifications-selecting suppliers-price determination-forward buying-mixed buying strategy-price forecasting-buying seasonal commodities-purchasing under uncertainty-demand management-price forecasting-purchasing under uncertainty-purchasing of capital equipment-international purchasing	**11**
Unit - 4	**Warehouse Management** Warehousing functions – types - Stores management-stores systems and procedures-incoming materials control-stores accounting and stock verification-Obsolete, surplus and scrap-value analysis-material handling-transportation and traffic management –operational efficiency-productivity-cost	**11**

	effectiveness-performance measurement	
Pedagogy:	Constructivist, Integrative, Reflective and Enquiry based	
References/ Readings:	Text Books 1. J.R.Tony Arnold, Stephen N. Chapman, Lloyd M. Clive, Materials Management, Pearson, 2012. 2. P. Gopalakrishnan, Purchasing and Materials Management, Tata McGraw Hill, 2012 Reference Books 1. A.K.Chitale and R.C.Gupta, Materials Management, Text and Cases, PHI Learning, 2nd Edition, 2006 2. A.K.Datla, Materials Management, Procedure, Text and Cases, PHI Learning, 2nd Edition, 2006	
Course Outcomes:	After going through this course, the students will be able to: CO 1. Understand the fundamental aspects of basics of materials management CO 2. Analyse requirement of analysis for material planning CO 3. Apply inventory management models. CO 4. Create Skills for purchasing practices and storage in warehouse.	

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Name of the Programme : **Master of Engineering (Industrial Engineering)**
Course Code : **MEC-532**
Title of the Course : **Energy Auditing**
Number of Credits : **4**
Effective from AY : **2024-25**

Pre-requisites for the Course:	**Nil**	
Course Objectives:	The course will enable students to: 1. Understand the fundamental concepts of Energy Management & Auditing 2. Illustrate competency in different methods of Energy Auditing for Energy Conservation. 3. Apply expertise in Energy Auditing for Thermal and Electrical Utilities. 4. Develop analytical and Technical skills for Energy Auditing	
Content:	**Basics of Thermodynamics and Electrical Engineering**	**No of hours**
Unit - 1	**Introduction**: Energy and environment, need for renewable and energy efficiency, need and importance of energy conservation and management Energy consumption patterns and energy conservation opportunities in Indian industry, agricultural, commercial, and residential sectors. **Energy Auditing** – methodology, analysis and reporting. Portable and online instruments used for energy auditing.	**11**
Unit - 2	**Costing of utilities**: Determination of cost of steam, compress air and electricity. Methods of financial analysis: 1) Simple payback period 2) Time value of money (future value, net present value) 3) Return on investment (ROI) 4) Internal rate of return (IRR) **Cogeneration**: Definition, Need, Application, Advantages, Classification, Saving potentials.	**11**
Unit - 3	**Energy Conservation in Thermal Utilities:** Energy conservation in refrigeration and air conditioning system, compressed air system. Energy conservation in steam generation and supply system. Boiler performance, Boiler efficiency Waste Heat Recovery: Classification, Advantages and application, commercially viable waste heat recovery devices, saving potential.	**12**
Unit - 4	**Insulation**: Materials of insulations form of insulations, desirable properties of insulations, and economic thickness of insulations. Refractories. **Electrical system**: energy conservation in motors, energy efficient motors, power factor improvement, variable speed drive. Lighting: Illumination levels, Fixtures, timers, energy-efficient illumination.	**11**

Pedagogy:	Constructivist, Integrative, Reflective and Enquiry based
References/ Readings:	Text Books 1. Energy conservation – related booklets published by National Productivity Council (NPC), New Delhi. 2. Petroleum Conservation Research Association (PCRA), New Delhi. Reference Books 1. IGC Dryden, editor: The efficient use of energy (Bitterworths) 2. W.S. Turner, Editor: Energy Management Handbook (Wiley) 3. Patrick Steven R., Patrick Dale R., Fordo Stephen: Energy conservation Guide Book, The Fairmont Press Inc.
Course Outcomes:	After going through this course, the students will be able to: CO 1. Understand the fundamental aspects of Energy Management. CO 2. Apply the concepts of Energy Auditing, Energy Conservation and Waste heat recovery CO 3. Analyse proficiency in Energy Auditing. CO 4. Create Analytical and Technical Skills for Energy Auditing.

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Research Specific Elective (RSE) Courses

Name of the Programme : For All Master of Engineering Programmes
Course Code : REC-561
Title of the Course : Engineering Research & Publication
Number of Credits : 4
Effective from AY : 2024-25

Pre-requisites for the Course:	Nil	
Course Objectives:	The course will enable the students to 1. Understand the importance of literature review, defining the research objectives. 2. Explain qualitative and quantitative methods of data analyses and its importance. 3. Classify research publications, select appropriate journals based on research areas. 4. Practice ethics in publication and academic integrity	
Content:		**No of Hours**
Unit -1	**Overview of scientific research in engineering**, foundational and fundamental concepts like types of research and considerations for research in specific domains, motivation to do research, critical thinking, assumptions and hypotheses, basic and applied research, importance of formulation of broad research objectives	**11+4T**
Unit -2	**Purpose and Methodology of Literature Search and Review** of the scientific and engineering publications. Sources such as scholarly databases, public domain, open access, current literature, review articles, critical review and gap analysis, defining research objectives	**11+4T**
Unit -3	**Quantitative and qualitative Data –** importance of data in research, types of data, data collection techniques, Quantitative methods for analysis of data – statistical tools, mathematical modeling, simulation, experimental data, optimization methods; Qualitative data collection, preparing questioners, rating scale, conducting survey, validation of models.	**12+4T**
Unit- 4	**Preparation of Publications-** Elements of research publications, types of publications, writing for journal publications, basic requirements for publication, selection of journals, journal quality indicators, peer review, reply to comments and responses, publication ethics, references, citations, authorship, plagiarism, academic integrity	**11+3T**
Pedagogy:	Inquiry based learning, Integrative, Reflective Learning , Constructive learning and Collaborative learning	
References/ Readings:	1. Herman Tang, 'Engineering Research-Design, Methods and Publications', John Wiley and Sons, 2021, ISBN:9781119624486. 2. Michael Jay Katz, 'From Research to Manuscript', Springer Publication, 2009, ISBN:9781402094668.	

