B.Tech.

IN

PRODUCTION ENGINEERING

CURRICULUM
AND
SYLLABI

(Applicable from 2023 Admission onwards)

Department of Mechanical Engineering
NATIONAL INSTITUTE OF TECHNOLOGY CALICUT
Kozhikode - 673601, KERALA, INDIA

The Program Educational Objectives (PEOs) of B.Tech. in Production Engineering

PEO1	Excel in industry, technical profession and/or higher education by acquiring a strong foundation in mathematics, science and engineering fundamentals.
PEO2	Acquire scientific and engineering competencies to model, analyse, manage and improve manufacturing systems, and to provide solutions to manufacturing and allied industrial problems that are technically sound, economically feasible and socially acceptable.
PEO3	Exhibit professionalism, ethical attitude, communication and team working skills, multidisciplinary approach and an ability to relate engineering issues to the broader social context.

Programme Outcomes (POs) and Programme Specific Outcomes (PSOs) of B.Tech. in Production Engineering

PO1	**Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
PO2	**Problem analysis**: Identify, formulate, research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
PO3	**Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
PO4	**Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
PO5	**Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex engineering activities with an understanding of the limitations.
PO6	**The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
PO7	**Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
PO8	**Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
PO9	**Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
PO10	**Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
PO11	**Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one’s own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
PO12	**Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

PSO1	Ability to effectively utilize resources for improving the performance of production systems.
PSO2	Design processes and products ensuring quality and reliability.
PSO3	Utilize advanced materials, manufacturing processes and automation technologies in production systems.

CURRICULUM

Total credits for completing B.Tech. in Production Engineering is 150.

COURSE CATEGORIES AND CREDIT REQUIREMENTS:

The structure of B.Tech. programmes shall have the following Course Categories:

Sl. No.	Course Category	Number of Courses	Minimum Credits
1.	Institute Core (IC)	8	22
2.	Program Core (PC) and Program Electives (PE)	32 / 33	82
3.	Open Electives (OE)	8	24
4.	Institute Electives (IE) (Entrepreneurship Innovation (EI) + Digital / Automation Technologies (DA) + Humanities, Social Science, Management (HM))	6	18
5.	Activity Credits (AC)	--	4

COURSE REQUIREMENTS

The effort to be put in by the student is indicated in the tables below as follows:
L: Lecture (One unit is of 50 minute duration)
T: Tutorial (One unit is of 50 minute duration)
P: Practical (One unit is of one hour duration)
O: Outside the class effort / self-study (One unit is of one hour duration)

1. INSTITUTE CORE (IC)

a) Mathematics

Sl. No.	Course Code	Course Title	L	T	P	O	Credits
1.	MA1003E	Mathematics I	3	1*	0	5	3
2.	MA1013E	Mathematics II	3	1*	0	5	3
3.	MA2003E	Mathematics III	3	1*	0	5	3
4.	MA2013E	Mathematics IV	3	1*	0	5	3
		Total	**12**	**4***	**0**	**20**	**12**

*Optional for Students (can be replaced by self-study)

b) Basic Sciences and Drawing

Sl. No.	Course Code	Course Title	L	T	P	O	Credits
1.	PH1002E	Mechanics and Waves	3	0	0	6	3
2.	ME1011E	Engineering Graphics	2	0	2	5	3
		Total	**5**	**0**	**2**	**11**	**6**

c) Professional Communication and Professional Ethics

Sl. No.	Course Code	Course Title	L	T	P	O	Credits
1.	MS1001E	Professional Communication	3	0	0	6	3
2.	ME2001E	Professional Ethics	1	0	0	2	1
		Total	**4**	**0**	**0**	**8**	**4**

2A. PROGRAMME CORE (PC)

Sl. No.	Course Code	Course Title	L	T	P	O	Credits
1.	ME1401E	Engineering Mechanics	3	0	0	6	3
2.	ME1001E	Computer Programming and Numerical Methods	2	0	2	5	3
3.	ME1391E	Mechanical Workshop	0	0	2	1	1
4.	ME1311E	Materials Science	3	0	0	6	3
5.	ME1411E	Solid Mechanics	3	0	0	6	3
6.	ME1212E	Introduction to Fluid Mechanics and Machinery	3	0	0	6	3
7.	ME1213E	Thermodynamics and Heat Transfer	3	0	0	6	3
8.	EE1013E	Electrical Engineering	3	0	0	6	3
9.	EE1093E	Electrical Engineering Lab	0	0	2	1	1
10.	ME2101E	Fundamentals of Management	3	0	0	6	3
11.	ME2301E	Manufacturing Technology	3	0	0	6	3
12.	ME2391E	Production Technology Lab	0	0	3	3	2
13.	ME2091E	Machine Drawing	0	0	3	3	2
14.	ME2313E	Metrology & Computer Aided Inspection	3	0	0	6	3
15.	ME2411E	Design of Machine Elements	3	0	0	6	3
16.	ME2112E	Production Management	3	0	0	6	3
17.	CE2095E	Strength of Materials Lab	0	0	2	1	1
18.	ME2293E	Fluid Mechanics Lab	0	0	2	1	1
19.	ME3303E	Subtractive and Additive Manufacturing Processes	3	0	0	6	3
20.	ME3102E	Industrial Engineering	3	0	0	6	3
21.	ME3103E	Quantitative Techniques for Management	3	0	0	6	3
22.	ME3394E	Machining Science Laboratory	0	0	2	1	1
23.	ME3395E	Metrology & Computer Aided Inspection Lab	0	0	3	3	2

Sl. No.	Course Code	Course Title	L	T	P	O	Credits
24.	ME3311E	Computer Integrated Manufacturing	3	0	0	6	3
25.	ME3191E	Management Science Laboratory	0	0	3	3	2
26.	ME3396E	Computer Integrated Manufacturing Laboratory	0	0	2	1	1
27.	ME3099E	Project-Part-I	0	0	0	9	3
28.	ME4097E	Summer Internship	0	0	0	*	2
29.	ME4098E	Project-Part-II	0	0	0	9	3
		Total	**47**	**0**	**26**	**131**	**70**

2B. LIST OF ELECTIVES

Following courses may be credited under the categories mentioned in the table below:

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Categories			
								PE	EI	DA	HM
Industrial Engineering and Management											
1	ME2121E	Operations and Process Management	3	0	0	6	3	✔			✔
2	ME3121E	Fundamentals of Marketing	3	0	0	6	3	✔			✔
3	ME3122E	Design and Analysis of Management Information Systems	3	0	0	6	3	✔			
4	ME3123E	Work Design and Measurement	3	0	0	6	3	✔			
5	ME3124E	Cost Analysis and Control	3	0	0	6	3	✔			✔
6	ME3125E	Supply Chain Management	3	0	0	6	3	✔			✔
7	ME3126E	Management of Organisational Behaviour	3	0	0	6	3	✔			✔
8	ME3127E	Management of Human Resources	3	0	0	6	3	✔			✔
9	ME3128E	Quality Planning and Analysis	3	0	0	6	3	✔			✔
10	ME4121E	Technology Management	3	0	0	6	3	✔	✔		
11	ME4122E	Management of Lean Production Systems	3	0	0	6	3	✔			✔
12	ME4123E	Optimization Methods in Engineering	3	0	0	6	3	✔			

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Categories			
								PE	EI	DA	HM
13	ME4124E	Accounting and Finance for Engineers	3	0	0	6	3	✓			✓
14	ME4125E	Simulation Modelling and Analysis	3	0	0	6	3	✓		✓	
15	ME4126E	Human Factors in Engineering and Design	3	0	0	6	3	✓		✓	
16	ME4127E	Machine Learning for Data Science and Analytics	3	0	0	6	3	✓		✓	
17	ME4128E	Product and Process development	3	0	0	6	3	✓			
18	ME4129E	New Product Development	3	0	0	6	3	✓			
19	ME4130E	Business Analysis and Decision Making	3	0	0	6	3	✓			✓
20	ME4131E	Industrial Internet of Things	3	0	0	6	3	✓		✓	
Thermo-fluids and Energy Engineering											
21	ME2221E	Fundamentals of Combustion	3	0	0	6	3	✓			
22	ME2222E	Gas Dynamics	3	0	0	6	3	✓			
23	ME2223E	Computational Methods in Engineering	3	0	0	6	3	✓		✓	
24	ME2224E	Computational Fluid Dynamics	3	0	0	6	3	✓		✓	
25	ME2225E	Bio-fluid Mechanics	3	0	0	6	3	✓			
26	ME2226E	Waves on Fluid Interfaces	3	0	0	6	3	✓			
27	ME2227E	Introduction to Unmanned Aerial Systems	3	0	0	6	3	✓			
28	ME3221E	Automobile Engineering	3	0	0	6	3	✓			
29	ME3222E	Aerodynamics	3	0	0	6	3	✓			
30	ME3223E	Aerospace Propulsion	3	0	0	6	3	✓			
31	ME3224E	Refrigeration and Air-Conditioning	3	0	0	6	3	✓			
32	ME3225E	Hydrogen Energy Technologies	3	0	0	6	3	✓			
33	ME3226E	Renewable Energy Systems	3	0	0	6	3	✓			
34	ME3227E	Introduction to Rheology	3	0	0	6	3	✓			

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Categories			
								PE	EI	DA	HM
35	ME3228E	Transport Phenomena in Porous Media	3	0	0	6	3	✓			
36	ME3229E	Introduction to Cavitation	3	0	0	6	3	✓			
37	ME3230E	Battery Technologies for Electric Vehicles	3	0	0	6	3	✓			
38	ME3231E	Aeromechanics of Unmanned Aerial Systems	3	0	0	6	3	✓			
39	ME3232E	Design of Unmanned Aerial Systems	3	0	0	6	3	✓			
40	ME4221E	Experimental Methods in Fluid Flow and Heat Transfer	3	0	0	6	3	✓			
41	ME4222E	Neural Networks for CFD	3	0	0	6	3	✓		✓	
42	ME4223E	Cyber Physical Thermal and Energy Systems	3	0	0	6	3	✓			
43	ME4224E	Thermal Management in Electric Vehicles	3	0	0	6	3	✓			
44	ME4225E	Modeling, Simulation, and Prototyping of Unmanned Aerial Systems	3	0	0	6	3	✓		✓	
Manufacturing and Materials Science											
45	ME2324E	Mechatronics	3	0	0	6	3	✓		✓	
46	ME2334E	Techniques of Material Characterisation	3	0	0	6	3	✓			
47	ME2339E	Computer Graphics and Product Modelling	3	0	0	6	3	✓		✓	
48	ME3321E	Powder Metallurgy	3	0	0	6	3	✓			
49	ME3322E	Introduction to Modern Machining Processes	3	0	0	6	3	✓			
50	ME3323E	Design for Manufacturability	3	0	0	6	3	✓			
51	ME3325E	Machining Science and Machine Tools	3	0	0	6	3	✓			
52	ME3326E	Machine Tools and CNC Systems	3	0	0	6	3	✓			
53	ME3327E	Quality, Reliability and Maintenance	3	0	0	6	3	✓			✓
54	ME3328E	Artificial Intelligence in Manufacturing	3	0	0	6	3	✓		✓	

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Categories			
								PE	EI	DA	HM
55	ME3330E	Fluid Power Controls	3	0	0	6	3	✔			
56	ME3331E	Non-Destructive Testing and Evaluation	3	0	0	6	3	✔			
57	ME3332E	Mechatronics and Automation	3	0	0	6	3	✔		✔	
58	ME3333E	Additive Manufacturing: Fundamentals and Applications	3	0	0	6	3	✔			
59	ME3335E	Welding Science and Technology	3	0	0	6	3	✔			
60	ME3336E	Forming Technology	3	0	0	6	3	✔			
61	ME3340E	Industry 4.0 and Smart Enterprises	3	0	0	6	3	✔		✔	
62	ME4329E	Surface Engineering and Coating Technology	3	0	0	6	3	✔			
63	ME4337E	Functional Materials: Theory and Applications	3	0	0	6	3	✔			
64	ME4338E	Design of Jigs, Fixtures and Press Tools	3	0	0	6	3	✔			
Mechanics and Machine Design											
65	ME2421E	Theory of Elasticity	3	0	0	6	3	✔			
66	ME2422E	Newtonian and Analytical Mechanics	3	0	0	6	3	✔			
67	ME2423E	Elements of Mechanical Vibration	3	0	0	6	3	✔			
68	ME2424E	Life Cycle Assessment	3	0	0	6	3	✔			
69	ME3421E	Introduction to Finite Element Methods	3	0	0	6	3	✔		✔	
70	ME3422E	Nonlinear Dynamics and Chaos	3	0	0	6	3	✔			
71	ME3423E	Engineering Fracture Mechanics	3	0	0	6	3	✔			
72	ME3424E	Theory of Plasticity	3	0	0	6	3	✔			
73	ME3425E	Vehicle Dynamics	3	0	0	6	3	✔			
74	ME3426E	Introduction to Robotics	3	0	0	6	3	✔		✔	
75	ME3427E	Introduction to Tribology	3	0	0	6	3	✔			
76	ME3428E	Practical Finite Element Analysis	3	0	0	6	3	✔		✔	
77	ME3429E	Control Systems Engineering	3	0	0	6	3	✔		✔	
78	ME3430E	Vibration with Control	3	0	0	6	3	✔			
79	ME3431E	Mechanics of Composite Materials	3	0	0	6	3	✔			

Sl. No.	Course Code	Course Code	L	T	P	O	Credits	Categories			
								PE	EI	DA	HM
80	ME3432E	Vehicle Dynamics and Control	3	0	0	6	3	✓			
81	ME3434E	Design of Mechanical Systems	3	0	0	6	3	✓			
82	ME3435E	Applied Data-Driven Techniques in Engineering	3	0	0	6	3	✓		✓	
83	ME3436E	Product Design	2	0	2	5	3	✓			
84	ME4421E	Experimental Stress Analysis	3	0	0	6	3	✓			
85	ME4422E	Design of Power Transmission Elements	3	0	0	6	3	✓			
86	ME4423E	Mobile Robotics	3	0	0	6	3	✓		✓	
Project											
87	ME4099E	Project-Part-III	0	0	0	18	6				

3. OPEN ELECTIVES (OE)

Courses offered by Other Departments/Schools/Centres or Approved Online Platforms, with a limit on the maximum number of courses from such platforms specified as per BTech Ordinances and Regulations. In addition, PE courses offered by the Parent department shall be included in this category for students of the Parent department.

4. INSTITUTE ELECTIVES (IE)

In case of the Institute Electives, courses in the appropriate categories offered by other departments/schools/centres also can be credited instead of the courses offered by the department of Mechanical Engineering, subject to the approval from the Course Faculty and Faculty Advisor.

a) Entrepreneurship / Innovation Basket (EI):

Courses proposed by the Departments/Schools/Centres and approved by Institute Innovation Council. Total credits required is 3.

b) Digital Automation Technologies (DA):

Courses related to programming / automation tools & techniques / Industry 4.0. Total credits required is 6.

c) Humanities, Social Science, Management (HM):

Courses such as Indian and Foreign languages, Economics, Engineering Management, Financial Management and Design Thinking. Total credits required is 9.

5. ACTIVITY CREDITS (AC)

A minimum of 80 Activity Points are to be acquired for obtaining the 4 Activity Credits required in the curriculum.

Activity points acquired should be a minimum of 20 at the end of S4.
Activity points acquired should be a minimum of 40 at the end of S6.

PROGRAMME STRUCTURE

Semester I

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	MA1003E	Mathematics I	3	1	0	5	3	IC
2.	PH1002E	Mechanics and Waves	3	0	0	6	3	IC
3.	EE1013E	Electrical Engineering	3	0	0	6	3	PC
4.	MS1001E	Professional Communication	3	0	0	6	3	IC
5.	ME1401E	Engineering Mechanics	3	0	0	6	3	PC
6.	ME1001E	Computer Programming and Numerical Methods	2	0	2	5	3	PC
7.	EE1093E	Electrical Engineering Lab	0	0	2	1	1	PC
		Total	**17**	**1**	**4**	**35**	**19**	**--**

Semester II

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	MA1013E	Mathematics II	3	1	0	5	3	IC
2.	ME1011E	Engineering Graphics	2	0	2	5	3	IC
3.	ME1311E	Materials Science	3	0	0	6	3	PC
4.	ME1411E	Solid Mechanics	3	0	0	6	3	PC
5.	ME1212E	Introduction to Fluid Mechanics and Machinery	3	0	0	6	3	PC
6.	ME1213E	Thermodynamics & Heat Transfer	3	0	0	6	3	PC
7.	ME1391E	Mechanical Workshop	0	0	2	1	1	PC
		Total	**17**	**1**	**4**	**35**	**19**	**--**

Semester III

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	MA2003E	Mathematics III	3	1	0	5	3	IC
2.	ME2001E	Professional Ethics	1	0	0	2	1	IC
3.	ME2101E	Fundamentals of Management	3	0	0	6	3	PC
4.	ME2301E	Manufacturing Technology	3	0	0	6	3	PC
5.		DA Elective - 1	3	0	0	6	3	DA
6.		Open Elective - 1	3	0	0	6	3	OE
7.	ME2391E	Production Technology Lab	0	0	3	3	2	PC
8.	ME2091E	Machine Drawing	0	0	3	3	2	PC
		Total	**16**	**1**	**6**	**37**	**20**	**--**

Semester IV

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	MA2013E	Mathematics IV	3	1	0	5	3	IC
2.	ME2313E	Metrology & Computer Aided Inspection	3	0	0	6	3	PC
3.	ME2411E	Design of Machine Elements	3	0	0	6	3	PC
4.	ME2112E	Production Management	3	0	0	6	3	PC
5.		Entrepreneurship / Innovation Elective	3	0	0	6	3	EI
6.		Open Elective - 2	3	0	0	6	3	OE
7.	CE2095E	Strength of Materials Lab	0	0	2	1	1	PC
8.	ME2293E	Fluid Mechanics Lab	0	0	2	1	1	PC
		Minor Course - 1	3	0	0	6	3	MC
Total (Excluding the Minor Course)			**18**	**1**	**4**	**37**	**20**	**--**

Semester V

Sl. No	Course Code	Course Title	L	T	P	O	Credits	Category
1.	ME3303E	Subtractive and Additive Manufacturing Processes	3	0	0	6	3	PC
2.	ME3102E	Industrial Engineering	3	0	0	6	3	PC
3.	ME3103E	Quantitative Techniques for Management	3	0	0	6	3	PC
4.		HM Elective - 1	3	0	0	6	3	HM
5.		DA Elective - 2	3	0	0	6	3	DA
6.		Open Elective - 3	3	0	0	6	3	OE
7.	ME3394E	Machining Science Laboratory	0	0	2	1	1	PC
8.	ME3395E	Metrology & Computer Aided Inspection Lab	0	0	3	3	2	PC
		Minor Course - 2	3	0	0	6	3	MC
Total (Excluding the Minor Course)			**18**	**0**	**6**	**40**	**21**	**--**

Semester VI

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	ME3311E	Computer Integrated Manufacturing	3	0	0	6	3	PC
2.		HM Elective - 2	3	0	0	6	3	HM
3.		Programme Elective - 1	3	0	0	6	3	PE
4.		Open Elective - 4	3	0	0	6	3	OE
5.		Open Elective - 5	3	0	0	6	3	OE
6.	ME3191E	Management Science Laboratory	0	0	3	3	2	PC
7.	ME3396E	Computer Integrated Manufacturing Laboratory	0	0	2	1	1	PC

8.	ME3099E	Project-Part-I	0	0	0	9	3	PC
		Minor Course - 3	3	0	0	6	3	MC
		Total (Excluding the Minor Course)	**15**	**0**	**15**	**43**	**21**	**--**

Semester VII

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.		HM Elective - 3	3	0	0	6	3	HM
2.		Programme Elective - 2	3	0	0	6	3	PE
3.		Open Elective - 6	3	0	0	6	3	OE
4.		Open Elective - 7	3	0	0	6	3	OE
5.		Open Elective - 8	3	0	0	6	3	OE
6.	ME4097E	Summer Internship	0	0	0	*	2	PC
7.	ME4098E	Project-Part-II	0	0	0	9	3	PC
		Minor Course - 4	3	0	0	6	3	MC
		Total (Excluding the Minor Course)	**15**	**0**	**0**	**39**	**20**	**--**

Note: ME4097E Summer Internship (including the academic internship) is to be completed during the vacation after S6, and the evaluation will be done in S7. Working hours will be decided by the organization in which the internship is done.

Semester VIII

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	ME4099E / ME4xxxE	Project Part III / Programme Elective – 3, Programme Elective – 4	0/6	0	0	18/ 12	6	PE
2.	ME4096E	Activity Credits (minimum of 80 points)	--	--	--	--	4	AC
		Total	**0/6**	**0**	**0**	**18/ 12**	**10**	**--**

DETAILED SYLLABUS

CORE COURSES

MA1003E MATHEMATICS I
(Common to CE/ME/PE/MSE branches)

L	T	P	O	C
3	1	0	5	3

Total Lecture sessions: 39

Course Outcomes:

CO1: Find the limits, check for continuity and differentiability of real valued functions of one variable.
CO2: Find the limits, check for continuity and differentiability of real valued functions of two variables.
CO3: Find the maxima and minima of real valued functions of one or two variables.
CO4: Test the consistency of the system of linear equations and then solve it.
CO5: Diagonalise symmetric matrices and use it to find the nature of quadratic forms.

System of linear equations: Gauss elimination method, row echelon form, row space, row rank, existence and uniqueness, homogeneous system, Linear independence and span of row vectors, Linearly independent solutions, rank-nullity relation for homogeneous linear system. Eigenvalues and eigenvectors of a matrix, Cayley-Hamilton theorem, eigenvectors associated with distincteigenvalues, diagonalisation of matrices, symmetric, skew-symmetric and orthogonal matrices and their eigenvalues, orthogonal diagonalisation of symmetric matrices, bilinear and quadratic forms, definiteness of quadratic forms, transformation into principal axes.

Functions of one variable: limit, continuity, differentiability, local maxima and local minima, mean value theorems, Taylor's theorem, indeterminate form, L'hôpital's rule, integration, fundamental theorem of calculus, applications: finding volume and area, improper integrals, Gamma and Beta functions. Parameterised curves in space, arc length, tangent and normal vectors, curvature and torsion.

Functions of several variables: limit, continuity, partial derivatives, partial differentiation of composite functions, directional derivatives, gradient, applications like finding local maxima and local minima of functions of two variables, critical point, saddle point, Taylor's formula for two variables, Hessian, second derivative test, method of Lagrange multipliers, Evaluation of double integral, improper integrals, change of variables, Jacobian, polar coordinates, triple integral, cylindrical and spherical coordinates, applications:mass of a lamina, centre of gravity, moments of inertia.

References:

[1] Anton, H., Bivens, I., and Davis, S., 2015, *Calculus*, 10th ed., John Wiley & Sons, New York.
[2] Thomas, G. B., Weir, M.D., and Hass, J., 2015, *Thomas' Calculus*, 12th ed., India: Pearson Education, New Delhi.
[3] Kreyszig, E., 2015, *Advanced Engineering Mathematics*, 10th ed., John Wiley & Sons, New York.
[4] G. Strang, 2016, *Introduction to Linear Algebra*, Wellesley-Cambridge Press, Wellesley, MA.

PH1002E MECHANICS AND WAVES

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Solve problems in mechanics and oscillations using Newton's equations of motion.
CO2: Apply ideas of calculus of variations and Lagrangian for problems in classical mechanics.
CO3: Apply wave mechanics to describe interference, diffraction and polarization of waves.
CO4: Apply ideas of interference for various engineering problems.

Oscillations
Review of Newtonian Mechanics – Force – Newton's II law and equations of motion – examples – Oscillations – equation of motion – solutions of the equations – damped oscillations – forced oscillations – resonance – coupled oscillations

Lagrangian Mechanics
Constraints – generalized coordinates – degrees of freedom – Virtual Displacement – D'Alembert's Principle – Lagrangian – Variational Principle – Euler-Lagrange equations – examples – cyclic coordinates – conserved physical quantities

Wave Motion
Waves – longitudinal and transverse waves – wave equation – solutions – superposition principle –wave groups, group velocity and dispersion – interference of waves – diffraction – polarization

Light Waves and Interference
Light as a wave – Young's double slit experiment – fringe pattern – visibility – coherence – diffraction – interferometry – Michelson interferometer – Mach-Zehnder interferometer – LASER: working principle, characteristics and applications

References:

[1] D. J. Morin, 2008, *Introduction to Classical Mechanics: With Problems and Solutions*, Cambridge University Press.
[2] D. Kleppner and R. J. Kolenkow, 2017, *An Introduction to Mechanics (1st Edition)*, McGraw Hill.
[3] Spiegel M. R., 2007, *Theoretical Mechanics*, (Schaum Series), McGraw Hill.
[4] D. Halliday, R. Resnick and J. Walker, 2013, *Fundamentals of Physics (10th Edition)*, John Wiley & Sons.
[5] F. L. Pedrotti, L. M. Pedrotti and L. S. Pedrotti, 2017, *Introduction to Optics (3rd Edition)*, Cambridge University Press.

EE1013E ELECTRICAL ENGINEERING

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Acquire knowledge about the analysis of electric and magnetic circuits.
CO2: Acquire knowledge about the electrical measurements and measuring instruments.
CO3: Acquire knowledge about the fundamental principles and classification of electromagnetic machines.
CO4: Acquire knowledge about the major electrical machines such as transformers, dc machines, alternators and induction machines.

Electric and Magnetic Circuits
Node and mesh analysis of simple dc circuits - Thevenins theorem - Norton's theorem - Superposition theorem - star-delta transformation - alternating quantities - sinusoidal emf and current - frequency - average and rms values - representation of sinusoidal quantities - waveforms - phasors - Cartesian, polar and exponential forms - real, reactive and apparent power - power factor - analysis of simple RL, RC and RLC circuits - three phase system - phase sequence - balanced and unbalanced loads - power in three phase system - definition of magnetic quantities - analysis of simple magnetic circuits - Faraday's laws of electromagnetic induction - Lenz's law -,statically and dynamically induced emfs - self and mutual inductances - coefficient of coupling.

Electrical Measurements
Measuring instruments like voltmeters, ammeters, watt meters and energy meters - measurement of high and low resistances using voltmeter-ammeter method - measurement of power in single phase circuits - three voltmeter method - three ammeter method - wattmeter method - measurement of power in three phase circuits - two-wattmeter method - measurement of energy - single-phase energy meter.

Electromagnetic Machines
Fundamental principles - classification - static and rotating machines - transformers - generators - motors - elements of electromagnetic machines - windings - development of emf and torque - rotating magnetic field - introduction to power generation, transmission and distribution.

Major Electrical Machines
Transformers - construction - principle of operation - types - equivalent circuit - phasor diagram - voltage regulation - losses and efficiency - OC and SC tests - load test - applications.

DC Machines - construction - principle of operation - losses and efficiency - types - generators - emf equation - open circuit and external characteristics of shunt generator - motors - speed and torque equations - speed control - load test - performance characteristics of shunt and series motors - applications.

Alternators - construction - principle of operation - types - emf equation - voltage regulation - synchronous generators - synchronous motors - applications.

Induction machines - construction - principle of operation - types - three phase and single phase induction motors - torque vs slip characteristics - equivalent circuit - phasor diagram - losses and efficiency - methods of starting - speed control - load test - performance characteristics of squirrel cage and slip ring induction motors - applications.

References:

[1] Suresh Kumar, K.S., 2009, *Electric Circuits & Networks*, Pearson Education.
[2] Nahvi, M., and Edminister, J. A., 2014, *Electric Circuits* (*Schaum's Outlines)*, 6th ed., McGraw Hill.
[3] Sawhney, A. K., 2015, *A Course in Electrical, Electronic Measurements and Instrumentation*, Dhanpat Rai & Co., India.
[4] Clayton, A. E., and Hancock, N. N., 2003, *Performance and Design of DC Machines*, CBS Publishers and Distributors Pvt. Ltd.
[5] Nagarath, I. J., and Kothari, D. P., 2010, *Electric Machines*, 4th ed., Tata McGraw Hill Education Private Limited, New Delhi.
[6] Say, M. G., 1983, *The Performance and Design of Alternating Current Machines*, CBS Publishers and Distributors Pvt. Ltd.
[7] Toro, V. D., 1988, *Electrical Machines and Power Systems*, Prentice Hall.

MS1001E PROFESSIONAL COMMUNICATION

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions : 39

Course Outcomes:

CO1: Distinguish the role and purpose of communication at the workplace and for academic purposes.
CO2: Decide strategies and modes for effective communication in a dynamic workplace.
CO3: Combine multiple approaches for successful and ethical information exchange.
CO4: Estimate best communication practices to assist productivity and congeniality at the workplace.

Listening and Reading Comprehension
Conversation starters: introductions and small talk - Seek and provide information, clarification, polite enquiries, requests, congratulate people, apologise, give and respond to feedback - Describe graphs, tables, and charts - Words often confused: Lexicon and Meaning - Sense Groups - Listening for specific purposes: Listening to lectures, Summarise academic lectures for note-taking - Appropriate Language to Request and Respond - Public Speaking

Vocabulary and Speaking
Developing professional vocabulary - Basic Sentence Structures from Reading Texts - Concord - Functions of Auxiliary Verbs and Modals - Strategies for Effective Reading - Skimming and Scanning, Determine themes and main ideas, Predicting content using photos, images and titles - Critical Reading: Discussing and Summarising text points - Understanding Text Structures: sequencing, comparing and contrasting, relating cause and effect, problems and problem-solving - Discussing Rhetorical and Cultural Aspects in Texts - Text Appreciation: Drawing inferences, Framing Opinions and Judgments on Reading Text

Effective Writing
Note Making and Summarising: Prepare notes from reading texts, Paraphrasing - Use of Multimedia for Assistive Purposes - Paragraph Writing: cohesive devices to connect sentences in a paragraph - transitional devices - Use Text Structures in Paragraphs: sequencing, comparing and contrasting, relating cause and effect, problems and problem-solving - Avoiding Ambiguity and Cleft Sentences - Applications- Writing Instructions, Descriptions and Explanations - Official Letters of Request and Denial - Official E-mails - Abstract Writing - Digital Resources for Effective Communication

Communication at Workplace
Communication Theory - Process of Communication - Modes of Communication - Verbal and Non-Verbal Communication - Tone in Communication - Formal and Informal Communication at Workplace - Passive, Assertive and Aggressive Styles of Communication - Positive Body Language - Group Discussions - Presentation - Workplace Communication - Active Listening - Giving Feedback - Communication Etiquette - Persuasion - Negotiation - Tone and Voice - Telephone etiquette - Establishing Credibility in Conversations - Digital Communication and Netiquette: Conducting Oneself in Virtual Interactions, Constructive use of Social media - Ethical and Culturally Sensitive Communication: Ethical considerations in professional communication, Addressing diversity, Inclusive Communication Practices

References:
[1] Bhatnagar, N., and Bhatnagar, M., 2010, *Communicative English for engineers and professionals*, Dorling Kindersley.
[2] Foley, M., and Hall, D., 2018, *Longman advanced learners ’grammar: A self-study reference & practice book with answers*, Pearson Education.
[3] Garner, B. A., 2012, *HBR Guide to better business writing: Engage readers, tighten and Brighten, make your case*, Harvard Business Review Press.
[4] Hewings, M., 2013, *Advanced grammar in use: A reference and practice book for Advanced learners of English*, Cambridge University Press.
[5] Ibbotson, M., 2015, *Cambridge English for Engineering*. Cambridge University Press.
[6] Kumar, S., and Lata, P. 2015, *Communication Skills*. Oxford University Press.
[7] Sudarshana, N., and Savitha, C., 2016, *English for Technical Communication*. Cambridge English.

ME1401E ENGINEERING MECHANICS

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Determine the resultants of a force system.
CO2: Solve rigid body statics problems using equations of equilibrium.
CO3: Determine the first and second moments of area for planar surfaces.
CO4: Perform kinematic analysis of particles.
CO5: Solve particle dynamics problems using Newton's laws, energy methods and momentum methods

Equivalent force systems
Introduction: idealizations of mechanics, vector and scalar quantities, equality and equivalence of vectors, laws of mechanics, elements of vector algebra – Important vector quantities: position vector, moment of a force about a point, moment of a force about an axis – couple and couple moment: definition, couple moment as a free vector, moment of a couple about a line – Equivalent force systems: translation of a force to a parallel position, resultant of a force system, simplest resultant of special force systems – distributed force systems.

