COEP Technological University [COEP Tech]
(A Unitary Public University of Government of Maharashtra)
(Formerly College of Engineering Pune [COEP])

Department of Manufacturing Engineering and Industrial Management

NEP Compliant Curriculum Structure (UG Program) for Semester-V and VI

T.Y. B. Tech. (Manufacturing Science and Engineering)
(Effective from: A.Y. 2025-26)

List of Abbreviations:

Abbreviation	Title	No of courses	Credits	% of Credits
BSC	Basic Science Course	**5**	**14**	**8.75**
ESC	Engineering Science Course	**6**	**16**	**10**
PCC	Programme Core Course	**19**	**54**	**33.75**
PEC	Programme Elective Course	**6**	**20**	**12.5**
OE/SE	Open/School Elective (other than particular program)	**3**	**6**	**3.75**
MDM	Multidisciplinary Minor	**5**	**14**	**8.75**
VSEC	Vocational and Skill Enhancement Course	**5**	**6**	**3.75**
AEC-01	Ability Enhancement Course	**1**	**2**	**1.25**
AEC	Indian Language	**1**	**2**	**1.25**
HSSM	Entrepreneurship/Economics/ Management Courses	**2**	**4**	**2.5**
IKS	Indian Knowledge System	**1**	**2**	**1.25**
VEC	Value Education Course	**2**	**2**	**1.25**
RM	Research Methodology	**1**	**2**	**1.25**
CEA	Community Engagement Activity /Field Project	**1**	**2**	**1.25**
CCA	Co-curricular & Extracurricular Activities	**2**	**2**	**1.25**
INT	Internship	**3**	**12**	**7.5**
	Total	**63**	**160**	**100**

F.Y. B. Tech
Manufacturing Science and Engineering
[Level 4.5, UG Certifcate] Semester -I

Sr. No.	Course Type	Course Code	Course Name	L	T	P	S	Cr	Evaluation Scheme (Weightages in %)				
									Theory			Laboratory	
									MSE	TA	ESE	ISE	ESE
1	BSC	<tbd>	Matrix Algebra Univariate Calculus and Probability	2	1	0	1	3	30	10	60	--	--
2	BSC	<tbd>	Engineering Physics	2	0	2	1	3	30	20	50	CIE: 100	
3	ESC	<tbd>	Basics of Electrical & Electronics Engineering	2	0	2	1	3	30	20	50	CIE: 100	
4	ESC	<tbd>	Engineering Drawing and Graphics	1	0	4	1	3	CIE: 100			CIE: 100	
5	ESC	<tbd>	Engineering Mechanics	3	0	2	1	4	30	10	60	CIE: 100	
6	AEC	<tbd>	Communication Skills	1	0	2	0	2	CIE: 100			CIE: 100	
7	CCA	<tbd>	Liberal Learning Course	0	0	2	2	1	--	--	--	CIE: 100	
8	VSEC	<tbd>	Manufacturing Practices and Fab Lab - I	0	0	2	1	1	--	--	--	CIE: 100	
			Total	**11**	**1**	**16**	**6**	**20**					

[Level 4.5, UG Certificate] Semester -II

Sr. No.	Course Type	Course Code	Course Name	L	T	P	S	Cr	Evaluation Scheme (Weightages in %)				
									Theory			Laboratory	
									MSE	TA	ESE	ISE	ESE
1	BSC	<tbd>	Engineering Chemistry #	2	0	2#	1	3	30	20	50	CIE: 100	
2	BSC	<tbd>	Ordinary Differential Equations and Multivariate Calculus	2	1	0	1	3	30	10	60	--	--
3	BSC	<tbd>	Biology for Engineers	2	0	0	1	2	30	20	50	--	--
4	ESC	<tbd>	Systems in Mechanical Engineering	2	0	2	1	3	30	20	50	CIE: 100	
5	ESC	<tbd>	Programming for Problem solving	1	0	2	2	2	CIE: 100			CIE: 100	
6	ESC	<tbd>	Design Thinking and Idea Lab	0	0	2	1	1	--	--	--	CIE: 100	
7	PCC	<tbd>	Materials Science	2	0	0	1	2	30	20	50	--	--
8	VSEC	<tbd>	Manufacturing Practices and Fab Lab - II	0	0	2	0	1	--	--	--	CIE: 100	
9	IKS	<tbd>	Indian Knowledge System	2	0	0	1	2	CIE: 100			--	--
10	CCA	<tbd>	Office Automation	0	0	2	0	1	--	--	--	CIE: 100	
			Total	**13**	**1**	**12**	**8**	**20**					

Combined lab for Engineering Chemistry and Material Science

Legends: **L-Lecture, T-Tutorial, P-Practical, S-Self Study, Cr-Credits ISE-In-Semester-Evaluation, ESE-End-Semester-Evaluation , MSE-Mid-Semester-Evaluation, TA-Teachers' Assessment, CIE-Continuous-Internal-Evaluation**

Exit Course options to qualify for certification of School of Mechanical and Materials Engineering
Any Two (02) Skill based Courses of 8 credits:

1. Computer aided Geometric modelling (4 Credits)
2. Additive Manufacturing (4 Credits)
3. Metallurgical Lab Practice - I (4 Credits)
4. Basics of CNC Programming (4 Credits)
5. Basics of Robotics and AI (4 Credits)

[Level 5, UG Diploma] Semester III

Sr. No.	Course Type	Course Code	Course Name	L	T	P	S	Cr	Evaluation Scheme (Weightages in %)				
									Theory			Laboratory	
									MSE	TA	ESE	ISE	ESE
1	PCC	<tbd>	Strength of Material	2	0	0	1	2	30	20	50	--	--
2	PCC	<tbd>	Theory of Machines	3	0	0	1	3	30	10	60	--	--
3	PCC	<tbd>	Manufacturing Processes	3	0	2	1	4	30	10	60	50	50
4	PCC	<tbd>	Product & Systems Graphics	0	0	2	1	1	--	--	--	CIE: 100	
5	OE	<tbd>	Open Elective-I	2	0	0	1	2	30	20	50	--	--
6	HSMC	<tbd>	Indian language: Sanskrit / Pali	2	0	0		2	30	20	50	--	--
7	HSMC	<tbd>	Constitution of India & Universal Human Values	2	0	0		2	30	20	50	--	--
8	HSMC	<tbd>	Principles of Entrepreneurship	2	0	0	2	2	30	20	50	---	
9	CEA	<tbd>	Field Project*	0	0	4	1	2	--	--	--	CIE: 100	
			Total	**14**	**0**	**10**	**7**	**20**					

- **Field Project (Social) after semester-II during summer vacation and evaluation will be done in the starting of III semester.**

[Level 5, UG Diploma] Semester IV

Sr. No.	Course Type	Course Code	Course Name	L	T	P	S	Cr	Evaluation Scheme (Weightages in %)				
									Theory			Laboratory	
									MSE	TA	ESE	ISE	ESE
1	PCC	<tbd>	Engineering Thermodynamics and Heat Transfer	2	0	2	1	3	30	20	50	50	50
2	PCC	<tbd>	Fluid Power	2	0	2	1	3	30	20	50	50	50
3	PCC	<tbd>	Design of Machine Elements	2	0	0	1	2	30	20	50	--	--
4	PCC	<tbd>	Machining Science and Technology	3	0	2	1	4	30	10	60	50	50
5	OE	<tbd>	Open Elective-II	2	0	0	0	2	30	20	50	--	--
6	MDM	<tbd>	Multidisciplinary Minor-I	3	0	0	0	3	30	10	60	--	--
7	VSEC	<tbd>	CNC Programming & Machining	0	0	4	1	2	--	--	--	50	50
8	HSMC	<tbd>	Principles of Economics	2	0	0	1	2	30	20	50	---	
9	HSMC	<tbd>	Environmental Studies	0	0	2	0	1	--	--	--	CIE: 100	
			Total	**15**	**0**	**14**	**5**	**22**					

[Level 5, UG Diploma] Semester III (wef 2024-25)

[Lateral Entry]

Sr. No.	Course Type	Course Code	Course Name	L	T	P	S	Cr	Evaluation Scheme (Weightages in %)				
									Theory			Laboratory	
									MSE	TA	ESE	ISE	ESE
1	PCC	<tbd>	Strength of Material	2	0	0	1	2	30	20	50	--	--
2	PCC	<tbd>	Theory of Machines	3	0	0	1	3	30	10	60	--	--
3	PCC	<tbd>	Manufacturing Processes	3	0	2	1	4	30	10	60	50	50
4	PCC	<tbd>	Product & Systems Graphics	0	0	2	1	1	--	--	--	CIE: 100	
5	OE	<tbd>	Open Elective-I	2	0	0	1	2	30	20	50	--	--
6	HSMC	<tbd>	Indian language: Sanskrit / Pali	2	0	0		2	30	20	50	--	--
7	HSMC	<tbd>	Constitution of India & Universal Human Values	2	0	0		2	30	20	50	--	--
8	HSMC	<tbd>	Principles of Entrepreneurship	0	0	2	1	1	--	--	--	CIE: 100	
9	BSC	<tbd>	Mathematics	3	0	0	1	3	30	10	60	--	--
			Total	**17**	**0**	**6**	**7**	**21**					

- **Field Project (Social) after semester-II during summer vacation and evaluation will be done in the starting of III semester.**

[Level 5, UG Diploma] Semester IV

[Lateral Entry]

Sr. No.	Course Type	Course Code	Course Name	L	T	P	S	Cr	Evaluation Scheme (Weightages in %)				
									Theory			Laboratory	
									MSE	TA	ESE	ISE	ESE
1	PCC	<tbd>	Engineering Thermodynamics and Heat Transfer	2	0	2	1	3	30	20	50	50	50
2	PCC	<tbd>	Fluid Power	2	0	2	1	3	30	20	50	50	50
3	PCC	<tbd>	Design of Machine Elements	2	0	0	1	2	30	20	50	--	--
4	PCC	<tbd>	Machining Science and Technology	3	0	2	1	4	30	10	60	50	50
5	OE	<tbd>	Open Elective-II	2	0	0		2	30	20	50	--	--
6	MDM	<tbd>	Multidisciplinary Minor-I	3	0	0		3	30	10	60	--	--
7	VSEC	<tbd>	CNC Programming & Machining	0	0	4	1	2	--	--	--	CIE: 100	
8	HSMC	<tbd>	Principles of Economics	1	0	2		2	CIE: 100			50	50
9	HSMC	<tbd>	Environmental Studies	0	0	2		1	--	--	--	CIE: 100	
10	HSMC	<tbd>	Communication Skills	1	0	2	--	2	CIE: 100			CIE: 100	
			Total	**16**	**0**	**16**	**5**	**24**					

Legends: L-Lecture, T-Tutorial, P-Practical, S-Self Study, Cr-Credits ISE-In-Semester-Evaluation, ESE-End-Semester-Evaluation,MSE-Mid-Semester-Evaluation, TA-Teachers' Assessment, CIE-Continuous-Internal-Evaluation

Exit Course options for Diploma in Manufacturing Science

Two (02) Skill based Courses:

1. Geometric Dimensioning and Tolerancing and Product Inspection (4 credit)
2. Modern Prototyping Practice (4 credit)

UG Program Structure of Semester- V and VI
of
B. Tech. (Manufacturing Science and Engineering)

Semester V

Sr. No.	Course Type	Course Code	Course Name	L	T	P	S	Cr	Evaluation Scheme (Weightages in %)				
									Theory			Laboratory	
									MSE	TA	ESE	ISE	ESE
1	PCC		Metrology & Quality Control	2	0	2	1	3	30	20	50	50	50
2	PCC		Process Planning & Tool Design	2	0	2	1	3	30	20	50	50	50
3	PCC		Industrial Engineering and Management	2	0	0	1	2	30	20	50		
4	PCC		Kinematics and Dynamics of Machines	3	0	0	1	3	30	20	50		
5	PEC		Department Elective-I	3	0	2		4	30	20	50	50	50
6	OE		Open Elective-III-OPERATIONS RESEARCH/ RELIABILITY ENGG	2	0	0		2	30	20	50		
7	MDM		Multidisciplinary Minor-II	3	1	0		4	30	20	50		
8			Project stage-I	0	0	4		2				CIE-100	
9			Internship-II[#]	0	0	2	0	1				CIE-100	
Total Academic Engagement and Credits				17	0	16	4	24					

 # Summer internship-II (Industry/R&D/Academic institute) after IVth semester summer vacation and evaluation will be done at the start of Vth semester.

Program Elective Courses (PEC-1)- Semester-V

Sr. No.	Course Type	Course Name	Teaching Scheme					Credits
			L	T	P	S	Hrs	
1	PEC 1	Product Design and Development	3	0	2		5	4
2	PEC 1	Tribology in Design & Manufacturing	3	0	2		5	4
3	PEC 1	Mechatronics	3	0	2		5	4
4	PEC 1	Metal Forming Technology	3	0	2		5	4
5	PEC 1	Additive manufacturing	3	0	2		5	4

Semester VI

Sr. No.	Course Type	Course Code	Course Name	L	T	P	S	Cr	Evaluation Scheme (Weightages in %)				
									Theory			Laboratory	
									MSE	TA	ESE	ISE	ESE
1	PCC		Advances in CAD/CAM/CIM	2	1	2	1	4	30	20	50	50	50
2	PCC		Operations Research	3	0	0	1	3	30	20	50	--	--
3	PCC		Manufacturing Automation	3	0	2	1	4	30	20	50	50	50
4	PEC		Department Elective -II	3	0	2		4	30	20	50	50	50
5	MDM		Multidisciplinary Minor-III	3	1	0	1	4	30	20	50	--	--
6	VSEC		Smart Mfg. and Simulation Laboratory	0	0	2	1	1				CIE-100	
7			Project stage-II	0	0	2	1	2				CIE-100	
Total Academic Engagement and Credits				14	2	10	6	22				CIE-100	

Programme Elective Courses (PEC-2) - Semester-VI

Sr. No.	Course Type	Course Name	Teaching Scheme					Credits
			L	T	P	S	Hrs	
1	PEC 2	Design For Manufacturing and Assembly	3	0	2		5	4
2	PEC 2	Micro & Nano manufacturing	3	0	2		5	4
3	PEC 2	Advanced Joining Techniques	3	0	2		5	4
4	PEC 2	AI for Manufacturing	3	0	2		5	4
5	PEC 2	Fundamentals of Quantitative Techniques in Project Management	3	0	2		5	4

Exit Course options for B.Voc in Manufacturing Sciences

Two (02) Skill based Courses of 8 credits

Sr. No.	Course Type	Course Name	Teaching Scheme					Credits
			L	T	P	S	Hrs	
1	SEC	Computer Aided Inspection	0	0	8	1	5	4
2	SEC	Casting & Welding Technology	0	0	8	1	5	4

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Course: METROLOGY AND QUALITY CONTROL (MQC)

Course Code		**Scheme of Evaluation**	MSE, TA & ESE
Teaching Plan	2-0-2-1 = 3	**MSE-** 30	**TA-** 20
Credits	2	**ESE** -50	

Course Objectives:

- Selection of Tools and Techniques for determining geometry and dimensions
- Calibration of measuring tools
- Understand the advances in Metrology such as use of CMM.
- Application of Quality Control Techniques.

Syllabus:

Unit	Contents	Lecture
01.	**Introduction:** Meaning of Metrology, Precision, Accuracy, Methods and Errors in Measurement, Calibration. **Linear Measurement:** Standards, Line Standards, End Standard, Wavelength Standard, Classification of Standards, Precision and Non-Precision Measuring instruments and their characteristics, Slip Gauges. **Interferometry:** Introduction, Flatness testing by interferometry, NPL Flatness Interferometer. Study of Measuring Machines, Recent Trends in Engineering Metrology, use of interferometry for length, angle and surface roughness measurement. **Measurement System Analysis:**Introduction, Influence of temperature, operator skills and the instrument errors etc. on the MSA, Gauge R and R study. Metrology for Additive manufacturing, laser metrology and measurement. *Self Study*- Angle Measurement: Sine bar, Sine centres, Uses of sine bars, angle gauges, Auto Collimator, Angle dekkor, Constant deviation prism.	**06 L**
02.	**Limits, Fits and Tolerances:** Meaning of Limit, Fits and Tolerance, Cost–Tolerance relationship, concept of Interchangeability, Indian Standard System. **Design of limits Gauges:** Types, Uses, Taylor's Principle, Design of Limit Gauges, Three surface Generation. **Inspection of Geometric parameters:** GD&T symbols and concept,Straightness, Flatness, Parallelism, Concentricity, Squareness and Circularity. *Self Study*- Comparators:Uses, Types, Advantages and Disadvantages of various types of Comparators. Multigauge Measurement Systems.	**05 L**
03.	**Surface Finish Measurement:** Surface Texture, Meaning of RMS and CLA values, Roughness Measuring Instruments, Tactile and Non-tactile measuring instruments, difference between waviness and roughness, Grades of Roughness, Specifications, Assessment of surface roughness as per IS, Relationship between surface roughness and Manufacturing Processes. **Screw Thread Metrology**: External Screw Thread terminology, Floating Carriage Instruments, Pitch and flank Measurement of External Screw Thread, Application of Tool Maker's Microscope, Use of Profile Projector.	**05 L**

	Self Study- Gear Metrology**:** Spur Gear Parameters, Gear tooth thickness measurement: Gear tooth vernier calliper, Constant chord method, Span Micrometer.	
04.	**Introduction to Mechanical Measurements:** Importance of Measurements, Classification of measuring instruments, Generalized measurement system, Types of inputs for measurements. Concepts such as Linearity, Sensitivity, Static error, Precision, Reproducibility, Threshold, Resolution, Hysteresis, Drift, Span & Range etc. Errors in Measurements, Classification of errors in measurements, First order instruments and its response to step, ramp, sinusoidal and impulse inputs. Displacement measurement, Velocity Measurements. *Self-study*-Pressure Measurement, Temperature Measurement, Vacuum Measurement, Acceleration and strain measurement.	**04L**
05.	**Quality Control**: Meaning of Quality, Approaches- Deming's Approach, Juran's Approach, Quality of Product, Quality of Service, Cost of Quality, Value of Quality, and Difference between Inspection, Quality Control and Quality Assurance, Role of Quality in Present day environment. Meaning of quality Control, 100% Inspection and Selective Inspection, Statistics in Selective inspection, Quality Assurance system and standards. *Self Study*-Total Quality Management: 7 Tools of problem solving, Like cause and effect diagram, Pareto Analysis ,etc. QFD, Kaizen, 5s system, Quality Circles	**03 L**
06.	**Statistical Quality Control**: Interpretation of SPC Charts, benefits for use on shop floor, Control charts- Attribute (P, nP, C, U) and Variable (X bar, R chart and X & R chart), Sampling inspection, OC Curves and Sampling Plan, Process Capability Index (Cp, Cpk), Concept, Methods of determining Cp and Cpk. *Self Study*-ISO 9001-2000 Series of Standards: History and evolution of ISO 9000 series, importance and overview of ISO series, Structure of ISO 9001-2000 Series Standards, clauses of ISO 9000 series standards and their interpretation and implementation	**05 L**

Course outcomes:

1. Identify different measurement systems and common types of errors.
2. Describe and use different types of linear and angular measurement processes and instruments.
3. Explain and able to select appropriate techniques of interferometers, comparators and screw and gear measurements.
4. Explain surface roughness measurements, Optical instruments and 3Dmeasurements.
5. Explain industrial practices to analyze the cause for variation by statistical process control using variable and attribute control charts and sampling technique.