	3. Rob Dekkers, Lindsey Casey, Peter Langhorne, 'Making Literature Review Work', Springer Publications, 2022, ISBN:9783030900243 4. Meikang Qiu, Han Qiu, Yi Zeng, 'Research & Technical Writing for Science and Engineering', Taylor & Francis Publications, 2022, ISBN:9781003139058.
Course Outcomes:	After taking this course, student will be able to: CO 1. Understand the importance of literature review, defining the research objectives. CO 2. Explain qualitative and quantitative methods of data analyses and its importance. CO 3. Classify research publications, select appropriate journals based on research areas. CO 4. Practice ethics in publication and academic integrity

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Name of the Programme : For All Master of Engineering Programmes
Course Code : REC-562
Title of the Course : Literature Review & Technical Writing for Engineers
Number of Credits : 4
Effective from AY : 2024-25

Pre-requisites for the Course:	Nil	
Course Objectives:	The course will enable the students to 1. Understand the importance of literature review and writing a review paper. 2. Explain the method to be followed to write a review paper. 3. Classify data for qualitative and quantitative analysis 4. Demonstrate technical writing for conference.	
Content:		**No of Hours**
Unit -1	**Overview on Literature Review**, difference between objectives of literature review and research objectives; types of literature review, qualitative and quantitative reviews, search strategies, primary and secondary sources, database search strategies, field search, root search, complimentary search, meta-analysis	**12+4T**
Unit -2	**Database management of literature reviews**, bibliometric analysis, importance of writing a review paper, reply to comments and responses, publication ethics, references, citations, authorship, plagiarism, academic integrity; public domain, open access, current literature.	**11+4T**
Unit -3	**Technical writing on a specific research topic**, structure of the paper, abstract, introduction, experimental, simulation, analysis, discussion, inferences, title, acknowledgment, referencing, presentation of tables, figures, graphs, equations; comparison between technical writing for conference papers and journal paper	**11+4T**
Unit- 4	**Importance of data in research**, types of data, data collection techniques, Quantitative methods for analysis of data – statistical tools, mathematical modeling, simulation, experimental data, optimization methods; Qualitative data collection, preparing questioners, rating scale, conducting survey, validation of models.	**11+3T**
Pedagogy:	Inquiry based learning, Integrative, Reflective Learning, Constructive learning and Collaborative learning	
References/ Readings:	1. Rob Dekkers, Lindsey Casey, Peter Langhorne, 'Making Literature Review Work – Multidisciplinary Guide to Systematic Approaches', Springer Publications, 2022, ISBN:9783030900243. 2. Michael Jay Katz, 'From Research to Manuscript', Springer Publication, 2009, ISBN:9781402094668. 3. Herman Tang, 'Engineering Research-Design, Methods and Publications', John Wiley and Sons, 2021, ISBN:9781119624486. 4. Meikang Qiu, Han Qiu, Yi Zeng, 'Research & Technical Writing for Science and Engineering', Taylor & Francis Publications, 2022,	

	ISBN:9781003139058.
Course Outcomes:	After taking this course, student will be able to: CO 1. Understand the importance of literature review and writing a review paper. CO 2. Explain the method to be followed to write a review paper. CO 3. Classify data for qualitative and quantitative analysis CO 4. Demonstrate technical writing for conference.

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Semester – II
Programme Specific Core (PSC) Courses
Name of the Programme : Master of Engineering (Industrial Engineering)
Course Code : MEC-505
Title of the Course : Data Analytics
Number of Credits : 3
Effective from AY : 2024-25

Pre-requisites for the Course:	Basics probability concepts	
Course Objectives	**The course will enable students to:** 1. To understand the pattern of randomness found in real life situations 2. To study widely used discrete and continuous distribution along with their applications. 3. To estimate the unknown parameters of the population and implement hypothesis testing 4. To understand advanced statistical analysis through goodness of fit and regression	
Content		**No of hours**
Unit - 1	**Random Variable:** Introduction, Discrete and Continuous random variables, Characteristics-Mean, Variance and Distribution function, Moment-Generating function. Applications and numericals. **Function of One Dimensional Random Variable:** Discrete and continuous case, E and V-operators. Applications and numericals.	**10**
Unit - 2	**Discrete Probability distributions:** Bernoulli trial, Binomial, Geometric, Pascal and Poisson distribution. Mean, Variance, Distribution function. Important properties. Applications and numericals. No derivations. **Continuous Probability distributions:** Uniform, Exponential and Normal distribution. Mean, Variance, Distribution function. Important properties. Applications and numericals. No derivations.	**11**
Unit - 3	**Statistic and Sampling Distributions:** Population and the Sample, Statistic, Sampling distributions- Normal, Student's t-distribution, Chi-square and F distribution. No derivations. **Parameter Estimation: Point Estimation**: Concept, unbiased estimator, standard error, method of maximum likelihood. Point estimation of standard distributions- Bernoulli, Binomial, Geometric, Exponential and Normal. Derivations, applications and numericals. **Parameter Estimation: Confidence Interval Estimation:** Concept, Confidence interval on mean and difference in means of single and two normal population, variance known and unknown. Applications and numericals.	**12**