Rigid body statics
Equations of equilibrium: free-body diagram, free bodies involving interior sections, general equations of equilibrium – problems of equilibrium – static indeterminacy – Friction forces: laws of Coulomb friction, simple contact friction problems.

Properties of surfaces
First moment and centroid of plane area – second moments and product of area for a plane area: transfer theorems, rotation of axes, polar moment of area, principal axes.

Particle kinematics
Introduction – differentiation of a vector with respect to time – velocity and acceleration calculations in rectangular coordinates – velocity and acceleration in terms of path variables and cylindrical coordinates – simple kinematical relations and applications.

Particle dynamics
Newton’s law for rectangular coordinates – rectilinear translation – Newton’s law for cylindrical coordinates – Newton’s law for path variables – general motion of a system of particles – energy methods: introduction, conservative force field, conservation of mechanical energy, alternative form of work-energy equation – energy methods for a system of particles – methods of momentum for particles – Linear impulse and momentum relations for a single particle and system of particles – moment-of-momentum equation for a single particle and system of particles.

References:

[1] Shames, I. H., and Rao, G. K. M., 2005, *Engineering Mechanics – Statics and Dynamics*, 4th ed., Pearson Education India.
[2] Beer, F. P., Johnston Jr., E. R., Cornwell, P. J., Self, B. P., Mazurek, D. F., and Sanghi, S., 2019, *Vector Mechanics for Engineers – Statics and Dynamics.* 12th ed., McGraw Hill.
[3] Meriam, J. L., Kraige, L. G., and Bolton, J. N., 2021, *Engineering Mechanics – Statics and Dynamics*, 9th ed., Wiley.
[4] Hibbeler, R. C., 2017, *Engineering Mechanics – Statics and Dynamics*, 14th ed., Pearson.

ME1001E COMPUTER PROGRAMMING AND NUMERICAL METHODS

L	T	P	O	C
2	0	2	5	3

Total Sessions: 26L + 26P

Course Outcomes:

CO1: Develop simple programs using the basic features of Python programming language.
CO2: Use advanced features of Python to develop efficient programs for solving complex problems.
CO3: Obtain the numerical solutions of various problems using Python programming.

Basics of Python
Setting up Python and managing packages – Jupyter notebook and logical operators – variables and assignment – data structures: string, list, tuple, set, dictionary and arrays – functions: basics, local and global variables, advanced features – branching statements – iterations using loops.

Advanced Concepts
Object oriented programming – representation of numbers – errors and good programming practices – debugging – reading and writing data – visualization and plotting: 2D & 3D plots, maps & movies.

Numerical Methods using Python
Linear algebra: solution of a system of equations, eigenvalues and eigenvectors - least squares regression – interpolation – Taylor series – root finding – numerical differentiation.

References:

[1] Kong, Q., Siauw, T., and Bayen, A. M., 2021, *Python Programming and Numerical Methods: A Guide for Engineers and Scientists*, Academic Press.
[2] Kiusalaas, J., 2013, *Numerical Methods in Engineering with Python 3*, Cambridge University Press.
[3] Matthes, E., 2023, *Python Crash Course: A Hands-On, Project-Based Introduction to Programming*, 3rd ed., No Starch Press.
[4] Chapra, S. C., and Canale, R. P., 2021, *Numerical Methods for Engineers*, 8th ed., McGraw Hill.

EE1093E ELECTRICAL ENGINEERING LAB

Total Practical Sessions: 26

L	T	P	O	C
0	0	2	1	1

Course Outcomes:

CO1: Acquire hands on experience of measuring various electrical quantities.

CO2: Acquire hands on experience of conducting various tests on dc machines.

CO3: Acquire hands on experience of conducting various tests on transformers.

CO4: Acquire hands on experience of conducting tests on induction machines.

List of Experiments:

1. Determination of V-I characteristic of a linear resistor and measurement of high and low resistances using voltmeter-ammeter method.
2. Measurement of power in a single phase circuit using a wattmeter.
3. Measurement of power in a 3-phase circuit using two-wattmeter method.
4. Measurement of energy using a single-phase energy meter and verification by power measurement.
5. Determination of the open circuit and external characteristics of a dc shunt generator.
6. Load test on a dc shunt motor and the determination of its performance characteristics.
7. Load test on a dc series motor and the determination of its performance characteristics.
8. Determination of efficiency and regulation of a single phase transformer by conducting (i) OC and SC tests and (ii) load test.
9. Load test on a squirrel cage induction motor and the determination of its performance characteristics.
10. Load test on a slip ring induction motor and the determination of its performance characteristics.

References:

[1] Sawhney, A. K, 2015, *A Course in Electrical and Electronic Measurements and Instrumentation*, Dhanpat Rai & Co.

[2] Nagarath, I. J., and Kothari, D. P., 2010, *Electric Machines*, 4th ed., Tata McGraw Hill Education Private Limited.

[3] Say, M. G., 1983, *The Performance and Design of Alternating Current Machines*, CBS Publishers and Distributors Pvt. Ltd.

[4] Toro, V. D., 1988, *Electrical Machines and Power Systems*, Prentice Hall.

MA1013E MATHEMATICS II
(Common to CE/ME/PE/MSE branches)

L	T	P	O	C
3	1	0	5	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Find the parametric representation of curves and surfaces in space and evaluate integrals over curvesand surfaces
CO2: Understand the convergence of sequences and series and various methods of testing for convergence.
CO3: Solve linear ODEs with constant coefficients.
CO4: Formulate some engineering problems as ODEs and hence solve such problems.
CO5: Use Laplace transform and its properties to solve differential equations and integral equations.

Vector field: divergence, curl, identities involving divergence and curl, scalar potential. Line integral, independence of path, irrotational and solenoidal vector fields, Green's theorem for plane, parameterized surface, surface area and surface integral, flux, Gauss' divergence theorem, Stokes' theorem.

Numerical sequences, Cauchy sequence, convergence of sequences, series, convergence of series, tests for convergence, absolute convergence. Sequence of functions, power series, radius of convergence, Taylor series, periodic functions and Fourier series expansions, half-range expansions.

Existence and uniqueness of solution of first order ordinary differential equations (ODE)s, methods of solutionsof first order ODE, linear ODE, linear homogeneous second order ODEs with constant coefficients, fundamental system of solutions, Wronskian, linear independence of solutions, method of undetermined coefficients, solution by variation of parameters, Euler-Cauchy differential equations, applications of ODEs.

Laplace transform, sufficient condition for existence, inverse Laplace transform, Dirac delta function, transforms of derivatives and integrals, shifting theorems, convolution, differentiation and integration of transform, solution of differential equations and integral equations using Laplace transform.

References:
[1] Kreyszig, E., 2015, *Advanced Engineering Mathematics*, 10th ed., India: Wiley.
[2] Anton, H., Bivens, I., and Davis, S., 2015, *Calculus*, 10th ed., John Wiley & Sons.
[3] Arnold, V.I., 2006, *Ordinary Differential Equations*, Springer.
[4] Dyke, P., 2014, *An Introduction to Laplace Transforms and Fourier Series*, Springer.

ME1011E ENGINEERING GRAPHICS

L	T	P	O	C
2	0	2	5	3

Total Sessions: 26L + 26P

Course Outcomes:

CO1: Use Indian Standard Code of Practice in Engineering Drawing**.**
CO2: Represent engineering objects by orthographic views.
CO3: Convert orthographic views of an engineering object into the isometric view.
CO4: Use software for drawing and visualizing engineering objects.

Introduction to Engineering Graphics and Scales
Drawing instruments and their uses, lines, lettering and dimensioning, Engineering drawing using software - Geometrical construction – Importance of Scales in engineering graphics.

Orthographic Projections
First and third angle projections (using software) - Orthographic projection of points on principal, profile, and auxiliary planes - Orthographic projection of straight line in simple and oblique positions - Application of orthographic projection of line - Orthographic projection of planes in simple and oblique position on principal and profile planes - Orthographic projection of lines and planes on auxiliary planes - Orthographic projection of solids in simple and oblique positions on principal and profile planes - Orthographic projections of solids in oblique position using auxiliary plane method

Section, Development and Isometric view
Orthographic projection of solids in section - Development of surfaces of solids - Method of isometric projection (Using software).

References:

[1] Bhatt, N. D., 2023, *Engineering Drawing*, 54th ed., Charotar Publishing House.
[2] Agrawal, B., and Agrawal, C. M., 2019, *Engineering Drawing*, 3rd ed., McGraw Hill Education.
[3] Venugopal, K., and Raja, P.V., 2022, *Engineering Drawing + Auto CAD*, 6th ed., New Age Intl. Pvt Ltd.

ME1311E MATERIALS SCIENCE

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Correlate the structure with properties of engineering materials
CO2: Identify the techniques for material characterisation.
CO3: Relate the phase evolution in materials with the processing conditions.
CO4: Describe the deformation of metals and various thermo-mechanical treatments of alloys.
CO5: Identify the properties and applications of major metallic and non-metallic engineering materials.

Engineering materials: classification, requirements, properties and selection of engineering materials – structure of solids: crystalline and non-crystalline materials, crystal structures, metallic, ionic and covalent solids – solid solutions: interstitial, substitutional ordered and disordered solid solutions – Hume-Rothery rules – crystal imperfections – edge and screw dislocations – Burgers vector – interaction between dislocations – techniques for materials characterisation: optical microscopy, electron microscopy (SEM and TEM), energy and wavelength-dispersive spectroscopy, X-ray diffraction – grain size and grain size measurement – ASTM grain size number.

Phase diagrams: evolution of phase diagrams, phase rule, equilibrium diagrams of binary alloys, isomorphous (Cu-Ni), eutectic (Pb-Sn), detailed study of Fe-C systems, tie-line and lever rule – phase transformations: solidification of metals, homogeneous and heterogeneous nucleation,supercooling, critical radius – microstructural changes during solidification: grain growth, dendritic pattern, equiaxed and columnar grains – solidification and structure of castings: coring, homogenization – transformations in steel – T-T-T diagram – diffusion in solids: mechanisms of diffusion, Fick's laws of diffusion, applications.

Deformation of metals: cold working, hot working – elastic and plastic deformations: mechanisms of plastic deformation, deformation by slip, slip systems, slip planes and slip directions, multiplication of dislocations: Frank-reed source – deformation by twinning – critical resolved shear stress – strengthening mechanisms: work hardening, dispersion hardening, precipitation hardening, solid solution strengthening, grain refinement – creep: mechanism, creep resistant materials – fatigue failure – heat treatment of steels: stress relieving, annealing, normalising, hardening, tempering – annealing of a cold worked article: recovery, recrystallisation and grain growth – hardenability – surface hardening techniques.

Ferrous alloys: steels, alloy steels, tool steels, stainless steels – effect of alloying elements on properties of steels – cast irons: classification, structure, properties, applications – non-ferrous alloys: Major alloys of Al, Cu, Mg, Zn and Ti and their applications – non-metallic materials: plastics, elastomers, composites, ceramics and glasses – advanced engineering materials: smart materials, shape memory alloys, functionally graded materials, super alloys and high-entropy alloys – introduction to functional materials: electrochemical energy storage: battery materials, fuel cells, supercapacitors – photovoltaic cells – dielectric materials – thermoelectrics – biomaterials – nanomaterials – materials for hydrogen production and storage.

References:

[1] Callister, W. D., and Rethwisch, D. G., 2018, *Materials Science and Engineering*, John Wiley.
[2] Smith, W. F., Hashemi, J., and Presuel-Moreno, F., 2022, *Foundations of Materials Science and Engineering*, McGraw-Hill.
[3] Raghavan, V., 2013, *Material Science and Engineering: A First Course,* PHI Learning.
[4] Abbaschian, R., and Reed-Hill, R. E., 2009, *Physical Metallurgy Principles,* Affiliated East-West Press.
[5] Porter, D. A., Easterling, K. E., and Sherif, M. Y., 2009, *Phase Transformations in Metals and Alloys*, Taylor & Francis.
[6] Meyers, M. A., and Chawla, K. K., 2009, *Mechanical Behavior of Materials,* Cambridge University Press.
[7] Huggins, R. A., 2016, *Energy Storage Fundamentals, Materials and Applications*, Springer.
[8] Shackelford, J. F., 2021, *Introduction to Materials Science for Engineers,* Pearson Education.
[9] Kasap, S. O., 2005, *Principles of Electronic Materials and Devices*, McGraw-Hill.
[10] Askeland, D. R., and Wright, W. J., 2021, *The Science and Engineering of Materials,* Cengage Learning.

ME1411E SOLID MECHANICS

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Perform structural analysis of components with uniform stress distribution.
CO2: Design the shafts carrying torsional loads.
CO3: Perform stress analysis of beams under different loading conditions.
CO4: Carry out the deflection analysis of beams.
CO5: Use transformation of stresses and strains to analyse components with compound loading.
CO6: Analyse columns carrying axial compressive loads.

Components with Uniform Stress Distribution
Introduction: general concepts, definition of stress, stress tensor – stress analysis of axially loaded members – shear stresses and direct shear problems – strength-based design of members (deterministic method) − axial strains and deformations in bars – Hooke’s Law – Poisson's ratio – thermal strain – Saint Venant's principle – elastic strain energy – statically indeterminate systems – strain tensor – constitutive relationships for shear – generalized Hooke's law for isotropic materials – relationships between elastic constants – analysis of thin-walled pressure vessels.

Design of Shafts
Torsion of circular elastic bars: stress distribution and angle of twist – statically indeterminate problems – torsion of inelastic circular bars – strain energy in torsion – torsion of thin-walled tubes.

Stress Analysis of Beams
Axial force, shear force and bending moment diagrams: sign conventions, axial force, shear force and bending moments by direct approach and integration – bending stresses in beams: elastic flexure formula, bending stresses – elastic strain energy in bending – inelastic bending – elastic bending with axial loads – shear stresses in beams: shear flow and shear stress formula.

Deflection of Beams
Deflection of beams: direct integration method, superposition techniques, moment-area method – elementary treatment of statically indeterminate beams.

Transformation of Stress and Strain
Transformation of stresses and strains (two-dimensional case only): equations of transformation, principal stresses – Mohr's circles of stress and strain – strain gauge rosettes – compound stresses: superposition and its limitations, eccentrically loaded members.

Theory of Columns
Buckling theory – Euler's formula – effect of end conditions – eccentric loads and secant formula.

References:
[1] Popov, E. P., 2015, *Engineering Mechanics of Solids*, 2nd ed., Pearson Education.
[2] Beer, F. P., Johnston, E. R., DeWolf, J. T., Mazurek, D. F., and Sanghi, S., 2020, *Mechanics of Materials*, 8th ed., McGraw Hill Education India.
[3] Timoshenko, S. P., and Young, D. H., 2003, *Elements of Strength of Materials*. East West.
[4] Shames, I. H., and Pitarresi, J. M., 2015, *Introduction to Solid Mechanics*, 3rd ed., Pearson.
[5] Crandall, S. H., Dahl, N. C., Lardner, T. J., and Sivakumar, M. S., 2017, *An Introduction to Mechanics of Solids*, 3rd ed., Tata McGraw-Hill.
[6] Timoshenko, S. P., and Goodier, J. N., 1970, *Theory of Elasticity*. McGraw Hill International.
[7] Sadd, M. H., 2014, *Elasticity: Theory, Applications and Numerics*, 3rd ed., Academic Press.

ME1212E INTRODUCTION TO FLUID MECHANICS AND MACHINERY

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Understand fundamental concepts in fluid mechanics.
CO2: Apply principles of mass, momentum and energy conservation to fluid-flows.
CO3: Perform dimensional analysis, model and similitude.
CO4: Acquire knowledge of constructional details regarding hydraulic pumps and turbines.
CO5: Evaluate the performance, and select hydraulic pumps and turbines for various applications

Fluid properties and fluid statics
Fluid definition, continuum hypothesis and fluid properties- mass density, specific weight, specific volume, specific gravity, viscosity, compressibility, vapor pressure, surface tension and capillarity, types of fluids – Fluid statics: Fundamental equation, pressure measurement, forces on submerged bodies, buoyancy and stability.

Fluid flow equations, analysis and applications

Classification of flows: steady, uniform, incompressible, ideal, laminar and turbulent flows – Basic physical laws applied to a fluid flow; equation of continuity for one dimensional steady flow, momentum and energy equations – Euler's equation, Bernoulli's equation and Irrotational flow – Applications: Venturimeter, orificemeter, mouthpieces and Pitot tube.

Concepts of boundary layer, pipe flows, and dimensional analysis

Boundary layer concepts: Importance, flow separation and control — Laminar Pipe flow; Hagen Poiseuille flow – Hydraulic and energy gradient – Fanning, and Darcy-Weisbach equations –Moody's chart- commercial pipes- minor losses — Flow through pipes in series and parallel – Dimensional analysis: Importance of dimensional analysis, methods, Similitude: types of similitude — Dimensionless parameters: application of dimensionless parameters — Model analysis.

Hydraulic turbines

Classification of turbines — heads and efficiencies — velocity triangles. Axial, radial and mixed flow turbines. Pelton wheel, Francis turbine and Kaplan turbines- working principles — work done by water on the runner — draft tube. Specific speed — unit quantities — performance curves— governing of turbines, cavitation.

Hydraulic Pumps and systems

Impact of jets — Euler's equation — Theory of rotodynamic machines — efficiencies– velocity components at entry and exit of the rotor: velocity triangles — Centrifugal pumps– working principle — work done by the impeller — performance curves — Reciprocating pump- working principle — Rotary pumps –classification, Hydraulic systems: Lift, press, Ram, accumulators, fluid couplings, torques convertors.

References:

[1] Fox, R. W., McDonald, A. T., Pritchard, P. J., and Mitchell, J. W., 2018, *Fluid Mechanics*, Wiley publications.
[2] Cengel, Y. A., and John, M.C., 2019, *Fluid Mechanics Fundamental and Applications*, McGraw Hill Series.
[3] White, F.M., and Xue, H., 2022, *Fluid Mechanics*, McGraw Hill.
[4] Som, S. K., Biswas, G., and Chakraborty, S., 2017, *Fluid Mechanics and Fluid Machines*, McGraw Hill.
[5] Gupta, V., and Gupta, S. K., 2015, *Fluid Mechanics and its Applications*, New Age International Private Limited.
[6] Shames, I. H., 2013, *Mechanics of Fluids*, McGraw Hill Education.
[7] Kundu, P. K., Cohen, I. M., Dowling, and D. R., 2012, *Fluid Mechanics*, Elsevier.
[8] Munson, B. R., Okiishi, T. H., Huebsch, W. W., and Rothmayer, A.P., 2015, *Fluid Mechanics*, Wiley.
[9] D. G. Shepherd, 1956, *Principles of Turbo machinery*, Macmillan Compan,.
[10] Lal, J., 1975, *Hydraulic Machines*, Metropolitan book Co.
[11] Streeter, V., Wylie, E. B., and Bedford, K.W., 2017, *Fluid Mechanics*, McGraw Hill.
[12] Lal, J., 1975, *Fluid mechanics and Hydraulics*. Metropolitan.

ME1213E THERMODYNAMICS AND HEAT TRANSFER

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Evaluate energy transfers and efficiencies of thermo-mechanical systems.
CO2: Perform second law analysis of thermo-mechanical systems.
CO3: Evaluate rates of heat transfer by conduction, convection and radiation.
CO4: Perform overall design and performance calculations of heat exchangers.

Basic Concepts and First Law
Thermodynamic system – Properties – State and equilibrium – Processes and cycles – Forms of energy – Energy transfer- Zeroth law of thermodynamics – Temperature – First law of thermodynamics – Energy balance for closed system – Energy balance for steady-flow systems-Properties of pure substances – Phase change processes – Property tables – Ideal gas equation of state

Second Law
Second law of thermodynamics – Thermal energy reservoirs – Heat engines – Kelvin-Planck statement – Refrigerators and heat pumps – Clausius statement – Reversible and irreversible processes –Carnot and reversed Carnot cycles – Entropy – Increase of entropy principle – T-ds relations, Entropy change of pure substances.

Heat Conduction
Modes of heat transfer – Differential equations of heat conduction – Initial and boundary conditions – One dimensional steady state heat conduction – Critical radius of insulation – Heat transfer from finned surfaces – Transient heat conduction – Lumped parameter system.

Convective Heat Transfer
Differential and integral Formulations-Differential formulation of forced convection – Solution for forced convection over a flat plate – Forced convection in laminar tube flow with uniform wall heat flux condition – Correlations for forced convection.

Radiation Heat Transfer
Thermal radiation – Black body radiation – Radiation properties – Laws of thermal radiation – View factor – Radiation energy exchange between black, diffuse, and gray surfaces – Electrical analogy.

Heat Exchangers
Types of heat exchangers – Overall heat transfer coefficient – Rating and sizing - LMTD method – Effectiveness-NTU method.

References:

[1] Cengel, Y. A., and Boles, M. A., 2017, *Thermodynamics: An Engineering Approach*, 8th ed., McGraw Hill.
[2] Borgnakke, C., and Sonntag, R. E., 2020, *Fundamentals of Thermodynamics*, 10th ed., John Wiley & Sons.
[3] Moran, M. J., and Shapiro, H. N., 2018, *Fundamentals of Engineering Thermodynamics*, 8th ed., John Wiley & Sons.
[4] Cengel, Y. A., and Ghajar, A. J., 2020, *Heat and Mass Transfer: Fundamentals and Applications*, 6th ed., McGraw Hill Education.
[5] Bergman, T. L., Lavine, A. S., Incropera F. P., and De Witt, D. P., 2017, *Fundamentals of Heat and Mass Transfer*, 8th ed., John Wiley & Sons.
[6] Holman, J. P., 2010, *Heat Transfer*, 10th ed., McGraw Hill.

ME1391E MECHANICAL WORKSHOP

Total Practical Sessions: 26

L	T	P	O	C
0	0	2	1	1

Course Outcomes:

CO1: Identify and use various tools used in a machine shop and perform the basic lathe operations such as turning, facing, chamfering, knurling etc.
CO2: Identify and use various tools used in fitting and welding and perform operations such as chipping, filing, cutting, drilling, etc., and prepare multiple joints and welds
CO3: Identify and use various tools in carpentry & sheet metal work and perform multiple operations for the preparation of joints using wood and fabrication using sheet metal
CO4: Identify and use various tools in smithy & foundry and to practice forging, moulding and casting

The course is intended to expose the student to various manufacturing processes through hands on training in different sections of Central Workshop. During the course, the student learns the properties and selection of different materials and acquires the skill in using various tools and measuring devices.

1. **Machine Shop:** Study of the basic lathe operations. Turning, step turning, facing, chamfering, thread cutting, grooving, knurling etc.
2. **Fitting:** Study of tools- chipping, filing, cutting, drilling, tapping, about male and female joints, stepped joints. Cutting and edge preparation for lap and butt joints.
3. **Welding:** Study of arc and gas welding, accessories, joint preparation. Welding of lap and butt joints, Single V and Double V.
4. **Carpentry:** Study of tools and joints – planing, chiseling, marking and sawing practice, one typical joint- Tee halving/cross halving/Mortise and Tenon/ Dovetail.
5. **Sheet Metal:** Study of tools, selection of different gauge sheets, types of joints. Fabrication of a tray or a funnel.
6. **Smithy:** Study of tools. Forging of square or hexagonal prism/chisel/bolt.
7. **Foundry:** Study of tools, sand preparation. Moulding practice using the given pattern and demonstration on casting.

References:

[1] Chapman, W. A. J, 2007, *Workshop Technology - Parts 1 & 2*, 4th ed., New Delhi, CBS Publishers & Distributors Pvt. Ltd.
[2] O'Bren, A. (Editor), 2001, *Welding Handbook*. 9th ed., American Welding Society.
[3] Anderson, J., 2002, *Shop Theory*, Tata McGraw Hill.
[4] Douglass, J. H., 1995, *Wood Working with Machines*, McKnight & McKnight Pub. Co.
[5] Tuplin, W. A., 1996, *Modern Engineering Workshop Practice*, Odhams Press.
[6] Jain, P. L., 2009, *Principles of Foundry Technology*, 5th ed., Tata McGraw Hill.

MA2003E MATHEMATICS III

Total Lecture Sessions: 39

L	T	P	O	C
3	1	0	5	3

Course Outcomes:
CO1: Check for analyticity of complex functions and find conjugates of given harmonic functions.
CO2: Understand the concept of Fourier transforms and its applications in signal analysis.
CO3: Find series solution of second order linear equations with variable coefficients.
CO4: Model and solve PDEs using analytic methods.

Complex Analysis
Complex functions: derivative, analytic function, Cauchy-Riemann equations, harmonic functions – geometry of analytic functions: conformal mapping, linear fractional transformations, transformation by other elementary functions.

Fourier Integrals
Fourier integrals – properties and applications of Fourier transforms – Fourier cosine and sine transforms – finite Fourier transforms – convolution theorem.

Series solution of second order linear equations with variable coefficients
Ordinary point – power series method – Legendre equation – regular singular point – Frobenius method – Bessel equation.

Partial Differential Equations
Basic concepts – Cauchy's problem for first order equations - quasilinear and nonlinear PDEs of first order – Charpit's method – classification of second order partial differential equations, modelling: vibrating string, wave equation – separation of variables – use of Fourier series – D'Alembert's solution of the wave equation – heat equation: solution by Fourier series – heat equation: solution by Fourier integrals and transforms – Laplace equation – solution of PDEs by Laplace transforms.

References:
[1] Ponnusamy, S., Silverman, H., 2006, Complex *Variables with Applications*, Birkhäuser Boston.
[2] Ronald N Bracewell, 1986, *The Fourier Transform and its Applications*, 2nd ed., McGraw Hill.
[3] G. F. Simmons, 2017, *Differential Equations with Applications and Historical Notes*, 2nd ed., McGraw Hill.
[4] D. Greenspan, 2000, *Introduction to Partial Differential Equations*, 1st ed., Dover Publications
[5] E. Kreyszig, 2012, *Advanced Engineering Mathematics*, 9th ed., John Wiley and Sons.

ME2001E PROFESSIONAL ETHICS

L	T	P	O	C
1	0	0	2	1

Total Lecture Sessions: 13

Course Outcomes:

CO1: Develop a clear understanding of human values and use it as basis for all the activities.
CO2: Understand and follow the ethical aspects of engineering profession.
CO3: Align with the Code of Ethics prescribed by ASME in all professional activities.
CO4: Assimilate the elements of academic integrity and applicable Honour Codes, and adopt them in all relevant activities.

Human Values
Morals, values and ethics – integrity – work ethic – service learning – civic virtue – sharing – honesty – courage – valuing time – cooperation – commitment – empathy – self-confidence – character.

Ethics in Professional Practice
Ethics in professional context – ethical basis of engineering activities – ethical responsibilities to consumers and customers – safety and risk – ethics in management of intellectual property – environmental matters and sustainability.

Code of Ethics and Academic Integrity
ASME Code of Ethics: definition of ethics, fundamental principles, fundamental cannons – elements of Academic Integrity: honesty, trust, fairness, respect, responsibility – plagiarism as a violation of academic integrity – Honour Codes: specifying the expected ethical standards from the stakeholders of an organization.

References:

[1] A.F. Bainbridge, 2021, *Ethics for Engineers: A Brief Introduction*, CRC Press
[2] R.S. Naagarazan, 2022, *A Textbook on Professional Ethics and Human Values*, 3^{rd} ed., New Age International Pvt. Ltd.
[3] E.G. Seebauer and R.L. Barry, 2008, *Fundamentals of Ethics for Scientists and Engineers,* Oxford University Press.
[4] ASME Code of Ethics
[5] Tracey Bretag (Ed.), 2016, *Handbook of Academic Integrity*, Springer.

ME2101E FUNDAMENTALS OF MANAGEMENT

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Explain management, organization and the managerial skills.
CO2: Illustrate the functions of management.
CO3: Explain the functional areas of management and make business plans
CO4: Solve analytical models for managerial decisions and devise suitable wage incentive plans

Introduction to management: evolution of management; managerial skills and roles, functions of management-planning, organizing: organizational structures; directing; motivation; communication, controlling, leadership

Functional areas of management: Operations management, Human resource management: Marketing management: Financial management. entrepreneurship, business plans, corporate social responsibility, patents and Intellectual property rights.

Decision making: process, types, characteristics, principle of limiting factor, decision making under certainty, uncertainty, risk, Expected Monetary Value (EMV), Expected Opportunity Loss (EOL), Expected value of perfect Information (EVPI), decision trees, models of decision making. Break even analysis

Network Techniques for project management: critical path method; Programme Evaluation and Review Technique (PERT).

References:

[1] Koontz, H., and Weihrich, H., 2020, *Essentials of Management: An International Perspective*, 11th ed., McGraw Hill.
[2] Hicks, 2007, *Management: Concepts and Applications*, Cengage Learning.
[3] Panneer Selvam, R., 2012, *Production and Operations Management*, 3rd ed., PHI Learning.
[4] Kotler, P., Keller, K. L., Koshy, A., and Jha, M., 2012, *Marketing Management: A South Asian Perspective*, 14th ed., Pearson.
[5] Khan, M.Y., and Jain, P.K., 2008, *Financial Management*, Tata-Mcgraw Hill.

ME2301E MANUFACTURING TECHNOLOGY

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Identify suitable manufacturing process for a given product based on its functional requirement.
CO2: Apply fundamental knowledge in the analysis of casting, forming, joining and powder metallurgy processes.
CO3: Analyze the process characteristics and the evolution of material properties in casting, forming joining powder metallurgy processes.
CO4: Estimate energy requirement and select process parameters for casting, forming joining powder metallurgy and polymer processes.

Introduction to Manufacturing Processes, Fundamental approaches in Manufacturing, Materials and Manufacturing processes, classification, selection, applications of manufacturing processes, Effects of manufacturing processes on mechanical properties.

Casting: Types of casting processes and applications; Sand casting: patterns – types, materials and allowances; molds and cores–materials, making, and testing; design of gating system and riser; casting techniques of cast iron, steels, and nonferrous metals and alloys; analysis of solidification and microstructure development; Other casting techniques: Pressure die casting, Centrifugal casting, Investment casting, Shell mold casting; Casting defects and their inspection by non-destructive testing

Metal joining: classification; welding heat sources; fusion and non-fusion welding processes; gas welding; electric arc welding; arc welding machines; physics of welding arc; arc production; arc characteristics; metal transfer; arc blow; welding electrode; consumable and non-consumable arc welding, SMAW; GTAW; GMAW; SAW; AHW; PAW; resistance welding; electro slag welding; thermit welding; ultrasonic welding; electron beam welding; laser beam welding; solid state welding; welding metallurgy: Heat Affected Zone; weldability of ferrous and non-ferrous metals; design of weldments; joint design; residual stresses and distortion; defects in welding; testing of welded joints; brazing and soldering.

Metal Forming: Fundamental concepts of plastic deformation (stress-strain diagram, yield criteria) − hot and cold working processes − Principle, process and equipment for rolling, forging, drawing, extrusion, sheet metal forming − Advanced forming & near net shaped processing technologies − Load estimation for bulk (forging, rolling, extrusion, drawing) and sheet (shearing, deep drawing, bending) metal forming processes.

Powder metallurgy: Introduction to powder metallurgy, Applications, powder fabrication methods, metallic and ceramic powders, microstructural control, powder characterization, powder treatment: mixing granulation, degassing, coating; Powder compaction and sintering, Secondary treatments, cold and hot isostatic pressing. Processing of polymers – injection moulding, blow moulding, extrusion, compression moulding, thermoforming; Processing of polymer matrix composites – moulding.