Suggested learning resources:

1. R. K. Jain, A Textbook of Engineering Metrology, Khanna Publications Pvt. Ltd.22nd Edition, 2022.
2. Dr.S.P. Gupta, Statistical Methods, Sultan Chand and Sons, 46th Edition, 2021.
3. Grant and Leavenworth," Statistical Quality Control", McGraw Hill publication,2017
4. Amitava Mitra, Fundamental of Quality Control and improvement, Prentice Hall of India Publications, 4th Edition 2016
5. G.M.S. De Silva, Basic Metrology for ISO 9000 Certification Elsevier Publications, 3rd Edition 2002.
6. I.C. Gupta, A Text book of Engineering Metrology, Dhanpat Rai Publications Pvt. Ltd.6thEdition, 2004.
7. A.S.T.M.E., "Handbook of Industrial Metrology", Prentice Hall, ISBN 10: 0070015368,

1968.
8. G.S. Patnaik, Quality Assurance in Industries: A Comprehensive Guide to Quality Assurance in Industries, Notion Press Media Pvt. Limited, ISBN: 9781639403134, 1639403132.
9. Kumar D S," Mechanical Measurements and Control" Metropolitan publication, Delhi.,5th edition,2012
10. John S. Oahland, Total Quality Management, Elsevier Publications, 3rd Edition 2006.
11. P. N. Mukerjee, Total Quality Management, Prentice Hall of India Publications, 2nd Edition 2005.

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Course: METROLOGY AND QUALITY CONTROL LAB (MQC LAB)

Course Code		**Scheme of Evaluation**	Oral & Term Work
Teaching Plan	2-0-2-1 = 3	**Term Work**	50
Credits	1	**Oral**	50

Course Objectives:

- Selection of Tools and Techniques for determining geometry and dimensions
- Calibration of measuring tools.
- Understand the advances in Metrology such as use of CMM.
- Application of Quality Control Techniques.

Syllabus:

Term work consists of following experiments (Any Eight)

Assignment	**Contents**	**Practical**
01	Determination of Linear/Angular dimensions of a part using Precision and Non-Precision measuring Instruments.	**02hrs**
02	Precision angular measurement using a) Sine Bar, b) Auto Collimator, c) Angle Dekkor.	**02hrs**
03	Machine Tool alignment tests on any machine tool like Lathe, Drilling Machine or Milling machine (minimum three tests)	**04hrs**
04	Measurement of screw thread parameters using Floating Carriage Micrometer.	**02hrs**
05	Measurement of Gear parameters: a) Gear Tooth thickness and depth, b) constant Chord, c) Span Measurement, d) Pitch Circle Diameter.	**02hrs**
06	Surface Finish measurement using suitable instrument	**02hrs**
07	Interferometry: Measurement of surface flatness using optical flat.	**02hrs**
08	Study and Measurement of parameters using Profile Projector.	**04hrs**
09	Exercise on Design of Limit Gauges using Taylor's Principles.	**02hrs**
10	Study and Measurement of parameters using Tool Makers Microscope.	**02hrs**
11	Study and Measurement of parameters using Co-ordinate measuring machine (CMM).	**02hrs**
12	Measurement of circularity using comparator	**02hrs**

Course Outcomes:

1. Explain principle, construction and working of various measuring instrument.
2. Selection of proper instruments for measurement.
3. Calculation of least count of instrument, take reading using the instrument.
4. Collection and recording of data and analysis of data.

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Course: PROCESS PLANNING AND TOOL DESIGN (PPTD)

Course Code		**Scheme of Evaluation**	CE & ESE
Teaching Plan	2-0-2-1 =4	**MSE + TA**	30 + 20
Credits	3	**ESE**	50

Corse Objectives:

- To recognise Process Planning and Sequencing – Develop systematic methods for selecting manufacturing processes, sequencing operations, and optimizing production efficiency.
- To analyze Part Dimensions and Tolerances – Interpret engineering drawings, evaluate geometric tolerances, and ensure precision in manufacturing.
- To select Appropriate Tooling and Fixtures – Identify suitable cutting tools, jigs, and fixtures for different machining operations to enhance accuracy and productivity.
- To optimize Manufacturing Parameters – Study machining variables such as speed, feed, and depth of cut to improve surface quality, tool life, and overall process efficiency.

Syllabus:

Unit	Contents	Lecture
01.	**Fundamentals of Process Planning:** Introduction: basics of process planning, designing production workflow, tolerances, part features to manufacturability. Datum features, geometric accuracy, preliminary part print analysis, dimensioning, tolerances, and critical control features. Self study: Interpretation of engineering drawings, part print analysis.	**06 L**
02.	**Process Selection and Sequencing:** Approach to select manufacturing processes, sequence of operations, classification of processes into basic, principal, auxiliary, and supporting operations, cost-effectiveness, importance of process sequencing, optimizing production time and quality, stock preparation, blank selection with material estimation, time estimate and time standards. Self study: Study of traditional and advanced manufacturing process.	**08 L**
03.	**Jigs and Fixtures:** Study and Selection of Tooling: Standard and Special Tooling, Significance and purpose of jigs and fixtures and their functions in the manufacturing processes. Classification of jigs and fixtures. Design features of main elements of jigs and fixtures such as locating, clamping and guiding elements and their integration. Indexing, locking and auxiliary elements. Bodies, bases or frames of jigs and fixtures. Self-study: Basic principle of use of jigs and fixtures, applications in industry.	**07 L**
04.	**Fundamentals of Tool Design:** Introduction to basic principles of tool design, components of press tools, design objectives, economics of design, ergonomics, material selection, classification and components of press tools: dies, punches, and their applications. Self study: Overview of press tools, forging dies, and plastic moulds.	**05 L**
05.	**Design of Press Tools and Forging Dies:**	**08 L**

Design principles and applications of **press tools, forging,** metal forming processes. Types of dies, calculations for blank size, center of pressure, press capacity, various forces. Design of forging dies, Guidelines for selection of various design factors, parting line, draft, rib-web, Corner & fillet radius, shrinkage & die wear etc. Calculations related to stock size, forging forces, and die wear considerations to optimize tool life and efficiency.
Self study: Study of basic principle of bending and forging process.

06. Design of Die Casting Dies and Plastic Moulds: **08L**

Design considerations in die casting, feed system and flow system and ejection system, and heat transfer considerations, Common defects in die casting.
Moulding processes such as **injection moulding, blow moulding, and compression moulding**. Common defects in moulding, their remedies.
Self-study: Basic principle of die casting, plastic moulding and its components, applications.

Course outcomes:

1. Analyse the dimensions, tolerances, and control of various features of parts.
2. Select and assign sequence of machining processes from basic to principal processes.
3. Identify and select the appropriate tools and toolings for major machining operations to be performed on workpiece.
4. Comprehend the design aspects of Jigs and Fixtures, press tools and moulding dies.
5. Figure out the analytical/ theoretical analysis of press tools and moulding dies.

Suggested learning resources:

1. Cyril Donaldson, George H. Le Cain, V.C. Goold, "Tool Design", Tata McGraw Hill Publishing Company Ltd., 2000, 3rdEdition.
2. Vukota Boljanovic, "Sheet Metal Forming Processes and Die Design", Industrial Press, New York, 2004.
3. Wilson, Fundamentals of Tool Design, A.S.T.M.E., Prentice Hall of India.
4. S. K. Basu, S.N. Mukherjee, R. Mishra, Fundamental of Tool Engineering Design, Oxford & IBH Publishing Co. Pvt. Ltd., 1979.
5. J. R. Paquin, R. E. Crowley, Die Design Fundamentals, Industrial Press Inc., 2nd Edition, 1987.
6. Gideon Halevi and Roland D. Weill, (1995),) Principles of Process Planning: A Logical Approach.
7. K.G. Swift and J.D. Booker, (2013,) Manufacturing Process Selection Handbook
8. Peter Scallan Process, (2000) Planning: The Design/Manufacture Interface.
9. P.C. Sharma, (2005), A Textbook of Machine Tools and Tool Design.

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Course: PROCESS PLANNING AND TOOL DESIGN (PPTD) -LABORATORY

Course Code		**Scheme of Evaluation**	Oral & Term Work
Teaching Plan	2-0-2-1 = 3	**Term Work**	50
Credits	2	**Oral**	50

Course Objectives:

- To analyse part drawings for dimensions, tolerances, and surface requirements to support accurate manufacturing planning.
- To select suitable processes, tools, jigs, and fixtures based on component geometry and production needs.
- To analyse and plan machining sequences, datums, stock, and process sheets for efficient manufacturing.
- To optimize tooling methods and process design for improved productivity, quality, and cost-effectiveness.

Syllabus Contents:

The term work shall consist of record of any Six assignments on following topics:

i. Preliminary part print analysis for given components which includes study of part, its dimensions and tolerances and control of its features of parts.
ii. Preparation of tolerance chart for any two components also students must describe handling, basic processes for manufacturing, sequence of operations. Study of Special processes, if necessary, related surfaces to be machined, Assembly Process if any for the given parts.
iii. Analysis of Part Dimensions of given component: Shape of part as flatness, straightness, roundness, geometrical shapes, symmetry, job requirement of finish on part.
iv. Drawing of arrangement of locators, for standard shaped components like rectangular prism, pyramids, cylinder, tube, cones and any one nonstandard component for good geometric control Manufacturing Processes.
v. Identification and list our sequence of various manufacturing processes to be performed on a given component/works-piece, from a drawing such as Basic Processes, Principal Processes, Major Operations and Auxiliary Processes, Supporting Operations.
vi. Study and Selection of Tooling: Standard and Special Tooling. Use of Jigs and Fixtures, Selection of Equipment, Tooling. Economics of Tooling.
vii. Study of conventional tooling methods for commonly Machined Surfaces, Tooling ideas for Typical features on a job. Multi tooling setups, new tools and tooling methods
viii. Study of the machined parts and initial data required for process design from the point of manufacture:
ix. Planning the sequence of machining operations along with selection of machining operations along with selection of machine tools, cutting tools, jigs and fixtures, cutting variables as well as fixing in process dimensions and gauging.

i) Datum features/surfaces and their selection.
ii) Stock preparations and blank selection with material estimate.
iii) Time estimate and time standards.
iv) Process sheet design for the complete manufacture of the machined parts

Course outcomes:

At the end of the laboratory work, students will demonstrate the ability to

1. Analyse the dimensions, tolerances, and control of various features of parts.
2. Select and assign sequence of machining processes from basic to principal processes.
3. Identify and select the appropriate tools and toolings for major machining operations to be performed on the workpiece.
4. Prepare process plan and flow diagram for given component.

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Course: INDUSTRIAL ENGINEERING AND MANAGMENT (IEM)

Course Code		**Scheme of Evaluation**	CE & ESE
Teaching Plan	2-0-0-1 = 2	**MSE+TA**	30+20
Credits	2	**ESE**	50

Course Objectives:

- To understand Industrial Engineering and Organizational Concepts – Learn the role of industrial engineering and contributions of Taylor and Gilbreth. Study organizational structures, elements, and types.
- To analyze Authority and Responsibility in Organizations – Explore different organizational types and understand authority, responsibility, delegation, and span of control.
- To evaluate Productivity and Its Measurement – Define productivity and analyze factors affecting it, including material, land, machine, and labor efficiency.
- To apply Principles for Efficiency Improvement – Use industrial engineering techniques to optimize productivity, enhance workflows, and improve organizational effectiveness.

Syllabus:

Unit	Contents	Lecture
01.	**Introduction:** Definition and Role of Industrial Engineering, Contribution of Taylor and Gilbreth, Organization: Concept of organization, characteristics of organization, elements of organization, organizational structure, organization charts; Introduction to types of organization- formal line, military organization, functional organization, line & staff organization; authority and responsibility, span of control, delegation of authority. Productivity: Definition of productivity, Productivity of materials, land, building, machine and power. Measurement of productivity: factors affecting the productivity. Self Study: Pioneers in IE	**05 L**
02.	**Method Study:** Method Study Definition, objective and scope of work-study. Human factors in work-study. Method Study : Definition, objective and scope of method study, activity recording and exam aids, Charts to record moments in shop - operation process charts, flow process charts, travel chart, two handed chart and multiple activity charts. Charts to record movement at work place - principles of motion economy, classification of moments, SIMO chart, and micro motion study. Definition and installation of the improved method, brief concept about synthetic motion studies Numerical), Introduction to Value Engineering and Value Analysis. Self Study: Case study of Value Engineering/Value Analysis	**07 L**
03.	**Work Measurements:** Definition, objectives and uses; Work measurement techniques. Work sampling - need, confidence levels, sample size determinations, random observation, conducting study with the simple problems. Time study:	**06 L**

Definition, time study equipment, selection of job, steps in time study. Breaking jobs into elements, recording information. Rating and standard rating, standard performance, scales of rating, factors affecting rate of working, allowances and standard time determination; Introduction to PMTS and MTM. (Numerical), Introduction to MOST.
Self Study: Application of MOST.

04. Principles of Management: **04 L**

Functions related to Planning, organizing, staffing, leading and controlling. Henri Fayol's Principles of Management, Division of Work, Authority and Responsibility, Discipline, Unity of Command, Unity of Direction, Subordination of Individual Interest, Remuneration, The Degree of Centralization, Scalar Chain, Order, Equity, employee stability, and Initiative.

05. Methods of job evaluations and merit rating: **06 L**

Job evaluation (Job analysis, job description, job specification, job classification, wage determination) Wages, salary, and incentives, Time wage system, Piece wage system, motivation, wage incentive plans Straight piece rate, Straight piece rate with guaranteed min. wage, Taylor's differential piece rate system, Halsey plan, Rowan plan, and Gantt plan. Personnel management, Performance appraisal and merit rating, methods of performance appraisal.
Self study: Numerical problems on Wage Incentives

Course outcomes:

1. Learn basics concepts of productivity and organization theory.
2. Understand the basic concepts of work study.
3. Apply the techniques of work study and improve productivity.
4. Understand the basic principles of industrial management.
5. Understand the need of personnel management and training of workers.
6. Apply various techniques for job analysis and evaluations.

Suggested learning resources:

1. Work Study, ILO
2. Basu S.K., Sahu K.C and Rajiv B, Industrial Organization and Management –. PHI New Delhi, 2012, ISBN No. 9788120344211.
3. M.S. Sanders and E.J. McCormick, "Human Factors in Engineering Design", VI Edition, McGraw Hill.
4. R.M. Barnes, "Motion and Time Study", Wiley International, 1980.
5. S. Dalela and Sourabh, "Work Study and Ergonomics". Standard Publishers, Latest Edition

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Course: KINEMATICS AND DYNAMICS OF MACHINES (KDM)

Course Code	MFG-250XX	**Scheme of Evaluation**	CE & ESE
Teaching Plan	3-0-0-1 = 3	**MSE & Internal**	30 + 20
Credits	3	**ESE**	50

Corse Objectives:

Students will be able to

- Explore various applications of cam and follower by analysing various types of motion and able to construct cam profile
- Understand the loading pattern and stress concentrations to see its impact on machine members
- Design the various types of gears used in industrial applications by understanding its design
- Explore the type of Clutches, brakes and its industrial applications.
- Understand the impact of bearing selection and its design process over its life.

Syllabus:

Unit	Contents	Lecture
01.	**Cams and Follower:** Introduction, Types of cam and Follower, Types and Analysis of motion, Uniform velocity, Simple harmonic motion, Uniform acceleration and retardation (Equal and unequal), and Cycloidal motion. Constructions of displacement, velocity and acceleration diagrams and cam profile for given follower motion.	**06 L**
02.	**Design for fluctuating loads:** Types of loads Elementary equations for stresses, stress concentration causes and remedies, Fluctuating stresses, S-N Diagram, Endurance limit, Factors affecting Endurance Strength, Design for Finite and Infinite life under reverse stresses, Cumulative damage, Soderberg's and Goodman's Diagram, Modified Goodman's Diagram, Design under combined stresses. Design of components like shaft, bolted joints, springs etc. subjected to variable loading.	**06 L**
03.	**Spur Gears:** Classification, Terminology, Law of Gearing, Velocity of sliding, Interference, Minimum number of teeth to avoid interference, Standard system of Gear tooth, Design of Spur Gears, Selection of Type of Gears, Force Analysis, Gear tooth Failures, Selection of Materials, Beam Strength, Wear Strength, Effective Load Calculation, Dynamic Load, Gear Design for Maximum Power Transmitting Capacity. **Helical Gears:** Virtual Number of Teeth, Force Analysis, Beam Strength, Wear Strength, Effective Load, Helical Gear Design.	**10 L**
04.	**Bevel Gears:** Force Analysis, Design Calculations of Bevel Gears, Beam Strength, Wear Strength, Effective Load. **Worm Gears:** Force Analysis, Friction in Worm Gears, Strength Rating of Worm Gears, Wear Rating of Worm Gears, Heat Dissipation.	**07 L**
05.	**Friction Clutches, Brakes:** Pivot collar friction, design consideration for plate, cone & centrifugal clutches. Design of various brakes, like band	**06 L**

brake, shoe brake, band & block brake, Disc Brakes, thermal considerations.

06.	**Rolling Contact Bearings:** Selection of bearing from Manufacturer's Catalogue, Design for variable loads and Speeds, Bearings with Probability of Survival other than 90%. **Sliding Contact Bearings:** Hydrostatic Step Bearing, Energy Losses in Hydrostatic Step Bearing, Reynold's Equation, Raimondi and Boyd Method, Bearing Design – Selection of Parameters, Sommerfeld Number, Constructional Details of Bearings, Temperature Rise.	**07 L**

Course outcomes:

1. To select the type of follower motion for the specific application.
2. Analyze the load-carrying members to be safe under their expected loading patterns commonly encountered by machine parts.
3. Analyze the stresses on the on different types of gear teeth considering various factors and design the gear pair to be safe under bending and pitting conditions.
4. Perform the design and analysis of various types of clutches and brakes to specify the required capacity to drive the given system reliably.
5. Understand bearing selection process to evaluate expected bearing life for industrial application

Suggested learning resources:

Textbooks:

1. V.B. Bhandari, "Design of Machine Elements", Tata McGraw Hill Publishing Company Ltd., 3rd Edition, 2010.
2. S. S. Rattan, "Theory of Machines", Tata McGraw Hill Publishing Company Ltd., 3rd Edition, 2009.