Unit - 4	**Tests of Hypotheses:** Introduction, Type I and type II errors, significance level and power of the test. Hypothesis testing on mean and difference in means of single and two normal population, variance known and unknown. Applications and numericals. **Goodness of Fit Test:** Chi-square test- Introduction, concept, algorithm for testing of standard distributions- binomial, geometric, Poisson, uniform and exponential distributions, P-value. Test for Independence. Applications and numericals. **Simple Linear Regression:** Simple Linear Regression Concept, development of regression model, data plots, residual-computation. Applications and numericals.	**12**
Pedagogy:	Classroom Teaching, Inquiry-Based Learning, Reflective, Integrative Learning	
References/ Readings:	**Text Books** 1. D. C. Montgomery, C. G. Runger, Applied Statistics and Probability for Engineers, 6th Edition, n Wiley India, 2016 2. Sheldon Ross, Introduction to Probability and Statistics for Engineers and Scientists, 5th Edition, Academic Press, 2014 3. R. E. Walpole, R. H. Myers, S. L. Myers, K. E. Ye; Probability and Statistics for Engineers and Scientists,9th Edition, Pearson Education India, 2013 **Reference Books** 1. R. A. Johnson, Probability and Statistics for Engineers, 8e, Prentice Hall of India, 2011. 2. T. Veerarajan; Probability, Statistics and Random Processes, 3e, Tata McGraw Hill India; 2017 3. A. R. Johnson, Probability and Statistics for engineers, Eighth Edition, Prentice Hall of India, New Delhi, 2015 4. J. Ravichandran, Probability and Statistics for Engineers, Wiley India, 2010	
Course Outcomes:	After going through this course, the students will be able to: CO 1. Understand the concepts of randomness, probability distributions, inferential statistics and curve fitting techniques CO 2. Analyse the characteristics of random variables, standard probability distributions, inferential statistics and curve fitting techniques CO 3. Compute the probabilities associated with random variable, probability distributions, parameters estimation and curve fitting techniques CO 4. Evaluate the behaviour of randomness for the probability distributions parameters estimation and curve fitting techniques	

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Name of the Programme : Master of Engineering (Industrial Engineering)
Course Code : MEC- 506
Title of the Course : Data Analytics Lab
Number of Credits : 1
Effective from AY : 2024-25

Pre-requisites for the Course:	Basics knowledge of using Microsoft Excel/VBA/SPSS/ MATLAB or any other statistical software	
Course Objectives:	The course will enable students to: 1. To perform statistical analysis of randomness and evaluate the probabilities of standard discrete and continuous random variables 2. To estimate the unknown parameters of the population 3. To perform hypothesis test, goodness of fit test and test for independence 4. To perform linear regression analysis	
Content		**No of hours**
List of Experiments	Perform any six experiments from the list given below using Microsoft Excel/VBA/SPSS/ MATLAB or any other statistical software: 1. Understand the randomness of the different random variables graphically and analyse its characteristics 2. Evaluate the probabilities of standard discrete distributions 3. Evaluate the probabilities of standard continuous distribution 4. Calculate the point estimates of standard discrete distribution and continuous distributions 5. Calculate confidence interval on mean and difference in means of single and two normal population, variance known and unknown 6. Perform hypothesis testing on mean and difference in means of single and two normal populations, variance known and unknown 7. Perform goodness of fit test for standard discrete and continuous distributions 8. Perform test for independence of the given data 9. Perform simple linear regression analysis and compute the residuals	**30**
Pedagogy:	Software-based Learning	
References/ Readings:	**Text Books** 1. Lavine David M., Statistics for Managers, using Microsoft Excel, 8th edition, Pearson Education, 2017 2. Manisha Nigam, Data Analysis with Excel, 1st edition, Bpb, 2019 3. Rudra Pratap, Getting Started with MATLAB, 7th edition, Oxford University Press, 2019 4. D. C. Montgomery, C. G. Runger, Applied Statistics and Probability for Engineers, 6th Edition, n Wiley India, 2016 **Reference Books**	

	1. Ken Bluttman, Microsoft Excel Formulas and Functions for dummies, 5th edition, Wiley, 2020 2. Joseph Schmuller, Statistical Analysis with Excel for Dummies, 4th edition, Wiley, 2020 3. Mike Mcgrath, Excel VBA in easy steps, 4th edition, Bpb, 2017 4. R. A. Johnson, Probability and Statistics for Engineers, 8e, Prentice Hall of India, 2011. 5. T. Veerarajan; Probability, Statistics and Random Processes, 3e, Tata McGraw Hill India; 2017 6. J. Ravichandran, Probability and Statistics for Engineers, Wiley India, 2010
Course Outcomes:	CO 1. Understand the concepts of randomness, probability distributions, inferential statistics and curve fitting techniques CO 2. Analyse the characteristics of random variables, standard probability distributions, inferential statistics and curve fitting techniques CO 3. Compute the probabilities associated with random variable, probability distributions, parameters estimation and curve fitting techniques CO 4. Evaluate the behaviour of randomness for the probability distributions parameters estimation and curve fitting techniques

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Name of the Programme : Master of Engineering (Industrial Engineering)
Course Code : MEC-507
Title of the Course : Reliability Engineering
Number of Credits : 3
Effective from AY : 2024-25

Pre-requisites for the Course:	Basic knowledge of mathematics	
Course Objectives:	The course will enable students to: 1. learn reliability engineering and Life Testing concepts. 2. use reliability engineering and life testing knowledge to apply on different industrial cases. 3. perform reliability analysis on components/systems along with working with life testing models. 4. evaluate the product/system reliability and life testing model.	
Content:		**No of hours**
Unit - 1	**Reliability Engineering:** Need for Reliability, definition of reliability and its various measures, reliability analysis- Exponential, Normal, Lognormal and Weibull distribution. Derivation restricted only to only reliability and hazard function.	**12**
Unit - 2	**System Reliability:** Series, Parallel and Combined Series-Parallel systems, Complex systems, Three-State Devices. **Reliability Allocation:** Equal Apportionment technique, ARINC Apportionment technique, AGREE Allocation method	**12**
Unit - 3	**Probability Plotting:** Exponential, Normal, Lognormal and Weibull. **Fault Tree Analysis and Failure Mode Effect Analysis:** Concepts and applications.	**12**
Unit - 4	**Life Testing:** Life tests with censoring and without censoring, tests with and without replacement, burn-in testing, environmental test, temperature tests, humidity tests. Mechanical shock tests. **Accelerated Life Testing:** Concepts, Methods for ALT data quantification, Temperature stress and failure rates, Erying model power model/stress scale model. **Highly Accelerated Life Testing:** Advantages, goal and plan.	**12**
Pedagogy:	Constructivist, Integrative, Reflective and Enquiry based	
References/ Readings:	**Text Books** 1. E. Ebeling; An Introduction to Reliability and Maintainability Engineering; Tata McGraw Hill; 2000. 2. K. C. Kapur, L. R. Lamberson; Reliability in Engineering Design; Wiley India; 1997. 3. V. N. A. Naikan, Reliability Engineering and Life Testing, PHI Learning Pvt. Ltd., 2009 **Reference Books** 1. S. S. Rao; Reliability Engineering, Pearson Education; 2016 2. E. A. Elsayed; Reliability Engineering, Wiley; 2021	
Course Outcomes:	**After going through this course, the students will be able to:** CO 1. Understand the concepts of Reliability Engineering and Life Testing.	