References:

[1] Ghosh, A., and Mallik, A.K., 2010, *Manufacturing Science*, Affiliated East-West Press Pvt. Ltd.
[2] Rao, P. N., 2019, *Manufacturing Technology Vol. I: Foundry, Forming and Welding*, McGraw Hill.
[3] Kalpakjian. S., and Schmid, S.R., 2020, Manufacturing Engineering and Technology, Pearson.
[4] Heine, R., Loper, C. and Rosenthal, P., 2004, *Principles of Metal Casting*. Tata McGraw Hill.
[5] Little, R., 2004, *Welding and welding Technology*. Tata McGraw Hill.
[6] Hoffman, O. and Sachs, G., 2012, *Introduction to Theory of Plasticity for Engineers*. Literary Licensing.
[7] Flemings, M. C., 1974, *Solidification Processes,* McGraw Hill, American Welding Society, Welding Hand Book.
[8] Doyle, L. E., 1984, *Manufacturing Processes and Materials for Engineers*, Prentice Hall of India.
[9] Taylor, H. F., Flemings, M. C. and Wulff, J., 1959, *Foundry Engineering,* John Wiley & Sons.
[10] Olson, D.L., Siewert, T.A., Liu, S., Edwards, G.R., (eds.)*, 1993, ASM HandBook – Vol. 6. Welding, Brazing and Soldering,* ASM International.
[11] German, R. M., 1994, *Powder Metallurgy Science,* Metal Powder Industries Federation.
[12] Upadhyaya, A., and Upadhyaya, G. S., 2011, *Powder Metallurgy: Science, Technology and Materials*, CRC Press.

ME2391E PRODUCTION TECHNOLOGY LAB

L	T	P	O	C
0	0	3	3	2

Total Practical Sessions: 39

Course Outcomes:

CO1: Apply the knowledge of machine tools and materials to select a suitable machining process for a given component.
CO2: Analyse the influence of machining parameters on the material characteristics.
CO3: Develop parts employing subtractive or additive manufacturing techniques.
CO4: Select the proper material characterisation technique to understand the changes in the microstructure after the manufacturing process.

Machine tools and machining processes – classification - specifications of machine tools: general features, parts and functions - cutting tool materials and types - cutting variables - selection of speeds, feeds and depth of cut - use of cutting fluids - work holding methods and devices - tolerance and surface finish - machining operations on lathe, milling machine, grinding machine, EDM, etc. - part programming and operation of CNC machines - part modelling, tessellation and 3D printing of components – Perform the welding operation and understand the associated microstructural changes in the HAZ generated.

List of suggested exercises:

1. Lathe operations: step turning, taper turning, thread cutting, knurling, drilling, cutting force measurement using lathe tool dynamometer.
2. Gear cutting: Spur gear/helical gear cutting.
3. Shaping operation: Rectangular groove cutting.
4. Grinding: Study of the surface and centreless grinding parameters on the surface roughness.
5. CNC manual part programming and execution in turning and milling machines.
6. Study on EDM/wire-EDM and advanced material characterisation techniques such as Scanning Electron microscope, X-ray diffractometer, and nano indenter.
7. Additive manufacturing/3D printing - Modelling of a 3D part using Solidworks/CATIA and tessellation of surfaces using software and printing in the machine.
8. Study the microstructural evaluation in the HAZ and determination of hardness after Metal Arc Welding (MAW) operation.

References:

[1] Chapman, W. A. J., 2019, *Workshop Technology Vol II*, Routledge.
[2] Knight, W., Boothroyd, G., 2005, *Fundamentals of Metal Machining and Machine Tools*. McGraw Hill, CRC Press.
[3] Chowdhary, H., Roy, N., 2016, *Elements of Workshop Technology - Volume II - Machine Tools*, Media Promoters and Publishing.
[4] HMT, 2004, *Production Technology*, Tata McGraw Hill.
[5] Olaf D., Axel N., Damien M., 2019, *A Practical Guide to Design for Additive Manufacturing*, Springer Nature.
[6] Rao, P. N., 2019, *Manufacturing Technology Vol. I: Foundry, Forming and Welding*, McGraw Hill Education.

ME2091E MACHINE DRAWING

Pre-requisites: Knowledge of Engineering Graphics

L	T	P	O	C
0	0	3	3	2

Total Practical Sessions: 39

Course Outcomes:
CO1: Draw mechanical engineering components adopting the Indian Standard Code of practice.
CO2: Create assembly and production drawings of mechanical engineering systems.
CO3: Read drawings and understand mechanical engineering systems.
CO4: Perform computer aided drafting of mechanical engineering components and systems.

Drawing Sheets:
1. Conversion of orthographic projections in to pictorial view for the complex machine parts
2. Drawing of complex parts with sectional views
3. Screw threads and screwed fasteners
4. Simple assemblies I: couplings and keys / shaft joints / pipe joints
5. Simple assemblies II: engine components / bearings
6. Complex Assembly drawings: machine vice / lever safety valve / lathe tailstock / water pump / crane hook
7. Production drawing I: conventions of geometric dimensioning and tolerancing (GD&T)
8. Production drawing II: Exercise on reading, interpreting and developing production drawings

CAD Exercises:
1. Modeling of 3D parts from orthographic views
2. Assembly of parts and motion simulation of mechanical systems
3. Preparation of drawings from CAD models
4. Complicated assemblies and creation of assembly drawings
5. Development of production drawings using CAD software

References:
[1] Bhatt, N. D., Panchal,V. M., and Ingle, P. R., 2016. *Machine Drawing,* 50th ed. Charotar Publishing House.
[2] Narayana, K. L., Kannaiah, P., and Reddy, K.V., 2009, *Machine Drawing,* 3rd ed. New Age.
[3] John, K. C., and Varghese, P. I, 2009, *Machine Drawing.* PHI Learning Private Limited.
[4] Gill, P. S., 2013, *A Textbook of Machine Drawing,* 18th ed. S. K. Kataria & Sons.
[5] Sidheswar, N., Kannaiah, P., and Sastry, V. V. S., 2007, *Machine Drawing.* Tata McGraw-Hill.
[6] Singh, A., *Machine Drawing: Includes AutoCAD*, 2010, 2nd ed. Tata McGraw-Hill.
[7] BIS Standards: IS919, IS2102 and IS8000, Bureau of Indian Standards.

MA2013E MATHEMATICS IV

L	T	P	O	C
3	1	0	5	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Apply the basics of probability theory in solving real life problems.
CO2: Identify the distribution and transformation of random variables.
CO3: Use techniques of statistical inference and its applications.
CO4: Apply regression and correlation for analysing real life problems.

Probability Distributions
Random variables – expectation of a function of a random variable – mean, variance and moment generating function of a probability distribution – Chebyshev's theorem – binomial distribution – Poisson distribution - geometric distribution – hyper-geometric distribution – normal distribution – uniform distribution – gamma distribution – beta distribution – Weibull distribution.
Transformation of a random variable, probability distribution of a function of a random variable, jointly distributed random variables, marginal and conditional distributions, bi-variate normal distribution, joint probability distribution of functions of random variables**.**

Statistical Inference
Population and sample – collection and presentation of data – sample size determination – experimental design - the sampling distribution of the mean (σ known and σ unknown) – sampling distribution of the variance – point estimation – maximum likelihood estimation – interval estimation – point estimation and interval estimation of mean and variance – tests of hypothesis – hypothesis tests concerning one mean and two means – hypothesis tests concerning one variance and two variances – estimation of proportions – hypothesis tests concerning one proportion and two proportions – analysis of rxc contingency tables – Chi-square test for goodness of fit.

Analysis of variance
General principles – completely randomised designs – randomised block design.

Regression and correlation
Curve fitting – method of least squares – estimation of simple regression models and hypotheses concerning regression coefficients – correlation coefficient: estimation of correlation coefficient, hypothesis concerning correlation coefficient – estimation of curvilinear regression models.

References:
[1] S. Ross, 2014, *A First Course in Probability*, 9th ed., Pearson.
[2] R. A. Johnson, Miller and Freund, 2011, *Probability and Statistics for Engineers*, 8th ed., Prentice Hall of Indian.
[3] W. W. Hines, D. C. Montgomery, D. M. Goldsman and C. M. Borror, 2003, *Probability and Statistics for Engineering*, 4th ed., John Wiley & Sons.
[4] S.M. Ross, 2014, *Introduction to Probability and Statistics for Engineers and Scientists*, 5th ed., Academic Press (Elsevier).

ME2313E METROLOGY AND COMPUTER AIDED INSPECTION

L	T	P	O	C
3	0	0	6	3

Total Lecture sessions: 39

Course Outcomes:

CO1: Explain the basic terms and definitions in metrology vocabulary.
CO2: Calculate the measurement uncertainty according to the international standards.
CO3: Design and plan full factorial experiments involving several factors.
CO4: Describe and explain the working of common instruments used for dimensional measurement.
CO5: Describe and explain the use of computers in measurement and inspection.

Introduction: Role of metrology in mass production. Terms related to quantities and units, measurement, results, errors, accuracy, precision, trueness, calibration, uncertainty, traceability, maximum permissible error etc.

Computation of measurement uncertainty: overview, sources, type A – large, small sample and regression, Type B – normal, uniform and triangular distributions, determination of combined standard uncertainties and expanded uncertainties for uncorrelated inputs, correlated inputs, numerical approach, Monte Carlo simulation, applications in conformity assessment and decision making, case studies.

Experiment planning: Theory vs experiment, problems with analysis of past data / improperly conducted experiments, case-studies, demonstration using software, generating factorial designs.

Dimension measurement: Common errors – Thermal, alignment, elastic, gauge design, gauge blocks, Interferometry - Calibration of gauge blocks, laser interferometry - calibration of machine tools. Surface texture measurement – Basics, Methods, Filtering, Amplitude, spacing and hybrid parameters.

Computer Aided Inspection: Coordinate Measuring Machines – Configurations, subsystems, applications, Geometric Dimensioning and Tolerancing – Symbols, measurement, computation, Machine Vision: Image acquisition, file formats and compression, imaging geometry, pixel relationships, preprocessing, segmentation, description.

References:

[1] Kirkup, L. and Frenkel, R.B., 2006, *An Introduction to Uncertainty in Measurement using the GUM*, Cambridge University Press.
[2] Lawson, J., and Erjavec, J., 2017, *Basic Experimental Strategies and Data Analysis for Science and Engineering*, Taylor and Francis.
[3] Figliola, R.S., and Beasley, D.E., 2021, *Theory and Design for Mechanical Measurements*., John Wiley & Sons.
[4] Flack, D., and Hannaford, J., 2012, *Fundamental Good Practice in Dimensional Metrology*, National Physical Laboratory.
[5] Leach R., and Smith S.T., (ed.), 2018, *Basics of Precision Engineering*, Tayor and Francis.
[6] Raghavendra, N.V., and Krishnamurthy, L., 2013, *Engineering Metrology and Measurements*, Oxford University Press.
[7] Groover, M P., 2020, *Automation, Production Systems, and Computer-Integrated Manufacturing*, 5^{th} ed, Addison Wesley.

ME2411E DESIGN OF MACHINE ELEMENTS

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Demonstrate understanding of the design process and fundamental failure theories.
CO2: Apply the principles of strength and stiffness to design basic machine components and joints.
CO3: Analyze and implement design standards to create shafts that meet specified requirements
CO4: Develop gear systems that exhibit strength and durability following industry standards and best practices.
CO5: Following established standards and practices, evaluate and select rolling contact bearings for diverse applications.
CO6: Design machine components and products giving due importance to manufacturability.

Introduction to design:
Design process; design factors; tolerances and fits; principles of standardization; introduction to ASME, AGME, and BIS standards, selection of materials; strength of mechanical elements; stress concentration; theories of failure; impact load; fatigue loading; consideration of creep and thermal stresses in design.

Threaded fasteners and joints:
Threaded fasteners: thread standards; stresses in screw threads; bolted joints; preloading of bolts; eccentric loading; welded joints: types of welded joints; stresses in butt and fillet welds; torsion and bending in welded joints; welds subjected to fluctuating loads; design of welded machine parts and structural joints.

Power shafting:
Stresses in shafts; design for static loads; reversed bending and steady torsion; design for strength and deflection; design for fatigue loading; critical speed of shafts; stresses in keys; design of keys.

Design of gears:
Spur and helical gears, tooth loads, gear materials; design stresses, basic tooth stresses; stress concentration, service factor; velocity factor; bending strength of gear teeth; Buckingham's equation for dynamic load; surface strength and durability; design of spur gears for strength and wear.

Rolling contact bearings:
Bearing types; bearing life; static and dynamic capacity; selection of bearings with axial and radial loads; lubrication; seals, shaft, housing, and mounting details.

Design for manufacturing:
General design recommendations for rolled sections, forgings, screw machine products, turned parts, machined round holes, parts produced on a milling machine, welded parts, and castings; modification of design for manufacturing easiness for typical products.

References:

[1] Shigley, J. E., and Mischke, C. R., 2003, *Mechanical Engineering Design*, 6th ed. Tata McGraw-Hill.
[2] Siegel, M. J., Maleev, V. L., and Hartman, J. B., 1965, *Mechanical Design of Machines*, 4th ed. International Textbook Company.
[3] Phelan, R. M., 2005, *Fundamentals of Mechanical Design*, 3rd ed. Tata McGraw-Hill.
[4] Doughtie, V. L., and Vallance, A.V., 1964, *Design of Machine Elements*. Tata McGraw-Hill.
[5] Juvinall, R.C., and Marshek K. M., 2000, *Fundamentals of Machine Component Design*, 3rd ed. John Wiley & Sons.
[6] Norton, R. L., 2013, *Machine Design*, 5th ed. Pearson Education.

Data Handbooks (allowed for reference during examinations)

[1] P.S.G. Tech., 2015, *Machine Design Data Handbook*, Kalaikathir Achchagam.
[2] Mahadevan, K., and Reddy B., 2013, *Design Data Handbook for Mechanical Engineers*, 4th ed. CBS Publishers and Distributors.
[3] Bhandari V. B., *Machine Design Data Book*, 2nd ed.

ME2112E PRODUCTION MANAGEMENT

Pre-requisites: Knowledge on fundamentals of management

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Comprehend the issues associated with managing the operations.
CO2: Identify layout planning issues and evaluate layout plans.
CO3: Identify the characteristics of time series data and apply simple moving averages for demand forecasting.
CO4: Identify production planning hierarchy; develop and evaluate material plans and operational schedules.
CO5: Develop simple inventory policies
CO6: Apply statistical quality control measures to monitor the process

Introduction
Historical development of operations and supply chain management; operations strategy and competitiveness; measuring process performance, characteristics of modern production systems; push and pull production systems.
Facilities planning
Objectives of facility planning; facility design: flow, space and activity relationship, flow patterns, layout planning, systematic layout planning; types of layout: process layout, product layout, group technology layout.
Demand Forecasting
Time series analysis, components of time series, moving average, simple exponential smoothing, simple regression, error measurement, tracking signal.
Production planning and control
Production planning and control framework, aggregate planning, master production scheduling; Material Requirements Planning (MRP): technical issues, Using the MRP system.
Production activity control, types of Gantt chart, flow shop scheduling (makespan optimisation), job prioritisation methods, performance measures.
Inventory Control
Functions of inventory, inventory problem classification, relevant cost, selective inventory control, independent demand systems (continuous review and periodic review inventory control systems), deterministic models, sensitivity analysis, all unit quantity discount, economic production quantity, introduction to probabilistic models, basic concepts of supply chain management.
Quality Control
Statistical process control, control charts for variables, X-bar and R charts, control charts for attributes, p and c charts, introduction to acceptance sampling.

References:
[1] Chase, R. B., Shankar, R., and Jacobs, F. R., 2015, *Operations and Supply Chain Management*, 14th ed., McGraw Hill Education (India).
[2] Tersine, R. J., 1994, *Principles of Inventory and Materials management*, 4th Edition, Prentice-Hall International.
[3] Jacobs, F. R., Berry, W. L., Whybark, D. C., and Vollmann, T. E., 2015, *Manufacturing Planning and Control for Supply Chain Management*, 6th ed., McGraw Hill Education (India).
[4] Tomkins, J. A., White, J. A., Bozer, Y. A., and Tanchoco, J. M. A., 2013, *Facility Planning*, 4th ed., Wiley India.
[5] Grant, E. L., and Leavenworth, R. S., 2017, *Statistical Quality Control*, 7th ed., McGraw-Hill Education (Indian Edition).
[6] Hopp, W. J., and Spearman, M. L., 2013, *Factory Physics*, 3rd ed., Waveland Press, Inc.

CE2095E STRENGTH OF MATERIALS LABORATORY

Pre-requisites: Knowledge of Solid Mechanics

L	T	P	O	C
0	0	2	1	1

Total Practical Sessions: 26

Course Outcomes:

CO1: Demonstrate material testing procedure as per Indian Standards

CO2: Compile reports and present the results based on the test data complying to the codes/regulations

CO3: Make use of codes and other reference materials for standard property data.

CO4: Interpret the results and recommend the suitability of a material for a given load case.

List of Exercises:

1. Tension test on MS rod
2. Shear Test on MS rod
3. Torsion test on MS specimen
4. Hardness tests on metals
5. Impact tests on metals
6. Bending test on steel beam
7. Spring test: open and close coiled springs
8. Compression test on cubes and cylinders determination of modulus of elasticity
9. Study of extensometers and strain gauges

References:

[1] Timoshenko, S. P., 1988, *Strength of materials*, CBS publishers.

[2] Gere, J. M., 2001, *Mechanics of Materials*, Thomson.

[3] Relevant IS Standards.

ME2293E FLUID MECHANICS LAB

Pre-requisites: Knowledge of Fluid Mechanics

L	T	P	O	C
0	0	2	1	1

Total Practical Sessions: 26

Course Outcomes:

CO1: Calibrate various flow measuring devices and measurement of fluid properties
CO3: Evaluate forces and energy terms associated with fluid-solid interaction
CO3: Evaluate the boundary effects for various geometries and flow conditions.
CO4: Evaluate the performances of fluid machines.

List of Suggested Experiments:

1. Determination of meta-centric height of a floating body.
2. Calibration of a flow measuring device such as venturimeter / orificemeter.
3. Calibration of triangular/rectangular notches
4. Flow through a small orifice
5. Determination of force due to the impact of a water jet on a flat plate.
6. Verification of Bernoullis' theorem.
7. Determination of losses in a piping system.
8. Measurement of lift and drag on a given specimen in an air flow using counterweights
9. Performance evaluation of a Pelton turbine / Francis turbine.
10. Performance evaluation of a Centrifugal pump / Gear pump.

List of Additional Experiments:

1. Determination of surface tension using axis switching of fluid jets exiting from orifices
2. Determination of force due to the impact of a water jet on a curved plate.
3. Determination of viscosity using Stokes relation.
4. Determination of energy loss across the shock front in a hydraulic jump for supercritical Froude number
5. Determination of drag force on a circular cylinder using wake survey method.
6. Demonstration of Particle Imaging Velocimetry
7. Demonstration of Reynolds experiment for laminar to turbulent transition
8. Performance evaluation of a Reciprocating pump.

References:

[1] White, F. M., 2015, *Fluid Mechanics*, McGraw Hill.
[2] Fox, R. W., Mitchell, J. W., and McDonald, A. T., 2020, *Introduction to Fluid Mechanics*, Wiley.
[3] Lal, J.,1975, *Hydraulic Machines*, Metropolitan book Co.

ME3303E SUBTRACTIVE AND ADDITIVE MANUFACTURING PROCESSES

Total Lecture sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Explain the influence of tool geometry on cutting performance, define the nomenclature of single point and multipoint cutting tools as per the industrial standards.
CO2: Analyse and predict the cutting forces, power requirements in machining based on different analytical models and on mechanics of metal/material cutting.
CO3: Analyse the capabilities of various modern machining processes and select best suitable process for a given application.
CO4: Explain various machine tool mechanisms and design the machine elements, jigs and fixtures for different operations and applications.
CO5: Explain different additive manufacturing systems and processes based on their capabilities and limitations for processing polymers, metals, ceramics and other engineering materials.

Machining; basic machine tools; single and multi-point cutting tools, tool geometry and materials, mechanics of chip formation: orthogonal and oblique cutting, shear angle, velocity relationship; merchant's analysis of cutting forces; cutting power estimation; Inserts: coatings, nomenclature; tool life and wear; economics of machining; principles of modern machining processes: AJM, ECM, EDM, USM, EBM, LBM.

Basic concepts of machine tools; tool - work motions; machine tools for various machining processes; kinematics of machine tools and gear boxes; feed and speed mechanism; machine tool drives; machine tool dynamics; gear manufacture: milling, hobbing and shaping; special purpose machine tools; hydraulic control of machine tools: components of hydraulic circuits, control circuits and their characteristics; testing of machine tools; jigs and fixtures: basic principles of location, type and mechanics of locating and clamping elements, design of jigs and fixtures.

Introduction to additive manufacturing (AM), ISO/ASTM definition, AM process chain, benefits and comparison with conventional manufacturing, ASTM classification of AM processes, AM file formats and pre-processing, AM technologies: vat polymerization, powder bed fusion, material extrusion, material jetting binder jetting, sheet lamination, direct energy deposition, hybrid AM technologies- key strengths, process, applications, case studies, recent research and development, Introduction to various ISO/ASTM/IS standards for AM.

References:

[1] Ghosh, A., and Mallik, A.K., 2010, *Manufacturing Science*, Affiliated East West Press.
[2] Boothroyd, G., and Knight, W.A., 2005, *Fundamentals of Metal Machining and Machine Tools*, CRC press.
[3] Bhattacharyya, A., 1984, *Metal Cutting, Theory and Practice*, New Central Book Agency.
[4] Chattopadhyay, A.B., 2017, *Machining and Machine Tools*, Wiley.
[5] Shaw, M.C., 2004, *Metal Cutting Principles*, Oxford University Press.
[6] Kalpakjian, S., and Schmid, S.R., 2020, *Manufacturing Engineering and Technology*, Pearson.
[7] Groover, M.P., 2018, *Fundamentals of Modern Manufacturing*, Wiley.
[8] Kempster, M.H.A., 1974, *An Introduction to Jig and Tool Design*, Butterworth-Heinemann.
[9] Gibson, I., Rosen, D., Stucker, B., Khorasani, M., 2021, *Additive Manufacturing Technologies*, Springer Nature.
[10] Paul, C.P., and Jinoop, A.N., 2021, *Additive Manufacturing Principles, Technologies and Applications*, McGraw Hill.

ME3102E INDUSTRIAL ENGINEERING

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Describe the concept of productivity and conduct work study techniques to improve productivity
CO2: Apply the various methods of method study and work measurement in a work space
CO3: Demonstrate ability to decide on facility location and line balancing in operations management
CO4: Comprehend on the emerging concepts and applications in designing work systems

Introduction
Scope of Industrial Engineering: Evolution of Industrial Engineering approach, nature of work, physical work systems – cycle time analysis of manual work and in worker machine systems – service operations – office work
Productivity
Productivity concepts: productivity measures – work study: role of work study in improving productivity – working conditions, introduction to lean systems
Method study
Basic procedure of method study: various types of charts and diagrams, motion study, THERBLIGS, memomotion and micromotion study, SIMO chart, principles of motion economy – design of workplace layout.
Work measurement
Techniques for estimation of standard time: basic procedure of time study, determination of time standards, performance rating factor approaches, allowances, standard time, work sampling: statistical basis of work sampling, application issues in work sampling, predetermined motion time systems: methods time measurements – Maynard operations sequence technique
Facility design
Facility location factors: evaluation of alternative locations, types of plant layout and their evaluation, computer aided layout design techniques, assembly line balancing, materials handling systems
Overview of ergonomics
Engineering anthropometry: work-space design, statistical basis of anthropometry, use of anthropometric data in design

References:

[1] I.L.O., 2015, *Introduction to Work Study: Indian Adaptation*, 3rd ed., Oxford & IBH Publishing.
[2] Barnes, R. M., 2009, *Motion and Time Study: Design and Measurement of Work*, 7th ed., John Wiley & Sons.
[3] Freivalds, A., and Niebel, B. W., 2013, *Niebel's Methods,Standards and Work Design*, 12th ed., McGraw-Hill.
[4] Groover, M. P., 2007, *Work Systems and the Methods, Measurement, and Management of Work*, Pearson Prentice Hall.

ME3103E QUANTITATIVE TECHNIQUES FOR MANAGEMENT

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Formulate and solve decision problems using linear programming.
CO2: Explain and apply the concept of shadow prices.
CO3: Formulate and solve distribution-allocation problems.
CO4: Analyze waiting line system and Game theory.

Models in operations research: principles of modelling − formulation of linear programming models −graphical solution of linear programs in two variables − principles of the Simplex method: Simplex method in Tableau form − Big M Method − sensitivity analysis − duality concept: general primal-dual relations − model building − solving problems using software tools.

Formulating transportation problems − transportation Simplex method − assignment problems and Solution − network flow models: shortest-route problem, minimum spanning tree problem, maximum flow problem − Lagrange multiplier method for constrained optimization problems.

Dynamic programming: multistage decision process, principle of optimality, examples − queuing theory: basic structure of queuing models, role of exponential distribution, performance measures of a queuing system − single server queuing models: unlimited queuing, limited queuing.

Theory of games: pure strategies, games with the saddle point, mixed strategies, principles of dominance, solutions of games using graphical method and linear programming method − simulation: Monte Carlo simulation, manufacturing applications.

References:

[1] Taha, H. A., 2023, *Operations Research: An Introduction*, 11th ed., Pearson Education.
[2] Hillier, F. S., and Lieberman, G. J., 2014, *Introduction to Operations Research*, 10th ed., Tata McGraw Hill.
[3] Srinivasan, G., 2017, *Operations Research: Principles and Applications*, 3rd ed., PHI Learning.
[4] Ravindran, A., Philips, D., and Solberg, J. J., 1989, *Operations Research: Principles and Practice*, 2nd ed., John Wiley & Sons.
[5] Hadley, G., 2002, *Linear Programming*, Narosa Book Distributors.
[6] G. Srinivasan, *Fundamentals of Operations Research*, [online] available: http://nptel.ac.in/courses/112106134/1

ME3394E MACHINING SCIENCE LABORATORY

Total Practical Sessions: 26

L	T	P	O	C
0	0	2	1	1

Course Outcomes:

CO1: Develop CNC part programs from production drawings, and implement it in CNC Machines to fabricate the part.
CO2: Grind and measure various tool angles of single point cutting tool and analyse insert geometry.
CO3: Perform machining experiments by following design of experiment principles and analyse the results.
CO4: Conduct experiments, measure and analyse cutting forces during machining operations.
CO5: Perform various machining experiments in EDM, WEDM and CNC machining centres.

Programming on CNC machines; grinding of tool angles; analysing of inserts; measurement of cutting forces; study of influence of cutting fluids on machining; surface integrity studies on parts machined; experiments on cylindrical grinding machines; microhardness testing; material removal rate and tool wear rate studies on EDM; study of cutting parameters on thrust and torque on drilling, studies on micromachining centre, dynamometer, Sensors and IoT Gateway for machining analytics, optical microscope, 3D optical profiler, nano-indenter, FDM machines, WEDM, thermal imager,

List of Suggested Exercises:

1. Study of the effect of machining parameters on cutting forces during turning operation.
2. Design of experiment-based study on the effect of grinding parameters on surface roughness of low carbon steel specimens during centreless grinding operation.
4. Metallurgical evaluation of specimens using metallurgical microscope.
5. CNC part program development and execution for turning and milling operations
6. Grinding of tool angles of a single point lathe tool and its measurement using tool makers microscope
7. Studies on micro machining centre, FDM machine, nano-indenter and wire-cut electrical discharge machine.
8. Study on the effect of machining parameters on tool wear.
9. Design of experiment-based study on the effect of EDM parameters on material removal rate
10. Sensors and IoT gateway for analyses of machining performance

References:
[1] Chattopadhyay, B., 2017, *Machining and Machine Tools*, Wiley.
[2] Venkatesh V.C., and H. Chandrasekaran, 1987, *Experimental Techniques in Metal Cutting*, Prentice-Hall of India.
[3] Boothroyd G. and Knight, W.A, 2005, *Fundamentals of Metal Machining and Machine Tools*, CRC press.
[4] Rao, P. N., 2017, *CAD/CAM: Principles and Applications*, McGraw Hill.
[5] Shaw, M. C., 2012, *Metal Cutting Principles*, Oxford University Press.

ME3395E METROLOGY AND COMPUTER AIDED INSPECTION LAB

Total Practical Sessions: 39

L	T	P	O	C
0	0	3	3	2

Course Outcomes:

CO1: Plan and conduct experiments involving a single factor.
CO2: Use common measuring instruments.
CO3: Determine the measurement uncertainty after carrying out the measurement.
CO4: Explain the principle and working of specialized measuring instruments.

List of Experiments:

1. Measurement of screw threads using Universal Measuring Microscope, Three wire method, Thread pitch micrometer, etc.
2. Measurement of straightness error using autocollimator, spirit level, etc.
3. Calibration of pressure gauge using dead weight tester.
4. Calibration of dial gauge using dial gauge calibrator.
5. Calibration of LVDT based height measuring device using Gauge Blocks.
6. Measurement of strain using strain gauges and strain indicator using various bridge arrangements.
7. Determination of defects in materials using Ultrasonic Flaw Detector.
8. Measurement of gear profile error and other parameters using profile projector, disc micrometer, gear tooth vernier, etc.
9. Measurement of cutting tool angles using Tool Maker's microscope.
10. Calibration of thermocouples using constant temperature bath, study of platinum resistance strain gauge, etc.
11. Determination of time constant of a thermometer.
12. Study of surface texture measurement using stylus type profilometer.
13. Conduct gauge R & R study.
14. Measurement of area using planimeter, identifying and experiencing the feel of different limits and fits
15. Study of CNC CMM, Articulated Arm CMM with laser scanner, roundness testing machine, 3D optical profilometer, laser scan micrometer, coating thickness measurement, sound level measurement, spring tester, etc.

References:

[1] Raghavendra, N.V. and Krishnamurthy, L., 2013, *Engineering Metrology and Measurements*, Oxford University Press.
[2] Figliola, R.S. and Beasley, D.E. 2021, *Theory and Design for Mechanical Measurements*, John Wiley & Sons.
[3] Kirkup, L. and Frenkel, R.B., 2006, *An Introduction to Uncertainty in Measurement using the GUM*, Cambridge University Press.
[4] ISO/ASME/IS standards.

ME3311E COMPUTER INTEGRATED MANUFACTURING

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Apply fundamental knowledge in mathematics for generating and transforming graphicentities using computers.
CO2: Apply geometric reasoning principles to extract features from CAD data.
CO3: Create CNC part programs for turning, milling and drilling operations using various CAD/CAM software.
CO4: Apply principles of CAD, CAM and communication networks to integrate manufacturingactivities.

Introduction to CIM: Automation; Production Systems; Group Technology; Cellular Manufacturing; Elements of Computer Integrated Manufacturing Systems; Concurrent Engineering; Design for Manufacture and Assembly.

Computer Graphics and CAD: 2D and 3D transformations; plane and space curves; surface description and generation; principles of solid and surface modeling; Constructive Solid Geometry and Boundary Representation; CAD file formats and Data structure.

Manufacturing Planning and Control: Computer Aided Process Planning; Material requirements planning; Capacity planning; Shop floor control and data collection.

CNC Machine tools: Fundamentals of CNC machine tools; constructional features; drives and controls; CNC manual part programming and computer-assisted part programming; STEP-NC; Cyber Physical Machine Tools.

Computer Integrated Manufacturing Systems: Automated material handling; Computer-aided inspection; Industrial robotics and machine vision; Rapid prototyping and 3D printing; Networks and data communication; Product data exchange and integration; Integration based on STEP standards

Advances in CIM Systems: Applications of Artificial Intelligence; Machine Learning and Deep Learning in CIM; Digital Manufacturing; Smart Manufacturing; IoT and Cloud based manufacturing.

References:

[1] Patel, C.D., Chen, C.H., 2022, *Digital Manufacturing*, Elsevier.
[2] Groover, M.P. 2016, *Automation, Production Systems, and Computer Integrated Manufactu*ring, Pearson.
[3] Pande, S.S. 2012, *Computer Graphics and Product Modeling for CAD/CAM*, Narosa.
[4] Rogers, D.F. and Adams, J.A., 2017, *Mathematical Elements of Computer Graphics*, McGraw Hill.
[5] Rogers, D.F., 2017, *Procedural Elements for Computer Graphics*, McGraw Hill.
[6] Rao, P.N., 2010, *CAD/CAM – Principles and Applications*, McGraw Hill.

ME3191E MANAGEMENT SCIENCE LABORATORY

Total Lecture Sessions: 39

L	T	P	O	C
0	0	3	3	2

Course Outcomes:

CO1: Develop awareness about application of scientific methods in operation function of any enterprise and in supply chain management.
CO2: Understand the practical situations in operations of a firm and develop appropriate models, methods, and procedures, and identify appropriate solution procedures for the models and methods developed.
CO3: Apply theoretical knowledge in solving the practical and operational and supply chain management problems.
CO4: Develop visual representation of results, conduct analysis, derive inferences and work as a team.