Reference Book:

1. R.S. Khurmi J. K. Gupta, "Theory of Machines", Eurasia Publishing House (Pvt.) Ltd, 2nd Edition 2020.
2. R.S. Khurmi J. K. Gupta, "A Textbook of Machine Design", S. Chand Publication, 25th Edition, 2020.
3. Joseph E. Shigley, John J. Uicker, "Theory of Machines and Mechanisms", Cambridge University Press, 6th Edition, 2023.
4. Thomas Bevan, "Theory of Machines", Pearson Education, 3rd Edition. 2010.
5. Robert L. Norton, "Design of Machinery", McGraw Hill Higher Education, 5th Edition, 2012.
6. Robert L. Mott, P.E, "Machine elements in mechanical design", Pearson Prentice Hall Publication 4th Edition, 2020.

Department of Manufacturing Engineering & Industrial Management
Programme Elective Courses

Sr. No.	Course Type	Course Name	Teaching Scheme					Credits
			L	T	P	S	Hrs	
1	PEC 1	Product Design and Development	3	0	2	-	5	4
2	PEC 1	Tribology in Design & Manufacturing	3	0	2	-	5	4
3	PEC 1	Mechatronics	3	0	2	-	5	4
4	PEC 1	Metal Forming Technology	3	0	2	-	5	4
5	PEC 1	Additive Manufacturing	3	0	2	-	5	4

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Course: PRODUCT DESIGN AND DEVELOPMENT (PDD)

Course Code	PEC 1	**Scheme of Evaluation**	MSE,TA & ESE
Teaching Plan	3 hrs /week	**MSE**	30
Credits	4	**ESE**	50
Practical Plan	2 hrs/ week	**TA**	20

Course Objectives:

- Understand the fundamental concepts of Innovation, Product design & development.
- Understand Product Study and market study & benchmarking along with difference in product development and product design.
- Understand importance of Human factors in product design, Physical Ergonomics principles and issues, Ergonomic assessment tool, Cognitive issues in product design.
- Apply concept of concurrent design, product profit and competitiveness, Break even analysis, economics of new product design.
- Apply different considerations to solve real world product design problems.
- Explore advanced Product design tools and their applications.

Syllabus:

Unit	Contents	Lecture
01.	**Introduction to Product Design:** Definition of Product design, Design by evolution, innovation, Essential factors of Product design, Product development team: definition, composition, team roles, Myer-Briggs type indicator, team structure, team building, team evaluation; Product Development Planning: Steps of planning, basic planning and scheduling tools; S-curves: definition, scurves, Technology readiness Levels (TRLs)..	**08L**
02.	**Product design Considerations:** Product strategies (four strategies), Time to market, Product and market, The three S's, (Standardization, Simplification, Specialization), Procedure adopted by Industrial designers, Types of models, Role of aesthetics, Functional design practice (Biasing, Cascading, Regeneration, Redundancy, Compatibility, and matching considerations in product design.	**08 L**
03.	**Customer Needs** Customer satisfaction: Kano diagram, customer populations, types of customer needs, customer need models; Customer needs gathering methods Establishing Product Function Product Teardown & Experimentation Functional Decomposition: product function, sub function, abstraction, constraints; Modeling process: Function Analysis System Technique (FAST), Subtract and Operate procedure; Function structure: phases modeling process; Function structure decomposition; Product Teardown: phases of product teardown process; teardown methods; measurement and experimentation; Post teardown reporting; application of product teardown.	**08 L**
04.	**Ergonomics in Product design:** Anthropometry, design of controls, design for displays, Man/machine interaction, Ergonomic considerations, Workplace layouts, heating and ventilations, lighting considerations.	**06 L**
05.	**Product Economics:**	**06 L**

	Design for safety, Reliability, and environmental consideration, Economic analysis, Profit and competitiveness, Break even analysis, Economics of new product design	
06	**Rapid Prototyping:** Physical Prototypes Physical Models and Experimentation Physical models, Prototypes, Types of prototypes, uses of prototypes. Rapid prototyping techniques, Scale, Dimensional analysis, Physical prototype design and planning..	**06 L**

Suggested learning resources:

1. Handbook of Research on New Product Development Edward Elgar PublishingPeter N. Golder, Debanjan Mitra 2018
2. The Design of Everyday Things Basic Books, Donald A. Norman
3. Just Enough Research Mule Books, Erika Hall, 2024
4. The COMPLETE BOOK of Product Design, Development, Manufacturing, and Sales by Steven Selikoff -2020
5. Product Design by Kevin Otto & Kristin Wood, Pearson.
6. Product Design & Development, Karl T. Ulrich.
7. New Product Development, Tim Jones & Butterworth Heinmann, Oxford.
8. New Product Development: Design & Analysis, Roland Engene Y.,Inetoviez John Wiley and Sons Inc.
9. Product Design for Manufacture and Assembly, Amherst, Geofferry Boothroyd, Peter Dewhurst and Winston Knight.

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Course: PRODUCT DESIGN AND DEVELOPMENT -LABORATORY

(Any six laboratory assignments)

S.No	Name of the Laboratory assignment
01	Case study preparation of Product evolution of an engineering product
02	Product graphics design of any one consumer product
03	Case study preparation on customer need gathering of a product
04	Establishing of a Product Function of one concept product
05	Product Teardown of anyone engineering/consumer durable product
06	Benchmarking of anyone engineering/consumer durable product
07	Case study preparation of Ergonomic design of any one consumer durable product
08	Prototyping of a product concept using 3D Printing, Digital fabrication tools

Course outcomes:

At the end of the course, students will demonstrate the ability to

1. Learn basic concepts Learn basics of product design process and morphology of design.
2. Learn Concept design, detail design, manufacturing, marketing, Introduction strategy of new product.
3. Gain learning about optimization tools and ergonomic principles applied on typical product design as well as concept of value engineering in new product design.
4. Understand concurrent design, product profit and competitiveness, Break even analysis, economics of new product design.
5. Learn how to apply/ solve real world product design problems.
2. Learn about various advanced Product design tools.

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Course: TRIBOLOGY IN DESIGN AND MANUFACTURING

Course Code	MFG(DE)-250XX	**Scheme of Evaluation**	CE & ESE
Teaching Plan	3-0-2-1 = 3	**MSE & TA**	30 + 20
Credits	3	**ESE**	50

Course Objectives:

- Introduction of tribology to explain the fundamental principles of tribology
- Develop an understanding of various wear mechanisms
- Enable the students with the knowledge to select appropriate lubricants:
- Enable students to apply tribological principles to design and manufacturing:
- Foster an understanding of the importance of tribology in Manufacturing engineering

Syllabus:

Unit	Contents	Lecture
01.	**Tribology** Introduction, Importance of Tribology in Design, Tribology in Industry, Economic Considerations, effects of surface preparation on Tribology. **Friction** Introduction, Laws of friction, kinds of friction, causes of friction, area of contact, friction measurement, theories of friction. **Wear** Types of wear, various factors affecting wear, cutting tool wear & coating, measurement of wear, wear between solids and flowing liquids, theories of wear.	**08 L**
02.	**Lubricants and Lubrication** Introduction, Lubricant properties- physical and chemical, basic modes of lubrication, types of lubricants, Seals-Static and dynamic. Tribology in manufacturing processes viz. Forging, drawing, extrusion, rolling etc. Lubricants used for wire ropes.	**06 L**
03.	**Hydrodynamic Lubrication** Theory of hydrodynamic lubrication. Mechanism of pressure development in oil film. Two-dimensional Reynolds equation, pressure distribution in journal bearings - long & short, Load Carrying capacity, Somerfield number, importance of radial clearance, eccentricity ratio minimum oil film thickness etc., Heat Balance equations. Fixed bearing design using Raymondi and Boyd concept. **Hydrodynamic Thrust Bearing** Introduction, flat plate thrust bearing, pressure distribution equation, load, centre of pressure. Tapered thrust bearing, Friction in thrust bearing, Heat Balance equations.	**08 L**
04.	**Hydrostatic Lubrication** Basic concept, operations, advantages and limitations. Flow of viscous fluid through rectangular slot, Circular pad bearing and conical bearing, load	**08 L**

carrying capacity and flow of lubricants. Bearing power, energy losses in bearing and film thickness, bearing temperature. Rigidity of bearing design.

05. Elastohydrodynamic and Aerostatic Lubrication **06 L**

Principle and applications, Hertz Theory, Pressure viscosity term in Reynolds's equation, Ertel-Grubin equation. Introduction to Aerostatic Bearing and its application.

06. Hydrostatic Squeeze Film **06 L**

Introduction, parallel rectangular plate, Circular plate approaching each other and cylinder near plane, pressure distribution, squeeze load and time of approach.

Course outcomes:

1. Understand basic concept of tribology to evaluate friction and wear of materials.
2. Classify various types of lubricants to learn their applications.
3. Design hydrodynamic bearing under various load carrying capacity, power loss and heat balance in bearing.
4. Analyze performance of hydrostatics bearing by optimizing bearing parameters.
5. Understand basic principles of Elestohydrodynamics bearing and aerostatics bearing to know their applicability.
6. Apply fundamentals of Hydrostatics Squeeze film to solve problems on Squeeze load, time of approach etc.

Suggested learning resources:

Textbooks:

1. Basu S.K., Sengupta S. N. and Ahuja B.B. "Fundamentals of Tribology" PHI Learning, Ltd. India.
2. Majumdar B. C. "Introduction to Tribology and Bearings", S. Chand and Company Ltd., New Delhi.

Reference Book:

1. Bharat Bhushan, "Principles and Applications of Tribology", John Wiley and Sons.
2. Sahu P., "Engineering Tribology", PHI Learning, Ltd. India
3. Fuller D.D. "Theory and Practice of Lubrication for Engineers". John Wiley and Sons.
4. Neale M. J. "Tribology hand Book", Butterworths. London.
5. Orlov P., "Fundamentals of Machine Design", Vol. IV, MIR Publication.
6. Cameron A. "Basic Lubrication Theory", Wiley Eastern Ltd.
7. 'Hailing J., "Principles of Tribology", McMillan Press Ltd., 1975.
8. Ghosh M.K., Majumdar B.C. and Sarangi M., "Theory of lubrication", Tata McGraw Hill Education Pvt. Ltd., New Delhi.

List of Experiments

Sr. No.	Title of Experiment	Duration
1	To Study the measurement of Friction and Wear using Pin-on disk Tribometer under static loading.	2 hrs
2	To Study the measurement of Friction and Wear using Pin-on disk Tribometer under dynamic loading.	2 hrs
3	To Study the measurement of Friction and Wear using dry bearing test rig Tribometer.	2 hrs
4	To Study the lubricant property using Four Ball tester	2 hrs
5	To Study the measurement of TAN and TBN of the Oil	2 hrs
6	To Study the measurement of Viscosity of the Oil	2 hrs
		12 hrs

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Course: MECHATRONICS

Course Code		**Scheme of Evaluation**	Theory:	Practical:
Teaching Plan	3-0-2-0	MSE+TA	30+20	50
Credits	04	ESE	50	20

Theory Course Objectives:
By the end of this course, students will be able to:

- Understand the fundamentals of Mechatronics systems, their architecture, and their significance in modern manufacturing environments.
- Develop an understanding of sensors, actuators, controllers, and their integration in automated systems.
- Analyze and design basic control systems applicable in mechanical and manufacturing domains.
- Explore interfacing technologies, including microcontrollers, PLCs, and HMIs for real-time control.
- Apply Mechatronics principles to develop intelligent, automated systems for industrial and shop-floor applications.

Syllabus:

Unit	**Contents**	**Lecture**
01.	**Mechatronics:** Introduction to Mechatronics, Application areas of Mechatronics, Mechatronic Design Processes, Introduction to Measurement Systems, Control Systems System Response: Introduction, Input -Output model equation and system characterization, Instantaneous, Lagging and Delay Response, Transient Response Specification, Test Signals, Signals, Bandwidth and Frequency Response, Dynamic Characteristics of Measurement, Frequency Response of a System.	07L
02.	**Digital Logic**, Circuits, Systems and Hardware: Digital Logic, Boolean Algebra, Karnaugh Maps, Combinational Logic and Circuits, Timing Diagrams, Design of Logic Networks, Sequential Logic, Devices and Circuits, Integrated Circuit System Design. 21 **Microprocessors and Microcontrollers:** Introduction, Microprocessor-based Digital Control, Microprocessor Architecture, Memory, Input/Output Hardware, Microcontrollers, General Requirements for control and their implementation in Microcontrollers, Classifications, Applications.	07L
03.	**Input/Output Systems:** Interfacing, Input/Output Addressing, Interface Requirements, Peripheral Interface Adapters, Serial Communications Interface, Examples of Interfacing, Machine to machine to communication. (M2M).	07L
04.	**Sensors, Transducers and Actuators**: Introduction to Sensors and Transducers, Performance characteristics – static and dynamic, Sensor working Principles, Selection of sensors	07L
05.	**Microcontrollers and Connectivity technologies:** Introduction to use of open-source hardware (Arduino & Raspberry Pi); shields/modules for GPS, GPRS/GSM, Bluetooth, RFID, and Xbee, integration with wireless networks, databases and web pages; web and mobile phone apps.	07L
06.	**Signal Conditioning and Signal Processing:** Signal conditioning, Digital Signals, Data Acquisition, Digital Signal Processing, Pulse modulation. Analog Signal	07L

Processing, Analog to Digital Conversion. **Data Acquisition:** Introduction, Elements of a Data Acquisition and Control System, Overview of the Input/Output Process, Analog to Digital (A/D) Conversion, Digital to Analog (D/A) Conversion, Data Acquisition Case Studies, Data Acquisition and Control Case Studies.

Course Outcomes:
Upon successful completion of the theory component, the student will be able to:

1. Explain the role and structure of Mechatronics systems in modern manufacturing.
2. Identify and describe the working principles of sensors and actuators used in manufacturing automation.
3. Interpret and design simple control circuits using analog and digital techniques.
4. Interface and program basic hardware (PLCs/Microcontrollers) for shop-floor automation.
5. Evaluate and propose Mechatronics-based solutions for industrial manufacturing challenges.

Laboratory Course Objectives:
By the end of the laboratory component, students will be able to:

- Provide hands-on experience in sensor, actuator, and controller integration.
- Develop and simulate automation systems using PLCs and relevant software tools.
- Implement real-time control and data acquisition systems using microcontrollers and DAQs.
- Strengthen system-level thinking by building functional Mechatronics subsystems.
- Enhance skills in diagnosing and troubleshooting hardware/software issues in Mechatronic setups.

List of Experiments: (Any Seven)

1. Study and Interfacing of Sensors (Inductive, Capacitive, IR, Ultrasonic)
2. Calibration and Operation of Linear and Rotary Encoders
3. Interfacing of Actuators (Solenoids, Relays, Stepper and Servo Motors)
4. PLC Programming for Bottle Filling or Pick-and-Place System
5. Simulation and Implementation of Conveyor Sorting System Using PLC
6. Data Acquisition and Analysis Using NI DAQ or Arduino-Based System
7. Closed-Loop Control of DC Motor (Speed/Position) Using PID Controller
8. Pneumatic and Electro-Pneumatic Control Circuit Design Using Simulation Tools (e.g., Fluid SIM)
9. Integration of HMI with PLC for Industrial Process Control
10. Condition Monitoring of Motors or Rotating Systems Using Vibration Sensors and FFT Analysis
11. Smart Assembly System Using Arduino and Sensors (e.g., smart nut tightening)
12. Force/Strain Measurement Using Strain Gauges on Mechanical Components
13. Temperature Monitoring and Control of Heating Element Using Thermocouple and Arduino/PID
14. Vision-Based Object Identification and Sorting Using Basic Image Processing (OpenCV/MATLAB)
15. Simulation of Automated Manufacturing Cell Using Digital Twin Software (e.g., Siemens Tecnomatix/Factory I/O)

Course Outcomes:
Upon successful completion of the laboratory component, the student will be able to:

1. Demonstrate practical skills in working with various industrial sensors and actuators.
2. Design and simulate automation processes using PLCs and HMI tools.
3. Build and test real-time control circuits using microcontrollers and DAQ systems.
4. Integrate mechanical and electrical components to construct functional Mechatronics subsystems.

5. Analyze performance, debug issues, and optimize Mechatronics-based systems for manufacturing applications.

Suggested learning resources:

Text Books

1. Appu Kuttan, Introduction to MECHATRONICS, Oxford Univ Press, 2010
2. Er R K Rajput, A Textbook of Mechatronics, S Chand Publishing, 2007

Reference Books

1. W. Bolton, Mechatronics - Electronic Control systems in Mechanical and Electrical Engineering, 2nd Edition, Addison Wesley Longman Ltd., 1999.
2. Devdas Shetty, Richard A. Kolk, Mechatronics System Design, PWS Publishing company, 1997
3. Bradley, D. Dawson, N.C. Burd and A.J. Loader, Mechatronics: Electronics in Products and Processes, Chapman and Hall, London, 1991.
4. Brian Morris, Automated Manufacturing Systems - Actuators, Controls, Sensors and Robotics, Mc Graw Hill International Edition, 1995.
5. Wolfgang Gopel, Sensors- A comprehensive Survey Vol I & Vol VIII, VCH, Wiley
6. Hanocha H. (2012), Actuators – Basics and applications 3/e, Springer.

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Course: METAL FORMING TECHNOLOGY

Course Code	PEC 1	Scheme of Evaluation Theory	MSE,TA& ESE	Scheme of Evaluation for Lab	CIE /ESE
Teaching Plan	3-2-0= 5	**MSE +TA**	30 +20	**Term work**	50
Credits	4	**ESE**	50	**Oral**	50
		Total	100	**Total**	100

Course Objectives:

- Understand the fundamental concepts of various metal forming processes and apply analytical methods to assess them.
- Apply theoretical principles to solve practical challenges in material forming processes such as rolling, drawing, forging, and extrusion.
- Develop a comprehensive understanding and appreciation of the scope and complexity of material forming.
- Grasp the fundamental aspects of formability and metalworking principles.
- Apply different yield criteria to solve metal forming problems effectively.
- Explore advanced metal forming processes and their applications.