	CO 2. Apply the knowledge gained to reliability engineering and life testing on different industrial cases. CO 3. Analyze reliability measures and life testing models. CO 4. Evaluate the product/system reliability, life testing model.

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Name of the Programme : **Master of Engineering (Industrial Engineering)**
Course Code : **MEC- 508**
Title of the Course : **Reliability Engineering Lab**
Number of Credits : **1**
Effective from AY : **2024-25**

Pre-requisites for the Course	Knowledge of MS-EXCEL	
Course Objectives:	The course will enable students to: 1. Perform probability plotting. 2. Determine probability distribution of failure times. 3. Compute reliability for failure distributions. 4. Perform FMEA 5. Estimate life using Accelerated life testing	
Content:		**No of hours**
Practical	Perform the following experiments using standard software like MS-EXCEL, MINITAB, ISOGRAPH, etc 1. Probability plotting for data having Exponential, Normal, Lognormal and Weibull distribution. 2. Determination of Statistical Distribution of failure times. 3. Reliability computation for Exponential, Normal, Lognormal and Weibull distribution. 4. Failure Mode Effect Analysis 5. Accelerated Life Testing	**30**
Pedagogy:	Constructivist, Integrative, Reflective and Enquiry based	
References/ Readings:	**Text Books** 1. K. S. Stephens ; Reliability Data Analysis with Excel and Minitab; ASQ Press; 2011. 2. K. K. Pochampally, S. M. Gupta, Reliability Analysis with Minitab, CRC Press, 2016. **Reference Books** 1. C. E. Ebeling; An Introduction to Reliability and Maintainability Engineering; Tata McGraw Hill; 2000. 2. S. S. Rao; Reliability Engineering, Pearson Education; 2016	
Course Outcomes:	After going through this course, the students will be able to: CO 1. Understand the basic functions available in standard software like MS-EXCEL, MINITAB, ISOGRAPH, etc CO 2. Apply the programming function on failure times. CO 3. Analyze the failure time distributions, FMEA and ALT using standard software. CO 4. Evaluate the failure time distributions, FMEA and ALT using standard software.	

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Name of the Programme : Master of Engineering (Industrial Engineering)
Course Code : MEC-509
Title of the Course : Operations and Project Management
Number of Credits : 3
Effective from AY : 2024-25

Pre-requisites for the Course	Knowledge of MS-EXCEL	
Course Objectives:	The course will enable students to: 1. Comprehend the important concepts of operations and project management 2. Demonstrate the use of techniques of operations and project management for effective planning and control of projects and operations 3. Investigate real life situations using techniques in operations and project management. 4. Evaluate situations to provide solutions to industrial problems related to operations and project management.	
Content:		**No of hours**
Unit - 1	**Concepts of operations planning and control:** Concept in Operation Planning and concepts for various operational system in manufacturing and service sectors. **Demand forecasting:** Need and importance of Forecasting, Input-Output of forecasting Model, Techniques: Delphi Method, Simple and Moving average, Exponential Smoothing, Correlation and Regression Analysis, Minimizing forecasting errors - MAD, Tracking Signal. **Facility Location**: Concept and quantitative methods in Plant Location and Layout-Nature of location decision, situations that influence location decision, Location of facilities for service businesses, Location models - Factor rating method, Weighted factor rating method, Centre of gravity method, Break-even analysis.	**12**
Unit - 2	**Plant Layout**- Layout and its objectives, Types of plant layout-Product layout, process layout, fixed position layout, cellular manufacturing layouts, and Hybrid layouts. **Assembly line balancing and Material Handling:** -Concept and importance -Objectives -Techniques	**11**
Unit - 3	**Sequencing and Scheduling** -Scheduling operations - Scheduling in low volume systems -Sequencing Concept -Single, Two and Three processor system **Inventory control:**	**11**

Issued on: 22/01/2025

	-Dependent and independent demand -Need for inventory control -Methods of inventory analysis - EOQ models for purchasing and manufacturing situation without shortages.	
Unit - 4	**Project management:** -Use of network techniques in Project management. -Concepts in project management - CPM, PERT - -Slack and Float -Crashing -Gantt Charts -Use of computers in project planning and monitoring	**11**
Pedagogy:	Inquiry-Based, Reflective, Integrative, collaborative Learning	
References/ Readings:	**REFERENCE TEXT BOOKS:** 1. Schaum's Outline of Operations Management Joseph Monks, McGraw Hill,1996 2. Operations Management, Roger G. Schroder, International Students Edition, McGraw Hill, 3rd edition, 2009 3. The Management of Operations, Jack P. Meredith, John Wiley and Sons, 5th edition. 4. Production and Operations Management, S. N. Chary, Tata McGraw Hill, 5th edition, 2012 5. Supply Chain Management, Chopra Sunil and Peter Meindl, Pearson Education Inc., 5th edition, 2012 6. Operations Management, William J. Stevenson, McGraw-Hill, 2010 7. Production and Operations management, R. Pannerselvam, Prentice Hall of India, 3rd edition, 2012	
Course Outcomes:	After going through this course, the students will be able to: CO 1. Understand the objectives and techniques of operations and project management CO 2. Apply techniques of operations and project management for effective management of operations CO 3. Analyze situations using qualitative and quantitative techniques in operations and project management. CO 4. Evaluate situations to provide solutions to industrial problems.	