List of Suggested Exercises:

1. Supply chain operation simulation for serial supply chain performance evaluation using role play games like supply chain role play game, vendor managed inventory-based supply chain role play game, etc.
2. Supply chain operation simulation under different inventory policies using software packages, like Supply Chain Inventory Policy Analyser (SCIPA) software, four-stage serial supply chain inventory policy analyser, etc.
3. Production system performance evaluation using ARENA, WITNESS, TECNOMATIX plant simulator, etc.
4. Mathematical programming model formulation, solution and sensitivity analysis for some typical problems using LINGO, AMPL, GAMS, etc.
5. Application of statistical process control for a production system using the experimental setup for construction of X-bar, R chart and process capability determination
6. Material requirements planning for a product using the setup for preparation of assembly chart, product structure and material planning.
7. Material requirements plan generation under rolling through time for components of a product using a software package (MNMRP software package)
8. Process layout design for a typical problem using layout planning software.
9. Study the effect of performing a task repeatedly and to understand the principles of learning curve for expressing the rate of learning.
10. Visual acuity test: dark adaptation analysis
11. Stopwatch time study of a drill press operation
12. Use of machine learning and Python programming in solving problems related to operations management.
13. Supply chain modelling and analysis using AnyLogistix software package.

References:

[1] Pillai, V. M., Hunagund, I. B., and Krishnan, K. K., 2011, "Design of robust layout for Dynamic Plant Layout Problems," *Computers & Industrial Engineering*, Vol. 61, pp. 813–823.
[2] Francis, R. L., McGinnis, L. F., and White, J.A. Jr., 2015, *Facility Layout and Location: An Analytical Approach*, Pearson.
[3] Ravindran, D. P., and Solberg, J. J., 2007, *Operations Research: Principles and Practice*, Wiley.
[4] L. O., 2011, *Introduction to Work Study: Indian Adaptation*, Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi.
[5] Grant, E., and Leavenworth, R. S., 2017, *Statistical quality Control*, McGraw-Hill Education, India.
[6] Jacobs, F. R., Berry, W. L., Whybark, D. C. and Vollmann, T. E., 2015, *Manufacturing Planning and Control for Supply Chain Management*, 6th ed. McGraw Hill Education.
[7] Géron, A., 2019, *Hands-On Machine Learning with Scikit-Learn*, Oreilly, USA.
[8] Ivanov, D., 2021, *Supply chain simulation and optimization with anyLogistix*, 5th updated edition, Berlin School of Economics and Law.

ME3396E COMPUTER INTEGRATED MANUFACTURING LABORATORY

L	T	P	O	C
0	0	2	1	1

Total Practical Sessions: 26

Course Outcomes:

CO1: Create solid models of parts and assemblies and perform design and simulation of simple mechanisms using various CAD software.
CO2: Conduct finite element analyses using commercial software.
CO3: Conduct multibody dynamics analysis using commercial software.
CO4: Create robot programs for performing various operations.

List of Suggested Experiments:

1. Part modeling using CAD software like Creo, CATiA, Nx, etc.
2. Modeling assemblies using CAD software.
3. Static structural analysis using finite element software.
4. Modal analysis using finite element software.
5. Thermal analysis using finite element software.
6. Coupled temperature displacement analysis using finite element software.
7. Kinematic analysis using multi body dynamics software.
8. Dynamic analysis multi body dynamics software.
9. CNC part program development using CAD/Mastercam software.
10. PLC Programming and testing.
11. Robot programming and accuracy measurements.

References:

[1] Rogers D.F. and Adams, J.A. 2009, *Mathematical Elements for Computer Graphics*, Tata McGraw Hill.
[2] Rogers, D.F., 2010, *Procedural Elements for computer Graphics*, Tata McGraw Hill.
[3] Cook, R.D Malkus, D.S. Plesha, M.E. and Witt, R.J., 2007, *Concepts and Applications of Finite Element Analysis*, Wiley.
[4] Koren, Y, 2005, *Computer Control of Manufacturing Systems*, McGraw Hill Education.
[5] Rao, P.N. Tewari, N.K. and Kundra, T.K., 2017, *Computer Aided Manufacturing*, Tata McGraw Hill.
[6] Ramamurthy, V., 2000, Computer Aided Mechanical Design and Analysis, Tata McGraw Hill.
[7] Rattan, S.S., 2014, *Theory of Machines*, Tata McGraw-Hill.
[8] Groover, M.P., 2016, *Automation, Production Systems, and Computer Integrated Manufacturing.* Pearson Education.
[9] Hindustan Machine Tools, 2017, *Mechatronics*, McGraw Hill Education.

ME3099E PROJECT-PART-I

Total Hours of Own Effort: 117

L	T	P	O	C
0	0	0	9	3

Course Outcomes:

CO1: Identify a project of importance to professional engineering practice and conduct its feasibility study.

CO2: Review available literature and determine the state of art about the problem.

CO3: Work together as a team to achieve the project goals in stipulated time.

CO4: Make oral presentations and written reports about the work carried out.

CO5: Demonstrate professional ethics and responsibility towards society.

Students are required to select broad areas related to Mechanical / Production Engineering or of interdisciplinary nature for carrying out the project work. Students sharing similar interests form groups and select project guide(s). Subsequently, a specific project topic has to be identified in consultation with the project guide(s) and based on a survey of literature. Formulating the problem definition, objectives, methodology and work plan follow. The feasibility of the topic is assessed in a preliminary review conducted by an evaluation panel in the proposed area of study. The same panel will also evaluate the progress during the mid-semester review and the final outcome in the end-semester review. The students have to present their work before the panel during each review and also submit a project report in the prescribed format at the end of the semester.

ME4097E SUMMER INTERNSHIP

Course Outcomes:

CO1: Understand the working culture of an industry / research institute.
CO2: Work on challenging real-life projects, under guidance from experienced professionals.
CO3: Develop soft-skills like communication and team working.
CO4: Carry out interactions with the society, which would help in the professional career.

Summer internship with a total duration 6-10 weeks after 6^{th} semester is mandatory for all the B.Tech. students. It is to be preferably done in an Industry / R&D organization / Govt. Departments / Start-up companies / reputed academic and other institutions in India or abroad (R.15.3). Hence, the students may work on research projects / product development at NIT Calicut also – especially, if they are unable to find internship opportunities outside the institute – but, the work must be done completely during the vacation between 6^{th} and 7^{th} semesters. Evaluation of the work done and awarding the credit for the same are to be done in the 7^{th} semester.

The major objectives of Summer Internship are the following:

1. Familiarise the students to the working styles of industries, research organizations, etc.
2. Work on challenging real-life problems.
3. Improve the soft skills like communication, team working, etc., and equip the students to be ready for the professional career.

ME4098E PROJECT-PART-II

Total Hours of Own Effort: 117

L	T	P	O	C
0	0	0	9	3

Course Outcomes:

CO1: Develop socially relevant products or conduct theoretical/analytical/experimental studies of practical engineering problems

CO2: Develop self-learning capability and an ability to identify and correct own mistakes.

CO3: Work together as a team to acquire project management skills and achieve project goals in stipulated time.

CO4: Make oral presentations and written reports about the work carried out.

CO5: Demonstrate professional ethics and responsibility towards society.

The project work started in VI semester may be continued in VII semester (or in special cases, a new project can be selected in VII semester). Students are expected to carry out complementary studies of theoretical/analytical/experimental nature based on the results obtained in Project Part I to complete a comprehensive project. They are required to present their work before a panel in the domain of study for the mid-semester and end-semester evaluations. A final report describing the details of the entire project work is also to be submitted to the Department in the prescribed format. The end-semester evaluation will involve an oral defense of the report and viva-voce examination. Students are expected to demonstrate professional ethics and commitment towards the society and environment throughout their project work. Ideally, the scope and deliverables of the project should be so as to culminate in publication(s) / patent(s) / copyright(s).

ELECTIVE COURSES: INDUSTRIAL ENGINEERING AND MANAGEMENT

ME2121E OPERATIONS AND PROCESS MANAGEMENT

Pre-requisites: Knowledge on fundamentals of management

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Explain the characteristics of production systems.
CO2: Design a process and evaluate the process performance
CO3: Apply suitable forecasting techniques
CO4: Evaluate and apply inventory plans and operational schedules.
CO5: Apply statistical quality control measures to monitor the process

Production process and service design
Historical development of operations and supply chain management; characteristics of modern production systems: push and pull production systems; Manufacturing processes: Various manufacturing processes, organisation of manufacturing processes (layouts). Manufacturing process flow design. Introduction to designing service organisations
Process design and analysis: Process flow charting, measuring process performance, Little’s law
Forecasting; time series analysis: components of time series, moving average, simple exponential smoothing, simple regression, error measurement, tracking signal.

Production planning and control
Aggregate production planning, master production scheduling. Material Requirements Planning (MRP): technical issues, using the MRP system, production activity control, types of Gantt chart, flow shop scheduling (makespan optimisation), job prioritisation methods, performance measures.
Inventory control: functions of inventory, inventory problem classification, relevant cost, selective inventory control, independent demand systems, deterministic models, sensitivity analysis, all unit quantity discount, economic production quantity, Introduction to probabilistic models.
Quality Control: statistical process control, control charts for variables, X-bar and R chart, control charts for attributes, P and C chart, introduction to acceptance sampling.

References:
[1] Chase, R. B., Shankar, R., and Jacobs, F. R., 2015, *Operations and Supply Chain Management*, 14th ed. McGraw Hill Education (India) Private Limited.
[2] Jacobs, F. R., Berry, W. L., Whybark, D. C., and Vollmann, T. E., 2015, *Manufacturing Planning and Control for Supply Chain Management*, 6th ed., McGraw Hill Education (India).
[3] Grant, E. L., and Leavenworth, R. S., 2017, *Statistical Quality Control*, 7th ed. McGraw-Hill Education (Indian Edition).

ME3121E FUNDAMENTALS OF MARKETING

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Outline the fundamental concepts of marketing, marketing
CO2: Segment and target a market with proper positioning of products
CO3: Conduct market research and consumer research.
CO4: Communicate about the product and effectively utilize various sales promotion tools.
CO5: Understand the concepts of product development process and sales promotion.

Introduction to marketing: marketing definitions, important terms in marketing, evolution of marketing; value and satisfaction; philosophies of marketing; functions of marketing; marketing environment; auditing a marketing environment.

Product life cycle; marketing planning process; Strategic Business Unit (SBU), evaluation of SBUs; Market segmentation: process of segmentation, basis of market segmentation, criteria for market segmentation; marketing mix variables; market targeting; positioning: types and errors.

Marketing research: marketing research process, research objectives, research plan development. New product development; sales promotion tools.

References:
[1] Kotler, P., Keller, K. L., Koshy, A., and Jha, M., 2020, *Marketing Management*, 13th ed., Prentice Hall of India.
[2] Ramaswamy V. S., and Namkumari, S., 2010, *Marketing Management*, 4th ed., Om Books.
[3] Stanton, W. J., Etzel, M. J., and Walker, B. J., 1991, *Fundamentals of Marketing*, McGraw-Hill International Edition.
[4] Malhotra, N. K., and Dash, S., 2019, Marketing Research, 7th ed. Pearson Education.

ME3122E DESIGN AND ANALYSIS OF MANAGEMENT INFORMATION SYSTEMS

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Understand the terminologies of management information system (MIS) and illustrate building blocks in MIS.
CO2: Illustrate MIS design tools and design a management information system.
CO3: Perform verification and validation of a MIS and explain capability maturity model.
CO4: Demonstrate various software testing approaches and recent developments in information systems.

Introduction of Management Information Systems

Concepts of data and information– steps of producing information from data, economies of information, analysis of system, management and formal information system concepts; building blocks in information systems– system design forces, information management life cycle, types of MIS, capabilities and complements; applications of information systems in decision making.

Information System Design

General steps in Information system design– systems investigation and requirements engineering; system analysis and general system design; charting tools for system analysis and design; Introduction to database management – classification of data items, types of code structures, forms design; general file storage considerations– composition and classification of data files, selection consideration for file media and file organization methods; concepts of data structures, data association, sorting and searching techniques; Data warehousing and data mining.

Implementation of MIS

System implementation– verification and validation of software system, software metric and models, introduction to capability maturity model, software testing approaches, training and post implementation audit; recent developments in information systems; security features in global information systems.

References:

[1] Burch, J. G. Jr., and Grudnitski, G., 1989, *Information Systems: Theory and Practice*, 5th ed., John Wiley & Sons.
[2] Hawryszkiewycz, I. T., 1989, *Introduction to Systems Analysis and Design*, Prentice Hall of India.
[3] Sommerville, I., 2001, *Software Engineering*, 6th ed., Pearson Education Asia.
[4] Lucas, H. C., 1992, *Analysis, Design, and Implementation of Information Systems*, 4th ed., McGraw-Hill.
[5] O’ Brien, J. A., 1999, *Management Information Systems*, 4th ed., Tata McGraw-Hill.

ME3123E WORK DESIGN AND MEASUREMENT

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Comprehend the fundamental concepts of productivity, work design and work measurement
CO2: Apply various techniques of engineering work study and anthropometric data in work design
CO3: Judge the application of fundamental principles in working conditions
CO4: Devise solutions for the real-world problems in work environment design

Productivity
Productivity concepts: productivity measures, factors contributing to productivity improvement, role of work study in improving productivity

Work design
Methods study: scope of work design, procedure for methods study, process analysis, process charts, operation analysis, manual work design – principles of motion economy – manual work and design guidelines, energy expenditure, heart rate, subjective ratings of perceived exertion, NIOSH lifting guidelines – multitask lifting guidelines

Work measurement
Techniques for estimation of standard time: basic procedure of time study, determination of time standards, performance rating factor approaches, allowances, standard time, work sampling, statistical basis of work sampling, predetermined motion time systems: Maynard operations sequence technique, experiments on estimation of standard time.

Work environment design
Nature of man-machine systems: characteristics, working conditions, Design of cognitive work, information theory, Human information processing model: Hick-Hyman law – design principles for display of visual information, quantitative and qualitative displays – design principles for display of auditory information – human-computer interaction

Ergonomics
Engineering anthropometry: work-space design, statistical basis of anthropometry, use of anthropometric data in design.

References:

[1] Freivalds, A., and Niebel, B. W., 2013, *Niebel's Methods, Standards and Work Design*, 12th ed., McGraw-Hill.
[2] Barnes, R. M., 2002, *Motion and Time Study: Design and Measurement of Work*, 7th ed., John Wiley & Sons, NY.
[3] Sanders M. S., and McCormick, E. J., 1987, *Human Factors in Engineering and Design*, 6th ed., McGraw-Hill.
[4] Salvendy, G., 1997, *Handbook of Human Factors & Ergonomics*, Inter-science.
[5] Groover, M. P., 2007, *Work Systems and the Methods, Measurement, and Management of Work*, Pearson Prentice Hall.

ME3124E COST ANALYSIS AND CONTROL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Explain the terminology, basic concepts and principles of cost accounting
CO2: Analyze costing of materials, labour and overhead
CO3: Illustrate job costing, process costing and activity based costing
CO4: Construct and interpret breakeven chart and volume-profit graph
CO5: Analyze material, labour and overhead variances

Accounting concepts - rules of debit and credit - journal entries - ledger posting.

Cost concepts - income measurement - profit planning, control - decision making.

Costing and control of materials - system of accounting for materials issued. Inventory control techniques - economic order quantity - reorder point - safety stock - cost of inventory - costing methods; costing and control of labour - wage plans - labour turnover; Costing and control of factory (manufacturing) overheads; Costing and control of administrative, selling and distribution overheads.

Job-order and batch costing - accounting for manufacturing overheads - accounting for nonmanufacturing overheads; process; joint and by-product costing - cost accumulation in process costing - determination of equivalent units - normal and abnormal losses; Joint products - allocation of joint costs - sell or process further (by-product costing); variable costing and absorption costing; activity drivers, activity-based costing system.

Volume-cost-profit analysis - application of breakeven analysis - construction and interpretation of breakeven chart and volume-profit graph; standard costs and quality costs; cost variance analysis - material, labour and overhead variances - revenue and profit variance analysis; Responsibility accounting, short-run decision analysis for different decision situations.

References:
[1] Khan, M. Y., and Jain, P. K., 2013, *Management Accounting: Text, Problems and Cases*, 6th ed., Tata McGraw-Hill.
[2] Horngren, C. T., Datar, S. T., and Rajan, M. V., 2012, *Cost Accounting: A Managerial Emphasis*, 14th ed., Pearson.
[3] Khan, M. Y., and Jain, P. K., 2008, *Cost Accounting and Financial Management*, Tata McGraw-Hill.

ME3125E SUPPLY CHAIN MANAGEMENT

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Explain the fundamental concepts in supply chain management.
CO2: Analyze the role of logistical drivers in a supply chain.
CO3: Model a supply chain network and solve using solvers.
CO4: Perceive case studies on real world supply chain decisions and apply problem solving methods.

Introduction and a strategic view of supply chains: decision phases in a supply chain, process views of supply chain; enablers of supply chain performance; supply chain performance in India: challenges in maintaining supply chain in India; supply chain strategy and performance measures, supply chain performance measures, enhancing supply chain performance; supply chain drivers, framework for structuring drivers.

Introduction to inventory management: types of inventory, inventory related costs; managing inventories in a supply chain: single stage inventory control, inventory control policies, impact of service level on safety stock; transportation strategy: distribution network design options for a transportation network, vehicle scheduling in transportation, case discussion.

Network design and operation decisions, framework for network design decisions; facility location and capacity allocation models: network optimization models, capacitated plant location models, gravity location models, network operations model, model building using Excel solver and anyLogistix; case discussion, innovations in supply chains; supply chain coordination: Bullwhip effect, quantifying the bullwhip effect, remedial strategies for coping with the bullwhip effect.

References:

[1] Shah, J., 2016, *Supply Chain Management –Text and Cases*, 2nd ed., Pearson Education.
[2] Chopra, S., and Meindel, P., 2016, *Supply Chain Management: Strategy, Planning, and Operation*. Pearson Prentice Hall of India.
[3] Levi, D. S., Kaminsky, P., Levi, E. S., and Shankar, R., 2008, *Designing and Managing the Supply Chain: Concepts, Strategies, and Case Studies*. Tata McGraw-Hill.
[4] Chase, R. B., Shankar, R., Jacobs, F. R., and Aquilano, N. J., 2018, *Operation and Supply Chain Management*, Tata McGraw-Hill.
[5] Shapiro, J. F., 2007, *Modeling the Supply Chain*. Thomson Learning.

ME3126E MANAGEMENT OF ORGANISATIONAL BEHAVIOUR

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Summarize the systematic approach to studying Organizational Behavior (OB) and its significance in management.

CO2: Synthesize the foundations of group behavior, and the distinctions between groups and teams to create a comprehensive framework for building effective teams in an organizational context.

CO3: Assess the influence of organizational structure and culture on employee behavior, and develop strategies for influencing and managing cultural change in organizations.

Introduction to Organisational Behaviour (OB): Management and Organizational Behavior - Systematic study in OB - Contributing disciplines in OB - Developing an OB model. The individual: Understanding Diversity - Prejudice and Discrimination in Organizations - Cross-Cultural OB - Implementing Diversity Management, Attitudes and Behavior - Emotions and moods - Personality Attributes Relevant to OB - Perception and Individual Decision Making, Motivation: Classic theories - Contemporary Theories.

Group Process: Foundations of Group Behavior - Defining and Classifying Groups - Stages of Group Development - Group Decision Making - Differences Between Groups and Teams - Types of Teams - Creating Effective Teams - Interpersonal Communication - Cross-Cultural Communication - Leadership - leadership types - power- conflict and negotiation- negotiation methods- Sources of Conflict- Types of Conflict- Conflict Management Approaches

Organisational Process: Foundations of Organisational structure - Centralization and decentralization - Common Organisational designs - New design options, Organizational Culture - Creating and Sustaining Culture - Influencing Organizational Cultures - Organizational Change - Change and employee behaviour, Resistance to change - Approaches to Managing Organizational Change.

References:

[1] Robbins, S.P., Judge, T.A., and Vohra, N., 2018, *Organisational Behavior*, 18th ed., Pearson Education.
[2] Luthans, F., Luthans, B. C., and Luthans., K. W., 2021, *Organizational Behavior: An Evidence-Based Approach*, Information Age Publishing.
[3] McShane, S., and Von Glinow, M. A., 2022, *Organisational Behavior*, 5th ed., McGraw-Hill.
[4] Hersey, P., Balaschard, K. H., and Johnson, D. E., 2013, *Management of Organisational Behavior*, 10th ed., Pearson Education.

ME3127E MANAGEMENT OF HUMAN RESOURCES

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Formulate strategies for addressing diversity issues within the workplace, taking into consideration the principles of HRM.

CO2: Assess the ethical considerations in personnel management and propose strategies for maintaining a fair and equitable work environment.

CO3: Evaluate the role of organizational design and restructuring strategies in shaping industrial relations within an organization.

Human Resource Management

Historical evolution - topology of companies - concept of an involved employee - HR issues - corporate and HR strategy - linking business and HR planning - HR instruments - diversity issues.

Personnel Management

Personnel functions - personnel management environment in India - manpower planning - recruitment - selection and Induction of employees - staff training and development, latest trends in selection and training - career planning - job analysis and design - compensation planning - salary administration - job evaluation - merit rating, learning curve based compensation - Human Resource Management System,

Industrial Relations

Concept, Scope, Evolution, Approaches, Actors and Models, Conflict and cooperation - Bi-partitism - Tri-partitism - Industrial Relations in changing scenario- organizational design - dimensions - restructuring strategies; work organization - organizational development - change agents - process of organizational change.

References:

[1] Dessler, G., and Varkkey, B., 2020, *Human Resource Management*, 16th ed. Person Education.

[2] Tarique, I., Briscoe, D.R., and Schuler, R.S., 2022, *International Human Resource Management: Policies and Practices for Multinational Enterprises*, 6th ed., Routledge (T&F), New York.

[3] Zeuch, M. (editor), 2016, *Handbook of Human Resources Management*, Springer-Verlag, Heidelberg.

[4] Brewster, C., Houldsworth, E., Sparrow, P., and Vernon, G., 2023, *International Human Resource Management*, Kogan Page.

ME3128E QUALITY PLANNING AND ANALYSIS

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Estimate the process parameters applying statistical models.
CO2: Design the experiments and interpret the results.
CO3: Design and Construct control charts for quality control.
CO4: Design the sampling plans and understand the sensitivity of the plans.

Introduction to quality management, history, definition, dimensions; responsibility for quality, cost of poor quality, TQM framework; customer satisfaction: customer perception of quality, voice of customer; continuous process improvement; describing variation: discrete distributions, continuous distributions, probability plots; point estimation of process parameters, statistical inference for a single sample, two samples.

Analysis of Variance: single factor experiment, two factorial experiment, linear regression models,.

Chance and assignable causes; variable and attribute charts; rational subgrouping; control charts for variables: average, range, standard deviation charts; control charts for attributes; chart for fraction nonconforming; chart for count of non-conformities; construction of operating characteristic curves, process capability, six sigma.

Sampling plans:types of sampling plans, single sampling plan, double sampling plan; design of sampling plan; construction of operating characteristic curve; acceptance quality level; average time to inspection, average outgoing quality; reliability – life-history curve, system reliability, testing.

References:

[1] Montgomery, D.C., 2018, *Statistical Quality Control A Modern Introduction*, 6th ed. Wiley-India, New Delhi.
[2] Juran, J.M., and Gryna, F.M., *1995, Quality Planning and Analysis*, 3rd ed. Tata McGraw-Hill, New Delhi.
[3] Grant, E.L., and Leavenworth, R.S., 2000, *Statistical Quality Control*, 7th ed. Tata McGraw-Hill, USA.
[4] Besterfield, D.H., 2004, *Quality Control*, 7th ed. Pearson Education, New Delhi.

ME4121E TECHNOLOGY MANAGEMENT

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:
CO1: Comprehend the technology environment.
CO2: Analyze the implications of environment during the development and diffusion process.
CO3: Strategize the developed product for the integration of the technology with business.
CO4: Evaluate the commercial potential of a new technology.

Technology: Innovation and Diffusion
Technology: scope, definition and characteristics, strategic, operational and management issues, classification of technology; technology environment: the long-wave cycle, evolution of production technology, evolution of product technology; critical factors in managing technology: technology-price relationship, the timing factor, managing change, productivity and competitiveness, leaders versus followers; types of innovation output, classification of innovation, technology life cycle curves; diffusion of technology: dynamics of diffusion, Bass model of diffusion, mechanisms of diffusion, factors driving diffusion; case discussion: market life-cycles, transition and disruptions.

Technology Planning
Technology planning framework; methods of knowledge mapping: chronological mapping, co-word based mapping, cognitive mapping, conceptual mapping; forecasting technology: S-curves, Delphi technique, morphological analysis; critical technology and technology maps; technology audit model: technology roadmap.
Integrating Technology and strategy: perspectives on strategy, connecting technology and strategy, technology and the value chain. product evaluation matrix, BCG matrix, X-Y coordinate positioning matrix, M-by-N matrix, SWOT matrix; formulation of technology strategy: concept of core competence, case discussion on product development.

Role of Entrepreneur and Business model
The Entrepreneur's Role, Task and Personality, A Typology of Entrepreneurs: Defining Survival and Success, Entrepreneurship as a Style of Management, The Entrepreneurial Venture and the Entrepreneurial Organisation, Identify Problems Worth Solving, Customer Identification, Choosing a Direction Opportunity recognition and entry strategies: Business model identification.
Opening the Window: Gaining Commitment, Gathering the Resources. Development of business plan as an entrepreneurial tool. Definition of intellectual property, importance of IPR; TRIPS and its implications; patent, copyright, industrial design and trademark.

References:

[1] Khalil, T., 2009, *Management of Technology*, Tata McGraw-Hill.
[2] Narayanan, V.K., 2002, *Managing Technology and Innovation for Competitive Advantage*, Pearson Education Asia.
[3] Khanka, S.S., 2006, *Entrepreneurial Development*, S. Chand & Co.
[4] Barringer, B.R. and Ireland, D., 2009, *Entrepreneurship*, Prentice Hall.
[5] Gaynor, G.H., 1996, *Handbook of Technology Management*, McGraw-Hill.
[6] Burgelman, R.A., Christensen, C.M., and Wheelwright, S.C., 2011, *Strategic Management of Technology and Innovation*, 5th ed. Tata McGraw-Hill.
[7] Shane, S., 2014, *Technology Strategy for Managers and Entrepreneurs*, Pearson Education.
[8] Kaplan, 2022, *Business and Technology*, Kaplan Publishing.

ME4122E MANAGEMENT OF LEAN PRODUCTION SYSTEMS

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course outcomes:

CO1: Apply continuous improvement tactics and strategies, to identify and address process inefficiencies and waste.
CO2: Evaluate the impact of small lot production on competitive criteria, lot sizing, and lot-size reduction strategies.
CO3: Analyze the role of focused factories, Group Technology, and cellular manufacturing in optimizing facility layouts and production flow analysis

Introduction to Lean Principles

Evolution of manufacturing; Toyota Production System: features; fundamentals of continuous improvement: continuous improvement as tactics and strategy - finding improvements: PDCA cycles - value analysis / value engineering - basic problem solving and improvement tools - value stream mapping - Nemawashi; value adding and waste elimination: Toyota's seven wastes - Lean principles - Five Ss; customer-focused quality: Total Quality Management - Six Sigma - statistical process control.

Small lot production

Lot size basics - lot sizing - lot-size reduction - effect of lot size reduction on competitive criteria - case of large process batches. Setup-time reduction: traditional approaches for setups - set-up reduction methodology: SMED - techniques for setup reduction. Maintaining and improving equipment: equipment maintenance and competitiveness - equipment effectiveness - preventive maintenance programme - total predictive maintenance. Pull production systems: production control systems - pull systems and push systems - conveyance Kanban - production Kanban - other mechanisms for signal and control.

Focused Factories and Group Technology

Ways of doing work - facility layouts - Group Technology - Focused Factory - production flow analysis. Workcells and cellular manufacturing: Workcell concepts - Workcell applications - Workcell design - Workers in cells - equipment issues.

References:

[1] Nicholas, J., 2018, *Lean Production for Competitive Advantage: A comprehensive Guide to Lean Methodologies and Management Practices*, 2nd ed. Routledge, Taylor and Francis.
[2] Nicholas, J., 2001, *Competitive Manufacturing Management: Continuous Improvement, Lean Production, and Customer-Focused Qualities*, Tata McGraw-Hill.
[3] Askin, R.G., and Goldberg, J.B., 2007, *Design and Analysis of Lean Production Systems*, Wiley Student Edition.
[4] Singh, N., and Rajamani, D., 2011, *Cellular Manufacturing Systems: Design, Planning & Control*, Springer New York, NY.
[5] Korgaonker, M.G., 2000, *Just In Time Manufacturing*, Macmillan Publishers.
[6] Hirano, H., 2019, *JIT Implementation Manual: The Complete Guide to Just-in-Time Manufacturing*, CRC Press.
[7] Roser, C., 2021, *All About Pull Production: Designing, Implementing, and Maintaining Kanban, CONWIP, and other Pull Systems in Lean Production*, AllAboutLean.com Publishing.

ME4123E OPTIMIZATION METHODS IN ENGINEERING

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Formulate engineering problems as mathematical optimization problems.
CO2: Explain the techniques of optimization for engineering problems.
CO3: Apply computer software to solve engineering optimization problems.
CO4: Explain the heuristic optimization methods.

Introduction: statement of an optimization problem, classification of optimization problems − mathematical formulation of optimization problems − engineering applications of optimization − fundamental concepts in optimization: concave functions, convex functions, local optima, global optima − principles of optimization of unconstrained and constrained problems − necessary and sufficient conditions of optimality

Linear programming methods of optimization: Simplex method, two-phase method − duality concept −sensitivity analysis − integer programming: branch-and-bound algorithm.

Algorithms for non-linear optimization problems: algorithms for single variable optimization problems, golden section search method, Newton-Raphson method − algorithms for multi-variable optimization problems: steepest descent method, quadratic programming − solving optimization problems using solvers

Evolutionary algorithms: working principles of Genetic Algorithm, Simulated Annealing, Ant Colony Optimization, Particle Swarm Optimization

Multi-objective optimization: concept of Pareto-optimality − Multi-criterion decision problem: analytic hierarchy process.

References:

[1] Arora, J.S., 2016, *Introduction to Optimum Design*, 4th ed. Academic Press.
[2] Belegundu, A.D., and Chandrupatla, T.R., 2018, *Optimization Concepts and Applications in Engineering*, 3rd ed. Cambridge University Press.
[3] Deb, K., 2011, *Optimization for Engineering Design*, 2nd ed. Prentice-Hall of India.
[4] Nagesh Kumar, D., *Optimization Methods* [online] Available: http://nptel.ac.in/course.php
[5] Rao, S.S., 2019, *Engineering Optimization*, 5th ed. Wiley.
[6] Ravindran, A., Ragsdell, K.M., and Reklaitis, G.V., 2006, *Engineering Optimization: Methods and Applications*, 2nd ed. Wiley India.
[7] Taha, H.A., 2019, *Operations Research: An Introduction*, 10th ed. Pearson Education.
[8] Winston, W. L., 2004, *Operations Research: Applications and Algorithms*, 4th ed. Brooks/Cole Cengage Learning.

ME4124E ACCOUNTING AND FINANCE FOR ENGINEERS

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Explain the basic accounting concepts and construction of financial statements.
CO2: Analyze and interpret the financial statements.
CO3: Evaluate the time value of money and its applications to capital market.
CO4: Apply the tools of capital planning and budgeting.

Financial Accounting Principles and Statements
Personal Cash flow forecasting and management, Financial Accounting: need, accounting concepts, classification of items in balance sheet, formats of balance sheet, construction of balance sheet, accounting equation technique; inventory valuation methods: depreciation valuation techniques; construction of profit and loss account; statement of changes in financial position, working capital basis (funds flow statement); cash flow statement; recording of transactions: classification of accounts, rules of debit and credit, journal entries, ledger postings; trial balance and work sheet

Financial statement analysis: ratio analysis, liquidity ratios, leverage ratios, profitability ratios, activity ratios, integrated analysis of ratios.