Syllabus:

Unit	**Contents**	**Lecture**
01.	**Introduction of forming processes:** Strain hardening Concept of flow stress determination, Theory of plasticity, Yield criteria for ductile materials- Von-mises criteria, Tresca Criteria, flow stress concept. Effect of temperature, strain rate, metallurgical Microstructure, chemical composition, and mechanical properties, for Classification of material forming process. Concept of Formability, formability limits and formability diagram.	**08L**
02.	**Forging:** Introduction, classification of forging processes. Forging equipment- Hammers, presses, furnaces etc. construction, working capacities and selection of equipment. Basic forging operations such as drawing, fullering, edging, blocking etc. wing Forgeability tests, design of forging as a product, Slab Method of Analysis friction in forging. Forging defects and the remedies. New technologies: Liquid metal forging, isothermal forging, No draft forging, P/M forging, Rotary swaging, roll forging, Lubrications in forging.	**06 L**
03.	**Wire and Tube Drawing:** Introduction rod and wire drawing machines - construction and working. Preparation of stock for wire drawing. Wire drawing dies, material and design. Patenting heat treatment. Variables in wire drawing, Maximum reduction in wire in one pass, forces required in drawing. Multiple drawing, work hardening, lubrication in wire drawing. **Tube drawing:** Methods, force calculation, stock penetration. lubrication in tube drawing	**06 L**
04.	**Rolling of Metals:** Scope and importance of rolling. Types of Rolling Mills- Construction and working. Roll bite, reduction, elongation and spread. Deformation in rolling and determination forces required. Process variables, redundant deformation. Roll flattening, Roll camber - its effect on rolling	**06 L**

process, mill spring. Defects in rolling. Automatic gauge control- Roll pass classification & design. Lubrication in rolling. Sheet Metal Forming, blanking, bending, drawing and deep drawing

05.	**Extrusion:** Types - Direct, reverse, impact, hydrostatic extrusion. Dies for extrusion, stock penetration. Extrusion ratio Force equipment (with and without friction), metal flow in extrusion, defects. Role of friction and lubricants. Manufacture of seam-less tubes.	**06 L**
06	**Advanced metal forming processes:** High velocity forming- principles, comparison of high velocity and conventional Forming processes. Explosive forming, Magnetic pulse forming, Electrohydraulic Forming, Incremental Sheet Forming Micro-forming, Micro coining, micro-extrusion, Micro-bending Stretch forming, Micro-Incremental Sheet Forming coining embossing, curling spinning, flow forming advantages, limitations, and application of the process, Joint "extrusion-rolling" process, slitting rolling, surface flexible rolling, flow forming, forming of composite materials.	**09 L**

Course outcomes:

At the end of the course, students will demonstrate the ability to

1. Learn basic concepts of different metal forming process and the application of concept to analyze the processes.
2. Learn application of theoretical approach to solve practical problems associated with different material forming processes such as rolling, drawing, forging, and extrusion.
3. Gain an understanding and appreciation of the breadth and depth of the field of material forming.
4. Understand the various basics of formability, working on metals.
5. Learn how to apply various yield criterions to metal forming problems.
6. Learn about various advanced metal forming processes.

Material Forming Technology Laboratory syllabus: -

Course Objectives:

Exp. No	Contents	**Practical (hours)**
01.	Study of Flow Stress Determination in Metal Forming	02
02.	Verification of Von-Mises and Tresca Yield Criteria	02
03.	Study for Forging Slab Analysis	02
04.	Study of Wire Drawing: Effect of Die Angle and Lubrication	02
05.	Rolling Force Analysis and Thickness Reduction Study	04
06	Extrusion Process Simulation and Die Design Optimization	02
07	Formability limit curve evaluation for forging	04
08	Effect of Lubrication on Metal Forming Processes	02
09	High-Velocity Forming: Explosive and Magnetic Pulse Forming	02
10	Study of Advanced forming processes & simulation	02

Suggested learning resources:

1. Dieter, Mechanical Metallurgy, ISBN0071004068
2. G.W. Rowe, "Principles of industrial metal working process", Edward Arnold ISBN8123904282.
3. Chapman W.A.J, "Workshop Technology", Volume I, II, III, CBS Publishers and distributors, 5th Edition,2002.

4. Degarmo, Black and Kohser, “Materials and processes in Manufacturing”, Prentice Hall of India. 2nd Edition, 1998.
5. Dr. R. Narayanswamy, Metal Forming Technology, Ahuja Book Co. ISBN8176190020
6. P.N. Rao, “Manufacturing Technology”, Tata Mc-GrawHill ISBN0070087695
7. S.K. Hajra Choudhary and S.K. Bose, “Elements of workshop Technology” Volume I, II, Asia Publishing House, 10th Edition 2000
8. ASM Metal handbook Vol: 14 Forming and Forging.
9. O.P. Khanna and M. Lal, “Production Technology”, Vol. I,II, Dhanpat Rai Publication, 5 th Edition, 1999.
10. B.S. Raghuwanshi, “Workshop Technology”, Dhanpatrai Publication, 9th Edition, 1999

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Course: ADDITIVE MANUFACTURING (AM)

Course Code		**Scheme of Evaluation**	Continuous Evaluation (CE) & ESE (End Semester Exam)	Scheme of Evaluation for Lab	CE & ESE
Teaching Plan	3-0-2-0 = 5	**MSE+ TA**	30 + 20 Marks	Term work	50 Marks
Credits	4	**ESE**	50 Marks	Oral	50 Marks

Course Objectives:

- Students will be able to gain fundamental and advanced knowledge in the field of Additive Manufacturing and its industrial applications associated with Manufacturing, Aerospace, Architecture, Biomedical, and Creative designing.
- Students will be skilled to analyze for adopting AM to make a product, or a part of the product, in comparison to the traditional method.
- Students will be able to critically analyze the requirement and produce an efficient part using optimized design, material and AM method.

Syllabus:

Unit	Contents	Lecture
01.	**Introduction to Additive Manufacturing (AM)** Introduction to AM, AM evolution, Distinction between AM and CNC machining, Advantages of AM, AM process chain; Conceptualization, CAD, conversion to STL, Transfer to AM, STL, AMF, AMF file formats, STL file manipulation, Machine setup, build, removal and clean up. Integration of Reverse Engineering and Rapid Prototyping. **Self-Study:** AMF, 3DF file formats	**08 L**
02.	**Classification of AM processes** VAT Photo-polymerisation (liquid photopolymer resin based); Material Jetting (Ink Jet, continuous or Drop on Demand) approach; Binder Jetting (Polymer or metal powder and liquid binder based); Material Extrusion (FDM, Metal, Ceramic extrusion based); Powder Bed Fusion (Metal, Polymer and Ceramic based DMLS, EBM, SLS, SLM); Sheet Lamination (Ultrasonic AM, laminated object manufacturing (LOM), Solid State AM); Directed Energy Deposition: DED (Laser engineered net shaping, directed light fabrication, direct metal deposition, 3D laser cladding) Special Types: WAAM, Jelly based, paper and Pulp **Self-Study:** Application of AM in Bio Medical field	**10 L**
03.	**Post processing of AM parts** Support material removal, strength improvement, stress relieving processes (Annealing, Normalising, HISP Furnace), surface texture improvement, accuracy improvement, aesthetic improvement, preparation for use as a pattern, property enhancements using non-thermal and thermal techniques. Measurement of parts manufactured through AM process, Surface roughness measurement. **Self-Study:** Comparison and analysis between various Post processing methods.	**06 L**

Unit	Contents	Lecture
04.	**Design for AM** Motivation, Design for manufacturing and Assembly concepts and objectives, AM unique capabilities, exploring design freedoms, Design tools for AM, Part Orientation, Removal of Supports, hollowing out parts, Inclusion of Undercuts and Other Manufacturing Constraining Features, Interlocking Features, Reduction of Part Count in an Assembly, Identification of markings/ numbers etc. Materials used in AM, Testing and standards for materials, Functionally Graded Materials (FGM). **Self-Study:** DFAM with Generative Design	**08 L**
05.	**Design and selection of machine components** Selection of components in assembly and construction of AM Machine - Axes, Linear motion guide ways, Ball screws, Motors, Bearings, Encoders/ Glass scales, Process Chamber, Safety interlocks, Sensors, Energy delivery, Material delivery, Nozzle and Heating Systems **Self-Study:** Standards in AM	**06 L**
06.	**AM Applications: Rapid Tooling** Convectional Tooling Vs. Rapid Tooling, Classification of Rapid Tooling, Direct and Indirect Tooling methods, Soft and Hard Tooling methods. Functional models, Pattern for investment and vacuum casting, medical models, art models, Engineering analysis models, new materials development, Bi-metallic parts, Re-manufacturing, maintenance and Hybrid AM. Application examples for Aerospace, defense, automobile, Bio-medical and general engineering industries, Construction using AM. **Self-Study:** Part Customization using AM	**04L**

Theory Course outcomes:

The student will show their ability at a professional level to:

1. Learn the technological shift from conventional manufacturing techniques to additive manufacturing technology and understand the process chain of AM
2. Understand the process of classification of AM and their working principles.
3. Assess the quality of 3D printed parts based on surface finish and geometrical properties by application of post processing techniques.
4. Design the parts for AM by applying process knowledge and computational design tools and application requirements.
5. Explore the assembly and basic construction of Open ware 3D printers.
6. Identify how, when and where AM can create the impact over wide range of applications.

Laboratory Course Objective:

1. Students will be able to gain fundamental knowledge by assembling 3D printer to print quality components.
2. Students will be able to utilize different 3D printing machines to compare the quality aspects with process parameters for different 3D printed components.
3. Students will be skilled in reverse engineering concepts by scanning and handling the point cloud data.

Laboratory Syllabus:

Sr. No.	Contents	Hours
01.	3D Printing Software : Introduction of 3D Printing Software, process parameters for Additive Manufacturing Technology (CURA, GRABCAD Print)	2
02.	Demonstration of STL editing and rectification software	2
03.	Demonstration and hands on experience on various additive manufacturing machines with suitable post processing techniques.	8
04.	Assembly of AM Machines – Assembly and Construction of FDM Technology 3D Printing Machine.	6
05.	3D Scanners- Introduction to Reverse Engineering and 3D Scanning, Types of 3D scanners - working principles, Setup and use of 3D scanners, 3D point cloud data collection and processing with the help of associated software Programme like Artec, David, etc., Application oriented case study.	8

Laboratory Course outcomes:

The student will show their ability at a professional level to:

- Understand the basic construction of additive manufacturing machines, different systems like Energy delivery, Material delivery, Nozzle and Heating Systems, suitable post processing techniques and its comparison by demonstrating on various 3D Printing and post processing machines.
- Learn the use of 3D printing software and Analyze the effect of various process parameters to evaluate the quality of 3d printed components.
- Develop the FDM based 3D printer by performing its assembly.
- Understand the working principles of 3D scanners and its applications in the field of Additive Manufacturing.

Suggested learning resources:

Textbooks:

1. Chua Chee Kai, Leong Kah Fai, "Rapid Prototyping: Principles and Applications", World scientific, 2003.
2. Ian Gibson, David W Rosen, Brent Stucker., "Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing", Springer, 2010
3. Ali K. Kamrani, Emand Abouel Nasr, "Rapid Prototyping: Theory and Practice", Springer, 2006.

Reference Books:

1. Paul C. Bave: CAD Principles and Applications
2. Understanding of Additive Manufacturing, Andreas Gebhardt, Hnaser Publishers, 2011.
3. D.T. Pham, S.S. Dimov, Rapid Manufacturing: The Technologies and Applications of Rapid Prototyping and Rapid Tooling, Springer 2001
4. Pulak Mohan Pandey, Nishant Kumar Singh, Yashvir Singh Additive Manufacturing: Advanced Materials and Design Techniques, CRC Press 2024.

Open Elective-III

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Course: OPERATIONS RESEARCH (Open Elective-III)

Course Code		**Scheme of Evaluation**	**MSE, TA & ESE**
Teaching Plan	2-0-0-0 = 2	MSE- 30	TA- 20
Credits	2	ESE -50	

Course Objectives:

- To understand the methodology of OR problem solving and formulate linear programming problem.
- To develop formulation skills in transportation models and finding solutions
- To understand the basics in the field of game theory and assignment problems
- To know the basics of dynamic programming and simulation.
- To know how project management techniques help in planning and scheduling a project

Syllabus:

Unit	**Contents**	**Lecture**
01.	**Introduction:** Operations Research: Development, history, definitions, objectives, characteristics, limitations, phases, and applications. Optimization models and their classifications. **Linear Programming:** Formulation of LP problem, Simplex method (minimization / maximization cases). Degeneracy in LP, Duality in LP, Sensitivity analysis.	6 L
02.	**Transportation:** Introduction, methods for finding initial basic solution. Test of optimality Maximization Transportation problem. Degeneracy. **Assignment Problem:** Introduction. Solution methods. Variations of the assignment problem. Traveling Salesman Problem.	6 L
03.	**Sequencing Models:** Scheduling and sequencing. Assumptions in sequencing models. Processing "n" jobs on "m" machines. Graphical Method. **Inventory Control System (Quantitative Approach):** Introduction. Meaning of Inventory Control. Functional classifications of Inventories. Advantages of Inventory Control. Deterministic Inventory Models: economic lot size with instantaneous replenishment with and without shortage costs, economic lot size models with quantity discount.	7 L
04.	**Queuing Theory:** Queuing Systems: Introduction, cost associated with, Classification of queuing models. Kendall's notations. Models: {(M/M/1): (α / FSFS)}. Single server models. **Simulation:** Introduction to discrete event Simulation. Monte -Carlo Simulation. Problems related to Monte-Carlo Simulation. **Theory of Games:** Introduction, two–person zero-sum game. Minimax and Maximin principle. Saddle point. Methods for solving game problems with mixed strategies. Introduction to graphical and iterative methods for solving game problems.	7 L
05.	**Network Models:** Introduction to PERT / CPM. Concepts and construction of network diagrams. Critical path and project duration, floats, network crashing, optimum project duration and cost, PERT activity, time estimate, probability of completion of a project on before specified time, resource allocation and load smoothening, minimal Spanning tree, shortest route and maximal Flow problems.	7 L

Course outcomes:

1. Recognize the importance and value of Operations Research and linear programming in solving practical problems in industry.
2. Interpret the transportation models' solutions and infer solutions to the real-world problems.
3. recognize and solve game theory and assignment problems.
4. Know when simulation and dynamic programming can be applied in real world problems.
5. Gain knowledge of drawing project networks for quantitative analysis of projects.

Suggested learning resources:

Textbooks:

1. Gupta P. K. and Hira D. S.: Operations Research, S Chand & Company Ltd, Reprint 2022
2. Sharma S. D., Kedar Nath: Operations Research, Ram Nath& Co. Reprint 2024

Reference Book:

1. Schwartz M.M. "Metals Joining Manual". McGraw Hill Books, 1979.
2. Tylecote R.F. "The Solid Phase Welding of Metals". Edward Arnold Publishers Ltd. London, 1968.
3. Sharma J. K.: Mathematical Models in Operations Research, Tata McGraw – Hill Publishing Company Limited.
4. Taha H. A.: Operations Research - An Introduction, Prentice Hall of India Pvt. Ltd.
5. Wagner H. N.: Principles of Operations Research with applications to Managerial Decisions, Prentice Hall of India Pvt. Ltd.
6. R. Panneerselvam: Operations Research, Prentice Hall of India Pvt. Ltd.
7. Wiest J. D. & Levy F. K.: Managerial Guide to PERT/CPM, Prentice Hall of India Pvt. Ltd.

NPTEL – Swayam

- https://onlinecourses.nptel.ac.in/noc25_mg34/course

Open Elective-III

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Course: RELIABILITY ENGINEERING (Open Elective-III)

Course Code		**Scheme of Evaluation**	CE & ESE
Teaching Plan	2-0-0-0 = 2	**MSE** +TA	30 +20
Credits	2	**ESE**	50

Corse Objectives:

- To understand basic concepts of Reliability
- To categorize the configuration and analyze the of system reliability.
- To identify failure modes and critical analysis through FMECA
- To apply reliability testing methods for life assessment

Syllabus:

Unit	Contents	Lecture
01.	**Fundamental concepts of Reliability** Reliability definitions, failure, failure density, failure Rate, hazard rate, Mean Time to Failure (MTTF), Mean Time Between Failure (MTBF), pdf, cdf, safety and reliability, life characteristic phases, modes of failure, areas of reliability, quality and reliability assurance rules, importance of reliability	**08 L**
02.	**System Reliability & Allocation Techniques** Series, parallel, mixed configuration, k- out of n structure, analysis of complex systems, conditional probability method, cut set and tie set method, Redundancy & Types, Reliability allocation or apportionment, reliability apportionment techniques - equal apportionment, AGREE, ARINC, reliability predictions from predicted unreliability, minimum effort method	**08 L**
03.	**Failure Analysis** Failure mode, effects analysis (FMEA), Failure mode, effects and criticality analysis (FMECA)-Case Studies, RPN, Basic symbols, Ishikawa diagram for failure representation, Fault Tree construction and analysis - case studies, minimal cut & tie set methods	**06 L**
04.	**Reliability Testing** Introduction to reliability testing, Stress strength interaction, Testing for Reliability and Durability- Accelerated Life Testing and Highly Accelerated Life Testing (HALT)	**06 L**

Course outcomes:

CO1. Understand basic concepts of reliability
CO2. Analyse reliability of system and apply allocation methods.
CO3. Identify various failures and failure modes and to create a FMEA & fault tree diagram.
CO4. Evaluate system reliability through reliability tests

Books:

1. L. S. Srinath, Reliability Engineering, EWP , 4th Edition 2016
2. E. Balgurusamy, Reliability Engineering, McGraw Hill Education 2002
3. S. S. Rao, Reliability Based Design, Mc Graw Hill Inc. 1992

4. E. E. Lewis, Introduction to Reliability Engineering, John Wiley and Sons.2022
5. Alessandro Birolini, Reliability Engineering Theory and Practice, Springer,2017
6. B. S. Dhillon, Maintainability, Maintenance and Reliability for Engineers, CRC press 2020.
7. K. C. Kapoor and L. R. Lubersome, Reliability in Engineering Design Willey Publication, 2014
8. Basu S.K, Bhaduri , Terotechnology and Reliability Engineering, Asian Books Publication.2003

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Course: MDM : SALES & DISTRIBUTION

Course Code	**PCC**	**Scheme of Evaluation**	Oral & Term Work
Teaching Plan			
Credits	4		

Course Objectives:

A Sales & Distribution syllabus aims to equip students with

- The Knowledge and Skills to manage & document Sales effectively,
- Encompassing areas like Quotations, Customer Orders, Deliveries & Invoices
- Interfaces between Sales, Production, Materials Management and Finance.
- Leading to careers in areas like Sales & Marketing
- Sales reporting & Customer Management

Syllabus:

Unit	Contents	Hrs
01	**Introduction to Sales & Distribution:** Definition of Sales, Marketing, Sales transactions, Flow of Processes in Sales & Distribution. Sales Activities, Customer Inquiries, Quotations, Order Acknowledgement. Importance of Master Data: Customer Master, Material Master, Pricing Master Data, Sales Orders, Deliveries, Billing, Account Document **Self Study:** Enterprise Structure and Sales Processes	9L
02	**Different Sales Order Types:** Standard Order, Rejection and Return process, Third Party Sales Orders, Consignment Stock, Availability of Stocks and Available to Promise, Discount, Rebate, Scheduling Agreement, **Self-Study:** Order Types and Integration with MRP, Production Planning and Finance	9L
03	**Pricing:** Pricing Procedures, Dependencies of Pricing, Pricing Master Data **Self Study:** Pricing Strategies	4L
04	**Delivery Types and Transportation:** Standard Delivery, Return Delivery, Delivery without ref, Intra and Inter Company Stock Transfer, Dangerous Goods and handling, Managing Delivery Notes to Customers, Transportation **Self-Study:**	9L
05	**Billing Types,** Standard Billing Document Type, Credit Memo, Debit Memo, Proforma Invoice, Inter Company Billing **Self-Study: Invoicing and Billing Types**	9L
06	**Special Processes in Sales:** Handling Make to Order, Make to Stock, Consignment Stock, JIT, Rebate Agreements, Stock Transport Self study: Assignments on Case Study provided	8L
07	**Basic Features of module in ERP systems**: Terms used in SD module, SD Organizational Structure, Material master data, SD Customer master data, SD Processes: Order to Cash, Generation of reports and its analysis **Self Study:** Integration of Sales with Finance, Materials Management and Production Planning.	8L
	Total	**56L**

Course outcomes:

Student will show their ability at a professional level to:

1. **Understanding Principles:** Students will grasp the fundamental principles of Sales management, including its scope, importance, and functions in both manufacturing and service sectors.
2. **Sales & Distribution:** They will learn about the Sales cycle, Deliveries, Billing Types and Documentation
3. **Interface: Sales Processes interface with Finance, Materials Management and Production Planning, Impact of Sales and collection of Customer outstandings on other areas,**
4. **Reports: Analysis of Reporting and continuous Improvement.**
5. **ERP Systems:** They'll learn how to implement and utilize Enterprise Resource Planning (ERP) systems for Sales and Distribution.