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Name of the Programme : Master of Engineering (Industrial Engineering)
Course Code : MEC-510
Title of the Course : Operations and Project Management Lab
Number of Credits : 1
Effective from AY : 2024-25

Pre-requisites for the Course	Knowledge of MS-EXCEL	
Course Objectives:	The course will enable students to: 1. Develop problem-solving and group-working skills, and to gain a deep understanding of operations management. 2. Identify the various dimensions of production planning and control and their inter- linkages with forecasting. 3. Explain the use of techniques of operations and project management for effective planning and control of projects and operations 4. Analysis real life situations using techniques in operations and project management.	
Contents:		**No of hours**
	1. Introduction to the Operation and Project Management Laboratory session: Discussion on operations management in a broader context, and present the issues of competition, strategy and productivity. 2. Industrial case study that outlines (both internal and External) reasons for demise, and whether operations management played a significant role in the demise. 3. Using the Excel template demonstrate the forecasting quantitative techniques used in the industry. 4. Study any type of Store and identify an area of the store that has the characteristics of each of these processing types: job shop, batch, repetitive and continuous. 5. Developing Project Activities through AI [ChatGPT] 6. Produce a Gantt chart, using established tools and techniques, to Schedule the completion of all work elements.	**30**
Pedagogy:	Inquiry-Based, Reflective, Integrative, collaborative Learning	
References/ Readings:	**REFERENCE TEXT BOOKS:** 1. Schaum's Outline of Operations Management Joseph Monks, McGraw Hill,1996 2. Operations Management, Roger G. Schroder, International Students Edition, McGraw Hill, 3rd edition, 2009 3. The Management of Operations, Jack P. Meredith, John Wiley and Sons, 5th edition.	
Course Outcomes:	After going through this course, the students will be able to: CO 1. Identify the objectives and techniques of operations and project management CO 2. Apply techniques of operations and project management for	

	effective management of operations CO 3. Analyze situations using qualitative and quantitative techniques in operations and project management. CO 4. Evaluate situations to provide solutions to industrial problems.

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Programme Specific Elective (PSE) Courses
Name of the Programme : Master of Engineering (Industrial Engineering)
Course Code : MEC-533
Title of the Course : Supply Chain Management
Number of Credits : 3
Effective from AY : 2024-25

Pre-requisites for the Course	Basic knowledge of materials Management	
Course Objectives:	1. The course employs a strategic structure that identifies and illustrates facilities, inventory, transportation, and information as the key drivers of supply chain performance in order to help students understand what creates a competitive advantage. 2. The course provides guidelines for the students for implementing SCM initiatives to learn basically the "why, what and how" of supply chain management. 3. The course will help students, in revisiting the management policies being practiced in the industry. 4. The course conforms to the immediate requirements of aspirants for post graduate studies in Industrial Engineering, Mechanical Engineering and Management Colleges.	
Content:		**No of hours**
Unit – 1	History, Product Life Cycle, Manufacturing and Service Supply Chains, Flow of Material Information and Funds, Push & Pull System, Mass Production, Mass Customization, Customization, Localization, Responsive & Efficient Supply Chain, Zone of Strategic Fit, Supply Chain Surplus Predictable Variability, Managing Supply & Demand in predictable variability situation, Forward Buying Quantitative and qualitative Supply chain performance measures	**12**
Unit – 2	Types of facilities, Role of Network Design in Supply Chain, Factors influencing network design decisions, Framework for Facility Location Decisions, Gravity Location Model Basic EOQ Model, Quantity Discounts (All unit), Cycle Service Level, Safety Inventory, Evaluating Safety inventory in Demand uncertainty, Evaluating safety inventory in Supply uncertainty, Impact of aggregation on safety Inventory, Bullwhip Effect, Vendor Managed Inventory	**12**
Unit – 3	Key Players in Transportation, Modes of Transportation, Design Options, Transportation- Inventory Trade-off, Transportation-Responsiveness Trade-off, Savings Matrix Method, Vehicle Routing by Sweep, Nearest Neighbour, Nearest Insert, Farthest Insert Role of Distribution in Supply Chain, Factors Influencing Distribution Network Design, Design Options for a Distribution Network.	**12**

	Role of Information Technology in Supply Chain, Typical IT Solutions, EBusiness, B2B, B2C, Logistics, Reverse Logistics, 3PL, 4PL.	
Unit – 4	Supplier Relationship Management Strategy, Critical Dimension of Relationship, Typology of Relationship, Relationship Path, Relationship Matrix. Customer Relationship Management Strategy, Elements of Strategic Supply Chain Environmental, Social and Governance (ESG) in Supply Chain	**9**
Pedagogy:	Constructivist, Integrative, Reflective and Enquiry based	
References/ Readings:	**TEXTBOOKS** 1. S. Chopra, P. Meindl, D. V. Kalra; Supply Chain Management – Strategy; Planning and Operation; Pearson Education; 6e; 2016 2. R. P. Mohanty, S. G. Deshmukh; Supply chain Management - Theories and Practices; Biztantra; 2005 3. J. Shah; Supply Chain Management Text and Cases; Pearson Education; 2009 **REFERENCES** 1. G. Raghuram, N. Rangaraj; Logistics and Supply Chain Management: Cases and Concepts; Macmillan India Ltd; New Delhi; 2000 2. K. S. Bhat; Logistics Management; Himalaya Publishing house; 2009 3. T. D. Chaudhuri, I. Ghosh; Application of Multi Criteria Decision Making in Management; Lambert Academy publishing; 2015 4. Rear Admiral Sanjay Roye, Decoding ESG - A Comprehensive Guide to Environmental, Social and Governance Principles, Whitehouse publishing, 1st Edition, 2024 5. Vipul Arora, Essence of ESG, Pendown press, 1st Edition, 2024	
Course Outcomes:	On completing this course students will be able to: CO 1. Understand the basic concepts and role of drivers, customer & supplier relationships and performance measures associated with supply chain CO 2. Apply the supply chain and network design concepts in real life situations. CO 3. Analyze case studies on supplier selection, various business models and tourism business in Goa CO 4. Evaluate economics of scale and cost trade-offs pertaining to drivers of supply chain.	