Cost Volume profit, Marginal costing, Absorption costing

Market Evaluation
Time value of money. Introduction to Excel. Capital structure, stocks and bond valuation: basic bond valuation, yield to maturity, valuation of ordinary shares, constant growth model, variable growth model; relationship among financial decisions, return, risk and share values.

Financial planning
Budgeting, types of budget, preparation of budget; working capital computation: identifying relevant cash flows; capital budgeting techniques: traditional (payback, accounting rate of return) and discounted cash flow techniques (net present value, internal rate of return, profitability index); resolving the conflict of net present value: internal rate of return differences.

References:
[1] Ramachandran, N., and Kakani, R.K., 2020, *Financial Accounting for Management*, 5th ed. Tata McGraw-Hill.
[2] Khan, M.Y., and Jain, P.K., 2018, *Financial Management*, 8th ed. Tata McGraw-Hill.
[3] Khan, M.Y., and Jain, P.K., 2021, *Management Accounting*, 8th ed. Tata McGraw-Hill.
[4] Lal, J., and Srivastava, S., 2014, *Financial Accounting*, 3rd ed. S. Chand.

ME4125E SIMULATION MODELLING AND ANALYSIS

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Apply simulation approach to model static and dynamic systems, with an understanding of the principles of generating random numbers and random variates.

CO2: Develop input data models for simulation and conduct verification & validation tests on simulation models.

CO3: Evaluate the performance of systems by analysing the output of the simulation models.

CO4: Develop simulation models using simulation software and develop insightful reports.

Systems and system environment: components of a system, discrete and continuous systems, model of a system, types of models; steps in simulation study: technique of simulation, comparison of simulation and analytical methods;

Monte Carlo simulation: simulation of queuing systems, simulation of inventory systems; concepts in discrete event simulation; random number generation: techniques for generating random numbers, tests for random numbers, random variate generation, inverse transform method.

Input modelling for simulation: data collection, identifying the distribution with data, parameter estimation; goodness of fit tests: Chi square and Kolmogorov-Smirnov tests; verification and validation of simulation models; output analysis for a single model: measures of performance and their estimation, output analysis for terminating simulations and steady state simulations.

Simulation modelling and analysis of manufacturing systems; introduction to simulation software: simulation model building and analysis using Excel and ARENA.

References:

[1] Altiok, T. and Melamed, B., 2014, *Simulation modeling and analysis with Arena*, 5th ed., Elsevier.
[2] Banks, J., Carson, J.S., Nelson, B.L., and Nicol, D.M., 2014, *Discrete-Event System Simulation*, 5th ed. Pearson Education.
[3] Deo, N., 1997, *System Simulation with Digital Computer*, Prentice Hall of India.
[4] Law, A.M., 2017, *Simulation Modelling and Analysis*, 4th ed. McGraw-Hill Education.
[5] Rossetti, M.D., 2015, *Simulation Modelling and ARENA*, 2nd ed. Wiley-Blackwell.
[6] Robinson, S., 2014, *Simulation: The Practice of Model Development and Use*, 2nd ed. Palgrave Macmillan.
[7] Oakshott, L., 1997, *Business Modelling and Simulation*, Pitman Publishing.
[8] Gordon, G., 1995, *System Simulation*, 2nd ed. Prentice Hall of India.
[9] Ross, S.M., 2002, *Simulation*, 3rd ed. Academic Press.
[10] Fishman, G.S., 1973, *Concepts and Methods in Discrete Event Digital Simulations*, Wiley.
[11] Carrie, A.S., 1988, *Simulation of Manufacturing Systems*, John Wiley & Sons Ltd.

ME4126E HUMAN FACTORS IN ENGINEERING AND DESIGN

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:
CO1: Comprehend cognitive work design and information processing in engineering and design
CO2: Identify the human capabilities and limitations for a system design
CO3: Explore biomechanical bases of ergonomics in design
CO4: Estimate the work physiology and devise strategy for improvement

Human factors and Ergonomics
Introduction to Human factors and Ergonomics: systems description, nature of man-machine systems and characteristics, Design of cognitive work: information theory, human information processing model, information input and processing, perception, attention, mental workload, display of visual information, display of auditory information – specific design principles, tactual and olfactory displays, cutaneous senses, speech communication

Biomechanical bases of ergonomics
Static biomechanical analysis and models: work physiology, energy and energy sources of the body, categories of work, metabolism, physical work capacity, aerobic capacity, assessment of aerobic capacity – fatigue and its evaluation – manual work and design guidelines – energy expenditure: heart rate, NIOSH lifting guidelines – multitask lifting guidelines
.

Engineering anthropometry and work-space design
Statistical basis of anthropometry: use of anthropometric data in design, principles of work design, design of work surfaces, science of seating, cumulative trauma disorders, fundamental risk factors and prevention – work environment design – shift work and working hours: work rest scheduling, experiment on designing a workplace using the anthropometric data collected.

References:
[1] Sanders, M.S., and McCormick, E.J., 1992, *Human Factors in Engineering and design*, 7th ed. McGraw-Hill.
[2] Tayyari, F., and Smith, J.L., 1997, *Occupational Ergonomics: Principles and applications*, Kluwer Academic Publishers.
[3] Gavriel, S., 1997, *Handbook of Human Factors & Ergonomics*, Inter-science.
[4] Murrell, K.F.H., and Schnauber, H., 1986, *Ergonomics*, Econ.
[5] Freivalds and Niebel, B.W., 2013, *Niebel's Methods,Standards and Work Design*, 12th ed, McGraw-Hill.
[6] Salvendy, G., 1997, *Handbook of Human Factors & Ergonomics*. Inter-science.
[7] Groover, M.P., 2007, *Work Systems and the Methods, Measurement, and Management of Work*, Pearson Prentice Hall.

ME4127E MACHINE LEARNING FOR DATA SCIENCE AND ANALYTICS

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Outline the basic concepts of Statistics for data science and machine learning.
CO2: Illustrate the supervised and unsupervised machine learning algorithms.
CO3: Apply machine learning algorithms for solving practical problems.
CO4: Analyse the performance of machine learning algorithms and apply ensemble learning algorithms.

Introduction of Statistics
Sampling distributions, central limit theorem, distributions of the sample mean and the sample variance for a normal population; test of hypothesis: mean of normal population, one-tailed and two tailed tests, F-test, and Chi-Square test; analysis of variance (ANOVA) – one-way and two-way classifications; relation between statistics and machine learning; introduction to Python and its libraries.

Supervised Machine Learning
Introduction to algorithms in machine learning – classification, tools to analyse algorithms, algorithmic technique: divide and conquer, randomization in algorithms, supervised machine learning – linear regression, multiple linear regression: cost function and gradient descent, logistic regression, problem of over fitting; discriminant analysis, classification trees, K Nearest Neighbours, Support Vector machine; overview of ensemble learning models.

Unsupervised Machine Learning
Introduction to unsupervised learning – association rules: Apriori algorithm, clustering methods – K-means, hierarchical clustering, density-based clustering: DBSCAN; hyperparameter tuning; dimensionality reduction – principal component analysis (PCA) algorithm, factor analysis; Introduction to reinforcement learning, neural networks, and deep learning.

References:

[1] Montgomery, D.C., and Runger, G.C., 2013, *Applied Statistics and Probability for Engineers*, 6th ed. Wiley.
[2] Hair, J.F., Black, W.C., Babin, B.J. and Anderson, R.E., 2015, *Multivariate Data Analysis*, 7th ed. Pearson New International.
[3] Hastie, T., Tibshirani, R., and Friedman, J., 2008. *The Elements of Statistical Learning: Data Mining, Inference and Prediction*, 2nd ed. Springer, USA.
[4] Géron, A., 2019, *Hands-On Machine Learning with Scikit-Learn*, Oreilly, USA.
[5] Kumar, U.D., 2021, *Business Analytics*, Wiley, India.
[6] Pradhan, M., and Kumar, U.D., 2019, *Machine Learning using Python*, Wiley, India.
[7] Muller, A., 2016, *Introduction to Machine Learning with Python: A Guide for Data Scientists* (Greyscale Indian Edition), Oreilly, USA.

ME4128E PRODUCT AND PROCESS DEVELOPMENT

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Explain the principles and methodologies in engineering design and their relevance in product realization
CO2: Comprehend the four stages of product development and conduct product cost analysis
CO3: Analyze the voice of the customer and apply techniques for customer-oriented product design
CO4: Design and conduct experiments using experimental design techniques to optimize product and process parameters

Ideas and methods currently used in product realisation process
Basic terms in engineering design, Japanese contributions in product development, Innovation, Quality dimensions, six sigma and ISO standards, benchmarking

Product and process design and development team method
Integrated product and process design and development team requirement, four stages of product development, product cost analysis: determining the cost of products, voice of the customer, Quality Function Deployment, Product functional requirements and functional decomposition

Product Concepts and Embodiments
Initial feasibility analysis, Concept generation and the search for solutions, TRIZ principles, Bio-inspired concepts, product modularity and architecture, concept evaluation and selection

Design for Assembly and Disassembly
Assembly principles and guidelines, Design for disassembly guidelines, materials selection

Design for X
Life-cycle engineering: Reliability, Failure identification techniques; Poka-Yoke, design for maintainability, design for packaging, design for environment, Ergonomics: usability, human factors, and safety

Product and Process Improvement
Experimental design, guidelines for designing experiments, statistical process control, factorial analysis, Taguchi method, Failure Mode Effect Analysis.

References:
[1] Magrab, E.B., Gupta, S.K., McCluskey, F.P., and Sandborn, P.A., 2010, *Integrated Product and Process Design and Development,* 2nd ed. CRC Press.
[2] Crawford, M. and Benedetto, A.D., 2020, *New Products Development*, 11th ed. McGraw Hill.
[3] Ulrich, K.T., and Eppinger, S.D., 2016, *Product Design and Development*, 5th ed. McGraw Hill
[4] Trott, P., 2009, *Innovation Management and New Product Development,* 4th ed. Pearson India.
[5] Savransky, S.D., 2000, *Engineering of creativity: introduction to TRIZ methodology of inventive problem solving*, 1st ed. CRC Press.
[6] Besterfield, D.H., Besterfield, C., Besterfield, G.H., Besterfield, M., Urdhwareshe, H. and Urdhwareshe, R., 2020, *Total Quality Management*, 5th Edition.

ME4129E NEW PRODUCT DEVELOPMENT

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Comprehend the stages of new product development for generating and evaluating product ideas

CO2: Develop skills in market research and analysis for product planning

CO3: Gain insights into concept development, prototyping, and testing

CO4: Analyze case studies to understand successful and unsuccessful product launches

Strategic elements of product development

Importance of new products, characteristics of successful products, role of innovation in business growth, duration and cost of product development, challenges of product development

Development process

Product development process, concept development, process flows, opportunity identification and selection process, product platform planning, modularization, product innovation charter, Kano model, voice of the customer, quality function deployment

Concept generation and evaluation

Concept screening and scoring, analytical attribute techniques, gap maps, trade-off analysis, cumulative expenditure curve, decay curve, life cycle A-T-A-R model

Concept testing and development

Purpose of concept testing, concept statement, benefit segmentation, joint space maps, preference regression, scoring model, analytic hierarchy process

Product architecture

Physical elements of a product, types of modularity, implications of the architecture, establishing the architecture, delayed differentiation, component commonality, industrial design.

References:

[1] Crawford, M., and Benedetto, A.D., 2020, *New Products Development*, 11th ed. McGraw Hill.

[2] Ulrich, K.T., and Eppinger, S.D., 2016, *Product Design and Development*, 5th ed. McGraw Hill

[3] Magrab, E.B., Gupta, S.K., McCluskey, F.P., and Sandborn, P.A., 2010, *Integrated Product and Process Design Development,* 2nd ed. CRC Press.

[4] Trott, P., 2009, *Innovation Management and New Product Development,* 4th ed. Pearson India.

[5] Besterfield, D.H., Besterfield, C., Besterfield, G.H., Besterfield, M., Urdhwareshe, H. and Urdhwareshe, R., 2020, *Total Quality Management*, 5th Edition, Pearson.

ME4130E BUSINESS ANALYSIS AND DECISION MAKING

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Demonstrate a clear understanding of basic concepts in business analytics and proficiency in spreadsheets
CO2: Analyze data and create insightful visualizations using business intelligence tools
CO3: Apply Expected Monetary Value and Decision Trees for decision analysis and risk assessment
CO4: Develop critical thinking skills to interpret statistical findings, regression analysis results, and simulation outcomes for solving business problems

Introduction to business analytics
Basic concepts, variables, scales of measurement, time series data, outliers and missing data. Application of spreadsheets for filtering, sorting and summarizing. Measures of statistics, application of Pivot Tables, Business case discussion

Business Intelligence (BI) Tools for Data Analysis
Importing Data into Excel with Power Query, Data Analysis with Power Pivot, Business case discussion, Data Visualization with Tableau Public, Data Cleansing.

Probability and Decision Making under Uncertainty
Probability Essentials, Probability Distribution of a Random Variable, Decision Making under Uncertainty: Elements of Decision Analysis, Expected Monetary Value and Decision Trees, Business case discussion

Statistical Inference
Sampling and Sampling Distributions, Sampling methods, point and interval estimates, Confidence Interval Estimation, Sample Size Selection, Hypothesis Testing: Concepts in Hypothesis Testing, Hypothesis Tests for a Population Mean, Variance and Proportions, Tests for Normality, Chi-Square Test for Independence.

Regression Analysis and Time Series Forecasting
Scatterplots: Graphing Relationships, Correlations: Indicators of Linear Relationships, Simple Linear Regression, Introduction to Multiple Regression, Validation of the Fit, Inferences about the Regression Coefficients

References:
[1] Albright, S.C., and Winston, W.L., 2020, *Business Analytics: Data Analysis and Decision Making*, 7th ed. Cengage Learning.
[2] Black, K., 2012, *Business Statistics*, 7th ed. Wiley Publication.
[3] Levine, D.M., Szabat, K.A., Stephan D.F., and Mariappan, P., 2022, *Business Statistics a First course,* 8th ed. Pearson Education Publication.
[4] Levin, R.I., Rubin, D.S., Siddiqui, M.H., and Rastogi, S., 2017, *Statistics for Management,* 8th ed. Prentice-Hall Inc. Publication.
[5] Montgomery, D.C., and Runger, G.C., 2016, *Applied Statistics and Probability for Engineers*, 6th ed. Wiley Asia Publication.
[6] Levine, D.M., Stephan, D.F., and Szabat, K.A., 2017, *Statistics for Managers – Using Microsoft Excel*, 8th ed. Pearson Publication.
[7] Winston, W.L., 2019, *Microsoft Excel 2019 Data Analysis and Business Modeling*, 6th ed. Prentice-Hall Inc. Publication.
[8] Vohra, N.D., 2021, *Business Statistics: Text and Problems - With Introduction to Business Analytics*, McGraw Hill.

ME4131E INDUSTRIAL INTERNET OF THINGS

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Explain Industrial Internet of Things and Cyber Physical manufacturing.
CO2: Model and Analyse Cyber Physical and Cyber Manufacturing systems.
CO3: Explain Architectural design patterns for industrial Internet of Things.
CO4: Analyse AI and data Analytics for Industrial Internet of Things.
CO5: Evaluation of Workforce and Human Machine Interaction and Application of Industrial Internet of Things.

Understanding Industrial Internet of Things (IIoT):
Industrial Internet of Things and Cyber Manufacturing Systems, Application map for Industrial Cyber Physical Systems, Cyber Physical Electronics production.

Modelling of CPS and CMS:
Modelling of Cyber Physical Engineering and manufacturing, Model based engineering of supervisory controllers for cyber physical systems, formal verification of system, components, Evaluation model for assessments of cyber physical production systems.

Architectural Design Patterns for CMS and IIoT:
CPS-based manufacturing and Industries 4.0., Integration of Knowledge base data base and machine vision, Interoperability in Smart Automation, Enhancing Resiliency in Production Facilities through CPS. Communication and Networking of IIoT.

Artificial Intelligence and Data Analytics for manufacturing:
Application of CPS in Machine tools, Digital production, Cyber Physical system Intelligence, Introduction to big data and machine learning and condition Monitoring.

Evaluation of Workforce and Human Machine Interaction:
Worker and CPS, Strategies to support user intervention. Introduction to Advance manufacturing and Innovation Ecosystems.

Application of IIoT:
Smart Metering, e-Health Body Area Networks, City Automation, Automotive Applications, Home Automation, Smart Cards, Plant Automation, Real life examples of IIOT in Manufacturing Sector.

References

[1] Jeschke,S., Brecher, C., Song, H., and Rawat, D.B. (Editors), 2017, *Industrial Internet of Things: Cyber Manufacturing System*, Springer
[2] Chaouchi, H. (Editor), 2010, *The Internet of Things: Connecting Objects to the Web*, Willy Publications
[3] Hersent, O., Boswarthick, D., and Elloumi, O., 2011, *The Internet of Things: Key Applications and Protocols*, 2nd Ed, Willy Publications
[4] Holdowsky, J., Mahto, M., Raynor, M.E., and Cotteleer, M., 2015, *Inside the Internet of Things (IoT)*, Deloitte University Press
[5] Vermesan, O., and Friess, P., 2022, *Internet of Things- From Research and Innovation to Market Deployment*, River Publishers Series
[6] Wainewright, P., *Five thoughts from the Father of the Internet of Things* (Online Article), https://diginomica.com/five-thoughts-from-the-father-of-the-internet-of-things#:~:text=We%20don't%20have%20any,what%20all%20our%20technology%20does. (Accessed on 04-22-2023)
[7] *How Protocol Conversion Addresses IIoT Challenges*: White Paper By RedLion. https://www.lakelandengineering.com/wp-content/uploads/2018/08/White-Paper-Red-Lion-How-Protocol-Conversion-Addresses-IIoT-Challenges.pdf, (Accessed on 04-22-2023)
[8] Girardin, G., Bonnabel, A., and Mounier, E., 2014, *Technologies Sensors for the Internet of Things Businesses & Market Trends 2014 -2024*, Yole Development Copyrights.

ELECTIVE COURSES: THERMO-FLUIDS AND ENERGY ENGINEERING

ME2221E FUNDAMENTALS OF COMBUSTION

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO 1: Describe the basic principles, concepts and combustion theories of classical fuels.

CO2: Calculate adiabatic flame temperature, chemical equilibrium composition,rate of chemical reaction and compute auto-ignition process

CO 3: Compute laminar flame speed and describe characteristics of premixed and non-premixed combustion

CO 4: Describe turbulent characteristics of premixed and non-premixed flames

Introduction to combustion, review of thermodynamic laws, reactants and products mixtures, heats of reacting and formation, stoichiometry, standard enthalpies and enthalpy of formation, enthalpy of combustion and heating, adiabatic flame temperatures, chemical equilibrium, Gibb's function, chemical kinetics, global and elementary reactions, reaction rates, mechanisms, unimolecular, chain and chain branching reactions, H_2–O_2 chemical mechanisms, reaction orders, temperature and pressure dependence on rate coefficients.

Explosion, deflagration and detonation, detonation phenomenon – Hugoniot relations; explosion limits. Premixed laminar flames, laminar flame structure, structure of CH_4-Air flame, flame velocity and flame thickness, simplified and detailed analysis of laminar flame, effect of equivalence ratio on flame speed and flame thickness, flame quenching and ignition, stability limits of laminar flames – flammability limits, quenching distance, flame stabilization, Experimental determination of flame speeds, turbulent flames – rate of reaction, regimes and flame speed.

Laminar diffusion flames: structure, theoretical models, turbulent diffusion flames, non-dimensionalization and conserved scalars. Liquid fuel combustion- Droplet combustion; simple model for evaporating and burning droplet: conservation of mass, energy and species, burning rate constant and droplet lifetime, D^2-law, droplet combustion in convective environment, spray combustion model, Solid fuel combustion – diffusion theory.

References:

[1] Turns, S. R., and Haworth, D. C., 2020, *An Introduction to Combustion: Concepts and Applications*, 3rd ed., McGrawHill.
[2] Kuo, K. K., 2012, *Principles of Combustion*, 2nd ed., Wiley India Pvt Ltd.
[3] Warnatz, J., Maas, U., and Dibble, R. W., 2006, *Combustion: Physical and Chemical Fundamentals, Modelling and Simulation, Experiments, Pollutant Formation*, 4th ed., Springer.
[4] Glassman, I., Yetter, R. A. and Glumac, N. G., 2014, *Combustion*, Academic Press.
[5] Williams, F.W., 2019, *Combustion Theory*, CRC Press.
[6] Strahle, W. C., 1993, *An Introduction to Combustion*, CRC Press.
[7] Mukhopadhyay, A., and Sen, S., 2019, *Fundamentals of Combustion Engineering*, CRC Press.

ME2222E GAS DYNAMICS

Pre-requisites: Knowledge of Thermodynamics and Fluid Mechanics

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Analyse the compressibility effects through constant and variable area duct
CO2: Demonstrate knowledge of designing a nozzle for supersonic flows
CO3: Analyse the effects of irreversible mechanisms in supersonic flows
CO4: Demonstrate knowledge of designing ducts with realistic situations for supersonic flows

Thermodynamics concepts; Basic fluid flow equations; Continuity, momentum, energy equations; differential form of these equations, Navier-Stokes equation; introduction to compressible flows: equations for one-dimensional compressible flows, speed of sound, Mach number; qualitative difference between incompressible, subsonic and supersonic flows; adiabatic flow ellipse.

Quasi one-dimensional flow equations; isentropic flow through a duct; area-velocity relation; use of gas tables and charts; converging and convergent-divergent nozzles; over-expanded and under-expanded nozzle; choking; normal shocks in one-dimensional flow: normal shocks relations, Prandtl's relation, Rankine-Hugoniot relations; oblique shocks, oblique shock relations; supersonic flow over a wedge, shock polar; Prandtl-Meyer expansion waves, and relations.

One-dimensional flow with friction in constant area duct: Fanno curve, and Fanno flow relations; effect of friction on flow properties, frictional choking; isothermal flow; one-dimensional flow with heat addition: Rayleigh curve, effect of heat addition, thermal choking; generalized one dimensional flow with effects like area variation, friction and heat transfer.

References:

[1] Anderson, J. D., 2021, *Modern Compressible Flow with Historical Perspective*, 4th ed. McGraw-Hill.
[2] Oosthuizen, P. H., and Carscallen, W.E., 2014, *Introduction to Compressible Fluid Flow*, 2nd ed. CRC Press.
[3] Liepmann, H. W., and Roshko, A., 2003, *Elements of Gas Dynamics*, Dover Publications.
[4] Zucker, R. D., and Biblarz, O., 2002, *Fundamentals of Gas Dynamics*, 2nd ed. John Wiley & Sons.
[5] Zuckrow, M. J., and Hoffman, J. D., 1976, *Gas Dynamics*, Vol. 1, John Wiley & Sons.
[6] Shapiro, A. H., 1953, *The Dynamics and Thermodynamics of Compressible Fluid Flow*, Vol.1, John Wiley & Sons.
[7] Yahya, S.M., 2010, *Fundamentals of Compressible Flow*, New Age International.

ME2223E COMPUTATIONAL METHODS IN ENGINEERING

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Solve nonlinear equations in a single variable
CO2: Compute derivatives and integrals
CO3: Solve Initial-Value Problems
CO4: Discretize PDEs and plot/visualize the numerical solutions

Solution of Equations in one variable: Bisection, Fixed-Point Iteration, Newton-Raphson, Secant Regula Falsi methods; Interpolations: Lagrange, Newton’s Divided Difference, Inverse, Splines.

Numerical Differentiation; Richardson’s Extrapolation; Numerical integration: Rectangular, Trapezoidal, Simpson‘s 1/3 & 3/8, Composite Trapezoidal rule, Romberg Integration, Adaptive Quadrature, Gauss quadrature.

Initial-Value Problems for Ordinary Differential Equations: Euler‘s, Heun‘s, Runge-Kutta, Mutistep Methods.

Finite difference method for Elliptic Partial Differential Equations (PDEs) with treatment of different Boundary Conditions.

System of linear algebraic equations: Tridiagonal Matrix Algorithm, Jacobi Iteration, Gauss-Seidel. Eigenvalues of a Matrix by iteration (Power Method).

Visualization of numerical solutions.

References:
[1] Jaluria, Y., 2012, *Computer Methods for Engineering with MATLAB Applications*, 2nd ed., CRC Press.
[2] Chapra, S. C., and Canale, R. P., 2016, *Numerical Methods for Engineers*, 7th ed., McGraw-Hill Education India Pvt. Ltd.
[3] Griffith, D. V., and Smith, I. M., 1991, *Numerical Methods for Engineers: A Programming Approach*. CRC Press.
[4] Burden, R. L. and Faires, J. D., 2012, *Numerical Analysis*, 9th ed., Cengage Learning India.
[5] Cheney, W., and Kincaid, D., 2021, *Numerical Mathematics & Computing*, 7th ed., Cengage Learning India.
[6] Kreyszig, E., 2015, *Advanced Engineering Mathematics*, 10th ed., Wiley India Pvt. Ltd.

ME2224E COMPUTATIONAL FLUID DYNAMICS

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Formulate problem definition for fluid and heat flows using governing equations in various forms
CO2: Discretize the governing equations using Finite Difference or Finite Volume Method
CO3: Solve iteratively the set of linear algebraic equations
CO4: Demonstrate numerical solution techniques (using coding and Commercial CFD software) to reveal underlying physics

Tensor Algebra, Reynolds Transport Theorem, Governing equations in various forms (Cartesian, Vector, Tensor, Conservative, Non-Conservative, Cylindrical), Classification of Partial Differential Equations, Types of Boundary Conditions.

Finite Difference or Finite Volume method, Discretization, Normalization, Types of errors and boundary conditions, Consistency, Stability, Convergence, Lax equivalence theorem, Domain/Mesh/Time Independent Solutions, Numerical dissipation and dispersion, Von-Neumann Stability Analysis, Consistency Analysis.

Characteristic of Coefficient Matrix, Diagonal Dominance, Jacobi-Iteration, Gauss-Seidel Successive Over-relaxation, Stream-function and Vorticity formulation, Marker and Cell (MAC), Simplified Marker and Cell (SMAC) algorithms.

References:

[1] Anderson Jr., J. D., 2017, *Computational Fluid Dynamics the Basics with Applications*, McGraw-Hill Education.
[2] Hoffmann, K. A., and Chiang, S. T., 2000, *Computational Fluid Dynamics for Engineers-Volume I*, 4th ed., Engineering Education System Wichita.
[3] Tannehill, J. C., Anderson, D. A., Pletcher, R. H., 2016, *Computational Fluid Mechanics and Heat Transfer*, 3rd ed., Taylor & Francis.
[4] Muralidhar K., and Sundararajan, T., 2017, *Computational Fluid Flow and Heat Transfer*, 2nd ed., 10th reprint Narosa.
[5] Ozisik, M. N., 2017, *Finite Difference Methods in Heat Transfer*, 2nd ed., CRC Press.
[6] Chung, T. J., 2010, *Computational Fluid Dynamics*, 2nd ed., Cambridge University Press.
[7] Ghoshdastidar, P. S., 1998, *Computer Simulation of Flow and Heat Transfer*, 4th ed., Tata McGraw-Hill.
[8] Date, A. W., 2009, *Introduction to Computational Fluid Dynamics*, 1st paperback ed., Cambridge Univ. Press.
[9] Ferziger, J. H., and Peric, M., 2002, *Computational Methods for Fluid Dynamics*, 3rd ed. Springer.

ME2225E BIO-FLUID MECHANICS

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO 1: Develop analytical and numerical approach to solve bio-fluid flow problems.
CO 2: Apply two-fluid models to bio-fluid mechanics problems
CO 3: Explain physiology of the human organ system.
CO 4: Apply fluid mechanics to blood flow models and analyze arterial diseases

Elements of continuum mechanics: Non-Newtonian fluids, Biological transport processes; basic heat and mass transfer concepts; conservation laws; turbulent flow equations, solution techniques. Two-phase flows: definitions, phase couplings; mixture models—homogeneous, drift-flux, separated flow models, porous media flow.

Reviews of Biomechanics: Principal stresses, equilibrium constraint, deformation analysis, stress-strain relationships; simplifications. Bio-fluid Dynamics concepts: Bio-fluid compartment models, Models of bio-fluid flows, tissue heat and mass transfer, joint lubrication, cell transport and micro-vascular beds. Blood rheology; cardiovascular systems: transport dynamics, heart, and blood vessels.

Analysis of arterial diseases: vessel occlusion, aneurysm. Bio-fluid mechanics of organ systems: heart and cardiovascular system, lungs and respiratory system, kidney and urinary system, liver, brain, intraocular system (eye). Blood pumps and artificial heart and lung. Case studies in bio-fluid dynamics—modeling and simulations; examples in Nano-drug delivery in micro-channel, particle deposition and targeting in lung airways, stented abdominal aortic Aneurysms model.

References:
[1] Kleinstreuer, C., 2006, *Biofluid Dynamics: Principles and Selected Applications*, CRC press.
[2] Mazumdar, J. 2016, *Biofluid Mechanics*, World Scientific.
[3] Waite, L., and Fine, J., 2007, *Applied Biofluid Mechanics*, McGraw Hill.
[4] Ostadfar, A., 2016, *Biofluid Mechanics: Principles and Applications*, Elsevier-Academic Press.
[5] Chandran, K. B., Rittgers, S. E., Yoganathan, A. P., 2012, *Biofluid Mechanics: The Human Circulation*, CRC Press.
[6] Grotberg, J. B., 2021, *Biofluid Mechanics: Analysis and Applications*, Cambridge University Press.

ME2226E WAVES ON FLUID INTERFACES

Pre-requisites: Knowledge of Fluid Mechanics

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyse waves at fluid interfaces for broad-length scales.

CO2: Analyse the gravity waves in industry as well as ocean applications

CO3: Analyse the gravity waves at shallow water depths.

CO4: Analyse the gravity waves in a rotating frame of reference.

CO5: Analyse the effect of surface tension on interfacial waves at smaller length scales.

Surface gravity waves

Surface gravity waves. Linear wave theory. Basic equations and free surface boundary conditions. Kinematics: Particle path and stream lines. Dynamics: dispersion relation, phase and group velocity, wave induced pressure. Superposition of linear waves. Energy considerations. Viscous effects.

Deep and shallow depths

Deep and shallow limits of gravity waves. Phase velocity. Deep-water formulation. Characteristics. Detailed analysis of Shallow water equations. Waves associated with discontinuity: Hydraulic jump. Rotating systems: Flow governing equations in the rotating frame. Gravity waves in the presence of Coriolis effects. Poincaré waves. Kelvin waves.

Surface waves in smaller length scales

Scale separation of surface waves: capillary waves and capillary-gravity waves. Effect of surface tension. Capillary length scale. Capillary waves- small amplitude wave theory. Features. Waves on liquid films.

References:

[1] Pedlosky, J., 2003, *Waves in the Ocean and Atmosphere*, Springer.
[2] Vallis, G. K., 2006, *Atmospheric and Oceanic Fluid Dynamics: Fundamentals and Large-scale Circulation*, Cambridge University Press.
[3] Kundu, P. K., Cohen, I. M., 2015, *Fluid Mechanics*, Academic Press.
[4] Lighthill, J., 2001, *Waves in Fluids*, Cambridge University Press.
[5] Vanden-Broeck, J. M., 2010, *Gravity-capillary free-surface flows*, Cambridge University Press.

ME2227E INTRODUCTION TO UNMANNED AERIAL SYSTEMS

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Differentiate the types of UAS and explain their characteristics
CO2: Illustrate the concepts of aeromechanics and structures of UAS
CO3: Demonstrate the concepts of UAS electronics, allied technologies and applications.

Introduction: Definitions of Drone, UAV, RPA, History, Difference between aircraft and UAV, DGCA Classification of UAVS; Types and Characteristics of Drones: Fixed, Multi-rotor, and Flapping Wing, Components and functions.

Aeromechanics and structures: Forces acting on UAV, Physical properties and structure of the atmosphere, Aerodynamics, Angle of attack, Mach number, Lift and Drag, Propulsion and airplane structures, Unmanned-Aircraft Geometry and Configurations, Aircraft Geometry Relationships, Configuration Drivers, Wing System Configurations, Tail Configurations, Fuselage System Configurations, Rotorcraft Configurations.