Suggested learning resources:
Textbooks:

1. Sales & Distribution Management (Latest Edition), Panda Tapan K., Sahadev Sunil, Oxford University Press
2. Sales & Distribution Management – Text & Cases (2nd Edition), Krishna K. Havaldar, Vasant M. Cavale, Tata McGraw-Hill

Reference Books:

1. Sales Management: Decisions, Strategies & Cases, Richard R. Still, Edward W. Cundiff, Norman A.P. Govoni, Pearson Education, Latest Edition
2. Sales Management: Concepts Practice, and Cases, Johnson F.M., Kurtz D.L., Scheuing E.E., Tata McGraw- Hill, Latest Edition
3. Selling & Sales Management, David Jobber, Geoffrey Lancaster, Pearson Education, Latest Edition
4. Sales Management, Tanner, Honeycutt, Erffmeyer, Pearson Education, Latest Edition
5. Sales Force Management, Mark W. Johnston, Greg W. Marshall, Tata McGraw-Hill, Latest Edition

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PROJECT-I (Semester-V)

Sr No	Items	Description of activity
1	**Scope** **(TRL-2)**	Research Problem Identification, Literature, objective, methodology and Architecture / Plan of work
2	**Student project group**	Four students maximum per project. The student group remained the same till the completion of the three stages of the project. No change in topic / group / guide is allowed in subsequent stages of projects. In case of eventuality, alternate guide may be allotted.
3	**Problem statement identification**	It is mandatory for faculty members to float projects with carefully selected problem statements well in advance. The project should be floated and allotted within a week after the 5th semester registration process is over. Since the project will run for one and half years, it is required by the department to float topics for the choice of students. The project topic should be in line with National Mission / Atmanirbharbharat / Industry requirements/ Funding body requirements / socially relevant project / Sustainable Development Goals (SDGs)
4	**Project topic selection**	The student group shall choose a project topic amongst the available topics given by the department based on the previous semester CGPA.
5	**Self-Study material for the student**	The department should recommend relevant online / offline self-study materials on IPR, technical paper writing, plagiarism, safety, NDA, Regulatory standards, for example- BIS, etc.
6	**End Semester Evaluation process**	The end semester evaluation shall be based on project power point presentation and well-structured project report. The evaluation shall be done by the panel of at least three members including one of them is project guide.

Evaluation sheet for Project-I

MIS No	Name of student	Research problem identification	Literature	Objective	Project Report	Viva Voce and presentation skill	Out of 50 marks
		10 M	**10 M**	**10 M**	**10M**	**10M**	

Semester VI

Sr. No.	Course Type	Course Code	Course Name	L	T	P	S	Cr	Evaluation Scheme (Weightages in %)				
									Theory			Laboratory	
									MSE	TA	ESE	ISE	ESE
1	PCC		Advances in CAD/CAM/CIM	2	1	2	1	4	30	20	50	50	50
2	PCC		Operations Research	3	0	0	1	3	30	20	50	--	--
3	PCC		Manufacturing Automation	3	0	2	1	4	30	20	50	50	50
4	PEC		Department Elective -II	3	0	2		4	30	20	50	50	50
5	MDM		Multidisciplinary Minor	3	1	0	1	4	30	20	50	--	--
6	VSEC		Smart Mfg. and Simulation Laboratory	0	0	2	1	1				CIE-100	
7			Project stage-II	0	0	2	1	2				CIE-100	
8	ELC		Internship-III	0	0	6		1				CIE-100	
Total Academic Engagement and Credits				14	2	10	6	23					

Semester VI

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ADVANCES IN CAD/CAM/CIM

Course Code		**Scheme of Evaluation**	Continuous Evaluation (CE) & ESE (End Semester Exam)	Scheme of Evaluation for Lab	CE & ESE
Teaching Plan	2-1-2-1	**MSE+ TA**	30 + 20 Marks	Term work	50 Marks
Credits	4	**ESE**	50 Marks	Oral	50 Marks

Course Objectives:

Advances in CAD/CAM/CIM Course aspires to provide students with the ability of

- Understanding the basic fundamentals of computer aided design and to learn 2D & 3D transformations of the basic geometrical entities along with their representation using parametric and solid representation techniques.
- Obtaining an understanding of the fundamental theory of the FEA method and demonstrate the ability to evaluate and interpret FEA analysis results for design and evaluation purposes
- Learning the concepts of computer aided manufacturing, classification of NC machines based and use of G and M codes to develop part programmes.
- Providing exposure of various concepts of CIM, Computer Aided Inspection, CAPP & ERP.
- understanding concepts of Group Technology & its utilization leads to formation of machines cell

Syllabus:

Unit	**Contents**	**Hrs**
01	**Introduction to CAD-CAM** Introduction: Trends in Modern Manufacturing, Product Cycle and CAD/CAM, Functional relationship, Elements of CAD Hardware. Computer Graphics: Transformation- Introduction, Formulation, Translation, Rotation, Scaling, Reflection, Homogenous Representation, Concatenated Transformation, Inverse Transformations. **Self Study:** Elements of CAD Hardware	4L
02	**Solid Modelling Representation Techniques:** Solids:- Introduction, Geometry & Topology, Solid Representation, Boundary Representation, Constructive Solid Geometry, Sweeps, Solid Manipulations, Feature Based Modelling, Cloud Based Solid Modelling Techniques **Self Study:** Types of Primitive solid geometries and its developments in solid modelling	5L
03	**Surface Modelling Techniques:** **Curves:-** Introduction, Analytic Curves, Parametric representation, Line, Circle, Parabolas, Hyperbolas, Ellipses, Conics. Geometric continuity (C0, C1, C2) and Visual continuity (G0, G1, G2), Synthetic Curves, Hermite Cubic Spline, Bezier Curve, B-Spline Curve and NURB **Surface:** - Introduction, Surface Representation, Analytic Surface, Synthetic Surfaces, Hermite bicubic Surface, Bezier surfaces, B-spline Surfaces, Coons Surface, Reverse Engineering, Computer aided inspection and quality control **Self Study:** Types of Curves and surfaces, it's applications in Surface Modeling	5L
04	**Finite Element Analysis**	5L

Introduction to FEA, Advantages & Disadvantages of FEA & its applications, what is FEA, Functional Approximation method, Finite Difference Method, Steps involved in FEA, Stiffness matrix & its properties, Derivation of Stiffness matrix, Types of Elements.

Self Study: Advantages & Disadvantages of FEA & its applications

05 NC Programming

Machine Tool Co-ordinate System, Machine zero, Job zero, Cutter Programming, Tool Offsets, Programming Steps, NC Programming Languages, G-codes and M-codes. Turning Center programming, Machining Center programming, Advance features of Controller. 4L

Self Study: Machine zero-Job zero

06 Computer Integrated Manufacturing (CIM)

Computer application in manufacturing, Computer integrated production management system, inventory material requirement planning, manufacturing resource planning, enterprise resource planning. Computer aided process planning (CAPP): Retrieval CAPP, generative CAPP and computer assisted shop floor control. 4L

Introduction to PLM

Self Study: enterprise resource planning application in manufacturing

07 Group Technology

Part Families, Part classification and coding, production flow analysis, Rank Order Clustering Algorithm, machine cell design and Cellular manufacturing 3L

Self Study: Applications of Group Technology

Total 30L

Sr. No.	List of Tutorials	Hrs
01	Tutorial 1- Numerical on Transformation Matrices	2 L
02	Tutorial - Numerical on Solid representation Schemes	2 L
03	Tutorial - Numerical on curve Representation techniques	2 L
04	Tutorial - Numerical on Finite Element Analysis	2 L
05	Tutorial - Numerical on G-M Code programming	2 L
05	Tutorial - Numerical on Group technology and Rank order Method	1 L
06	Tutorial - Numerical on MRP	1 L
	Total	**12 L**

Sr. No.	List of Assignments	Hrs
01	Introduction to CAD Software - Part Design	2 L
02	Introduction to CAD Software - Assembly Design	2 L
03	Introduction to CAD Software - Drafting	2 L
04	Introduction to CAE - Finite Element Analysis and ANSYS Software	2 L
05	FEA Assignment: Simply Supported Beam, Cantilever Beam	2 L
06	FEA Assignment: Chair Problem	2 L
07	FEA Assignment: Workbench Overview	2 L
08	CAM Assignment : Turning Programming	2 L
09	CAM Assignment : Milling Programming	2 L
	Total	**18 L**

Course outcomes:

The student will show their ability at a professional level to:

1. **Solve** the problems based on transformations of geometrical entities and develop its representation in a CAD system to validate the results.
2. **Represent** the mathematical expression of geometrical entities to Evaluate and Validate developed curves, surfaces, and solids.
3. Learn the concept of FEA and its implementation to **Evaluate** and analyse FEA results for component design.
4. Explain and **Classify** NC machines and its working principles to **Develop** NC programs using manual part programming techniques.
5. Discuss the various concepts of CIM such as production planning and control, process planning, MRP, and ERP to **Solve** the problems based on MRP during its implementation in large scale manufacturing.
6. Explain the Group technology to **Apply** the concepts of production flow analysis and rank order clustering to **Formulate** machine cells

Suggested learning resources:

Textbooks:

1. Mikel P. Groover and Emory W. Zimmers: Computer Aided Design and Manufacturing, Prentice Hall.
2. T. Kundra, Rao P.M., Tiwari N.K. : Numerical Control and Computer Aided Manufacturing, Tata McGraw Hill

Reference Books:

1. Nanua Singh: Systems Approach to Computer-Integrated Design and Manufacturing, John Wiley and Sons, Inc.
2. P. Radhakrishnan and Subramaniam: CAD / CAM / CIM, Wiley Eastern Ltd.
3. Venuvinod, PK., MA. W., Rapid Prortotyping – Laser Based and Other Technologies, Kluwer, 2004. Paul C. Bave: CAD Principles and Applications
4. Mikell P. Groover: Automation, Production systems & Computer Integrated Manufacturing, Prentice Hall.
5. Ibrahim Zeid: Mastering in CAD-CAM, Tata McGraw Hill Publication.

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Course: OPERATIONS RESEARCH (OR)

Course Code		**Scheme of Evaluation**	**MSE, TA & ESE**
Teaching Plan	3-0-0-1 = 3	MSE- 30	TA- 20
Credits	3	ESE -50	

Course Objectives:

- To understand the methodology of OR problem solving and formulate linear programming problem.
- To develop formulation skills in transportation models and finding solutions
- To understand the basics in the field of game theory and assignment problems
- To know the basics of dynamic programming and simulation.
- To know how project management techniques help in planning and scheduling a project

Syllabus:

Unit	**Contents**	**Lecture**
01.	**Introduction:** Operations Research: Development, history, definitions, objectives, characteristics, limitations, phases, and applications. Optimization models and their classifications. **Linear Programming:** Formulation of LP problem, Simplex method (minimization / maximization cases). Degeneracy in LP, Duality in LP, Sensitivity analysis. Self Study: Numerical on Big M/Two-phase method.	6 L
02.	**Transportation:** Introduction, methods for finding initial basic solution. Test of optimality Maximization Transportation problem. Degeneracy, Tran-shipment problem. **Assignment Problem:** Introduction. Solution methods. Variations of the assignment problem. Traveling Salesman Problem. Self Study: Numerical on Transhipment problems.	6 L
03.	**Sequencing Models:** Scheduling and sequencing. Assumptions in sequencing models. Processing "n" jobs on "m" machines. Graphical Method. **Scheduling:** Multiple jobs single machine sequencing methods- FCFS, EDD, LFT, etc. **Inventory Control System (Quantitative Approach):** Introduction. Meaning of Inventory Control. Functional classifications of Inventories. Advantages of Inventory Control. Deterministic Inventory Models: economic lot size with instantaneous replenishment with and without shortage costs, economic lot size models with quantity discount. Self Study: Price Break Curve	7 L
04.	**Queuing Theory:** Queuing Systems: Introduction, cost associated with, Classification of queuing models. Kendall's notations. Models: {(M/M/1): (α / FSFS)}. Single server models. **Simulation:** Introduction to discrete event Simulation. Monte -Carlo Simulation. Problems related to Monte-Carlo Simulation. **Dynamic Programming:** Distinguishing characteristics of D.P. Deterministic DP problems. Self Study: Numerical on Dynamic Programming	7 L
05.	**Replacement Models:** Replacement of capital equipment that deteriorates with time, Replacement of items that fail without deteriorating.	7 L

Theory of Games: Introduction, two–person zero-sum game. Minimax and Maximin principle. Saddle point. Methods for solving game problems with mixed strategies. Introduction to graphical, and iterative methods for solving game problems.
Self Study: Numerical on Game theory using LPP

06. **Network Models:** Introduction to PERT / CPM. Concepts and construction of network diagrams. Critical path and project duration, floats, network crashing, optimum project duration and cost, PERT activity, time estimate, probability of completion of a project on before specified time, resource allocation and load smoothening, minimal Spanning tree, shortest route and maximal Flow problems. 7 L
Self Study: Numerical on Minimum Spanning Tree

Course outcomes:

1. Recognize the importance and value of Operations Research and linear programming in solving practical problems in industry.
2. Interpret the transportation models' solutions and infer solutions to the real-world problems.
3. recognize and solve game theory and assignment problems.
4. Know when simulation and dynamic programming can be applied in real world problems.
5. Gain knowledge of drawing project networks for quantitative analysis of projects.

Suggested learning resources:

Textbooks:

1. Gupta P. K. and Hira D. S.: Operations Research, S Chand & Company Ltd., Reprint 2022
2. Sharma S. D., Kedar Nath: Operations Research, Ram Nath& Co., Reprint 2024.

Reference Book:

1. Schwartz M.M. “Metals Joining Manual”. McGraw Hill Books, 1979.
2. Tylecote R.F. “The Solid Phase Welding of Metals”. Edward Arnold Publishers Ltd. London, 1968.
3. Sharma J. K.: Mathematical Models in Operations Research, Tata McGraw – Hill Publishing Company Limited.
4. Taha H. A.: Operations Research - An Introduction, Prentice Hall of India Pvt. Ltd.
5. Wagner H. N.: Principles of Operations Research with applications to Managerial Decisions, Prentice Hall of India Pvt. Ltd.
6. R. Panneerselvam: Operations Research, Prentice Hall of India Pvt. Ltd.
7. Wiest J. D. & Levy F. K.: Managerial Guide to PERT/CPM, Prentice Hall of India Pvt. Ltd.

NPTEL – Swayam

- https://onlinecourses.nptel.ac.in/noc25_mg34/course

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Course: MANUFACTURING AUTOMATION(MA)

Course Code		**Scheme of Evaluation**	Theory :	Practical :
Teaching Plan	3-0-2-1	MSE+TA	30+20	50
Credits	04	ESE	50	50

Course Objectives:

- To introduce students to the fundamentals of manufacturing systems and automation
- To provide an understanding of different automation technologies used in modern manufacturing.
- To explore the applications of sensors, actuators, and control systems in industrial automation.
- To develop problem-solving skills for implementing automation solutions in real-world manufacturing environments.
- To explore industrial control systems and hardware components used in automation.