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Name of the Programme : Master of Engineering (Industrial Engineering)
Course Code : MEC-534
Title of the Course : Supply Chain Management Lab
Number of Credits : 1
Effective from AY : 2024-25

Pre-requisites for the Course	Basic knowledge of materials Management	
Course Objectives:	1. The course employs a strategic structure that identifies and illustrates facilities, inventory, transportation, and information as the key drivers of supply chain performance in order to help students understand what creates a competitive advantage. 2. The course provides guidelines for the students for implementing SCM initiatives to learn basically the "why, what and how" of supply chain management. 3. The course will help students, in revisiting the management policies being practiced in the industry. 4. The course conforms to the immediate requirements of aspirants for post graduate studies in Industrial Engineering, Mechanical Engineering and Management Colleges.	
Content:		**No of hours**
	Lab Sessions (15 sessions / sem): 1. Case Study on Tourism Supply Chain in Goa (02 sessions) 2. Case Study on global business (02 sessions) 3. Case study on local business (02 sessions) 4. Case study on online business (02 sessions) 5. Supplier Selection Case Study using AHP / TOPSIS (02 sessions) 6. Business Plan ideation / Business Plan selection / Business Plan Feasibility study / Business Plan Presentation (05 sessions)	**30**
Pedagogy:	Constructivist, Integrative, Reflective and Enquiry based	
References/ Readings:	1. S. Chopra, P. Meindl, D. V. Kalra; Supply Chain Management – Strategy; Planning and Operation; Pearson Education; 6e; 2016 2. R. P. Mohanty, S. G. Deshmukh; Supply chain Management - Theories and Practices; Biztantra; 2005 3. J. Shah; Supply Chain Management Text and Cases; Pearson Education; 2009	
Course Outcomes:	On completing this course students will be able to: CO 1. Understand the basic concepts and role of drivers, customer & supplier relationships and performance measures associated with supply chain CO 2. Apply the supply chain and network design concepts in real life situations. CO 3. Analyze case studies on supplier selection, various business models and tourism business in Goa CO 4. Evaluate economics of scale and cost trade-offs pertaining to drivers of supply chain.	

Name of the Programme : Master of Engineering (Industrial Engineering)
Course Code : MEC-535
Title of the Course : Facility Design
Number of Credits : 3
Effective from AY : 2024-25

Pre-requisites for the Course	Basic knowledge of Facility layout	
Course Objectives:	The course will enable students to: 1. Understand the fundamental concepts of Facility Design 2. Illustrate competency in Plant location analysis and design 3. Apply expertise to generate computerized layout solutions for plant layout design problem. 4. Develop analytical and Technical skills for Material Handling	
Content:		**No of hours**
Unit - 1	**Introduction:** Facilities design function- Scope, Objectives, need for layout study, types of layout problem, Types of flow pattern, Types of plant layout, Nature, Significance and Scope of Facilities Layout Planning, Facility design procedure **Plant location:** Facility location: Single facility location problem, Multiple facility location problem, Gravity facility location problem, Euclidean distance location problem.	**11**
Unit - 2	**Layout design:** Design cycle - SLP procedure manpower, machinery requirements – Computer algorithms - ALDEP, CORELAP, CRAFT. **Quantitative methods:** Group technology-Production Flow analysis (PFA), ROC (Rank Order Clustering), Quantitative analysis in cellular manufacturing.	**12**
Unit - 3	**Manual Assembly Lines:** Assembly workstations, Analysis of Single model assembly lines, Line, balancing problems, Line balancing algorithm: i) Largest candidate rule ii) Kilbridge and wester method iii) Ranked positional weight method iv) COMSOAL, Mixed model assembly lines, Line of balance. **Auxiliary Services Requirement Space:** Receiving and shipping, Storage, Warehousing, Maintenance and Tool room, Utilities. **Employee Services-Space requirements:** Parking lot, Employee entrances, Locker rooms, Toilets and Restrooms, Lunch room, Recreation, Drinking fountains, Aisles, Medical facilities.	**12**
Unit - 4	**Materials handling:** Cost justification, Goals of material Handling, Principles of material handling, MH problem solving procedure, Unit load concept, and Material handling system design. **Material Handling Equipment:** Receiving and shipping, Stores, Fabrication, Assembly, Shop floor, Warehousing, Packaging. Computer integrated material handling system.	**10**
Pedagogy:	Inquiry-Based Learning, Reflective, Integrative Learning	

References/ Readings:	**Text Books** 1. Plant layout & Material Handling, G. K. Agrawal, Jain Publishers, New Delhi. 2. Facilities Layout and Location: An analytical approach, Richard Francis L. and John A. White, Prentice Hall Inc., 1984. 3. Facilities planning, J. A. Tompkins and J. A. White, John Wiley, 1984. **Reference Books** 1. Facility layout and location –an analytical approach, Francis R.L and J.A. White Prentice Hall Inc, 1974 2. Facilities Planning and Materials Handling, Vijay Sheth, Marcle Decker, New York. 3. Practical Plant layout, Richard Muther, McGraw Hill Book Company, New York
Course Outcomes:	After going through this course, the students will be able to: CO 1. Describe the fundamental aspects of Energy Management. CO 2. Illustrate the concepts of Plant location analysis and design CO 3. Demonstrate proficiency in generating computerized layout solutions for plant layout design problem. CO 4. Create Analytical and Technical Skills for Material Handling.