Drone electronics: Sensors and Actuators, proximity, IMU, magnetometers, thermal imaging, vision, LiDAR, GPS, RTK, Smart Sensors etc.; Allied UAS Technologies and Applications: Artificial Intelligence, Machine learning, Data Analysis, Internet of things (IoT), Computer Vision etc; Introduction to Guidance, Navigation and Control; UAS applications and case studies.

References:

[1] Austin, R., 2010, *Unmanned Aircraft Systems UAV Design, Development and Deployment*, Wiley.
[2] Nelson, R. C., 1998, *Flight Stability and Automatic Control*, McGraw-Hill, Inc.
[3] Valavanis, K. P., 2007, *Advances in Unmanned Aerial Vehicles: State of the Art and the Road to Autonomy*, Springer.
[4] Fahlstrom, P. G., and Gleason T. J., 2012, *Introduction to UAV Systems*, John Wiley & Sons, Ltd.

ME3221E AUTOMOBILE ENGINEERING

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Discuss about various engine fueling and ignition systems.

CO2: Explain the construction and working of transmission and braking systems of automobiles.

CO3: Describe the steering and suspension systems of automobiles

CO4: Explain the significance of air pollution control.

CO5: Explain various electric/hybrid/hydrogen/fuel cell vehicle technologies

Internal combustion Engines: Two stroke and four stroke engines; SI and CI engines; constructional details; engine parts; variable valve timing technologies; cooling system: air cooling, water cooling; lubrication system and components; fuel system and components: sensors, multi point fuel injection system, gasoline direct injection system, air-assisted fuel injection system, common rail direct injection system; supercharger/turbo chargers; electronic ignition system, distributor less ignition system; starting systems and drives.

Transmission: Clutch, types of clutches; torque convertor; gear box: sliding-mesh, constant-mesh, synchro-mesh; planetary gear box transmission; dual-clutch transmission; continuous variable transmission; propeller shaft and joints; differential; limited slip differential; axles.
Brake system: Mechanical and hydraulic brakes, power-assisted brake, air brakes, electric brakes, anti-lock braking system (ABS), electronic brake force distribution system (EBD).

Steering system: Steering geometry, steering gears, power-assisted steering: hydraulic power steering (HPS), electric power hydraulic steering (EPHS), electric power steering (EPS).

Chassis and suspension: Chassis lay out, active, semi active and passive suspension systems, dampers and springs, torsion bars, rigid axle and independent suspensions, air suspension systems, wheels, tyres and tubes, Supplementary restraint system: air bags, pyrotechnic inflator, air bag control unit.

Air pollution: emission norms, exhaust treatment technologies, standards and regulations, Hydrogen, Fuel cell vehicles.

Electric Vehicles: EV System overview, Major components: Power converters, Energy storage, Traction motors, e-axles, Thermal management in EVs, Regenerative braking
Hybrid Electric Vehicles: Various types of hybrid vehicles, System overview, Major components, Electronic Throttle Control, CAN – Controller Area Network, Diagnostics.

References:

[1] Newton, K., Steeds, W., and Garret, T. K., 2004, *Motor Vehicle*, 13th ed. Butterworth-Heinemann.
[2] Crouse, W.H., and Anglin, D. L., 1995, *Automotive Engines*, 8th ed. McGraw-Hill.
[3] Heisler H., *Advanced Vehicle Technology*, 2002, 2nd ed. Butterworth–Heinemann.
[4] Crouse, W. H., and Anglin D, L., 2008, *Automotive Transmission and Power Trains construction*, 10th ed. McGraw Hill.
[5] Crouse, W. H., and Anglin, D. L., 2004, *Automotive mechanics*, 10th ed. Tata McGraw-Hill.
[6] Sajith ,V. ,and Thomas, S., 2017, *Internal Combustion Engines*, 1st ed. Oxford University Press.
[7] Ehsani, M., Gao, Y., Gay, S. E. and Emadi, A. 2004, *Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design*. CRC Press.
[8] Hussein, I. 2021, *Electric and Hybrid Vehicles: Design Fundamentals*, 3rd ed. CRC Press.
[9] Tom Denton, 2020, *Electric and Hybrid Vehicles*, 2nd ed., Routledge.

ME3222E AERODYNAMICS

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Apply basic criterion to model the flying devices
CO2: Model lifting and non-lifting flows
CO3: Design novel wings with maximum lift to drag ratio
CO4: Analyze the lift and drag in wings under practical conditions

Basic fluid flow equations, Reynolds transport theorem, integral and differential formulations of continuity and momentum equations, Navier-Stokes equation; equations for incompressible inviscid flows; fluid circulation and rotation, vorticity; stream function; velocity potential; complex potential; Blasius theorem for force and moment on bodies; governing equations for irrotational incompressible flow; elementary flow patterns and their superposition.

Flow past a cylinder: lifting flow and non-lifting flow; Magnus effect; Kutta-Joukowski theorem; conformal transformation: Joukowski transformation; airfoils: nomenclature; Kelvin‘s circulation theorem; vortex sheet; Kutta condition; thin airfoil theory: symmetric airfoil, cambered airfoil; airfoil characteristics: flow over airfoil; comparison with the real case; aerodynamic center, pitching moment.

Incompressible flow over finite wings: downwash and induced drag; vortex filament; Biot-Savart Law; Helmholtz theorems; horseshoe vortex; ground effects; Prandtl’s lifting line theory: elliptic lift distribution, general list distribution; effect of aspect ratio: swept and delta wings; airfoils in compressible flow; small-perturbation theory.

References:

[1] Anderson Jr., J. D., 2023, *Fundamentals of Aerodynamics*, 7th ed., McGraw Hill.
[2] Houghton, E. L., Carpenter, P. W., Collicott, S. H., and Valentine, D. T., 2016, *Aerodynamics for Engineering Students*, 7th ed., Butterworth-Heinemann Ltd.
[3] Kuethe, A. M., and Chow, C-Y., 2009, *Foundations of Aerodynamics: Bases of Aerodynamic Design*, 5th ed. Wiley India Pvt. Ltd.
[4] Katz, J., and Plotkin, A., 2001, *Low Speed Aerodynamics*, 2nd ed., Cambridge Univ. Press.
[5] Panton, R. L., 2006, *Incompressible Flow*, 3rd ed., Wiley.

ME3223E AEROSPACE PROPULSION

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO 1: Describe the principles of aerospace propulsion and characterize jet propulsion systems.
CO 2: Describe aircraft propulsion systems, components, their principles of operations, and characteristics.
CO 3: Discuss chemical propellants based solid and liquid propellant rockets
CO 4: Explain important mechanisms of hybrid rockets.

History of aerospace propulsion, Principles of jet propulsion, thrust of a Jet Engine, Factors affecting thrust, Afterburner and Water Injection Technique for thrust augmentation, Air-breathing Engine Performance Parameters: Specific Thrust, Thrust Power, Specific Impulse, TSFC, Propulsive Efficiency, Thermal Efficiency and Numerical on jet engine cycle analysis.

Aircraft Propulsion Systems: Aircraft Inlets, subsonic and supersonic Inlets, compressors: centrifugal and axial Types, velocity diagrams, combustion chambers: Principle of operation, classification of combustion Chambers, Turbines: Types of turbines, Operating Principle, velocity triangles, degree of reaction, Performance characteristics.

Rocket Propulsion, classification, types, applications, definitions, Rocket principle, Rocket equation, parameters of rockets, propulsive efficiency, staging and clustering. Rocket nozzle and performance: gas expansion, shape, area ratio, performance loss, types of nozzles, Bell nozzle, unconventional nozzle, mass flow rate and characteristic velocity, thrust, thrust coefficient, efficiencies, specific impulse. Motion in space.

Chemical propellants: classification, characteristics, energy release, criteria for choice of propellants, solid, liquid and hybrid propellants. Solid propellant rockets: Burning ignition, and rate of burning, factors affecting rate of burning, components. Liquid Propellant rocket: Injectors, propellant feed system, performance and choice of feed system, thrust chamber, turbo pumps, and complexity of liquid propellant rocket. Liquid Monopropellant rockets: Hydrazine monopropellant rockets, catalyst bed loading, performance and application.

Hybrid rockets: Propellants; burning mechanism; mixing devices and turbulators, combustion initiation, multi-port fuel grains, paraffin wax for hybrid rockets, Advantages of hybrid rockets over solid and liquid propellant rockets.

References:
[1] Turner, M. J. L., 2009, *Rocket and Spacecraft Propulsion: Principles, Practice and New Developments*, Springer.
[2] Rammurthi, K., 2016, *Rocket Propulsion*, Trinity Press.
[3] Hill, P. G., and Peterson, C. R., 1991, *Mechanics and Thermodynamics of Propulsion*, Pearson.
[4] Sutton, G. P., and Biblarz, O., 2017, *Rocket Propulsion Elements*, Wiley.
[5] Mishra, D. P., 2017, *Fundamentals of Rocket Propulsion*, CRC Press.
[6] Mattingly, J. D., and Boyer, K., 2017, *Elements of Propulsion: Gas Turbines and Rockets*, AIAA Education Series.
[7] Heister, S. D., Anderson, W. E., Pourpoint, T. L. and Cassady, R. J., 2019, *Rocket Propulsion*, Cambridge Aerospace Series, Cambridge University Press.
[8] Mukunda, H. S., 2017, *Understanding Aerospace Chemical Propulsion*, I K International Publishing House Pvt. Ltd.

ME3224E REFRIGERATION AND AIR-CONDITIONING

Pre-requisites: Basic knowledge of Thermal Engineering

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Explain the fundamental principles of various refrigeration cycles
CO2: Analyse and evaluate the performance of vapour compression refrigeration systems
CO3: Learn about the basic components of refrigeration systems and the working fluids
CO4: Analyse and evaluate the performance of various air conditioning systems

Introduction
Review of fundamentals of thermal engineering. Basic refrigeration systems – vapour compression refrigeration system (VCRS), vapour absorption refrigeration system (VARS), air cycle refrigeration system, steam jet refrigeration system, thermoelectric system, solar refrigeration system and vortex tube system. Joule-Thomson coefficient and inversion temperature. Reversed Carnot cycle and its limitations, Bell-Coleman, Joule or Reversed Brayton cycle. Aircraft refrigeration cycles, Introduction to Cryogenics.

Vapour compression refrigeration systems
Standard vapour compression refrigeration cycle, actual VCRS, superheat horn and throttling losses, superheating and subcooling in VCRS. Multi-stage VCRS – multi-pressure systems, multi-evaporator systems, cascade systems. LiBr – H_2O based VARS and NH_3 – H_2O based VARS.

Refrigeration system components
Classifications of compressors, performance characteristics of reciprocating compressors. Classifications of evaporators & condensers and their characteristics. Expansion devices – capillary tube and thermostatic expansion valves.

Refrigerants
Classification of refrigerants, refrigerant properties, water and lubricating oil compatibility, environmental impact, Montreal / Kyoto protocols, eco-friendly refrigerants. Refrigeration tools – evacuation and charging unit, recovery and recycling unit, vacuum pumps.

Psychrometry and air-conditioning systems
Psychrometry – properties, processes and chart. Thermal comfort, infiltration and ventilation, winter heating load estimations, summer cooling load estimations, RSHF, bypass factor. Applications with specified ventilation air quantity, use of ERSHF and GRSHF, application with low latent heat loads and high latent heat loads.

References:
[1] Arora, C.P., 2021, *Refrigeration and Air-Conditioning*, 4th ed., McGraw Hill.
[2] Stoecker, W.F and Jones, J. W., 2014, *Refrigeration and Air Conditioning*, 2nd ed., McGraw Hill.
[3] Obrzut, J., Whitman B., Silberstein E., Tomczyk J. and Johnson B., 2020, *Refrigeration and Air Conditioning Technology*, 6th ed., Delmar Cengage Learning.
[4] Kreith F., Wang S.K. and Norton P., 2019, *Air Conditioning and Refrigeration Engineering*, 1st ed., CRC Press.

ME3225E HYDROGEN ENERGY TECHNOLOGIES

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Explain the concepts of hydrogen production and storage technologies.
CO2: Describe various futuristic applications of hydrogen.
CO3: Apply thermodynamic laws to sorption systems.
CO4: Analyse the performance of sorption thermodynamic systems.

Hydrogen as energy carrier, Hydrogen production methods - green, gray, brown and blue hydrogen. Hydrogen storage technologies - compression, liquefaction and sorption systems. hydrogen distribution, Concept of adsorption and absorption systems. Concept of hydrogen absorption and CO_2 adsorption. Selection of adsorption/absorption materials. Characterization of adsorption/absorption materials incudes XRD, SEM, Edax and PCIs. Property relations. Effect of operating parameters.

Fundamentals of thermodynamic laws and thermodynamic cycles. Hydrogen sorption-based heating system, cooling system, compression system and energy storage system – working principle, thermodynamic cycle and performance analysis. Comparison with CO_2 sorption-based refrigeration system. Multi staging of thermodynamic systems.

Hydrogen based fuel cells, hydrogen combustion, use of Hydrogen in SI and CI engines - challenges and future, hydrogen safety, Design and analyses of thermodynamic systems. Hydrogen system modelling and optimization, Mathematical modelling for property measurement. Numerical modelling for performance estimation.

References:

[1] Miranda, P. E., 2018, *Science and Engineering of Hydrogen-Based Energy Technologies*, Elsevier.
[2] Sastri, M.V.C., Viswanathan, B., and Murthy, S.S., 1998, *Metal Hydrides*, Narosa Publishing House.
[3] Ballaney, P.L., 1966, *Thermal Engineering (Engineering Thermodynamics & Energy Conversion Techniques*, Khanna Publisheres.
[4] Herold K E, Radermacher R and Keli S A, 2016, *Absorption Chillers and Heat Pumps*, 2nd Edition, CRC Press.

ME3226E RENEWABLE ENERGY SYSTEMS

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Estimate the renewable energy potential for a specified location.

CO2: Illustrate the applications of various renewable energy systems.

CO3: Compute the energy conversion efficiencies of typical renewable energy systems

CO4: Assess the techno-economic viability of representative renewable energy systems

Introduction to sustainable energy: energy and environment, energy scenario and role of renewables - solar energy option: measurement and estimation of terrestrial solar radiation, solar thermal systems, analysis and testing of flat plate and concentrator systems, industrial process heating and power generation - photovoltaic conversion: commercial solar cells and efficiencies, photovoltaic systems and applications.

Wind energy conversion: wind resource assessment, modern wind turbines and their characteristics, power extraction and control strategies - small hydro power: resource assessment for small installations, classification of hydro turbines, performance analysis, selection and sizing - ocean thermal energy conversion: types of OTEC systems, practical considerations - geothermal energy: types of geothermal power plants, environmental aspects.

Biomass and biofuels: biomass energy conversion routes, combustion, gasification, pyrolysis, fermentation, anaerobic digestion for biogas, bio-diesel, bio-hydrogen production, biomass based power generation systems - hybrid energy systems integrating renewable and conventional sources - energy storage options - economic analysis: indices for economic evaluation of renewable energy projects, levelized cost of energy.

References:

[1] Sukhatme, S. P. and Nayak, J. K., 2017, *Solar Energy*, 4th ed., McGraw Hill.
[2] Kanoglu, M., Cengel, Y. A., and Cimbala, J. M., 2023, *Fundamentals and Applications of Renewable Energy*, 2nd ed., McGraw Hill.
[3] Twidell, J., 2021, *Renewable Energy Resources*, 4th ed., Routledge.
[4] Manwell, J. F., McGowan, J. G., and Rogers, A. L., 2010, *Wind Energy Explained-Theory, Design and Applications*, 2nd ed., Wiley.

ME3227E INTRODUCTION TO RHEOLOGY

Pre-requisites: Basic knowledge of fluid mechanics, vector calculus

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Describe the physics behind the flow behavior of various fluid systems.
CO2: Apply fundamentals of rheology to examine fluid flow problems.
CO3: Perform standard rheology tests and interpret the rheological data based on concepts of mechanical rheometry.
CO4: Illustrate the applications of rheology in various engineering domains.

Advanced Fluid Mechanics
Review of relevant continuum mechanics: Newtonian fluid mechanics, vector calculus, tensors describing stress, deformation and flow, strain, viscosity, modulus, conservation of mass, momentum transfer, Navier-Stokes equation, dimensionless numbers, creeping flow, Poiseuille flow, Couette flow, non-Newtonian fluids and different models

Rheology
Kinematics of deformation, fundamental models of material behavior: Hookean elastic solids, Newtonian viscous liquids, shear flows and extensional flows, Glossary on rheological terms with explanations, viscoelastic effects, dependence of dynamic viscosity on temperature, pressure, shear rate, Linear viscoelasticity: mechanical models (Kelvin, Maxwell), general linear viscoelastic model, generalized Maxwell model, nonlinear viscoelasticity, simple nonlinear viscosity models. time-temperature superposition.

Rheometry and Applications
Rotational rheometers, capillary/Slit Rheometers, rheometer design, rheometer demonstration, different measurement systems, inverse problems in rheometry. Rheological testing and measurements: rotational tests, relaxation tests, oscillatory tests, effects of viscosity on dynamics: complex moduli. Creep test and recovery, step strain, step strain rate, creep and relaxation functions.
Applications of non-Newtonian fluid rheology (polymers and suspensions), Microrheology.
Application of rheology to Industries: materials science, food engineering, polymer processing, chemical process industries, medical applications

References:

[1] Macosko, C. W., 1994, *Rheology: Principles*, Measurements, and Applications, Wiley.
[2] Phan-Thien, N., and Mai-Duy, N., 2017, *Understanding Viscoelasticity: An introduction to Rheology*, 3rd ed. Springer.
[3] Larson, R. G., 1999, *The Structure and Rheology of Complex Fluids*, Oxford University Press.
[4] Barnes, H.A., Hutton, J.F., and Walters, K., 1989. *An introduction to rheology*, Elsevier.
[5] Mewis, J., and Wagner, N.J., 2012, *Colloidal Suspension Rheology*, Cambridge University Press.

ME3228E TRANSPORT PHENOMENA IN POROUS MEDIA

Pre-requisites: Basic knowledge of Fluid Mechanics

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Develop mathematical models for flow and heat transfer in porous media using theoretical tools
CO2: Apply mathematical models of transport in porous media in practical applications
CO3: Develop numerical solvers using Lattice Boltzmann Method to simulate pore-scale flow
CO4: Apply CFD software tools to simulate REV-scale flow in porous media

Basic Theory: Representative elementary volume (REV), mass, momentum, energy and species transport. Darcy and Non-Darcy equations. Equivalent thermal conductivity, viscosity, dispersion. Multi-scale modelling.

Applications: Transport in fuel cell electrode, charge transport in porous media and electrochemical reaction. Modelling isothermal operation of lithium-ion cell. Porous media applications in biological systems, geological systems, methane recovery and CO_2 sequestration.

Modelling and simulation: Introduction to Lattice Boltzmann Method (LBM), Simulation of flow in porous media using CFD-software. Application of LBM in pore-scale simulation. Microstructure generation, permeability estimation using LBM.

References:

[1] Das M. K., Mukherjee, P. P. and Muralidhar K., 2018, M*odeling transport phenomena in porous media with applications*, Springer.
[2] Kaviany, M., 1995, *Principles of Heat Transfer in Porous Media*, Springer.
[3] Ingham, D. R., and I. Pop, I., 2005, *Transport Phenomena in Porous Media*, Volumes I-III, Edited, Elsevier.
[4] Bear, J., 1988, *Dynamics of Fluids in Porous Media*, Dover.
[5] Bear, J and Kluwer, Y. B., 1990, *Introduction to Modeling of Transport Phenomena in Porous Media*, Academic Publishers.
[6] Whitaker, S., 1999, *The Method of Volume Averaging*, Springer.
[7] Kruger, T., Kusumaatmaja, H., Kuzmin, R. A., Shardt, O., Silva, G., and Viggen, E. M., 2017, *The Lattice Boltzmann Method: Principles and Practice*, Springer.
[8] Inamuro, T., Yoshino, M., Suzuki, K., 2021, *An Introduction to Lattice Boltzmann Method: A numerical method for complex boundary and moving boundary flows*, World Scientific.

ME3229E INTRODUCTION TO CAVITATION

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Analyse the phase change phenomenon from liquid to vapour due to the reduction of ambient liquid pressure.
CO2: Analyse the effects of cavitation
CO3: Analyse the mathematical models of cavitation bubble implosion
CO4: Analyse applications in the biomedical and related fields by applying the concepts learned.

Introduction to cavitating flows

The physical phenomena of cavitation. Hydrodynamic and acoustic cavitation. Liquid-vapour interface. Vapour pressure. Surface tension induced pressure. Tensile strength of the liquid. Nucleation. Equilibrium condition for a cavitation nucleus. Heat and mass diffusion. Nucleation in flowing liquids. Factors influencing cavitation. significance of Cavitation number. Cavitation in pumps and hydro turbines.

Implosion of a spherical cavitation bubble

Mathematical modelling: Rayleigh-Plesset equation. Interpretation in terms of energy. Pressure field. Effect of viscosity and surface tension. Oscillations of the bubble. Characteristic scales. Non-dimensional form of Rayleigh-Plesset equation. Stability of the spherical interface.

Bubbles in non-symmetrical environment

Translation of a bubble. Features of Stokes flows. Oseen correction. Translation of a bubble with size change. Presence of solid surface or interface. Blake's approach. Kelvin impulse. Main forms of vapour cavities: Supercavitation and partial cavities; Cavitation in rotational flows; Evolution of a toroidal vapour core; Shear cavitation.

Mapping of bubbles, applications and control

Optical methods: High speed imaging; Sonoluminescence and Sonochemiluminescence. Acoustic methods. Biomedical applications of Cavitation: Cavitation bubble dynamics in tissues; Modelling; Cavitation enhanced thermal and mechanical effects. Cavitation in plant xylem tissues.

References:

[1] Brenner, C. E., 2014, *Cavitation and bubble dynamics*, Cambridge University Press.
[2] Franc, J. P., and Michel, J. M., 2004, *Fundamentals of cavitation*, Springer.
[3] Young, F. R., 1999, *Cavitation*, Imperial College Press.
[4] Wan, M., Feng, Y., and Haar, G., 2015, *Cavitation in biomedicines: principles and techniques*, Springer.

ME3230E BATTERY TECHNOLOGIES FOR ELECTRIC VEHICLES

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Recognize the basic physical concepts and thermodynamics involved in electrochemical reactions.

CO2: Select the appropriate battery system based on the application.

CO3: Describe the recent developments in battery systems for applications like electric vehicles.

Battery types: Lead–Acid, Nickel–Cadmium, Nickel–Metal Hydride and Lithium batteries, electrochemical double-layer capacitors, other battery types - working principles and characteristics, charge discharge processes and cycle life - materials used for various components - energy conversion, specific energy and power, operational factors, effect of temperature, self-discharge, battery testing, applications and comparison, battery selection.

Thermodynamics of batteries: reversible cell potential, energy balance, heat generation rate, overall cell potential, battery cell performance - thermal behaviour: aging mechanism, thermal runaway, heat generation rate and temperature variation, thermal behavior modeling,

Li-ion battery technology: electrode materials, electrolytes and separators, cell design and performance-manufacturing aspects, battery safety and abuse tolerance, coupling with other energy storage devices.

Battery usage in electric vehicles: vehicle types and requirements, battery design, battery management system, state functions, degradation basics and mechanisms, degradation analysis methods.

References:

[1] Bard, A. J., Faulkner, L. R., and White, H. S., 2022, *Electrochemical Methods: Fundamentals and Applications,* Wiley.
[2] Rosen, M. A., and Farsi, A., 2023, *Battery Technology-From Fundamentals to Thermal Behavior and Management*, Academic Press.
[3] Petrovic, S., 2021, *Battery Technology Crash Course-A Concise Introduction*, Springer.
[4] Berg, H., 2015, *Batteries for Electric Vehicles*, Cambridge University Press.

ME3231E AEROMECHANICS OF UNMANNED AERIAL SYSTEMS

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Describe the design process of UAS
CO2: Apply the concepts of aerodynamics of UAS
CO3: Model the flight dynamics of UAS

Introduction: Types of UAVs, applications, design process and design goals description of each sub-system and their roles, UAS as a System of Systems, Description of each sub-system and its role

Aerodynamics of fixed wing systems: Introduction to fixed wing aerodynamic performance – lift, drag, L/D, effect of pitching moment, wing loading, load factor, range, endurance, rate of climb etc., low Reynolds number aerodynamics.

Aerodynamics of rotary wing systems: Introduction to rotary wing aerodynamics – momentum theory, blade element theory, blade element momentum theory, rotors in axial and edgewise flight, Performance of rotary wing systems, range, endurance, rate of climb, maximum speed.

Introduction to flapping wing systems, flapping wing aerodynamics; Rigid Body Dynamics of UAVs, Equation of motion, Simple flight dynamic modelling, System identification methods.

References:

[1] Beard, R., and McLain, T., 2012, *Small Unmanned Aircraft: Theory and Practice*, Princeton University Press.
[2] Mettler, B., 2003, *Identification Modeling and Characteristics of Miniature Rotorcraft*, Springer.
[3] Shkarayev, S. V., Ifju, P. G., Kellogg, J. C., and Mueller, T. J., 2007, *Introduction to the Design of Fixed-Wing Micro Air Vehicles Including Three Case Studies*, AIAA Education Series.
[4] Leishman, J. G., 2000, *Principles of Helicopter Aerodynamics*, Cambridge Aerospace Series.

ME3232E DESIGN OF UNMANNED AERIAL SYSTEMS

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Discuss the anatomy of UAS
CO2: Estimate performance parameters and size of UAS
CO3: Assess the performance and stability of UAS

Introduction, classification of UAVs, Measurement of Flight Velocity and Standard Atmosphere, Anatomy of Airplane and Airfoil Nomenclature, Pitot and static tube and differential pressure sensor, Generation of Lift and Drag, Aerodynamic center and center of pressure, Various wing planform, Lifting line theory, NACA airfoil nomenclature, Airfoil and Finite wing, Interpreting airfoil data, Cl vs Alpha and drag polar, selection of airfoil.

Introduction to Airplane performance, Equation of motion, Thrust required and Power, Calculation of Performance parameters and selection of power plant, Climb Performance, Engine Sizing and Power Plant selection, Weight Estimation, Common propulsion systems, Electric propulsion, Battery Sizing.

Iterative weight estimation and Wing sizing, Wing Planform selection and sizing and Flight test of UAVs, Effect of variation of CG location and Static Stability, CG location and Longitudinal Static Stability, Contribution of tail in static stability and Neutral point, Trim Requirements of UAV, Performance analysis of UAVs.

References:
[1] Anderson, J. D., and Bowden, M. L., 2022, *Introduction to Flight*, McGraw-Hill.
[2] Pamadi, B. N., 2015, *Performance, Stability, Dynamics, and Control of Airplanes,* American Institute of Aeronautics & Astronautics.
[3] Anderson, J. D., 2012, *Aircraft Performance and Design*, Tata McGraw-Hill Edition.
[4] Sadraey, M. H., 2017, *Unmanned Aircraft Design: a Review of Fundamentals*, Springer Cham.

ME4221E EXPERIMENTAL METHODS IN FLUID FLOW AND HEAT TRANSFER

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Explain the challenges, error analysis and instrumentation associated with experiments.
CO2: Explain the theoretical and practical aspects of measurements related to fluid mechanics and heat transfer
CO3: Explore the various real life engineering application of fluid mechanics and heat transfer

Introduction

Basic concepts experimental methods, Introduction of modes of Heat transfer, Measurements and possible types Errors in measurement, accuracy, precision, resolution; experiment planning; Regression analysis, analysis of experimental data, error analysis, evaluation of uncertainties, propagation of uncertainties, statistical analysis, the normal distribution. Design of experiments: Goal of experiments, full factorial design, 2k factorial design, more on full factorial design, One half factorial design.

Velocity and Flow Rate Measurements

Pressure measurements techniques: Dynamic response considerations, dead-weight tester, Bourdon-tube pressure gage, diaphragm and bellows gages, Bridgman gage, Pirani thermal conductivity gage, Knudsen gage, ionization gage, Alphatron. Pressure-Sensitive Paint (PSP). Velocity measurement technique: Traditional and Non-traditional-Manometers, Pressure Transducers, Velocity Calculations. Flow rate measurement techniques: positive-displacement methods, flow-obstruction methods, sonic nozzle, flow measurement by drag effects, pressure probes, hot-wire and hot-film anemometers, magnetic flow meters. Flow visualization methods: smoke methods, shadowgraph, Schlieren photography, laser Doppler anemometer, laser-induced fluorescence, particle image velocimetry. Basic concept of flow Field Measurements by Particle Image Velocimetry (PIV).

Measurements of Temperature, Heat Flux and Heat Transfer Coefficient

Temperature measurements: Thermometry, thermoelectric thermometry: thermoelectric effects, Thermocouples, Practical aspects of thermoelectric thermometry, Resistance thermometry, Platinum resistance thermometer, RTD measurement circuits. Thermistors, Measurement of transient temperature, temperature measurement by radiation, transient response of thermal systems, Heat flux sensors: Foil type heat flux gauge, Transient analysis of foil gauge, thin film sensors, Axial conduction guarded probe and Slug type sensor. Thin film heat flux gauge - Transient operation. Temperature-Sensitive Paint. Systematic errors in temperature measurement. Film coefficient transducer and cylindrical heat transfer coefficient probe,

Data analysis and Examples from Laboratory Practice

Optical Thermography Techniques: Fundamental Principle, Infrared Thermography (IR) Technique, Infrared Thermography Technique-steady & unsteady, Transport-property measurement: traditional and non-tradition method. Measurement of thermo-physical properties, Gas concentration, Data Manipulation: Mechanical signal conditioning, Betz manometer, Optical measurement of twist angle in a wire, Signal conditioning, Signal Amplification and manipulation, Examples from laboratory practice.

References:

[1] Han J. Ch., and Wright L., 2020, *Experimental Methods in Heat Transfer and Fluid Mechanics*, CRC Press.
[2] Mahfouz, I. A., 2022, *Instrumentation: Theory and Practice, Part 1 Principles of Measurements*, Springer.
[3] Venkateshan, S.P., 2015, *Mechanical Measurements*, John Wiley & Sons Ltd.
[4] Figliola R. S., and Beasley, D., 2015, *Theory and Design for Mechanical Measurements*, Wiley & Sons.
[5] Panigrahi P.K., and Muralidhar K., 2013, *Imaging Heat and Mass Transfer Processes Visualization and Analysis*, Springer.
[6] Raghavendra N.V., and Krishnamurthy L., 2013, *Engineering Metrology and Measurements*, Oxford University Press.
[7] Panigrahi P. K. and. Muralidhar, K., 2012, *Schlieren and Shadowgraph Methods in Heat and Mass Transfer*, Springer.
[8] Holman, J. P., 2012, *Experimental Methods for Engineers*, McGraw-Hill.
[9] Lee, T.W., 2008, *Thermal and Flow Measurements*, CRC Press.
[10] Doebelin, E. O., 2015, *Measurement Systems*, McGraw-Hill.

ME4222E NEURAL NETWORKS FOR CFD

L	T	P	O	C
3	0	0	6	3

Total Lecture sessions: 39

Course Outcomes:

CO1: Explain fundamentals of Artificial Neural Networks (ANNs), deep learning architectures, optimization functions, and cost functions.
CO2: Describe the physics of 1D and 2D heat conduction equations and solve these equations using neural networks
CO3: Demonstrate the knowledge of 2D Navier-Stokes (NS) equations and vorticity-stream function formulation and the relationship between them.
CO4: Illustrate proficiency in using ML Libraries for fluid flow and heat transfer problems using computer programming

Introduction to Machine Learning, Basics of Neural Networks, logistic regression, Perceptron, shallow learning, deep learning, activation functions, optimization methods, stochastic gradient descent, RMSProp, Adam, backpropagation, Physics Informed Neural Network, computer implementation

Review of fluid dynamics, derivations of governing equations for fluid flows, 1D and 2D heat conduction equations, physical interpretations of governing equations, 2D Navier-Stokes equations for incompressible or compressible flow, primitive variable formulations, stream function vorticity formulation.

Applications of NN to fluid flow and heat transfer problems, lid driven cavity problem etc., boundary conditions, physics informed neural network architecture for solving lid driven cavity, gradient calculations for velocities, PyTorch, TensorFlow, DeepXDE libraries.