Syllabus:

Unit	**Contents**	**Lecture**
01.	**Introduction to Manufacturing Systems and Manufacturing Automation** :Overview of Manufacturing Systems and Their Evolution, Types of Manufacturing Systems: Job Shop, Batch, Mass, and Continuous Production, Fundamentals of Manufacturing Automation, Types of Automation: Fixed, Programmable, and Flexible, Automation Strategies in Manufacturing, Benefits and Limitations of Automation in Manufacturing, Industry 4.0 and Smart Manufacturing, Role of Artificial Intelligence and Industry 4.0 in Automation. **Self-Learning Topics:** Historical Evolution of Automation in Manufacturing, Case Studies on Automated vs. Traditional Manufacturing, Historical Development of Automation Technologies, Case Studies on Automation in Different Industries	07 L
02.	**Automated Material Handling and Storage Systems:** Functions and Types of Automated Material Handling Systems (AMHS), Automated Guided Vehicles (AGVs) and Autonomous Mobile Robots (AMRs), Automated Storage and Retrieval Systems (AS/RS), Conveyor Systems and Robotics in Material Handling **Self-Learning Topics:** Recent Advances in AGVs and AMRs, Case Studies on Smart Warehousing	07 L
03.	**Sensors, Actuators, and Control Systems in Automation:**, • Types of Sensors: Proximity, Vision, Force, and Temperature Sensors, Actuators: Hydraulic, Pneumatic, and Electric Drives, Programmable Logic Controllers (PLCs): Architecture and Programming, Supervisory Control and Data Acquisition (SCADA) Systems **Self-Learning Topics:** Smart Sensors and IoT in Manufacturing, Case Studies on Automated Quality Control	07 L

04.	**Single Station Manufacturing Cells: •** Fundamentals of Single Station Manufacturing Cells, Machine Cell and Machine Cluster, Manual, Automated, and Semi-Automated Workstations, Machine Tool Automation and CNC Systems, Process Optimization in Single Station Cells **Self-Learning Topics:** Advances in CNC and Adaptive Control Systems, Case Studies on Automated Machining Cells	07 L
05.	**Manual Assembly Lines – Single Model:** Introduction to Manual Assembly Lines and Their Importance, Line Balancing Problems and Methods (Largest Candidate Rule, Kilbridge & Wester Method, Rank Positional Weight Method), Single Model, Poka-Yoke: Motion step Method. **Self-Learning Topics:** Lean Manufacturing and its Impact on Assembly Line, Case Studies on Assembly Line Improvements	07 L
06.	**Automated Production Lines and Assembly Systems: •** Structure and Working of Automated Production Lines, Transfer Mechanisms: Linear and Rotary Transfer Lines, Control Strategies in Automated Production Systems, Buffering and Accumulation in Production Lines, Types of Automated Assembly Systems, Part Feeding and Orientation Techniques, Design for Automated Assembly (DFA) Principles, Performance Analysis and Economic Justification of Automated Assembly. **Self-Learning Topics:** Case Studies on Successful Implementation of Automated Production Lines, Simulation and Optimization of Automated Production, Advances in Automated Micro-Assembly Systems, Case Studies on DFA and Assembly Line Automation	07 L

List of Experiments: (Any seven)

The term work shall consist of record of any eight assignments on following topics:

1. Study & Design of basic hydraulic and pneumatic circuits: such as Standard ON-OFF and Pneumatic Latch.
2. Study & Design of Pneumatic or Hydraulic circuit for Two Push Button Control and Clamping of Work piece.
3. Study & Design of Pneumatic or Hydraulic circuit for material handling.
4. Study & experiments in Programmable Logic Controllers (PLC).
5. Study of Displacement, Level, Pressure controls.
6. Measurements & Design of circuit for Speed & Temperature measurements.
7. Study & Design of Simple Hydraulic or Pneumatic and Electro-Hydraulic or Electro Pneumatic Automatic Control Circuit Problem.
8. Study & Design of Electro-hydraulic or Electro-pneumatic Control Circuit Problem.
9. Study of Maintenance and Troubleshooting of Fluid Power Systems.
10. Study/Demonstration of Electric actuators equivalent to hydraulic and pneumatic actuators.

Course outcomes:

After successful completion of this course, students will be able to:

1. Understand the principles of manufacturing automation and its significance in industry.
2. Analyze different types of manufacturing systems and automation strategies.
3. Analyze different types of automated material handling and storage systems.

4. Evaluate the role of sensors, actuators, and control systems in automation.
5. Analyze the design and operation of single station manufacturing cells.
6. Apply assembly line balancing techniques to optimize manual assembly lines.
7. Evaluate the functioning of automated production lines and their control strategies.

Suggested learning resources:

Textbooks:

1. Mikell P. Groover, Automation, Production Systems, and Computer Integrated Manufacturing, Addison Wesley; 5th edition,2020, Prentice-Hall of India Private Limited.
2. W. Bolton, Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering,6th Edition 2022 Pearson Education Limited.
3. Frank Lamb, Industrial Automation: Hands On, Tata McGraw Hill.

Reference Book:

1. Geoffrey Boothroyd, "Assembly Automation and Product Design", CRC, Taylor & Francis Publishers.
2. N. P. Mahalik, Mechatronics: Principles, Concepts and Applications, Tata McGraw Hill.
3. S. R. Majumdar, Oil Hydraulic Systems: Principles and Maintenance, Tata McGraw Hill.
4. HMT Ltd. Mechatronics, Tata McGraw-Hill.
5. Joji P. Pneumatic Controls, Wiley India.

NPTEL Course:

"Manufacturing Automation" by Prof. Sonak Choudhary.
"Automation in Manufacturing", by Prof. Shrikrishna Joshi
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Programme Elective Courses (PEC-2) - SEMESTER-VI

Sr. No.	Course Type	Course Name	Teaching Scheme					Credits
			L	T	P	S	Hrs	
1	PEC 2	Design For Manufacturing and Assembly	3	0	2		5	4
2	PEC 2	Micro & Nano manufacturing	3	0	2		5	4
3	PEC 2	Advanced Joining Techniques	3	0	2		5	4
4	PEC 2	AI for Manufacturing	3	0	2		5	4
5	PEC 2	Fundamentals of Quantitative Techniques in Project Management	3	0	2		5	4

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Course: DESIGN FOR MANUFACTURING AND ASSEMBLY

Course Code	PEC 1	**Scheme of Evaluation**	MSE, TA & ESE
Teaching Plan	3 hrs /week	**MSE**	30
Credits	4	**ESE**	50
Practical Plan	2 hrs/ week	**TA**	20

Course Objectives:

- To Learn need of design for manufacturability.
- To Understand the influence of manufacturing processes on product design .
- To explore environmental aspects on design and manufacturing.
- To evaluate impact of assembly parameters on design and manufacturability.

Unit No.	Details	Lecture
1	**Introduction:** General design principles for manufacturability: strength and mechanical factors, mechanisms selection, evaluation method, Process capability: Feature tolerances, Geometric tolerances, Assembly limits, Datum features, and Tolerance stacks.	6 L
2	**Factors Influencing form Design:** Working principle, Material, Manufacture, Design- Possible solutions, Materials choice, Influence of materials on form design, form design of Welded members, forgings and castings.	6 L
3	**Component Design-I:** Machining Consideration: Design features to facilitate machining: drills, milling cutters, keyways, Doweling procedures, counter sunk screws, Reduction of machined area, simplification by separation, simplification by amalgamation, Design for machinability, Design for economy, Design for clampability, Design for accessibility, Design for assembly.	8 L
4	**Component Design-II:** Casting Consideration: Redesign of castings based on parting line considerations, Minimizing core requirements, machined holes, redesign of cast members to obviate cores. Identification of uneconomical design, Modifying the design, group technology, Computer Applications for DFMA	6 L
5	**Design for the Environment:** Introduction, Environmental objectives, Global issues, Regional and local issues, Basic DFE methods, Design guide lines, Example application, Lifecycle assessment, Basic method, Environmentally responsible product assessment, Weighted sum assessment method, Lifecycle assessment method, Techniques to reduce environmental impact, Design to minimize material usage, Design for disassembly, Design for recyclability, Design for remanufacture, Design for energy efficiency, Design to regulations and standards	8 L

6	**Design for Assembly**	6 L

Introduction to Assembly: The assembly process, Characteristics and applications, Example of common assembly, Economic significance of assembly, General taxonomies of assembly operation and systems, Assembling a product, Design for Assembly: Introduction, Design consideration, Design for Fasteners: Introduction, Design recommendation for fasteners.

Text Books & Reference Books:

1. Kevien Otto and Kristin Wood, Product Design. Pearson Publication, 2004.
2. Product design and development, by K.T. Ulrich and S.D. Eppinger, Tata McGraw Hill
3. Boothroyd, G, 1980 Design for Assembly Automation and Product Design. New York, Marcel Dekker.
4. Bralla, Design for Manufacture handbook, McGraw Hill, 1999.
5. Boothroyd, G, Heartz and Nike, Product Design for Manufacture, Marcel Dekker, 1994.
6. Dickson, John. R, and Corroda Poly, Engineering Design and Design for Manufacture and Structural Approach, Field Stone Publisher, USA, 1995.
7. Fixel, J. Design for the Environment McGraw Hill., 1996. 8. Graedel T. Allen By. B, Design for the Environment Angle Wood Cliff, Prentice Hall. Reason Pub.1996.

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Course: DESIGN FOR MANUFACTURING AND ASSEMBLY-LABORATORY

List of Practical:

1. Study and report on design principles for manufacturability
2. Study and report Influencing factors on Design.
3. Case study on Machining consideration
4. Case study on casting consideration
5. Case study on Life cycle assessment of product.
6. Case study on Assembly Aspects of Product.
7. Case study on design for environment

Course Outcomes:
At the end of the course, students will:

1. Learn how to modify or develop product design for ease of manufacture, considering advantages and limitations of various manufacturing processes.
2. Students can identify difficulties in manual and automated assembly of product and make changes in product design to minimize assembly difficulties by making the product design assembly friendly.
3. Exposed to strengths and weaknesses of various metal manufacturing processes so as to modify the product design and make necessary changes for suitable process.
4. Students can learn concept for design for environment

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Course: MICRO & NANO MANUFACTURING (MNM)

Course Code	PEC	**Scheme of Evaluation**	TA & MSE & ESE
Teaching Plan	3-0-2-0 = 4	**Theory**: TA & MSE & ESE	20 +30 + 50
Credits	4	**Lab**: MSE & ESE	50 + 50

Course Objectives:

- **Understand** the fundamental concepts, principles, and technologies associated with micro/nano manufacturing.
- **Analyze** the principles, processes, and applications of advanced micro-machining methods.
- **Evaluate** various nano-machining and finishing processes in terms of applicability, precision, and effectiveness.
- **Apply** micro-scale manufacturing techniques to design and produce miniaturized components for specific engineering applications.
- **Design and develop** micro sensors, actuators, integrating micro-manufacturing concepts to create functional microsystems for real-world applications.
- **Evaluate** biomedical applications of micro and nano manufacturing by assessing their performance, reliability, and impact on healthcare innovation.

Syllabus:

Unit	Contents	Hrs.
01.	**Fundamental of micro and nano technology** • Micro and Nanofabrication. • Concepts of Micro and Nano-Systems and Microsystems Products. • Microsystems and Microelectronics, Application of Microsystems. • Standardization and Commercialization Issues of Micro-Nano Systems.	6 hrs.
02.	**Micro Machining** • Ultra Sonic Micro Machining, Abrasive Water Jet Micro Machining. • Chemical and Electro Chemical Micro Machining, Electric Discharge Micro machining. • Electron and Laser Beam Micro Machining. • Hybrid Micro machining, Electro Chemical Discharge micro machining. • Machining of Micro gear, micro nozzle, micro pins and its applications. • Tool based micromachining (TBMM).	8 hrs.
03.	**Concepts of Micro Forming and Welding, and Micro Extrusion** • Micro and Nano structured surface development by Nano plastic forming, Roller Imprinting. • Micro bending and micro welding with LASER. • Electron beam for micro welding. • Metrology for micro machined components.	7 hrs.
04.	**Nano Machining and Finishing**	8 hrs.

- Focused Ion Beam Machining, Plasma Beam Machining, Electrochemical Nanomachining.
- Abrasive Flow Finishing, Magnetic Float polishing, Elastic Emission Machining, Chemo-Mechanical Polishing.
- Magnetic Abrasive Finishing, Magneto rheological finishing, Magneto Rheological abrasive flow finishing.

05. Micro Sensors, Micro Actuation 6 hrs.

- MEMS with Micro actuators, Micro fluidics.
- Micro/nano sensors: Classification of physical sensors, Integrated, Intelligent or Smart sensors.
- Bio sensing Principles and sensing methods, Biosensors arrays and Implantable devices, Innovative.
- Applications on Present Devices: Nano chips, Nanotubes and Nanowires, Integration of chips and microprocessors.

06. Synthesis and Characterization of Nano materials 7 hrs.

- Sol-Gel Synthesis, Inert Gas Condensation, High energy Ball Milling, Plasma Synthesis
- Synthesis of Carbon nano tubes
- **Microscopy techniques**: scanning electron microscopy, transmission electron microscopy, scanning tunneling microscopy, atomic force microscopy

Labs	**List of Experiments**	**Hrs.**
	Course Objectives	
01	Demonstration of micro turning	4 hrs.
02	Fabrication of micro holes and slots using Micro-EDM	4 hrs.
03	Fabrication of micro holes using Micro-ECM	4 hrs.
04	Laser Beam micromachining of micro features	4 hrs.
05	Hybrid micromachining	4 hrs.
06	Microscopy and vision system analysis of machined microfeatures	4 hrs.
	Total	**24 hrs.**

Course outcomes:

At the end of the course, students will be

1. **Explain** the fundamental principles and key technologies involved in micro- and nano-scale fabrication processes, microsystems, and their applications.
2. **Compare and analyze** various micro-machining methods based on process capabilities, limitations, and applications.
3. **Select and justify** suitable nano-finishing techniques based on precision requirements and material considerations.
4. **Demonstrate** an understanding of micro forming, micro welding, and micro extrusion to design, develop, and fabricate miniaturized components for industrial applications.
5. **Evaluate and discuss** integration of micro sensors and actuators, microfluidic devices, bio-sensors and demonstrate an understanding of micro-manufacturing techniques and functional requirements.
6. **Understand and apply** techniques for the synthesis and characterization of nanomaterials, utilizing microscopy methods to evaluate material properties and structures.

Suggested learning resources:

Textbooks:

1. Chang Liu (2011), Foundations of MEMS 2/e, Prentice Hall.
2. Jain V. K. (2011), Introduction to Micro Machining, Narosa Publishing House.
3. Murty B. S. (2013), Textbook of Nanoscience and Nanotechnology, Springer-Universities Press India.

Reference Books:

1. Bhattacharyya B. (2015), Electrochemical Micromachining for Nanofabrication, MEMS and Nanotechnology, William Andrew Publications (Imprint by Elsevier).
2. Bandopadhyay A. K. (2008), Nano Materials, New Age International Publishers (New Delhi).
3. Tai-Ran Hsu (2008), MEMS and Microsystems, John Wiley & Sons (New Jersey).
4. Jackson, M. J. (2007), Micro and Nano Manufacturing, Springer.
5. Bharat Bhushan (2010), Handbook of Nanotechnology, Springer.
6. Fahrner W. R. (2008), Nanotechnology and Nano Electronics, Springer International.
7. Senturia S. D. (2000), Micro-Systems Design, Springer.
8. Hanocha H. (2012), Actuators – Basics and applications 3/e, Springer.

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Course: ADVANCED JOINING TECHNOLOGY

Course Code		**Scheme of Evaluation**	Theory : CE & ESE	Practical :
Teaching Plan	3-0-1-0 = 4	MSE + TA	30 + 20	MSE : 50
Credits	04	ESE	60	ESE : 50

Corse Objectives:

- To impart knowledge of joining processes and their application
- To understand the various special/advanced welding processes
- Apply proper welding process for an industrial application
- To have practical overview of various welding process, welding standards, advanced welding process
- To gain knowledge on the principle of operation, advantages, limitations and applications of various special/advanced welding processes.

Syllabus:

Unit	Contents	Lecture
01.	**Fundamentals of Welding and Joining:** Physics of welding, Classification of welding processes, Brief review of conventional welding processes, Fundamental principles – Air Acetylene welding, Oxyacetylene welding, Carbon arc welding, Shielded Metal Arc welding (SMAW), Submerged Arc welding (SAW), TIG & MIG welding, Plasma Arc welding (PAW), Electroslag welding processes - advantages, limitations, and applications.	7 L
02.	**Resistance Welding Processes:** Principle of Resistance welding, Spot welding, Seam welding, Projection welding, Resistance Butt welding, Flash Butt welding, Percussion welding and High Frequency Resistance Welding processes - advantages, limitations and applications.	7 L
03.	**Solid State Welding Processes:** Cold Pressure welding, Diffusion Bonding, Explosive Welding, Ultrasonic Welding, Friction welding and its classification, Forge welding, Roll welding, Hot pressure welding processes - advantages, limitations and applications, Advances in adhesive bonding, Brazing and soldering, cladding.	7 L
04.	**Advanced Welding Processes:** Thermit welding, Atomic Hydrogen welding, Electron Beam welding, Laser Beam welding - principle, working and applications, Friction Stir Welding, Friction Stir Spot welding, Cold Metal Transfer - concepts, processes and applications, Under Water welding, Welding automation in aerospace, nuclear and surface transport vehicles, Automated welding, Remote welding, Robotic welding, Intelligent Systems for welding process automation. Welding of Non-metals: Plastic welding, Glass and ceramic welding, Biocompatible plastic to metal welding, Types of plastic welding	7 L

05. **Testing and Design of Weldments:** Design and quality control of welds. Edge preparation types of joints, weld symbols Design for fatigue. Destructive and non-destructive testing of weldments. Weldability Testing - tensile, bend hardness. Impact, notch and fatigue tests. Visual examination - liquid penetration test, magnetic particle examination. Radio graphs, ultrasonic testing. Life assessment of weldments. IS codes. 6 L

06. **Weld Metallurgy:** Weld thermal cycles and their effects, concept of weldability and its assessment. Heat affected Zone (HAZ) and its characteristics, Welding of dissimilar materials, pre and post welding heat treatments, welding defects, their causes and remedies. 6 L

List of Experiments: (Any eight)

Course Objectives

- Learn practical overview of welding process and learn welding standards
- Gain an insight on fundamentals of welding process
- Enhance the practical skills in welding technology
- Analyze various advanced welding processes.

1. Get acquainted with basic welding terms and welding symbols
2. Perform welding of Mild steel Plates by Gas Metal Arc Welding process. (GMAW)
3. Perform welding on of Mild steel/Stainless steel /Aluminium sheets by Gas Tungsten Arc Welding (GTAW)
4. Perform welding on Mild steel/Stainless steel sheets using Resistance Spot Welding for overlapping sheets
5. Perform welding on Aluminum sheets using Friction Stir welding and Friction Stir Spot welding (FSW/FSSW)
6. Perform welding using Mild steel/Stainless steel Laser Beam Welding (LBW)
7. Assessment of Mechanical Testing of weld specimen (Tensile test/bend test etc)
8. Assessment of welded joints using metallurgical tests (micro-structure and hardness variation).
9. Assessment of weld specimens using Non-Destructive Tests

Course outcomes:

1. Acquire knowledge of various conventional welding processes.
2. Explore the fundamentals and working of advanced Welding Processes.
3. Apply the knowledge to select the appropriate welding process based on application, customer requirement and specifications.
4. Analyze the weld metallurgy in a weld joint.
5. Evaluate a weld joint by inspection and testing of welded components
6. Suggest an appropriate measure or method to obtain a defect free weld.

Suggested learning resources:

Textbooks:

1. Parmer R.S., “Welding Engineering and Technology”, Khanna Publishers, New Delhi, 2022.
2. Little R.L., “Welding and Welding Technology”, Tata McGraw Hill Publishing Co., Ltd., New Delhi, 34th reprint, 2008.