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Name of the Programme : Master of Engineering (Industrial Engineering)
Course Code : MEC-536
Title of the Course : Facility Design Lab
Number of Credits : 1
Effective from AY : 2024-25

Pre-requisites for the Course:	Basic knowledge of Facility layout	
Course Objectives:	The course will enable students to: 1. Identify the facilities Design process steps using the traditional engineering design process 2. Understand how facility design for operations like warehouses, manufacturing and commercial facilities. 3. Apply expertise to generate computerized layout solutions for plant layout design problem. 4. Understand concepts for techniques of material handling and layout approaches used for facility design.	
Content:		**No of hours**
Unit - 1	Students can have hands on practices on plant layout optimization techniques and also evaluate the cases computerized layout improvements from research papers. Complete the lab titled: (Any Six) 1. Designing Layout for Just-in-Time Manufacturing. 2. Designing Layout for Warehouse Operations. 3. Facility Evaluation. 4. Product, Process, and Schedule Designing. 5. Determining Space Requirements. 6. Solving Layout Problem Using Systematic Layout Planning. 7. Plant location and its problems. 8. Computerized layout design. 9. Material handling equipment's. 10. Quantitative analysis in cellular manufacturing. 11. Service facilities	**30**
Pedagogy:	Inquiry-Based Learning, Reflective, Integrative Learning	
References/ Readings:	**Text Books** 1. Plant layout & Material Handling, G. K. Agrawal, Jain Publishers, New Delhi. 2. Facilities Layout and Location: An analytical approach, Richard Francis L. and John A. White, Prentice Hall Inc., 1984. 3. Facilities planning, J. A. Tompkins and J. A. White, John Wiley, 1984.	
Course Outcomes:	After going through this course, the students will be able to: CO 1. Design layouts within facilities, i.e., organize processes, departments and products within a facility using mathematical models, algorithms and heuristics. CO 2. Illustrate the concepts of Plant location analysis and design CO 3. Demonstrate proficiency in generating computerized layout	

	solutions for plant layout design problem. CO 4. Create Analytical and Technical Skills for Material Handling.

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Research Specific Elective (RSE) Courses

Name of the Programme : Electronics Communication and Instrumentation Engineering
Course Code : REC-563
Title of the Course : Statistics and Data Analysis for Engineering Research
Number of Credits : 2
Effective from AY : 2024-25

Pre-requisites for the Course:	Basic Knowledge of Statistics	
Course Objectives:	The course will enable the students to 1. Explain the different types of data and parameter estimations 2. Explain standard probability distributions 3. Select the appropriate parameter estimation & distribution method 4. Co-relate different Hypotheses	
Content:		**No of Hours**
Unit -1	**Data Analysis:** Types of data, data collection techniques, Quantitative methods for analysis of data – statistical tools, experimental data, Qualitative data collection, questioners, rating scale, conducting survey. Statistical Modeling and Graphical Diagnostics - Scatter Plot, Stem-and-Leaf Plot, Histogram, Box Plot **Correlation and Regression Modeling:** Basic concept and numericals.	**9**
Unit -2	**Probability distributions and Sampling distributions:** Basic introduction to Bernoulli, Binomial and Normal distribution. Basic introduction to Sampling distributions- Normal, t-distribution, Chi-square and F- distributions.	**7**
Unit -3	**Parameter estimation:** Point Estimation – Concept, unbiased estimator, method of maximum likelihood. Parameter estimation of standard distributions- Binomial and Normal. Confidence Interval Estimation - Concept, Confidence interval on mean of single normal population with variance known, Confidence interval on the ratio of variances of two normal distributions	**7**
Unit- 4	**Tests of Hypotheses:** Introduction, Type I and type II errors, significance level and power of the test, Test of hypotheses - on mean of single normal population with variance known, on variance of single normal population.	**7**
Pedagogy:	Inquiry based learning, Integrative, Reflective Learning, Constructive learning and Collaborative learning	
References/ Readings:	1. D. V Thiel, 'Research Methods for Engineers', Cambridge Press, 2014, ISBN:978-110-70-3-488 2. T. Mustafy, T. U Rahman, 'Statistics & Data Analysis for Engineers and Scientists', Springer, 2024, ISBN:9789819946600. 3. D. C. Montgomery, C. G. Runger, 'Applied Statistics and Probability for Engineers', 6th Edition, Wiley India, 2016, ISBN 0-471-20454-4	

	4. R. E. Walpole, R. H. Myers, S. L. Myers, K. E. Ye; Probability and Statistics for Engineers and Scientists ,9th Edition, Pearson Education India, 2013, ISBN 978-0-321-62911-1 5. J. Schmuller, Statistical Analysis with Excel for Dummies, 5th Edition, John Wiley & Sons, 2022.
Course Outcomes:	After taking this course, student will be able to: CO 1. Explain the different types of data and probability distributions. CO 2. Select the appropriate parameter estimation & distribution method CO 3. Apply estimators for the given situations. CO 4. Evaluate Hypotheses based on the statistical considerations.

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Name of the Programme : **Electronics Communication and Instrumentation Engineering**
Course Code : **REC-564**
Title of the Course : **Statistics and Data Analysis Lab**
Number of Credits : **2**
Effective from AY : **2024-25**

Pre-requisites for the Course:	Basic Knowledge of Statistics	
Course Objectives:	The course will enable the students to 1. Apply the different types of data and parameter estimations 2. Analyze standard probability distributions 3. Demonstrate parameter estimation & distribution methods 4. Co-relate different Hypotheses	
Content:		**No of Hours**
	Using open-source software like libreoffice or any proprietary software perform following experiments: 1. Obtain measures of central tendency and dispersion. 2. Obtain Quartiles, Percentiles and prepare Box-and-Whisker Diagram 3. Develop Pie chart, Bar Chart, Histogram and Stem-and-Leaf Plot, 4. Develop_correlation using Pearson's Correlation Coefficient and showing Scatter Diagrams and Trendlines 5. Develop Linear and Nonlinear Regression Models 6. Obtain probability values involving probability distributions – Binomial and Normal 7. Obtain values of Normal, t-distribution, Chi-square and F-statistic. 8. Develop confidence interval for single population and two populations with variance known. 9. Develop confidence interval on the ratio of variances of two normal distributions. 10. Perform test of hypotheses on mean/variance of single/ two population(s).	**60**
Pedagogy:	Inquiry based learning, Integrative, Reflective Learning, Constructive learning and Collaborative learning	
References/ Readings:	1. D. V Thiel, 'Research Methods for Engineers', Cambridge Press, 2014, ISBN:978-110-70-3-488 2. T. Mustafy, T. U Rahman, 'Statistics & Data Analysis for Engineers and Scientists', Springer, 2024, ISBN:9789819946600. 3. D. C. Montgomery, C. G. Runger, 'Applied Statistics and Probability for Engineers', 6th Edition, Wiley India, 2016, ISBN 0-471-20454-4 4. R. E. Walpole, R. H. Myers, S. L. Myers, K. E. Ye; Probability and Statistics for Engineers and Scientists ,9th Edition, Pearson Education India, 2013, ISBN 978-0-321-62911-1 5. J. Schmuller, Statistical Analysis with Excel for Dummies, 5th Edition,	