References:

[1] Brunton, S.L. and Kutz, J.N., 2022, *Data-driven science and engineering: Machine learning, dynamical systems, and control*, Cambridge University Press.
[2] Graupe, D., 2016, *Deep learning neural networks: design and case studies*, World Scientific Publishing Company.
[3] Aggarwal, C.C., 2018, *Neural networks and deep learning*, Springer.
[4] Anderson, J.D., Degrez, G., Dick, E. and Grundmann, R., 2013, *Computational fluid dynamics: an introduction*, Springer Science & Business Media.
[5] Tu, J., Yeoh, G.H., Liu, C. and Tao, Y., 2023, *Computational fluid dynamics: a practical approach*, Elsevier.
[6] Muralidhar, K, Sundararajan. T, 2014, *Computational Fluid Flow and Heat transfer,* Narosa.

ME4223E CYBER PHYSICAL THERMAL AND ENERGY SYSTEMS

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:
CO1: Develop models for fluid flow and thermal analysis of common mechanical system components
CO2: Perform numerical simulations of thermo-fluid system components
CO3: Apply the concept of digital twin to thermo-fluid systems for analysis and control
CO4: Demonstrate the use of system design and analysis tools such as Simcenter/Simulink

Introduction to thermal and energy systems: Governing equations of mass, momentum and energy, problem definition, classification and analysis of basic hydraulic components, flow measuring devices, steady-state and dynamic behaviour, engine systems: fuel, cooling, lubrication and ignition; power plant cycles and related components.

Numerical simulations of thermal and energy systems: Fundamentals of computational fluid dynamics (CFD): finite volume and finite element approaches, CFD solver fundamentals, salient features; numerical simulations of hydraulic components, automotive components/systems and thermal management systems.

Model-based system engineering: Digital twin for thermo-energy and automotive systems, Model-in-loop and Hardware-in-loop development approaches, static and dynamic analysis, multi-physics modelling of mechanical systems, system life cycle management

Hands on/Case studies: Virtual modelling and simulation analysis of thermal and energy systems, use of MATLAB/similar tools, application to automotive systems (e.g., battery modelling and thermal management), smart buildings, aerodynamics and flow analysis, hydraulic system analysis

References:

[1] Fox, R. W., Mitchell, J. W., and McDonald, A. T., 2020, *Introduction to Fluid Mechanics*, Wiley.
[2] Yunus A. Çengel and Ghajar, A.J., 2020, *Heat and Mass Transfer: Fundamentals and Applications*, McGraw-Hill Education.
[3] Tu, J., Yeoh, G.H., Liu, C. and Tao, Y., 2023, *Computational fluid dynamics: a practical approach*, Elsevier.
[4] Martin Eigner, 2021, *System Lifecycle Management - Engineering Digitalization*, Springer Vieweg.
[5] Vasiliu, N., Vasiliu, D., Călinoiu, C. and Puhalschi, R., 2018, *Simulation of fluid power systems with Simcenter Amesim*, CRC Press.
[6] Anderl, R. and Binde, P., 2018, *Simulations with NX/Simcenter 3D: Kinematics, FEA, CFD, EM and Data Management*, Carl Hanser Verlag GmbH Co.

ME4224E THERMAL MANAGEMENT IN ELECTRIC VEHICLES

Pre-requisites: Knowledge of Thermodynamics and Heat Transfer

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Apply principles of thermodynamics and heat transfer for thermal management in electric/hybrid vehicles.

CO2: Identify the appropriate technique for heat transfer enhancement and thermal control in electric/hybrid vehicles.

CO3: Analyse the performance of thermal systems integrated in electric/hybrid vehicles.

Review of thermodynamics, heat transfer and heat exchangers - introductory aspects of electric and hybrid vehicles: vehicle configurations, all-electric and hybrid vehicles, vehicle architecture, energy storage options and systems, various circuits, vehicle drive patterns and cycles-electric vehicle battery technologies: types currently in use and under development - impact of various loads and environmental conditions, battery management systems-need for thermal management in electric vehicles.

Cabin climate control: thermal comfort, control of vehicle indoor climate, cabin thermal loads, energy transfer mechanisms, HVAC unit components and operation, integration of air conditioning loop, technical challenges associated with cabin thermal control in electric and hybrid vehicles, design and analysis strategies, recent developments/case studies.

Phase Change Materials for passive thermal management: basic properties and types, measurement of thermal properties of PCMs, heat transfer enhancement, applications of heat pipes in thermal management, case studies related to applications in electric and hybrid electric vehicles.

Battery Thermal Management (BTM): thermodynamic analysis of battery system, energy balance across battery cell, heat generation and related issues, thermal runaway in battery and battery pack, temperature gradient, thermal inertia - types of cooling systems: liquid, air, refrigerant based, comparative analysis, performance assessment, mutual impact of cabin climate control and battery thermal system, electric motor cooling: combined electric motor and power electronics thermal management, overall thermal energy management of electric and hybrid vehicles.

References:

[1] Aloui, F., Varuvel, E. G., and Sonthalia, A., 2023, *Handbook of Thermal Management Systems: e-Mobility and Other Energy Applications*, Elsevier.
[2] Lemort, V., Olivier, G., and Pelsemaeker, G., 2023, *Thermal Energy Management in Vehicles*, Wiley.
[3] Petrovic, S., 2021, *Battery Technology Crash Course-A Concise Introduction*, Springer.
[4] Rosen, M. A., and Farsi, A., 2023, *Battery Technology-From Fundamentals to Thermal Behavior and Management*, Academic Press.

ME4225E MODELING, SIMULATION, AND PROTOTYPING OF UNMANNED AERIAL SYSTEMS

Pre-requisites: Knowledge of the aeromechanics of Unmanned Aerial Systems

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Perform structural modelling and simulation of UAS
CO2: Perform aerodynamic modelling and simulation of UAS
CO3: Explain the prototyping of UAS

Introduction to modelling and simulation, Engineering modelling, idealizations, and fidelity of models. Structural Modelling, Introduction of finite element method for structural analysis, Static analysis (strength-based design), Modal analysis (natural frequency and mode shapes), Impact modelling and analysis.

Aerodynamic Modelling, Introduction of Computational Fluid Dynamics (CFD), Problem setup, computational domain and mesh generation, Overview of turbulence modelling, Grid convergence, Post processing of data, Introduction to CFD modelling of propellers and rotor blades. Flight Dynamic Modelling, Solving Newton-Euler equations, Real time simulation, Hardware-in-the-loop simulation (HILS), Software-in-the-loop simulation (SILS).

Hardware realization of design, Commercial-off-the-shelf component selection, Integration of sub-systems, Prototyping of UAV, Manufacturing process for various structural components, Material selection, 3D printing and advanced materials, Composite based manufacturing, Making composite structures.

References:
[1] Beard, R., and McLain, T., 2012, *Small Unmanned Aircraft: Theory and Practice*, Princeton University Press.
[2] Cook, R. D., Malkus, D. S., Plesha, M. and Witt, R. J., 2007, *Concepts and Applications of Finite Element Analysis*, Wiley.
[3] Gupta, S. C., 2019, *Applied Computational Fluid Dynamics*, Wiley.

ELECTIVE COURSES: MANUFACTURING AND MATERIALS SCIENCE

ME2324E MECHATRONICS

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:
CO1: Explain various key elements or subsystems in mechatronics.
CO2: Develop PLC programming for automated systems and analyze control part.
CO3: Identify sensors, actuators and data acquisition systems for a given mechatronics system.
CO4: Analyze the requirements and advanced technologies of various subsystems in mechatronics system design through examples.

Introduction to mechatronics: key elements in mechatronics, design process, types of design: traditional and mechatronics designs; advanced approaches in mechatronics; real time interfacing; elements of data acquisition system; case studies of mechatronics systems, identification of key elements of various mechatronics systems, examples.

Introduction to signals, system and controls; system representation, linearisation, time delays, measures of system performance; closed loop controller: PID controller, digital controllers, controller tuning, adaptive control; introduction to microprocessors, micro-controllers and programmable logic controllers components, PLC, programming, examples.

Actuator and Sensors: fluid power and electrical actuators, piezoelectric actuator; sensors for position, motion, force and temperature, flow sensors-range sensors, ultrasonic sensors, fibre optic sensors, magneto-strictive transducer, selection of sensors; case studies on selection of actuators and sensors for mechatronics systems.

Advanced applications in mechatronics: sensors for condition monitoring, mechatronics control in automated manufacturing; artificial intelligence in mechatronics: fuzzy logic application in mechatronics, case studies and design of mechatronics systems.

References:
[1] Shetty, D., Kolk, R.A., 2015, *Mechatronics System Design*, Thomson Learning.
[2] Bolton, W., 2019, *Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering*, Pearson education.
[3] Dan, N., 2002, *Mechatronics*, Parson Education.
[4] Bishop, R.H., 2005, *Mechatronics*: An Introduction, CRC Press.
[5] HMT Ltd, 2000, *Mechatronics*, Tata McGraw Hill.
[6] Singh, B. P., 2004, *Microprocessors and Microcontrollers*, Galgotia Pub.
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[8] Kant, Krishna,2010, *Computer Based Industrial Contro*l, PHI.
[9] Merzouki, R., Samantaray, A.K., Pathak, P.M., Bouamama, B., 2013, *Intelligent Mechatronic Systems: Modeling, Control and Diagnosis*, Springer.

ME2334E TECHNIQUES OF MATERIAL CHARACTERISATION

Pre-requisite: Basics of the crystal structure of crystalline solids

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Evaluate mechanical properties of materials as per the standards.
CO2: Analyse the X-ray diffraction data and determine the crystal structure information.
CO3: Interpret the microstructure of metallic specimen using optical microscopy technique.
CO4: Apply the principles of scanning and transmission techniques for material characterisation.
CO5: Describe the principles of powder characterisation and thermal characterisation techniques.

Introduction to material characterisation and testing – elements of crystallography and crystal structures – symmetry elements – nature of chemical bonds and atomic arrangements in metals, ceramics and polymers – crystal defects and their significance.

Mechanical characterisation: Principles and characterisation techniques related to tensile, compressive, hardness, impact, fatigue, and fracture toughness measurement – International (ATSM/ISO) and Indian standards (IS) in mechanical testing of materials.

Microscopy techniques: principles of image formation – general concepts: resolution, magnification, contrast, depth of field, and depth of focus – Optical microscopy: basic principles and components – image formation – specimen preparation – contrast development – various imaging modes – image analysis – grain size determination.

Electron microscopy: Basic components of electron microscope – electron-materials interaction: elastic vs. inelastic scattering – coherent vs. incoherent scattering – interaction volume – scanning electron microscopy (SEM): Working principle – signal generation – essential components – Secondary and backscattered electron imaging – failure analysis and fractography – chemical analysis in SEM: energy and wavelength dispersive spectroscopy (EDS and WDS) – transmission electron microscopy (TEM): Working principle – signal generation – essential components – image formation and contrast generation - Electron Diffraction in TEM: diffraction pattern, applications.

X-ray Diffraction: Bragg's condition – scattering from unit cell – structure factor calculation for various crystal systems – crystal structure determination – experimental methods: Laue, rotating crystal and powder diffraction – diffraction profile and analysis: FWHM and line broadening, crystallite size and strain effect.

Introduction to atomic force microscopy (AFM) – powder characterisation: particle size analysis – BET surface area analysis – porosity and density measurements – thermal characterisation: DSC/DTA/TGA/Dilatometry.

References:

[1] Meyers, M.A., and Chawla, K.K., 2009, *Mechanical Behaviour of Materials*, Cambridge University Press.
[2] Douglas B.M., and Michael, W.D., 2012, *Fundamentals of Light Microscopy and Electronic Imaging*, Wiley.
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[4] Peter, J.G., John, H. and Richard, B, 2000, *Electron Microscopy and Analysis*, Routledge.
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[7] Michael, E.B., 2015, *Introduction to Thermal Analysis: Techniques and Applications*, Springer.

ME2339E COMPUTER GRAPHICS AND PRODUCT MODELLING

L	T	P	O	C
3	0	0	6	3

Total Sessions: Lecture 39

Course Outcomes:
At the end of the course, the student will be able to:

CO1: Explain the applications of computers in product development, product data management and product life-cycle management.
CO2: Create computer programs to implement various algorithms for generating geometric entities like line, circle and ellipse.
CO3: Create computer programs for performing 2D and 3D geometric transformations and projections of geometric entities.
CO4: Apply fundamental knowledge in mathematics to generate curves, surfaces and 3D objects.
CO5: Apply geometric reasoning principles to extract features from CAD data.

Computer applications in product development: Stages in Product development; Automation of functional activities, Product modelling; Geometric and Non-geometric data; Product Data Management (PDM); Product Life-cycle Management (PLM).
Overview of computer graphics: Mathematics for computer graphics; Graphics hardware and software; raster scan graphics; algorithms for generating line, circle and ellipse.
Transformations in computer graphics: 2D and 3D geometrical transformations: scaling; shearing; rotation; reflection; translation; Projections: parallel projections and perspective projections.
Modelling of planar and space curves: Non-parametric and parametric curves: cubic spline; Bezier curves; B-spline curves; NURBS.
Modelling of surfaces: Surface of revolution; sweep surface; linear Coons surface; Bezier surface; B-Spline surface.
Geometric modelling of 3D objects: Boundary Representation (B-Rep); Constructive Solid Geometry (CSG); Data structure for B-Rep and CSG models; Hybrid solid modellers; Feature based part modelling; Feature extraction from CAD models.
Product data exchange: Neutral file formats and exchange of product data; IGES and STEP
Hands on: Development of programs for transformations and modelling of curves and surfaces, use of commercial CAD packages for modelling and assembly of engineering components.

References:

[1] Rogers, D. F., and Adams, J. A., 2017, Mathematical *Elements of Computer Graphics*, McGraw Hill.
[2] Rogers, D. F., 2017, Procedural *Elements for Computer Graphics*, McGraw Hill.
[3] Pande, S. S., 2012, *Computer Graphics and Product Modeling for CAD/CAM*, Narosa,.
[4] Patel, C. D., Chen, C. H., 2022, *Digital Manufacturing*, Elsevier.
[5] Hearn, D. D. and Baker, M.P.,2022 *Computer Graphics*, Pearson.
[6] Foley, J. D., Dam, A. V., Feiner, S. K.,Hughes, J. F., 1996,*Computer Graphics: Principles and Practice in C*, Pearson.
[7] Mortenson, M. E., 1997, *Geometric Modeling*, John Wiley & Sons.
[8] Martin Eigner, 2021, *System Lifecycle Management - Engineering Digitalization*, Springer Vieweg.

ME3321E POWDER METALLURGY

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Compare the different powder production techniques used in P/M.
CO2: Analyse different compaction techniques used for shaping of P/M parts.
CO3: Assess various sintering techniques and their effects on sintered parts.
CO4: Appraise the various P/M processes for making engineering components.

Significance of powder processing technique compared to other metal forming techniques - scope of powder metallurgical industries - powder production techniques: mechanical fabrication, atomization, chemical reduction, carbonyl and electro-chemical processes – ceramic powder production - powder characterisation: particle size analysis, surface area, density and flowability measurements, microscopy techniques - powder conditioning: mixing and blending, lubrication and coating.

Powder compaction: cold and iso-static compaction, die compaction, injection moulding, slurry technique, slip casting, extrusion and rolling, hot iso-static pressing - pressing equipment and tooling -
Sintering: sintering stages, single component, material transport mechanisms, model studies: powder shrinkage experiments - sintering diagrams and sintering anomalies - multi-component sintering: solid phase and liquid phase, infiltration and reaction sintering – sintering defects - sintering atmospheres and equipment.

Powder metallurgy products: PM-Automobile components, HSS and carbide tools, porous parts, sintered carbides, cermet - ceramic components - Powder metallurgy and additive manufacturing –
Introduction to various international (ISO/ASTM) and Indian standards (IS) in powder metallurgy.

References:
[1] German, R. M., 1994, *Powder Metallurgy Science* Metal Powder Industries Federation.
[2] Upadhyaya, A. Upadhyaya, G.S. 2011, *Powder Metallurgy: Science, Technology and Materials*, CRC Press.
[3] Thummler, F., and Oberacker, R., 1994, *An introduction to Powder Metallurgy*, The Institute of Materials, The University Press, Cambridge.
[4] Eisen, W.B., 1998, *Powder Metal Technologies and Applications,* ASM International.
[5] Angelo P. C., Subramanian, R. 2015, *Powder Metallurgy*, PHI Pvt Ltd.

ME3322E INTRODUCTION TO MODERN MACHINING PROCESSES

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Identify suitable modern machining processes for a given component or geometry based on its functional requirement.
CO2: Apply fundamental knowledge in the analysis of modern machining processes.
CO3: Analyse the process characteristics of various processes on the surface and bulk material properties.
CO4: Estimate energy requirement and select process parameters for various processes.

Conventional and non-conventional machining processes-Introduction to advanced machining processes - classifications-Mechanical Machining Processes: Ultrasonic Machining(USM)- Abrasive Jet Machining(AJM)- Water Jet Machining (WJM)- Abrasive Water Jet Machining(AWJM) - Ice Jet Machining (IJM)- Magnetic Abrasive Finishing(MAF)- Abrasive flow finishing (AFF) – Magnetorheological finishing (MRF):Introduction, Machining set up, Working principle, Parametric analysis, Modelling- Merits, demerits and applications.

Thermal Machining Processes: Electro Thermal Processes-Electro Discharge Machining (EDM)-Wire Electro Discharge Machining (WEDM)- Electric Discharge Grinding (EDG)- Electric Discharge Diamond Grinding (EDDG), Laser beam machining (LBM), Plasma arc machining (PAM), Electron Beam Machining (EBM): Introduction, Machining set up -Working principle, Parametric analysis, Modelling, Merits, demerits and applications.

Chemical Machining (CM): Electro Chemical Machining (ECM)- Electrochemical Grinding (ECG), Electro stream Drilling (ESD), Shaped Tube Electrolytic Machining (STEM), Introduction, Machining set up -Working principle, Parametric analysis, Modelling, Merits, demerits and applications.

Hybrid machining processes: Concept, classification, process capabilities, and applications of various hybrid machining methods based on USM, EDM, ECM, Laser, etc., case studies, recent trends in research and development.

Micro machining; tool-based micromachining methods, cutting edge radius effect, minimum uncut chip thickness, micro turning, micro milling, unconventional micromachining methods – micro EDM, micro WEDM. Ultra-precision machining; mechanism of material removal, methods and applications, mechanics, applications.

References:

[1] Ghosh A. and Mallik, A.K. 2014, *Manufacturing Science*, Affiliated East West Press Ltd.
[2] Jain, V.K. 2009, *Advanced Machining Processes*, Allied Publishers.
[3] Pandey, P.C. 2017, *Modern Machining Processes*, Tata McGraw Hill.
[4] Mishra, P.K. 1997, *Nonconventional Machining*, Narosa.
[5] McGeough, J.A. 1988, *Advanced Methods of Machining*, Chapman and Halls.
[6] Kalpakjain, S. and Schmid, S.R. 2018, *Manufacturing Engineering and Technology*, Pearson.
[7] Groover, M.P. 2018, *Fundamentals of Modern Manufacturing*, Wiley.
[8] McGeough, J. 2002, *Micromachining of Engineering Materials*, Marcel Dekker, Inc.
[9] Jain., V.K., 2012, *Micromanufacturing Processes*, CRC press.

ME3323E DESIGN FOR MANUFACTURABILITY

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Explain the key concepts in various new manufacturing paradigms.
CO2: Analyze a proposed design from the point of view of assembly and manufacturing.
CO3: Use modern software tools to accurately model parts for specific manufacturing operations, model part costs, simplify products, find specific avenues to reduce manufacturing and assembly costs, benchmark products, and quantify improvements.
CO4: Quantitatively evaluate the impact of design choices on manufacturing cost.
CO5: Be able to use modern quality control concepts and approaches.

Introduction to Design for Assembly and Manufacturability (DFA/DFM): DFMA definitions and objectives, Introduction to DFMA tools Principles and practice of Design for Manufacturability and Assembly, Product Definition and Value Engineering, Customer requirements, Design requirements, Assembly analysis and manufacturing processes, Robust design, manufacturability, assembly, and environment, Selection of Materials and Processes;

DFM and DFA Guidelines- Product Design for Manual Assembly; Design for variety and platform design, Design for Injection Molding; Design for Sheetmetal Working; Design for Die-Casting, Sand Casting, and Investment Casting; Design for Machining; Design for other Miscellaneous Processes; Design for Human Factors; Advanced Application of DFM and DFMA tool, DFA in Aerospace Industry – Case Study.

Design for X; Design for Reliability, Design for Serviceability, Design for Environment, Design for Disassembly;

Robust Design: Tolerances; Process variability and control; Statistical Process Control; Six Sigma and DMAIC procedure; Taguchi Methods; ISO 9000, Taguchi Methods & Orthogonal Arrays, Failure Modes and Effects Analysis (FMEA)

References:

[1] Boothroyd, G. Dewhurst, P., and Knight,W.A., 2010, *Product Design for Manufacture and Assembly*, CRC Press.
[2] Meadows, J.D. 2009, *Geometric Dimensioning and Tolerancing, Applications, Analysis & Measurement*, ASME Press.
[3] Smith P.G., and D. G., Reinertsen, 1997, *Developing Products in Half the Time*, John Wiley & Sons Inc.
[4] Wheelwright C.S., and Clark, B.K., 2011, *Revolutionizing Product Development*, Free Press.
[5] Otto. K., and Wood, K., 2003, *Product Design*, Pearson.
[6] Ashby, M. F., 2019, *Materials Selection in Mechanical Design*, Elsevier.

ME3325E MACHINING SCIENCE AND MACHINE TOOLS

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Explain the influence of tool geometry on cutting performance, define the nomenclature of single point and multipoint cutting tools as per the industrial standards.
CO2: Analyse and predict the cutting forces, power requirements in machining based on different analytical models and on mechanics of metal/material cutting.
CO3: Propose an ideal machining/manufacturing process for fabricating advanced materials for specific applications with due considerations for the process capabilities and product quality requirements.
CO4: Identify suitable cutting tools, machine tools and optimal cutting parameters for various machining requirements by considering tool life/wear, machinability and surface integrity aspects.
CO5: Explain various machine tool mechanisms and design the machine elements, jigs and fixtures for different operations and applications.
CO6: Develop CNC part programs from production drawings (manual and CAD/CAM software based) and implement it in CNC Machines to fabricate the component.

Kinematic elements in metal cutting; tool nomenclatures; mechanics of chip formation: orthogonal and oblique cutting, shear angle, velocity relationship; merchant's analysis of cutting forces; cutting power estimation; Inserts: coatings, nomenclature; various types of drills; milling cutters and tool materials; material removal analysis in milling, drilling, grinding; effect of cutting variables on forces; tool failure analysis; theories of tool wear: measurement of tool wear; cutting tool dynamometers; thermal aspects of machining; tool life and economics of machining.

Basic concepts of machine tools; tool - work motions; machine tools for various machining processes; kinematics of machine tools and gear boxes; feed and speed mechanism; machine tool drives; machine tool dynamics; gear manufacture: milling, hobbing and shaping; special purpose machine tools; hydraulic control of machine tools: components of hydraulic circuits, control circuits and their characteristics; testing of machine tools; jigs and fixtures: basic principles of location, type and mechanics of locating and clamping elements, design of jigs and fixtures.

CNC machine tools: constructional features, drives and controls, feedback devices; interpolators: linear, circular interpolation and other emerging techniques; adaptive control systems; CNC part programming: post processors, use of various CAD/CAM software packages, CNC programming with CAD/CAM software, development of CNC programmes for special problems; micro/nano machining; additive manufacturing: recent developments; modern machining processes: mechanics, process parameters and applications of AJM, ECM, EDM, USM, EBM, LBM; hybrid machining Introduction to robotics and automation.

References:

[1] Ghosh, A., and Mallik, A.K., 2010, *Manufacturing Science*, Affiliated East West Press.
[2] Boothroyd G. and Knight, W. A. 2005, *Fundamentals of Metal Machining and Machine Tools*, CRC press.
[3] Chattopadhyay, A.B., 2017, *Machining and Machine Tools*, Wiley.
[4] Shaw, M.C., 2004, *Metal Cutting Principles*, Oxford University Press.
[5] Bhattacharyya, A., 1984, *Metal Cutting, Theory and Practice*, New Central Book Agency.
[6] Kalpakjian S., and Schmid, S.R. 2014, *Manufacturing Engineering and Technology*, Pearson.
[7] Pandey P.C., and Shan, H.S. 1980, *Modern Machining Processes*, Tata Mc Graw Hill.
[8] Sen G.C., and Bhattacharyya, A. 2009, *Principles of Machine Tools*, New Central Book Agency.
[9] Mehta, N.K. 2012, *Machine Tool Design and Numerical Control*, Tata McGraw Hill.
[10] Esposito, A., 2008, *Fluid Power with Applications*, Pearson.
[11] Kempster, M.H.A., 1974, An *Introduction to Jig and Tool Design*, Butterworth-Heinemann.
[12] Groover, M.P., 2015, *Automation, Production Systems, and Computer-Integrated Manufacturing*, PHI.
[13] Rao, P.N., 2010, *CAD/CAM: Principles and Applications*, Tata McGraw Hill.

ME3326E MACHINE TOOLS AND CNC SYSTEMS

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Evaluate specifications and select suitable machine tool for achieving product specifications.
CO2: Design of basic machine tool elements like gear box.
CO3: Estimate machining time, material removal rate and cost for various machining processes to aid in process planning.
CO4: Create and execute CNC part programs for drilling, turning and milling operations.

Introduction to machine tools; functional principles; classification of machine tools; kinematic structure; specifications of machine tools; calculation of machining time; machining operations: thread cutting; turning; facing; taper turning; form cutting with form tools; gear forming; gear shaping; gear hobbling; kinematics of gear shapers and gear hobbing machine; boring: boring tools; boring bars; drilling: fluted drills; deep hole drilling; grinding machines: types; construction features; wheel mounting; special purpose machine tools; automated machines; jig boring machines; super finishing; honing machines.

Power drives: methods of changing speed and feed in machine tools; design of speed gear box of machine tools; hydraulic drives and electric drives; design of machine tool structures; spindle and guide ways; vibration of machine tools: single and multi-degree systems with damping and without damping; vibration measurements; machine tool chatter; machine tools controls.

CNC machine: history; working principle; coordinate systems; positioning accuracy and repeatability of CNC machine tools; machining centers; design of CNC machine tools; mechatronic elements; sensors and transducers; feedback devices; DDA interpolation; tool changers; testing of machine tools; machine tool error analysis; CNC programming.

References:

[1] Chattopadhyay, A. B., 2017, *Machining and Machine Tools*, Wiley.
[2] Chapman, W. A. J., 1980, *Workshop Technology*, Vol. 1, 2 & 3. ELBS.
[3] Khaimovitch, E. M., 1965, *Hydraulic control of Machine Tools*. Pergamon Press.
[4] Bhattacharyya, A., 2008, *Principles of Machine Tools*. New Central Book Agency.
[5] HMT Limited, 1987, *Production Technology*. Tata McGraw Hill.
[6] Mehta, N.K., 2005, *Machine Tool Design & Numerical Control*, Tata McGraw Hill.
[7] Ernst, W., 1949, *Oil Hydraulics power and its Industrial applications*. McGraw Hill.
[8] Shaw, M.C., 1999, *Metal Cutting Principles*. CBS Publishers and Distributors.
[9] HMT Limited, 2008, *Mechatronics*, Tata McGraw Hill.
[10] Boothroyd, G., Knight, W.A., 2005, *Fundamentals of Metal Machining & Machine Tools*, CRC Press.

ME3327E QUALITY, RELIABILITY AND MAINTENANCE

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Analyse the link between quality and cost and assess the impact of quality costs on an organization.
CO2: Design and interpret control charts for variables and attributes for controlling and improving the quality of products, processes and services.
CO3: Design different acceptance sampling plans and analyse the risks related to quality aspects while using them.
CO4: Select and use the relevant quality, reliability and maintenance methods for controlling and improving production systems.
CO5: Use software-based quality tools for the preparation of control charts, designing acceptance sampling plans and performing reliability test data analyses.

Principles of Quality Management: Introduction, definitions of quality and related terms as per ASQ and ISO, dimensions of quality, tools for quality planning, quality control and quality assurance, quality costs and their categorifies, relationship between quality and quality costs, case studies of external failure costs, quality and engineering design process, quality function deployment (QFD), quality loss function, product control model and process control model for quality.

Quality Control and improvement: Process variation and sources, use of control charts, statistical basis of the control charts, derivation and choice of control limits, construction and interpretation of control charts for variables and attributes, rational sub groups, control chart sensitivity, OC curve, average run length, phase I and phase II control chart application.

Acceptance Sampling: The acceptance-sampling problem, lot formation and sampling, guidelines for using acceptance sampling, type A and type B OC curve, binomial nomograph, rectifying inspection, average outgoing Quality limit (AOQL), average total inspection, double, multiple, and sequential sampling, ASN curve, sampling systems, MIL STD 105E, switching rules, Dodge–Romig plans.

Industry practices related to Quality: Quality standards, process capability analyses and matrices, six sigma approach, ISO/TS 16949 Automotive industry action group (AIAG) manuals, measurement system analyses, advanced product quality planning (APQP), production part approval process (PPAP).

Reliability Engineering: Introduction to reliability, reliability matrices, hazard rate function, system reliability, reliability testing, statistical distributions in reliability analysis, types of failure time, fitting models, warranty analyses.

Maintenance Engineering: Types of maintenance systems: preventive, predictive, conditional monitoring, reliability-based maintenance, total-productive maintenance, Overall Equipment Effectiveness, ISO 55000 Asset management, Maintenance 4.0

References:

[1] Montgomery, D.C., 2019, *Introduction to Statistical Quality Control*, John Wiley and Sons.
[2] Mitra, A., 2021, *Fundamentals of Quality Control and Improvement*, John Wiley and Sons.
[3] Krishnamoorthi, K.S., Krishnamoorthi. P.V., 2019, *A First Course in Quality Engineering*, CRC Press
[4] Edward, G.S., Dean, V.N. 2017, *Acceptance Sampling in Quality Control*, CRC Press, Boca Raton.
[5] Elsayed, E.A., 2020, *Reliability Engineering*, John Wiley and Sons.
[6] Pochampally, K.S., Gupta, S. M., 2021, *Reliability Analysis with Minitab*, CRC Press.
[7] Mishra R. C., Pathak, K., 2012, *Maintenance Engineering and Management*, Prentice-Hall.
[8] Gulati, R., 2021, *Maintenance and Reliability Best Practices*, Industrial Press.

ME3328E ARTIFICIAL INTELLIGENCE IN MANUFACTURING

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Describe and explain the basic concepts of Artificial Intelligence and its applications.
CO2: Identify suitable methods to collect data for Artificial Intelligence systems.
CO3: Apply various algorithms for developing neural networks.
CO4: Apply Artificial Intelligence techniques for manufacturing applications.

Fundamentals: Historical development, key concepts and terminology, ethical and societal considerations. Problem Solving by Search: Fundamentals, application to manufacturing scenarios, case studies in manufacturing. Key AI Technologies: Machine learning and deep learning. Applications in quality control, predictive maintenance, and process optimisation. Role of data in AI applications and its acquisition in manufacturing.

Data sources in manufacturing, sensors IoT devices. Techniques for data acquisition and real-time monitoring in industrial settings. Challenges in managing and storing manufacturing data. Data preprocessing techniques for cleaning and structuring data. Feature selection and engineering for AI model inputs. Data visualisation and analysis techniques for manufacturing insights.

Supervised and Unsupervised Learning: Fundamentals, Overview of supervised and unsupervised learning algorithms, Applications in quality control, anomaly detection, and process optimization, Model selection and evaluation for manufacture. Deep learning techniques, convolutional neural networks and recurrent neural networks, Integration of robotics and AI in manufacturing processes, Case studies of AI-driven improvements in manufacturing efficiency and quality.

Real-world Applications in Manufacturing: AI-driven process optimization and quality control, AI's role in supply chain management, demand forecasting, and production scheduling. Sustainable and green manufacturing through AI. Future Trends and Preparing for Industry 5.0: Challenges and opportunities in the evolving landscape of AI in manufacturing. The role of AI in fostering innovation and competitiveness. Preparing for the future of manufacturing with AI skills and knowledge.