3. Kalpakjian S., "Manufacturing Engineering and Technology" Prentice Hall Pearson Education India; 8th edition, 2023.
4. J.F.Lancaster, " The Physics of welding", Pergamon, 2nd edition, 1986
5. J.A.Goldak, " Computational Welding Mechanics", Springer, 2005

Reference Book:

1. Schwartz M.M. "Metals Joining Manual". McGraw Hill Books, 1979.
2. Tylecote R.F. "The Solid Phase Welding of Metals". Edward Arnold Publishers Ltd. London, 1968.
3. AWS- Welding Hand Book. 8th Edition. Vol- 2. "Welding Process"
4. Nadkarni S.V. "Modern Arc Welding Technology", 1st edition, Oxford IBH Publishers, 2005.
5. Christopher Davis. "Laser Welding- Practical Guide". Jaico Publishing House, 1994.
6. Davis A.C., "The Science and Practice of Welding", Cambridge University Press, Cambridge, 1993.
7. Mishra. R.S and Mahoney. M.W, Friction Stir Welding and Processing, ASM,2007.

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- https://onlinecourses.nptel.ac.in/noc21_mm01/preview
- https://archive.nptel.ac.in/courses/112/103/112103263/
- https://onlinecourses.nptel.ac.in/noc20_me65/preview

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Course: ARTIFICIAL INTELLIGENCE IN MANUFACTURING(AIM)

Course Code		**Scheme of Evaluation**	Theory:	Practical:
Teaching Plan	3-0-2-0	**MSE+TA**	**30+20**	**50**
Credits	04	**ESE**	**60**	**50**

Course Objectives:

- To introduce students to the fundamentals of Artificial Intelligence (AI) and its applications in manufacturing.
- To familiarize students with AI techniques such as Machine Learning, Expert Systems, and Computer Vision for industrial applications.
- To explore the use of AI in process optimization, predictive maintenance, and quality control.
- To provide an understanding of AI-driven automation and smart manufacturing strategies.
- To develop problem-solving skills for implementing AI solutions in real-world manufacturing environments.

Syllabus:

Unit	Contents	Lecture
01.	**Introduction to Artificial Intelligence in Manufacturing:** Overview and Basics of AI- Definitions and Evolution, Industry 4.0 and Smart Manufacturing, Role of AI in Manufacturing Industries, Smart Manufacturing and Industry 4.0, Types of AI: Weak AI vs. Strong AI, Narrow AI, General AI, and Machine Learning	07 L
02.	**Machine Learning and Deep Learning for Manufacturing and its Application:** Basics and Fundamentals of Machine Learning (Supervised, Unsupervised, and Reinforcement Learning), Deep Learning and Neural Networks in Manufacturing, Applications of ML in Predictive Maintenance and Process Optimization, AI-driven Process Optimization and Quality Control, Case Studies on Machine Learning in Manufacturing and AI in Defect Detection and Demand Forecasting	07 L
03.	**AI for Predictive Maintenance and Fault Diagnosis:** Introduction to Predictive Maintenance and Condition Monitoring, AI-based Anomaly Detection Techniques, Use of IoT and Sensors for Predictive Maintenance, Case Studies on AI-enabled Fault Diagnosis.	07 L
04.	**Expert Systems and Decision Support in Manufacturing:** Introduction to Expert Systems, Knowledge Representation and Reasoning Techniques, AI-driven Decision Support Systems (DSS) in Manufacturing, Case Studies in AI for Process Planning and Scheduling.	07 L
05.	**Computer Vision and AI-based Quality Control:** Basics of Computer Vision and Image Processing, AI-based Inspection Systems for Defect Detection, Pattern Recognition and Object Classification, Case Studies: Vision-based Quality Control in Industries	07 L
06.	**Ethical Considerations, Challenges and Future Trends in AI for Manufacturing:** Ethical & Legal Aspects of AI in Manufacturing, Challenges in AI Adoption in Manufacturing, Digital Twin and AI Simulation for Manufacturing, Cybersecurity	07 L

and AI-driven Risk Management, Future Trends: Generative AI, Explainable AI and Edge AI, Case Studies on Emerging AI Technologies in Manufacturing

Course outcomes:

After successful completion of this course, students will be able to:

1. Understand the fundamental concepts of Artificial Intelligence and its applications in manufacturing.
2. Apply Machine Learning and Deep Learning techniques for process optimization and quality improvement.
3. Analyze AI-based predictive maintenance techniques to enhance equipment reliability.
4. Evaluate the effectiveness of AI-driven computer vision systems for quality control.
5. Design AI-enabled robotic and automation systems for smart manufacturing applications.
6. Assess the ethical implications and future developments of AI in manufacturing.

Laboratory Course Objectives:

1. To introduce students to fundamental AI techniques and their applications in manufacturing.
2. To provide hands-on experience with AI-based software and programming environments.
3. To demonstrate the application of AI in manufacturing tasks such as predictive maintenance, quality inspection, and process optimization.
4. To enable students to apply machine learning and deep learning techniques to manufacturing data.
5. To enhance students' ability to analyze and interpret AI-driven decision-making processes in industrial automation.
6. To prepare students for real-world AI applications in smart manufacturing environments.

List of Experiments: (Any seven)

The term work shall consist of record of any eight assignments on following topics:

1. Study of AI Tools for Manufacturing: AI-based software tools (Python, MATLAB, TensorFlow, OpenCV)
2. Data Acquisition and Preprocessing in AI & Manufacturing Applications
3. Machine Learning for Predictive Maintenance & Quality Control
4. AI-based Quality Inspection Using Computer Vision
5. AI-based Predictive Maintenance
6. AI in Production Planning and Scheduling
7. Deep Learning for Manufacturing Defect Detection
8. Automatic Identification and Data Capture using AI
9. AI-driven Digital Twin for Smart Manufacturing
10. AI-based Fault Diagnosis and Root Cause Analysis

Laboratory Course Outcomes (COs):

After successful completion of this course, students will be able to:

1. Demonstrate & Utilize proficiency in AI tools and programming for manufacturing applications.
2. Apply machine learning and deep learning models for process optimization and defect detection.

3. Develop AI-based quality inspection models using computer vision.
4. Analyze manufacturing data for predictive maintenance and fault diagnosis.
5. Implement AI-based automation and robotics for smart manufacturing processes.
6. Explore AI applications in digital twin technology and supply chain optimization.
7. Evaluate the impact of AI on sustainability and smart manufacturing systems.

Suggested learning resources:

Textbooks:

1. Alka Chaudhary, Intelligent Manufacturing and Industry 4.0, CRC Press
2. M. Dhivya, Artificial Intelligence (AI): Recent Trends and Applications, CRC Press
3. Rui Yang, Maiying Zhong, Machine Learning-Based Fault Diagnosis for Industrial Engineering Systems, CRC Press

Reference Book:

1. Hamid Parsaei, Manufacturing Decision Support Systems.
2. *Kamalakanta Muduli,* Intelligent Manufacturing Management Systems, Wiley.

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Fundamentals of Quantitative Techniques in Project Management

Course Code		**Scheme of Evaluation**	Theory:	Practical:
Teaching Plan	3-0-2-0	MSE+TA	30+20	50
Credits	04	ESE	50	50

Corse Objectives:

- To understand the forecasting techniques and apply it for real life applications.
- To apply network models for project analysis
- To apply decision making tools for multicriteria decision making
- To develop problem-solving skills in Integer/linear /Goal programming
- To apply inventory models/ queuing models for real life applications.

Course Contents:

Unit	Contents	Lecture
01.	**Demand Forecasting:** Elements of a Good Forecast,Forecasting and the Supply Chain ,Steps in the Forecasting Process, Forecast Accuracy, Approaches to Forecasting, Qualitative Forecasts , Executive Opinions, Salesforce Opinions, Consumer Surveys, Forecasts Based on Time-Series Data, Naive Methods, Techniques for Averaging, Other Forecasting Methods, Techniques for Trend, Trend-Adjusted Exponential Smoothing, Techniques for Seasonality, Techniques for Cycles, Associative Forecasting Techniques, Simple Linear Regression, Nonlinear and Multiple Regression Analysis, Monitoring the Forecast, Choosing a Forecasting Technique,	07 L
02.	Network techniques for project management, development of project network, time estimation, determination of critical path, scheduling when resources are limit, PERT and CPM models.	07 L
03.	Multi Criteria Decision Making, Analytical Tools: Simple Additive Weighting Method (SAW), Weighted Product Method (WPM), Analytical Hierarchy Process (AHP), TOPSIS, Modified TOPSIS, Graph Theory and Matrix Approach, formulation, Applications	07 L
04.	Introduction to Integer programming, Solution of Integer programming by various methods, Goal programming and parametric programming, Linear programming models, multi goal programming, Dynamic programming models	07 L
05.	Game theory- linear programming methods to solve mixed strategy games, Various models in queuing; inventory control models,	07 L
06.	Vehicle routing problems and various mathematical models, transshipment, travelling salesman problems; Simulation modelling & analysis	07 L

Course Outcomes:

At the end of course students will be able to

1. Apply forecasting techniques for real-life decision-making problems.
2. Analyze various network models in real life case studies
3. Apply multi criteria decision making in real life case studies
4. Solve Integer Programming, Linear Programming, Goal Programming models
5. Apply inventory models/ queuing models for real life applications

References:

1. Sharma J.K. : Operations Research Theory & Applications, Macmillan India Ltd.
2. Hamdy A. Taha : Operations Research, An Introduction, PHI Learning Pvt. Ltd., New Delhi.
3. Wagner Harvey M. : Principles of Operations Research with Applications to Managerial Decisions, Prentice Hall of India Pvt. Ltd., New Delhi.
4. Shenoy G.V. : Linear Programming Methods and Applications, New Age International, 2007
5. Prasanna Chandra, Project Planning: Analysis, Selection, Implementation and Review, Tata McGraw Hill. 7th Edition, 2009
6. Narendra Singh, Project Management and Control, HPH, 2003

Fundamentals of Quantitative Techniques in Project Management Lab

Course Objectives:

- To apply the forecasting techniques for real life applications.
- To apply network models for project analysis
- To use decision making tools for multicriteria decision making
- To develop problem-solving skills in Integer/linear /Goal programming
- To apply inventory models/ queuing models for real life applications.

The list of Experiments:

1. To analyse the past data and forecast the values using time series data to evaluate at least three qualitative forecasting techniques
2. To analyse averaging techniques, trend and seasonal techniques, and regression analysis, and solve typical problems. measures of forecast accuracy.
3. To analyse critical path, the sequence of activities and project's overall duration, and manage project activities effectively using CPM PERT tools
4. To analyse Case studies of scheduling and controlling project costs with crashing activities
5. To apply Simple Additive Weighting Method (SAW) method for solving MCDM case study
6. To use Weighted Product Method (WPM) for solving MCDM case study
7. To use Analytic Hierarchy Process (AHP) for solving MCDM case study
8. To use TOPSIS/Modified method for solving MCDM case study
9. To use Digraph method for solving MCDM case study
10. To solve the Goal programming/ Integer programming problem
11. To solve the inventory problem using inventory models.
12. To solve the queuing problem using Queuing Model

Course Outcomes

At the end of course students will be able to

1. Apply forecasting techniques for real-life decision-making problems.
2. Analyze various network models in real life case studies
3. Apply multi criteria decision making techniques in real life case studies
4. Solve Integer Programming, Linear Programming, Goal Programming models
5. Apply inventory models/ queuing models for real life applications

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Course: SMART MANUFACTURING & SIMULATION LABORATORY (SMSL)

Course Code	VSEC	**Scheme of Evaluation**	Oral & Term Work
Teaching Plan	0-0-2-1 = 2	**Term Work**	50
Credits	1	**Oral**	50

Corse Objectives:

1. **Understand** fundamental concepts and principles underlying smart manufacturing systems
2. **Apply** Simulation Software effectively to model, simulate, and analyze complex manufacturing and logistics processes
3. **Analyze** simulation data to identify bottlenecks, resource utilization, throughput, and system performance characteristics for effective decision-making
4. **Design and implement** IoT-based experiment for real-time data acquisition, remote monitoring, and automated control in manufacturing environments
5. **Evaluate** alternative smart manufacturing scenarios and logistical strategies using simulation models and IoT experiments
6. **Demonstrate** teamwork, effective communication, and technical documentation skills through collaborative lab experiments, simulation projects

Syllabus:

Lab	List of Lab Experiments	Hrs.
01	Basic elements of simulation model building using simulation software	2 hrs.
02	Building and simulation of a multi-stage simulation models in software	4 hrs.
03	Simulation of Manufacturing/Warehouse/Logistics models	2 hrs.
04	Simulation of Chemical Manufacturing Plants (continuous production)	2 hrs.
05	Simulate and control a conveyor belt system	2 hrs.
06	Case Study 1: Industrial application-based simulation model development	2 hrs.
07	Case Study 2: Industrial application-based simulation model development	2 hrs.
08	Real-time Monitoring and Control of a Manufacturing Process using IoT - Sensor data collection and communication over the network using ESP-32/Arduino	4 hrs.
09	Simulation of machine tool design from an ergonomics perspective using ErgoMaster	4 hrs.
	Total	**24 hrs.**

Course outcomes:

At the end of the course students will demonstrate the ability to:

1. Develop simulation models for various manufacturing and logistics scenarios using a simulation software package
2. Analyze simulation data from various manufacturing and logistics scenarios
3. Design IoT systems with networked sensors and actuators
4. Develop basic C++ code used for Arduino and ESP-32 based microcontrollers used in IoT.

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Course: Multi-Disciplinary Minor course
MATERIALS MANAGEMENT

Course Code		**Scheme of Evaluation**	MSE, TA & ESE
Teaching Plan	3-1-0-0 = 4	**MSE- 30**	TA- 20
Credits	4	ESE -50	

Course Objectives:

A Materials Management syllabus aims to equip students with

- the knowledge and skills to manage materials effectively,
- encompassing areas like procurement, inventory control,
- supply chain management, and logistics,
- leading to careers in areas like materials management,
- supply chain analysis, and procurement.

Syllabus:

Unit	Content	Hrs
01	**Introduction to Materials Management:** An overview – Introduction – Scope, Objective, Importance of Integrated approach to Materials Management, Classification and codification of materials, Specification in materials management, Standardization of materials **Self Study:** Classification and codification of materials	9L
02	**Material Planning** – Techniques of materials planning Introduction – Factors affecting material planning, Budgeting – Techniques of material planning - MRP Procedure & Pricing Capacity Management- Scheduling Orders- Production Activity control -Issues Receipt – Storage – Issue **Self Study:** Integration of MRP with Production Planning and Marketting	6L
03	**Inventories:** Definition-Classification of Inventories- Need for inventories – Merits & Demerits of Inventories **Self Study:** Merits & Demerits of Inventories	5L
04	**Inventory control techniques and principles**: Classification, codification, standardization – ABC analysis –VED, GOLF, FSN - HML Economic order quantity concept – Derivation of EOQ formula, modified EOQ , Case Studies Mathematical versions of modified EOQ models, Material forecasting **Self Study:** Material forecasting	9L
05	**Material storage systems:** Store and stores keeping, Principle of material handling, ASRS, Material Handling equipments, automated guided vehicle (AGV), Storage Occupational safety(material & equipment), stores layout, Material Storage Principles, Material Storage Methods and System – Design of Storage system, warehouse management system, 3rd Party warehouse Management **Self Study:** Automated guided vehicle (AGV),	9L
06	**Vendor Management System:** Vendor establishing Specification, Vendor selection, Price determination, Price forecasting, buying Strategy (forward, mixed), demand Management, Vendor development Replenishment systems, Vendor Performance Measurement, Functions of vendor Management Systems **Self Study:** Functions of vendor Management Systems	9L
07	**Basic Features of MM module in ERP systems**: Terms used in MM module, MM Organizational Structure, Material master data, MM vendor master data, Purchase information record, MM Processes: Procure-to-Pay Process, Generation of reports and its analysis **Self Study:** Integration of MRP with Production Planning and Marketting	9L

Total 56L

Course outcomes:

The student will show their ability at a professional level to:

6. **Understanding Principles:** Students will grasp the fundamental principles of materials management, including its scope, importance, and functions in both manufacturing and service sectors.
7. **Inventory Management:** Students will gain expertise in inventory control, optimizing stock levels, and minimizing waste through techniques like ABC analysis and VED analysis.
8. **Procurement & Purchasing:** They'll learn about the procurement cycle, ethical considerations, tendering processes, and legal aspects of purchasing.
9. **Warehousing & Material Handling:** Knowledge of material flow processes, warehouse management, and material handling techniques will be developed.
10. **Materials Planning & Forecasting:** Students will understand materials planning, forecasting, and replenishment strategies to ensure timely availability of materials.
11. **ERP Systems:** They'll learn how to implement and utilize Enterprise Resource Planning (ERP) systems for materials management.

Suggested learning resources:

Textbooks:

1. A. K. Chitale, R. C. Gupta : Materials Management - A Supply Chain Perspective, PHI Publications
2. Purchasing and Supply Management - Dobler and Burt
3. Materials Management - Dutta
4. Purchasing and Materials Management - K S Menon

Reference Books:

1. Handbook of Materials Management - Gopalkrishnan
2. Materials & Logistics Management - L.C.Jhamb
3. Introduction to Materials Management – Arnold
4. Logistics & Supply Chain Management – Martin Christopher

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PROJECT-II (Semester-VI)

Sr No	Items	Description of activity
1	**Scope (TRL-3)**	Continuation of Project-I, Planning, fabrication and development of hardware / software and execution; relevant standards.
2	**Self-Study material for the student**	The department shall recommend relevant online / offline self-study materials on Incubation, Innovation (online / offline)
3	**End Semester Evaluation process**	The end semester evaluation shall be based on project work in power point presentation and a project report. The evaluation shall be done by the panel of faculty members, at least three members including one of them is project guide.

Evaluation sheet for Project -II

MIS No	Name of student	Planning	Development of hardware / software	Experimentation	Project Report	Viva Voce and presentation skill	Out of 50 marks
		10 M	**10M**	**10M**	**10M**	**10M**	

INTERNSHIP-III,
(after semester VI, summer internship)

Sr No	Items	Type of Internship to be undertaken
1	**Nature of Internship**	Industry / R and D labs / Education institutes (HEI less than 100 NIRF rank) This should be decided by the nature of Project-I selected by the group of students in the 5th semester. A project guide should assist in grooming the student group in relevant areas to enhance their knowledge and skills.
2	**End Semester Evaluation process**	Individual student / Group of students shall submit a report followed by viva voce by the department level faculty members on the project report prepared by them. A template for report writing and evaluation format will be provided by the Nodal Officer, COEP Tech.