	John Wiley & Sons, 2022.
Course Outcomes:	After taking this course, student will be able to: CO 1. Apply the different types of data and parameter estimations CO 2. Analyze standard probability distributions CO 3. Demonstrate parameter estimation & distribution methods CO 4. Co-relate different Hypotheses

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Name of the Programme : **Electronics Communication and Instrumentation Engineering**
Course Code : **REC-565**
Title of the Course : **Statistical Techniques for Engineering Research**
Number of Credits : **2**
Effective from AY : **2024-25**

Pre-requisites for the Course:	Basic knowledge of Statistics and Probability	
Course Objectives:	The course will enable the students to 1. Understand the importance of statistical methods for research 2. Select the appropriate factorial design method for a given set of experimental plan. 3. Apply basic probability theorems and draw relevant inferences. 4. Analyze suitable probability model for given set of data	
Content:		**No of Hours**
Unit-1	**Overview on Statistical methods**, collection of data, one dimensional and two-dimensional statistical analysis, computation of central tendency and dispersion for grouped and ungrouped data, correlation preliminary, understanding variability in data.	**6**
Unit-2	**Design of Experiments**, Preparation of experimental plan, full factorial design, fractional factorial design, identification of parameters and levels, randomization, replication, blocking, interaction; numerical; Optimization methods for two parameters.	**9**
Unit-3	**Probability Preliminary**: Introduction to Probability, definition, Sample Space, Events, Conditional Probability, Theorem on total probability, Bayes' theorem. Random Variable: Introduction, Discrete and Continuous distribution, Characteristics- Mean, Variance and distribution function.	**8**
Unit-4	**Probability and Sampling Distribution**: Bernoulli, Binomial, Exponential, Normal, distribution. Mean, variance and distribution function, important properties, approximations and applications. Statistic and Sampling Distribution: Population and Sample. Statistic, Sampling distributions- Normal, t-distribution, Chi-square and F- distributions.	**7**
Pedagogy:	Inquiry based learning, Integrative, Reflective Learning, Constructive learning and Collaborative learning	
References/ Readings:	1. Tahvir Mustafy, Tauhid U Rahman, 'Statistics & Data Analysis for Engineers and Scientists', Springer, 2024, ISBN:9789819946600. 2. Jiju Antony, 'Design of Experiments for Engineers & Scientists', Elsevier, 2023, ISBN 978-044-315-1736 3. Douglas Montgomery, 'Design and Analysis of Experiments', Wiley India, Eighth Edition, 2013, 9788126540501 4. J. Ravichandran, Probability and Statistics for Engineers, Wiley India, 2010, ISBN: 9788126523504	

	5. R. Johnson, Probability and Statistics for engineers, Eighth Edition, Prentice Hall of India, New Delhi, 2015, ISBN 978-1-292-17601-7 6. J. Schmuller, Statistical Analysis with Excel for Dummies, 5th Edition, John Wiley & Sons, 2022.
Course Outcomes:	After taking this course, student will be able to: CO 1. Understand the importance of statistical methods for research CO 2. Select the appropriate factorial design method for a given set of experimental plans. CO 3. Apply basic probability theorems and draw relevant inferences. CO 4. Analyze suitable probability model for given set of data

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Name of the Programme : **Electronics Communication and Instrumentation Engineering**
Course Code : **REC-566**
Title of the Course : **Probability and Statistical Analysis Lab**
Number of Credits : **2**
Effective from AY : **2024-25**

Pre-requisites for the Course:	Basic knowledge of Statistics and Probability	
Course Objectives:	The course will enable the students to 1. Apply basic probability theorems and draw relevant inferences. 2. Analyze suitable probability model for given set of data 3. Demonstrate factorial design methods 4. Synthesize fractional and full factorial experimental design data	
Content:		**No of Hours**
	Using open-source software like libreoffice or any proprietary software perform following experiments: 1. Obtain probability values involving discrete probability distributions - Bernoulli, Binomial. 2. Obtain probability values involving continuous probability distributions - Exponential and Normal distributions. 3. Obtain values of Normal, t-distribution, Chi-square and F-statistic. 4. Obtain values of Mean, Variance and distribution function of Bernoulli and Binomial distribution. 5. Obtain values of Mean, Variance and distribution function of Exponential and Normal distributions. 6. Obtain values of central tendency of grouped and ungrouped data. 7. Obtain values of dispersion of grouped and ungrouped data. 8. Analyse experimental output using full factorial design. 9. Analyse experimental output using fractional factorial design. 10. Analyse a full case study in involving full factorial design or fractional factorial design.	**60**
Pedagogy:	Inquiry based learning, Integrative, Reflective Learning, Constructive learning and Collaborative learning	
References/ Readings:	1. Tahvir Mustafy, Tauhid U Rahman, 'Statistics & Data Analysis for Engineers and Scientists', Springer, 2024, ISBN:9789819946600. 2. Jiju Antony, 'Design of Experiments for Engineers & Scientists', Elsevier, 2023, ISBN 978-044-315-1736 3. Douglas Montgomery, 'Design and Analysis of Experiments', Wiley India, Eighth Edition, 2013, 9788126540501 4. J. Ravichandran, Probability and Statistics for Engineers, Wiley India, 2010, ISBN: 9788126523504 5. R. Johnson, Probability and Statistics for engineers, Eighth Edition, Prentice Hall of India, New Delhi, 2015, ISBN 978-1-292-17601-7 6. J. Schmuller, Statistical Analysis with Excel for Dummies, 5th Edition,	

	John Wiley & Sons, 2022.
Course Outcomes:	After taking this course, student will be able to: CO 1. Apply basic probability theorems and draw relevant inferences. CO 2. Analyze suitable probability model for given set of data CO 3. Demonstrate factorial design methods CO 4. Synthesize fractional and full factorial experimental design data

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