Exit Course options for B.Voc in Manufacturing Sciences

Two (02) Skill based Courses of 8 credits

Sr. No.	Course Type	Course Name	Teaching Scheme					Credits
			L	T	P	S	Hrs	
1	SEC	Computer Aided Inspection	0	0	8	1	5	4
2	SEC	Casting & Welding Technology	0	0	8	1	5	4

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Course: COMPUTER AIDED INSPECTION LAB (CAI LAB)

Course Code		**Scheme of Evaluation**	CE & ESE
Teaching Plan	0-0-4-1	**Term work**	50 Marks
Credits	2	**Practical**	50 Marks

Corse Objectives:
At the end of this course, students will be able to …

- Understand the basic elements of computer aided inspection (CAI)
- Understand the in-process measurement using gauge system
- Measure geometric and dimensional tolerances
- Examine alignment of the Machine tool

List of experiments:

1. Study and demonstration of Coordinate Measuring Machine (CMM)
2. Measurement of dimensional and Geometric Tolerance of the part using CMM
3. Study and demonstration of interferometer
4. Measurement of gear tooth profile using profile projector
5. Study and demonstration of Vision Measurement System
6. Machine Tool Alignment testing for CNC Lathe (Minimum 3 test)
7. Machine Tool Alignment testing for VMC (Minimum 3 test)
8. Study and demonstration of Automatic Force Microscope
9. In process Pneumatic Gauging
10. Assignment on various integrated software packages application for Computer Aided Inspection

Corse Outcomes:
At the end of this course, students will be able to …

1. Understand the computer aided inspection (CAI)
2. Measure Analyze the gear tooth profile terminology
3. Ensure the quality of the product by inprocess gauging
4. Inspecting the alignment of CNC & VMC

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Course: Casting & Welding Technology (BVOC)

Course Code		**Scheme of Evaluation**	CE
Teaching Plan	0-0-4-1 = 4	ICE	100
Credits	04		

Course Objectives:

1. Learn practical overview of various welding process and learn various welding standards
2. Gain an insight of sand preparation and foundry equipment
3. Enhance the practical skills in welding and casting technology
4. Analyze various advanced welding processes.

List of Experiments :

Welding :

1) Perform welding of Mild steel Plates by Gas Metal Arc Welding process. (GMAW)
2) Perform welding on of Mild steel/Stainless steel /Aluminium sheets by
    a. Gas Tungsten Arc Welding (GTAW)
3) Perform welding on Mild steel/Stainless steel sheets using Resistance Spot Welding for overlapping sheets
4) Perform welding on Aluminum sheets using Friction Stir welding and Friction Stir Spot welding
5) Perform welding using Mild steel/Stainless steel Laser Beam Welding (LBW)

Casting:

1. Understand design consideration of gating, riser and estimating cooling time for casting
2. Sand preparation and Testing (Determination of moisture content, Determination of Permeability)
3. Demonstration of production of a part of Cast iron using Pit Furnace/Induction Furnace
4. Inspection of Cast component (visual) and preparing report. The report includes causes of various defects.
5. Demonstration of Plastic moulding/Injection Moulding

Course outcomes:

1. Learn the fundamentals and working of various conventional and advanced welding processes
2. Understand practical aspects involved in various welding process
3. Prepare and select the process parameters for various welding process
4. Understand the moulding sand preparation and various aspects involved into it.
5. Apply the design consideration of gating, riser and estimating cooling time for casting

Suggested learning resources:

Textbooks:

- Little R.L., “Welding and Welding Technology”, Tata McGraw Hill Publishing Co., Ltd., New Delhi, 34th reprint, 2008.

- Christopher Davis. “Laser Welding- Practical Guide”. Jaico Publishing House, 1994.
- Mishra. R.S and Mahoney. M.W, “Friction Stir Welding and Processing”, ASM,2007.
- Heine, R. W. Loper, C.R. and Rosenthal, P.C. “Principles of Metal Casting”
- Ghosh A. and Malik, A.K. “Manufacturing Science “, Affiliated East-West Press Pvt. Ltd.
- Jain P.L “Principles of Focundry Techonology, McGraw Hill Books

Reference books:

- John Campbell, “Complete Casting Handbook,Metal Casting Processes, Metallurgy, Techniques and Design”, 2nd Edition 2015, Springer.
- K.G. Swift and J.D. Booker, “Manufacturing Process Selection Handbook,” 2013 Elsevier
- Davis A.C., “The Science and Practice of Welding”, Cambridge University Press, Cambridge, 1993.
- HA. Davidson,”Handbook of Precision Engineering:Joining Techniques” 1973Red Globe Press London
- A. F. Manz, “The Welding Power Handbook: A Basic Manual on Theory and Use of Arc Welding Power Supplies”1973,Amer Welding Society

NPTEL – Swayam

- https://nptel.ac.in/courses/112103305
- https://onlinecourses.nptel.ac.in/noc21_me82/preview

Honors- Manufacturing Systems Engineering

SEM V	Reliability and Maintenance Engineering
SEM VI	Metrology and Computer aided Inspections

(PME) Reliability and Maintenance Engineering

Teaching Scheme	Examination Scheme
Lectures: 4 hrs/week	MSE– 30 marks, TA-20 Marks End-Sem Exam – 50

Course Outcomes:

1. Student will be able to demonstrate the skills related to life cycle costing and condition based monitoring.
2. Student will understand various aspects of maintenance in practical situations.
3. Student will be able to handle various software's and equipments related to Terotechnology.

Syllabus Contents:

• Basic Probability, concept and various distributions. Concept of Reliability and analysis of various configurations of assemblies and sub-assemblies. Series, Parallel and other grouping.
• System reliability. Set theory, optimal Cut Set and Tie Set, 'star-delta' method, matrix method .
• System reliability determination through 'Event Tree' analysis and Fault tree analysis.
• Reliability, Availability and Maintainability of equipment. A number of case studies done in Indian perspectives using Short Sample, nonparametric reliability.
• Monte-Carlo simulation and Techno economic life. Optimal allocation of component reliability to achieve maximum system reliability- various techniques and methods such as Minimum Effort method, Proportional, Conditional, AGREE, ARINC, Fair & Kim's Algorithm,
• Failure Modes and Effects Analysis (FMEA), Failure Modes, Effects and Criticality Analysis (FMECA). R.P.N., Graph theory.
• Maintenance Management Practice –Various types of maintenance, breakdown, preventive, periodic or predictive, condition based maintenance as predictive preventive maintenance.
• Periodic Preventive Management – Scheduled maintenance and period for P.M.
• Life cycle cost taking into consideration maintenance, reliability, hazard function etc. Life cycle costing: Rigorous models, mathematical formulation .
• Condition based maintenance, using Vibration Signature, SOAP, ferrography, hot ferrography, Infra Red Camera, fluorescent dye, Quantum Debris Analysis using Particle Analysers and other diagnostic techniques.
• Reliability Centered Maintenance. Total Productive Maintenance: Organisation, merits and demerits. Types of maintenance and their comparison, computerized maintenance, maintenance management auditing and evaluation. Analytical methods in maintenance

References:

1. Bhadury and S.K. Basu, "Terotechnology: Reliability Engineering and Maintenance Management", Asian Books, New Delhi 2002.
2. A. K. Gupta, "Terotechnology & Reliability Engineering", McMillan Co.

3. A. K. S. Jardine, “Maintenance, Replacement & Reliability”, HMSO, London.
4. C.Singh and C.S. Dhillon, “Engineering Relaibility-New Techniques
And Applications”, John Wiley and Sons, Tata McGraw Hill Publishing Company Limited, New Delhi.
5. L.S.Srinath, “Concepts in Reliability Engineering” Affiliated East West Press.
6. K.C. Kapoor and L.R. Lubersome, “Reliability in Engineering Design” ,Willey
7. C. Singh and C.S. Dhillon, “Engineering Reliability New Techniques and
Applications” John Wiley and Sons.

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(PME) Metrology and Computer aided Inspections

Teaching Scheme	Examination Scheme
Lectures: 4 hrs/week	MSE– 30 marks, TA-20 Marks
	End-Sem Exam – 50

Course Outcomes:

1. Students will be able to handle high precision measurement requirements of industry.
2. Knowledge of different instruments used for high precision will be applied by the student in the industry and research work.

Syllabus Contents:

•Metrological concepts - Abbe's principle - need for high precision measurements - problems associated with high precision measurements.
• Standards for length measurement - Shop floor standards and their calibration
•Light interference - Method of coincidence - Slip gauge calibration - Measurement errors.Various tolerances and their specifications, gauging principles, selective assembly, comparators. Angular measurements - principles and instruments.
•Gear and Thread measurements.
•Surface and form metrology - flatness, roughness, waviness, roundness, cylindricity,
•Computer Aided Metrology - Principles and interfacing, software metrology.
•Laser metrology - Applications of Lasers in precision measurements.
•Laser interferometer, speckle measurements, laser scanners.
•Coordinate Measuring Machine - Types of CMM - Probes used - Applications - Non contact CMM using Electro optical sensors for dimensional metrology - Non contact sensors for surface finish measurements.
•Image processing and its application in Metrology.
•Large scale Metrology, Laser Trackers, Stereo vision, Micro and Nano Metrology.
•Metrology for additive manufacturing parts, CT Scan technologies in inspection

References:

1. K.J.Hume, “Engineering Metrology”, Kalyani Publisher Latest Editon, New Delhi.
2. R. K. Jain, “Engineering Metrology”, Khanna Publishers, New Delhi
3. I.C. Gupta, “Engineering Metrology”, Dhanapat Rai New Delhi
4. Robert G. Seippel , “Opto Electronics for Technology and Engineering”, Prentice Hall New Jersey, 1989.
5. Thomas G.G, “Engineering Metrology”, Butter worth publications-1974
6. Anil K. Jain, “Fundamentals of Digital image processing”, Prentice hall of India Pvt. Ltd. 2004
7. Dale H. Besterfield, “Total Quality Management”, Pearson Education Asia, 2002.
8. Manuals of Co-ordinate measuring machines and systems

Honors- Mechatronics

SEM V	Industrial Instrumentation and Control
SEM VI	Mechatronics System Design

(MCH) Industrial Instrumentation and Control

Teaching Scheme	Examination Scheme
Lectures: 4 hrs/week	MSE– 30 marks, TA-20 Marks End-Sem Exam – 50

Course Outcomes

1. Identify, formulate and solve a problem of Instrumentation and Control Engineering
2. Design and conduct experiments for measurement and ability to analyze and interprets data.
3. Demonstrate an understanding of sensors / transducers.

Syllabus Contents

General concepts and terminology of measurement systems, static and dynamic characteristics, errors, standards and calibration. Introduction, principle, construction and design of various active and passive transducers. Introduction to semiconductor sensors and its applications. Design of signal conditioning circuits for various Resistive, Capacitive and Inductive transducers and piezoelectric transducer. Introduction to transmitters, two wire and four wire transmitters, Smart and intelligent Transmitters. Design of transmitters. Introduction to EMC, interference coupling mechanism, basics of circuit layout and grounding, concept of interfaces, filtering and shielding. Safety: Introduction, electrical hazards, hazardous areas and classification, non-hazardous areas, enclosures – NEMA types, fuses and circuit breakers. Protection methods: Purging, explosion proofing and intrinsic safety.

References

1. M. Sze, “Semiconductor sensors”, John Wiley & Sons Inc., Singapore, 1994.
2. Noltingk B. E., “Instrumentation Reference Book”, 2nd Edition, Butterworth Heinemann, 1995.
3. L. D. Goettsche, “Maintenance of Instruments and Systems – Practical guides for measurements and control”, ISA, 1995.
4. John P. Bentley, Principles of Measurement Systems, Third edition, Addison Wesley Longman Ltd., UK, 2000.
5. Doebelin E. O, Measurement Systems - Application and Design, Fourth edition, McGraw-Hill International Edition, New York, 1992.

(MCH) Mechatronics System Design

Teaching Scheme	Examination Scheme
Lectures: 4 hrs/week	MSE– 30 marks, TA-20 Marks End-Sem Exam – 50

Course Outcomes

1. Demonstrate how mechatronics integrates knowledge from different disciplines in order to realize engineering and consumer products that are useful in everyday life.
2. Apply theoretical knowledge: understanding selection of suitable sensors and actuators; designing electro-mechanical systems.
3. Work with mechanical systems that include digital and analogue electronics as a data acquisition model.

Syllabus Contents

Rotational drives - Pneumatic Motors: continuous and limited rotation - Hydraulic Motors:continuous and limited rotation - Brushless DC Motors - Motion convertors, Fixed ratio,invariant motion profile, variators, remotely controlled couplings Hydraulic Circuits and Pneumatic Circuits.

Mechanical Systems and Design - Mechatronics approach - Control program control, adaptive control and distributed systems - Design process - Types of Design – Integrated product design - Mechanisms, load conditions, design and flexibility Structures, load conditions, flexibility and environmental isolation – Man machine interface, industrial design and ergonomics, information transfer from machine from machine to man and man to machine, safety.

Real time interfacing - Introduction Elements of data acquisition and control Overview of I/O process-Installation of I/O card and software - Installation of application software- Over framing.

Microcontrollers: Introduction to use of open source hardware (Arduino & Raspberry Pi); shields/modules for GPS, GPRS/GSM, Bluetooth, RFID, and Xbee, integration with wireless networks, databases and web pages; web and mobile phone apps.

Case studies on Data Acquisition - Transducer calibration system for Automotive applications Strain Gauge weighing system - Solenoid force - Displacement calibration system - Rotary optical encoder - Inverted pendulum control - Controlling temperature of a hot/cold reservoir - Pick and place robot - Carpark barriers.

Case studies on Data Acquisition and Control - Thermal cycle fatigue of a ceramic plate - pH control system - De-Icing Temperature Control System - Skip control of a CD Player - Autofocus Camera, exposure control.

Case studies on design of Mechatronics products - Motion control using D.C. Motor, A.C. Motor & Solenoids - Car engine management - Barcode reader.

References

1.W. Bolton, Mechatronics - Electronic Control systems in Mechanical and Electrical Engineering-, 2nd Edition, Addison Wesley Longman Ltd., 1999.
2.Devdas Shetty, Richard A. Kolk, Mechatronics System Design, PWS Publishing company, 1997
3.Bradley, D. Dawson, N.C. Burd and A.J. Loader, Mechatronics: Electronics in Products
4.and Processes, Chapman and Hall, London, 1991.
5.Brian Morris, Automated Manufacturing Systems - Actuators, Controls, Sensors and Robotics, Mc Graw Hill International Edition, 1995.
6.Gopal, Sensors- A comprehensive Survey Vol I & Vol VIII, BCH Publisher.

Honors - Project Management

SEM V	Quantitative Techniques in Project Management
SEM VI	Project Risk Management

(PPM) Quantitative Techniques in Project Management

Teaching Scheme
Lectures: 4 hrs/week

Examination Scheme
MSE – 30 marks , TA- 20 Marks
End-Sem Exam - 50

Course Outcomes:

At the end of course students will be able to

1. Apply techniques of conceptual modeling of real life decision making problems,.
2. Analyze various models in real life case studies and learn about decision making.
3. Simulate the models and optimize it.

Course Contents:

Introduction to Integer programming, Solution of Integer programming by various methods, introduction to Goal programming and parametric programming
Dynamic programming models;
Various models in queuing; inventory control models
Network theory- maximal flow and minimal spanning tree problems
Game theory- linear programming methods to solve mixed strategy games ,
Vehicle routing problems and various mathematical models, transshipment, travelling salesman problems;
Simulation modelling & analysis, optimization models used in manufacturing such as Linear programming models, multi goal programming etc.

References:

1. Sharma J.K. : Operations Research Theory & Applications, Macmillan India Ltd.
2. Rao, S.S: Optimisation in Design, New Age International Limited Publishers, Fourth Edition, 2008.
3. Hamdy A. Taha : Operations Research, An Introduction, PHI Learning Pvt. Ltd., New Delhi.
4. Wagner Harvey M. : Principles of Operations Research with Applications to Managerial Decisions, Prentice Hall of India Pvt. Ltd., New Delhi.
5. Shenoy G.V. : Linear Programming Methods and Applications, Wiley Eastern Ltd.
6. Deb Kalyanmay : Optimization in Engineering Design, PHI

(PPM) Project Risk Management

Teaching Scheme	Examination Scheme
Lectures: 4 hrs/week	MSE– 30 marks, TA-20 Marks
	End-Sem Exam - 50

Course Outcomes:
At the end of the course, students will demonstrate the ability to:

- Apply the concept of risk identification - across a variety of project categories and industry segments
- Apply qualitative and quantitative methods of risk assessment in project management scenarios
- Plan and pre-empt risks & apply risk mitigation strategies appropriately

Course Contents:
Project Risk Management, Role of Project Risk Management in Project Management, Good Risk Management Practice, Critical Success Factors for Project Risk Management

Principles and concepts of Project Risk , Individual Risks and Overall Project Risk, Stakeholder Risk Attitudes , Iterative Process , Communication, Responsibility for Project Risk Management, Project Manager's Role for Project Risk Management, Project Risk Management Processes

The project risk management approach , Establish the context , Risk identification , Qualitative risk assessment , Semi-quantitative risk assessment , Risk treatment , Monitoring and review, Communication and reporting , Project processes and plans , Simplifying the process , Managing opportunities

Planning and pre-empting risks- for unknown variables affecting a project/program/organization: Understanding Risk Mitigation & Stakeholder Management – techniques and methods

Introduction to developing a culture of planned risk taking and provisioning for financial and non-financial impact of such risks

References:

1. Dale F. Cooper, Stephen Grey, Geoffrey Raymond and Phil Walker, Project Risk Management Guidelines, Managing Risk in Large Projects and Complex Procurements, John Wiley & sons, 2005
2. Practice Standard.For Project Risk Management, Project Management Institute, Inc., 2009

Honors- Research

V	Quantitative Techniques in Project Management
VI	Design of Experiments

(PPM) Quantitative Techniques in Project Management

Teaching Scheme
Lectures: 4 hrs/week

Examination Scheme
MSE – 30 marks , TA- 20 Marks
End-Sem Exam - 50

Course Outcomes:

At the end of course students will be able to

1. Apply techniques of conceptual modeling of real life decision making problems,.
2. Analyze various models in real life case studies and learn about decision making.
3. Simulate the models and optimize it.

Course Contents:

Introduction to Integer programming, Solution of Integer programming by various methods, introduction to Goal programming and parametric programming
Dynamic programming models;
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1. Sharma J.K. : Operations Research Theory & Applications, Macmillan India Ltd., Reprint 2022
2. Rao, S.S: Optimisation in Design, New Age International Limited Publishers, Fourth Edition, 2024.
3. Hamdy A. Taha : Operations Research, An Introduction, PHI Learning Pvt. Ltd., New Delhi.
4. Wagner Harvey M. : Principles of Operations Research with Applications to Managerial Decisions, Prentice Hall of India Pvt. Ltd., New Delhi.
5. Shenoy G.V. : Linear Programming Methods and Applications, Wiley Eastern Ltd.

6. Deb Kalyanmay : Optimization in Engineering Design, PHI