References:

[1] Russell, S., and Norvig, 2022, *Artificial Intelligence: A Modern Approach*, Pearson India.
[2] Geron, A., 2019, *Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow*, O Reilly.
[3] Nilsson, N.J., 1998, *Artificial Intelligence – A New Synthesis*, Morgan Kaufmann Publishers, Inc.
[4] Tran, K.P., 2023, *Artificial Intelligence for Smart Manufacturing - Methods, Applications, and Challenges*, Springer.
[5] Chen, T.T., 2023, *Explainable Artificial Intelligence (XAI) in Manufacturing - Methodology, Tools, and Applications*, Springer.

ME3330E FLUID POWER CONTROLS

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Describe the hydraulic and pneumatic systems with various pump and motors.
CO2: Explain various actuators like DCV, flow control valve, check valve, solenoid valve, push button for hydraulic and pneumatic system.
CO3: Identify the various ISO symbols for simple circuit design for both hydraulic and pneumatic systems.
CO4: Design hydraulic and pneumatic circuits for various industry applications.

Introduction to oil hydraulics and pneumatics: their advantages and limitations, ISO symbols and standards in oil hydraulics and pneumatics, recent developments, applications; basic types and constructions of hydraulic pumps and motors: performance curves and parameters; hydraulic actuators; hydraulic control elements; direction, pressure and flow control valves; flow control valves; electro-hydraulic servo valves-specifications; selection and use of servo valves.

Electro hydraulic servomechanisms: electro hydraulic position control servos and velocity control servos; basic configurations of hydraulic power supplies; design and analysis of typical hydraulic circuits: use of displacement-time and travels-step diagrams; synchronization circuits and accumulator sizing; meter-in, meter - out and bleed-off circuits; fail safe and counter balancing circuits.

Components of pneumatic systems: direction, flow and pressure control valves in pneumatic systems; development of single and multiple actuator circuits; safety circuits; valves for logic functions: time delay valve, exhaust and supply air throttling; examples of typical circuits using displacement-time and travel-step diagrams; cascade method; Karnaugh-Veitech mapping method; travel-dependent control and time dependent control; combined control; program logic control (PLC); electro-pneumatic control and air hydraulic control; applications in assembly, feeding, metalworking, materials handling and plastics working of case studies & IoT.

References:

[1] Esposito. A., 2008, *Fluid Power with applications*, Pearson.
[2] Johnson, J.L. 2001, *Introduction to Fluid Power*, Delmar Cengage Learning.
[3] Joji, P. 2008, *Pneumatic Controls*, Wiley.
[4] Morse, A.C. 1963, *Electro hydraulic Servomechanism*, McGraw-Hill.
[5] Pippenger J.J. and Koff, R. M, 1959, *Fluid Power Control systems*, McGraw-Hill.
[6] Fitch., E.C. 1966, *Fluid Power Control Systems*, McGraw-Hill.
[7] Khaimovich, E.M., 1965, *Hydraulic Control of Machine Tools,* Pergamon.
[8] Watton, J., 1989, *Fluid Power Systems: Modeling, Simulation and Microcomputer Control*, Prentice Hall.
[9] Merritt, H.E., 1991, *Hydraulic control systems*, Wiley.
[10] Hasebrink. J. P., and Kobler. R., 1975, *Fundamentals of Pneumatics/ Electro pneumatics*, FESTO.
[11] Deppert, W., and Stoll, K., 1975, *Pneumatic Control-An introduction to the principles*, Vogel Verlag.
[12] Andersen, B.W., 2001, *The analysis and Design of Pneumatic Systems*, Krieger Publishing Company.
[13] Blackburn, J.., Reethof, G., and Shearer, J.L., 1966, *Fluid Power Control*, MIT Press.

ME3331E NON-DESTRUCTIVE TESTING AND EVALUATION

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:
CO1**:** Apply the various NDT techniques to identify the defects.
CO2: Select the suitable NDT techniques for various defects.
CO3: Identifying the nature and quantifying the defects.

Introduction to NDT: Destructive and non-destructive testing, Importance and scope of NDT, Visual optical methods, Microscope, endoscope, borescope, telescope. Liquid penetration test, principles, properties required for a good penetrants and developers - Types of penetrants and developers, interpretation and evaluation of penetrant test indications.

Magnetic particle inspection: Basic theory of magnetism, Magnetization methods, Field indicators, Particle application, Inspection.

Eddy current testing: Basic principle; Faraday's law, Inductance, Lenz's law, Self and Mutual Inductance, Impedance plane, Inspection system and probes, System calibration.

Radiography: Introduction to x-ray radiography, the radiographic process, X-ray and Gamma ray sources, Geometric principles, Factors governing exposure, radio graphic screens, scattered radiation, arithmetic of exposure, radiographic image quality and detail visibility, industrial X-ray tomography

Ultrasonic testing: Generation of ultrasonic waves, Horizontal and shear waves, Near field and far field acoustic wave description, Ultrasonic probes- Straight beam, direct contact type, Angle beam, Transmission/reflection type, and delay line transducers, acoustic coupling and media

Acoustic emission testing: Basic principle, Sources of acoustic emission, Source parameters, Kaiser-Felicity theory, Equipment and Data display, Source location schemes.

Applications of NDT: NDT in flaw analysis of Pressure vessels, piping NDT in Castings, Welded constructions, etc., Industrial applications and case studies

References:
[1] Louis Cartz,1995, Nondestructive Testing: Nondestructive Testing: Radiography, Ultrasonics, Liquid Penetrant, Magnetic Particle, Eddy Current, ASM International.
[2] Prasad. J., and Krishnadas Nair, C. G. 2017, *Non-destructive test and evaluation of materials*, Tata McGraw-Hill.
[3] Paul E. Mix, 2005, *Introduction to Nondestructive Testing: A Training Guide*, John Wiley & Sons.
[4] Baldev Raj, Thavasimuthu, M. Jayakumar, T., 2011, *Practical Non-Destructive Testing*, Narosa Publishing house.
[5] Krautkramer, Josef and Hebert Krautkramer,*1990, Ultrasonic Testing of Materials*, Springer- Verlag

ME3332E MECHATRONICS AND AUTOMATION

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:
CO1: Explain various key elements or subsystems in mechatronics.
CO2: Select sensors, actuators and data acquisition systems for a given mechatronics system.
CO2: Analyse the signals, system and controllers and develop PLC programming for automated systems.
CO4: Illustrate the existing drive systems and design low cost automation technologies using fluid power components.
CO5: Explain various elements, levels and strategies of automation.

Introduction to Mechatronic Systems: key elements in mechatronics, advanced approaches in mechatronics, real time interfacing; elements of data acquisition system; actuators and sensors: fluid power and electrical actuators, piezoelectric actuator; sensors for position, motion, force, strain and temperature, flow sensors, fibre optic sensors-, magnetostrictive transducer, selection of sensors, microsensors in mechatronics.

Introduction to Signals, system and controllers: Introduction to signals, system and control, system representation, linearization, time delays, measures of system performance; closed loop controllers: PID controller, adaptive control; introduction to microprocessors, micro-controllers and programmable logic controllers: components, PLC programming; sensors for condition monitoring; mechatronics control in automated manufacturing.

Introduction to automation: types, architecture of industrial automation systems; manufacturing plants and operations; automation strategies; levels of automation for industries; Drives and mechanisms of an automated system: drives: stepper motors, servo drives. balls screws, linear motion bearings, cams, systems controlled by camshafts, electronic cams, indexing mechanisms, tool magazines, and transfer systems.

Hydraulic and Pneumatic system hydraulic systems: flow, pressure and direction control valves, actuators, and supporting elements, hydraulic power packs, and pumps. design of hydraulic circuits; pneumatics: system components and graphic representations, design of pneumatic circuits

References:
[1] Shetty, D., Kolk, R. A., 2001, *Mechatronics System Design*, Thomson Learning.
[2] Mikell, G.P., 2016, *Automation, Production systems and Computer integrated manufacturing*, Pearson Education.
[3] Bolton, W., 2004, *Mechatronics*, Pearson education Asia.
[4] HMT Ltd., 1998, *Mechatronics*, Tata McGraw Hill.
[5] Singh, B.P., 1997, Microprocessors *and Microcontrollers*, Galgotia Pub.
[6] Frank D., Petruzella, 2010 *Programmable Logic Controllers*, Tata McGraw Hill.
[7] Blackburn, J.F., Reethof, G. and Shearer, J. L., 1980, *Fluid Power Control*, MIT Press.
[8] Anthony E., 2003, *Fluid Power with applications*, Pearson Education.
[9] Boucher, T.O., 1996, *Computer automation in manufacturing - an Introduction*, Chapman and Hall.

ME3333E ADDITIVE MANUFACTURING: FUNDAMENTALS AND APPLICATIONS

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Explain the fundamental principles and concepts of additive manufacturing (AM) technologies.
CO2: Compare the advantages and limitations of AM techniques compared to traditional manufacturing methods.
CO3: Apply strategies to improve the AM part quality by software modifications based on the knowledge about 3-D file structures and digital work flow of additive manufacturing
CO4: Analyze case studies and real-world applications of AM in industries such as aerospace, automotive, healthcare, and more.
CO5: Apply the design considerations for additive manufacturing

Introduction to additive manufacturing (AM): overview of additive manufacturing, brief history of additive manufacturing, advantages and limitations of additive manufacturing, comparison with traditional manufacturing methods, ISO/ASTM definitions, classifications, applications of AM (medical, aerospace, automotive, molds and tooling, remanufacture and repair, scanning and reverse engineering, engineered structures, functionally graded structures, etc.,) hybrid additive/subtractive systems, process steps.

CAD Models for AM, AM file formats, manipulation of STL files, part orientation and support structure generation, slicing methods, tool path planning, generation of 3D data for AM using CAD, demonstration of CAD CAM packages, CAPP for AM.

Additive Manufacturing Methods: process mechanism, process parameters, advantageous, limitation and applications of various AM technologies: Vat photo polymerization, Material Jetting, Material Extrusion, Binder Jetting, Sheet lamination, Powder bed fusion, Direct energy deposition, Wire Arc Additive Manufacturing, and other similar processes.

Design for additive Manufacturing, design guidelines for AM, Topology Optimization, AM materials, post processing: support removal, surface finish and geometry improvement, Aesthetic and property enhancement, safety considerations in AM, Introduction to hybrid AM systems. Introduction to various international (ISO/ASTM) and national standard (BIS) related to the AM. Recent advances in AM, 4D printing, bioprinting, case studies, hands on experience in designing and fabricating AM parts.

References:

[1] Gibson, I., Rosen, D., Stucker, B., Khorasani, M. 2021, *Additive Manufacturing Technologies*, Springer Nature.
[2] Paul C.P., and Jinoop, A.N., 2021, *Additive Manufacturing Principles, technologies and Applications*, McGraw Hill Education (India) Pvt. Ltd.
[3] Chua, C.K., Leong, K.F., 2019, *3D Printing and Additive Manufacturing: Principles and Applications*, World Scientific.
[4] Ehsan, T., Dyuti, S., Obehi, O., Liravi, I.F., Russo, P., Taherkhani, K., 2022, *Metal Additive Manufacturing*, John Wiley and Sons.
[5] Kumar,J..L.,Pandey, P. M.,and Wimpenny, D. I., 2019, 3*D printing and additive manufacturing technologies*. Singapore: Springer.

ME3335E WELDING SCIENCE AND TECHNOLOGY

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:
CO1: Explain the theoretical aspects and physics behind the joining of materials.
CO2: Identify appropriate welding process for a particular application.
CO3: Optimize welding parameters to achieve desired weldment properties.
CO4: Analyze the cause of various welding defects and avoid them.
CO5: Demonstrate the ability to assess weld quality by various inspection and testing routes.

Overview of Joining processes, application areas, welding process –Features, Types of joints in welding, Types of welds, Weld symbols, Weld Specification, Basic elements of a welding setup, Energy sources, Removal of Surface contaminants, Protection from atmospheric contamination, Control of weld metallurgy, Power density, Heat transfer mechanisms in Fusion Welding, Micro-structural zones in Fusion welding, Grain growth in Fusion welding, Micro-structural zones in Solid state welding, Mechanisms for obtaining material continuity.

Welding Processes-Oxy-Fuel gas welding, Arc welding, Arc Shielding in AW process, Flux in AW process, welding electrodes, shielded metal arc welding, Gas metal arc welding, Submerged Arc welding, Gas Tungsten Arc Welding, Physics of Arc welding, Polarity in Arc welding, Effect of Magnetic Fields on Arcs, Magnetic Arc Blow, Pulsed DC in Arc welding, Creation of arc plasma, Arc-Electrical features, Pulsed arc or pulsed current transfer, V-A Characteristics of an Arc, Constant current and voltage power sources.

Other Fusion Welding Processes - Thermite Welding, Resistance welding, High-Energy-Density Beam Welding Processes, Electron-beam welding, Laser-beam welding (LBW).

Solid state welding processes - Pressure Welding, Cold welding, Friction welding, Friction stir welding, Ultrasonic welding.

Heat flow in welds, Time-Temperature curves, generalized heat flow equation, Weld geometry and dimensionality of heat flow, Effect of welding parameters on heat distribution, Solidification rate, Cooling Rates.

Weld Defects- Geometric defects, Metallurgical defects, Residual stresses, Distortion, Discontinuity, Gas metal reactions, Porosity, Embrittlement Reactions, Hydrogen embrittlement, Hydrogen Cracking.

Weld Quality and Testing - Destructive tests, Non-destructive inspection of welds, Visual Inspection, Magnetic Particle Inspection, Liquid Dye Penetrant Inspection, X-Ray inspection, Ultrasonic testing, Air or water pressure testing.

Design of Weld joints - Transverse Butt Joint, Transverse fillet Joint, Circular fillet weld subjected to Torsion, Modelling and simulation of welding, Computational Study through software packages, Welding automation.

References:
[1] Parmer, R.S., 1997, *Welding Engineering and Technology*, Khanna Publishers.
[2] Howard, B.C., 1998, *Modern Welding Technology*, Prentice Hall.
[3] Linnert., G.E., 1994, *Welding Metallurgy*, 4th ed., Vol. I and II, AWS.
[4] Granjon, H., 1994, *Fundamentals of Welding Metallurgy*, Jaico Publishing House.
[5] Easterling, K. 1992, *Introduction to Physical Metallurgy of Welding*, Butterworth Heinmann Ltd.
[6] Saferian, D., 1985, *The Metallurgy of Welding*, Chapman and Hall.
[7] Mishra, R.S., and Mahoney M. W.2007, *Friction Stir Welding and Processing*, ASM.
[8] Sindo Kou, 2002, *Welding Metallurgy*, Wiley.
[9] Nadkarni., S.V., 1996, *Modern Arc Welding Technology*, Oxford IBH Publishers.
[10] Davis, C., 1994, *Laser Welding - A Practical Guide*, Jaico Publishing House.
[11] Messler, R. W., 2004, *Principles of Welding*, WILEY-VCH Verlag.
[12] Lancaster, J.F., 1999. Metallurgy of Welding, Springer.
[13] Little, R.A., 2017, *Welding and Welding Technology*, Tata McGraw Hill.

ME3336E FORMING TECHNOLOGY

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Apply fundamental knowledge of elasticity and plasticity in metal forming operations.
CO2: Evaluate forming load and power requirement associated with rolling, forging, drawing, extrusion, and sheet metal forming.
CO3: Select equipment and design tools & dies for metal forming operations.
CO4: Analyse metal forming operation using commercial finite element software.

Review of theory of elasticity: stress and strain relationships for elastic behaviour, Cauchy stress tensor, invariants − Theory of plasticity: introduction, stress-strain relationships, stress space − Yield criterion for metals: Von Mises' yield and Tresca's yield criterions and their representation in stress space, strain hardening: isotropic and kinematic hardening.

Introduction to metal forming: hot and cold working processes, effect of processing parameters on forming process, stress exponent, strain rate sensitivity and activation energy for deformation− Principle, process parameters, equipment and application of the forming processes: rolling; forging; drawing; extrusion; sheet metal forming− Advanced forming & near net shaped processing technologies − Load estimation for bulk (forging, rolling, extrusion, drawing) and sheet (shearing, deep drawing, bending) metal forming processes − powder metallurgy.

Equipment and tools used in metal forming operations: press working tools, types of presses, different types of dies and their design aspects, power presses − die cutting operations, punch & die size, scrap - strip layout − die design: drawing dies, die materials, press tonnage estimation, blank holding pressure, multiple draws.

Overview of constitutive relations in metal forming – geometric and material nonlinearity – Case studies: finite element analyses of material forming using commercial FEM software – Data driven approaches in metal forming.

References:

[1] Ghosh, A., and Mallik, A.K., 2001, *Manufacturing Science.* Affiliated East west Press.
[2] Kalpakjian, S., and Schmid, S.R., 2018, *Manufacturing Engineering & Technology* Pearson Education.
[3] Hosford W.F., and Caddell, R.M., 2011, *Metal Forming Mechanics and Metallurgy* Cambridge University Press.
[4] Hoffman O., and Sachs, G., 2012, *Introduction to Theory of Plasticity for Engineers*, Literary Licensing, LLC.
[5] Dieter, G.E., 2017, *Mechanical Metallurgy,* McGraw Hill Education.
[6] Semiatin, S.L., 1998, ASM *Handbook Volume 14A: Metalworking: Bulk Forming*, ASM International.
[7] Okereke M., and Keates, S., 2010, *Finite Element Applications: A Practical Guide to the FEM Process,* Cambridge University Press.

ME3340E INDUSTRY 4.0 AND SMART ENTERPRISES

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
At the end of the course, the student will be able to:

CO1: Assess various 3D data files and model data representations and select the suitable 3-D files for engineering applications.
CO2: Explain the structure and use of STEP files for interoperability applications related to product/system development.
CO3: Develop digital models for engineering system elements and propose reference architecture for digital twin modelling.
CO4: Apply the concepts of digital thread and digital twin aiding automation of product/system development activities

3-D model data files: Industry X.0 and business practices, digital technologies for smart enterprises, digital product design, 3D data digital forms, formats and semantics, point clouds, voxels, meshes, surface model - parametric and non-parametric, solid model - boundary representation (B-reps) and constructive solid geometry, properties, and applications of digital formats - form approaches, parametric modeling, procedural modeling, part digitalization, 3-D model data files for 3-D printing applications, generative design.

Digital thread: Native and neutral 3D files, structure and properties of STEP, STL, QIF, 3D PDF, JT, Parasolid, model-based definition (MBD), model-based engineering systems, model based enterprises, ISO 10303 standards for industrial automation systems and integration, semantics and ontology of STEP, information modelling using EXPRESS, part 21 files, XML files, application protocols, STEP AP 209- multidisciplinary analysis and design, AP233-systems engineering STEP AP203 , AP 214, STEP AP242, STEP AP STEP-NC AP238, STEP - NC compliant CNC ISO 14649 - digital semantic manufacturing modelling, STEP AP 239, STEP in the context of PDM and PLM.

Digital twin and Cyber Physical Systems : Digital twin, modelling approaches, service encapsulation of digital twin, ISO 23247, digital representation of engineering system elements, universally unique identifier, reference architecture, digital twin framework for manufacturing systems , automation markup language, OPC unified architecture, MT connect, digital twin for shop floors, Interaction mechanism in digital twin systems, multidimension models fusion, digital twins for prognostics and health management of engineering systems, configuration of cyber physical production systems (CPPS), real-time data from CPPS operation, sensor networks, protocols.

Applications and case studies: Applications and case studies of digital twin and digital thread in design and manufacturing, smart factories, Automation of downstream product development activities, QIF-based smart metrology and inspection, STEP-based simulation and analyses, cyber-physical machine systems, data-driven overall equipment effectiveness (OEE) analyses of smart factories.

Hands-on: Manipulation of STEP files for automation and system development, Virtual modelling and analyses of engineering system elements.

References:

[1] Martin Eigner, 2021, *System Lifecycle Management*, Springer Vieweg.
[2] John M.B. and Thomas H.B., 2019, *Effective Model-Based Systems Engineering*, Springer Nature.
[3] Patel D.D., Chen C.H., 2022, *Digital Manufacturing*, Elsevier, Netherlands.
[4] Zhang M, Tao F, and Nee A.Y.C.,2019, *Digital Twin Driven Smart Manufacturing*, Academic Press

[5] Sondipon A., Ranjan G., Mrittika G., Souvik C., 2023, *Digital Twin- A Dynamic System and Computing Perspective*, CRC Press.
[6] Xun X., and Nee A.Y.C.,2009, *Advanced Design and Manufacturing Based on STEP*, Springer, Verlag.
[7] Wang L., and Wang X.V., 2018, *Cloud-Based Cyber-Physical Systems in Manufacturing*, Springer Nature.

ME4329E SURFACE ENGINEERING AND COATING TECHNOLOGY

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Explain the concepts of surfaces, interfaces and coatings and its failure mechanisms.
CO2: Evaluate various surface modification and coating technologies.
CO3: Identify the functional coatings for various applications.
CO4: Analyse methods for characterisation of engineered surfaces.

Surface engineering – Introduction and need of surface engineering; Surface/ sub-surface regions and properties of importance for surface engineering; Surface properties; Surface characterization - surface topography measurement methods - stylus profilometer, Optical methods - interferometry, Scanning probe microscopy - scanning tunneling microscopy, Atomic Force Microscopy, Surface roughness parameters, Mechanical properties measurement - Surface hardness measurement techniques, coating thickness measurement, coating adhesion assessment, analysis of friction and wear of coating, Micrography - Optical microscopy, SEM, EDS, XRD, etc.

Surface damages - mechanisms of wear - adhesive, abrasive, erosive, cavitation, melting wear, corrosion, diffusive wear, etc., with their governing laws; Surface properties for wear & friction resistance, Surface tribology; Surface modification techniques - by controlling surface metallurgy, changing surface composition - carburizing, nitriding, carbonitriding, cyaniding, plasma carburizing and plasma nitriding, vacuum-based surface modification; Various standards followed in surface and coating.

Surface Coating Technologies- Introduction; CVD- reaction, adhesion of the surface coating, system and types; PVD; Evaporation deposition- Vacuum, Reactive, Cathodic arc; Sputtering- Magnetron, unbalanced Magnetron, Radiofrequency and pulsed DC, deposition and types; Weld surfacing - Cladding - TIG cladding, microwave cladding, explosive cladding, LASER cladding; Thermal spraying, flame spraying, HVOF, detonation spraying, cold spraying, arc spraying, plasma spraying, ion implantation, ion plating, and ion based deposition, boronizing, LASER alloying, electroplating, electroless plating, electrochemical conversion coatings, electrodeposited coatings, wetting etc.

References:

[1] Leach, R., 2013, *Characterization of areal surface texture*, Springer-Verlag.
[2] Davim, J.P., 2021, *Surface Engineering: Surface Modification of Materials*, Springer.
[3] Davis, J.R., 2001, *Surface Engineering for Corrosion and Wear Resistance*, ASM International.
[4] Martin, P.M., 2000, *Handbook of Deposition Technologies for Films and Coatings: Science, Applications and Technology*, Elsevier.
[5] Tracton, A.A., 2006, *Coatings Technology Handbook*, CRC Press Inc.
[6] Griesser, H.J., 2016, *Thin Film Coatings for Biomaterials and Biomedical Applications*, Woodhead Publishing Ltd.
[7] Mittal, K.L., 2004, *Polymer surface modifications: Relevance to adhesion*, Wiley.
[8] Smith, J., 2005, *Surface Engineering: Principles and Practices*, Wiley.
[9] Smith P., and Turner, R., 2017, *Surface Coating Analysis: A Comprehensive Report*, Technical Report No. ASME-TR-2017-123.

ME4337E FUNCTIONAL MATERIALS: THEORY AND APPLICATIONS

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Explain the principles underlying the properties of functional of materials
CO2: Analyse the structure-property correlation of advanced functional materials
CO3: Evaluate material properties through spectroscopy techniques.
CO4: Define the basic electrical and magnetic characteristics of materials by analysing their properties through a set of characterisation techniques.
CO5: Appraise the advanced forms of composites, their preparation and their applications as functional materials

Fundamental principles important to functional materials: Band structures, electronic properties, charge, mass, and energy transport in solids – Semiconducting materials and applications - Dielectrics, piezo- and ferroelectrics: theory, examples of materials and applications - electrical polarization in a wide range of frequencies - magnetic materials and properties - Optical active materials: theory, examples of materials and applications - Chemical, thermal, electrical, and mechanical interactions in solids - .Surfaces, Interfaces and size effects on properties – Biomaterials, theory and applications.

Electrical and magnetic characterization techniques: Impedance Analysis, dielectric breakdown, resistivity, conductivity, ferroelectric/piezoelectric parameters - analysis of magnetic parameters: VSM and impedance analyser.

Advanced functional composite Materials: Introduction to Composites and their applications as functional materials; Polymer-matrix Composites: properties, processing techniques, applications - Ceramic and Metal Matrix Composites: properties, processing techniques, applications

References:

[1] Kittel, C., 2005, *Introduction to Solid State Physics*, John Wiley.
[2] Kasap, S.O., 2018, *Principles of Electronic Materials and Devices,* McGraw-Hill.
[3] Solymar L., and Walsh, D., 2018, *Electrical Properties of Materials,* Oxford University Press.
[4] Wu, J., Cao, J., Han, W.-Q., Janotti, A., and Kim, H.-C., 2010, *Functional Metal Oxide Nanostructures,* Springer.
[5] Lindsay, S. M., 2010, *Introduction to Nanoscience,* Oxford University Press.
[6] Inamuddin, 2013, *Advanced functional polymers and composites: Materials, devices and allied applications*, Nova Science Publishers.
[7] Moulson, A. J., Herbert, J. M., 2013, *Electroceramics*, John Wiley.
[8] Buchanan, R. C., 2019, *Ceramic Materials for Electronics*, CRC press.

ME4338E DESIGN OF JIGS, FIXTURES AND PRESS TOOLS

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:
CO1: Explain tool geometry of single point cutting tools, milling cutters and drills
CO2: Design drill jigs/milling fixtures for typical part geometries.
CO3: Optimise material requirement for press working operations through proper strip layout.
CO4: Estimate press capacity and select equipment for press working operations.
CO5: Design die and punch set for various press working operations.
CO6: Create jigs/fixtures/tooling using various CAD/CAM software.

Introduction to tool engineering: Objectives, importance and principles; tool engineering; tool design; tool making; tool materials and heat treatment; computer applications in tooling design.

Design of cutting tools: Mechanics of chip formation; requirements of a cutting tool; geometry of single point cutting tools, milling cutters, drills, reamers; selection of carbide tools.

Design of jigs and fixtures: Principles of location and clamping; definition of jig; types of jigs; design of drill jigs; definition of fixture; types of fixtures; design of fixtures for various applications.

Design of dies: Press working terminologies; cutting and non-cutting operations; types of presses; cutting action in die; metal flow during drawing; estimation of press capacity; blank development; strip layout; design of punch and die for blanking, piercing, bending, forming and drawing operations.

Advances in tooling design: Tooling for CNC machines; modular fixture systems; quick change tooling; rapid tooling using additive manufacturing; computer assisted fixture design; computer assisted tooling design using commercial CAD/CAM software; computer assisted fixture planning and setup planning.

References:
[1] Venkataraman K., 2022, *Design of Jigs, Fixtures and Press Tools*, Springer Nature.
[2] Donaldson C., LeCain G. H., Goold V. C., Joyjeet Ghose, 2017, *Tool Design*, McGraw Hill.
[3] ASTME, 1984, *Fundamentals of Tool Design*, Prentice Hall of India.
[4] Kempster M. H. A., 2000, *Introduction to Jig and Tool Design*, Viva books.
[5] Hoffman E., 2010, *Jig & Fixture Design*, Cengage.
[6] Joshi P. H., 2017, *Jigs and Fixtures*, McGraw Hill.
[7] Rong Y. K., Zhu Y. S., 1999, *Computer-Aided Fixture Design*, Marcel Dekker.

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ELECTIVE COURSES: MECHANICS AND MACHINE DESIGN

ME2421E THEORY OF ELASTICITY

Pre-requisites: Knowledge of Solid Mechanics

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Describe the mechanics of deformable bodies with adequate mathematical vigour.
CO2: Formulate mathematical models using governing equations of elasticity.
CO3: Describe the various kinds of anisotropy and formulate problems in thermoelasticity.
CO4: Solve unsymmetric bending and non-circular torsion problems.
CO5: Solve 2-D and axisymmetric elasticity problems using various approaches.

Introduction to Three-dimensional Elasticity
Mathematical preliminaries – stress at a point: stress tensor, stress transformation, principal stresses and planes, Mohr’s circle, hydrostatic and pure shear states – strain at a point: strain tensor – analogy with stress tensor.

Equations of Elasticity
Equation of equilibrium – strain-displacement equations – compatibility conditions – constitutive equations – boundary conditions: traction, displacement and mixed boundary conditions – equations in cylindrical polar coordinates – general problem formulation and solution strategies.

Energy and Related Principles
Introduction to energy methods – uniqueness theorem – strain energy and complementary strain energy – Betti’s reciprocal theorem – principle of virtual work – minimum potential energy principle.

Anisotropic Elasticity and Thermoelasticity
Anisotropy: basic concepts, material symmetry, restrictions on elastic moduli – Thermoelasticity: heat conduction and energy equation, general uncoupled formulation, two-dimensional formulation.

Applications – Special Problems in Bending and Torsion
Special problems in bending: unsymmetric bending, shear centre, curved beams – Torsion of non-circular sections: examples using St. Venant’s theory and Prandtl’s stress function approach – analogies in torsion – torsion of narrow rectangular cross sections and thin walled hollow sections.

Simplification to Two-dimensional Problems
Plane stress and plane strain problems – Airy’s stress function approach, examples – axisymmetric problems: Lame’s problem, rotating disks and shrink fits.

References:
[1] Sadd, M. H., 2014, *Elasticity: Theory, Applications and Numerics*, 3rd ed. Academic Press.
[2] Timoshenko, S. P., and Goodier, J. N., 2010, *Theory of elasticity*, 3rd ed. Tata McGraw-Hill.
[3] Srinath, L. S., 2008, *Advanced Mechanics of Solids*, 3rd ed. Tata McGraw-Hill, New Delhi.
[4] Hartog, D., 2016, *Advanced Strength of Materials*, 1st ed. McGraw-Hill, New York.
[5] Tong, C. X., and Fung, Y. C., 2020, *Classical and Computational Solid Mechanics*, World Scientific.
[6] Nambudiripad, K. B. M., 2018, *Advanced Mechanics of Solids – A Gentle Introduction*, Narosa Publishing House.

ME2422E NEWTONIAN AND ANALYTICAL MECHANICS

Pre-requisites: Knowledge of Engineering Mechanics

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Formulate and solve engineering mechanics problems in system of particles and rigid body kinematics.
CO2: Solve 3-dimensional dynamics problems of rigid bodies.
CO3: Solve practical problems using the concepts of analytical mechanics.

Kinematics of System of Particles and Rigid Bodies
Review of particle kinematics and dynamics: Rectangular, path variables and cylindrical coordinate systems; Newton's Law for system of particles, Work-Energy equations for system of particles, Work-Energy expression based on center of mass, Linear momentum considerations for a system of particles, Impulsive forces, Impact, Moment-of-momentum method for a system of particles.

Kinematics of rigid bodies
Translation and rotation of rigid bodies, Chasles' theorem, Derivative of a vector fixed in a moving reference, Applications of the fixed-vector concept, General relationship between time derivatives of a vector for different references, Relationship between velocities of a particle for different references, Acceleration of a particle for different references.

Dynamics of Rigid Body
Moments and products of inertia: Formal definition of inertia quantities, Translation of coordinate axes, Transformation properties of inertia terms, Principal moments of inertia. Energy and impulse momentum methods for rigid bodies: Kinetic energy of rigid body, Work-energy relations, Angular momentum of a rigid body about any point in the body, Impulse-momentum equations, Impulsive forces and torques. Dynamics of general rigid-body motion: Euler's equations of motion and applications,three dimensional motion about a fixed point: Euler angles, equations of motion using Euler angles, Introduction to gyroscope.

Analytical Mechanics
Introduction to Analytical Mechanics: Principle of virtual work, D'Alembert's principle, Lagrange's equations of motion, Applications in dynamics and vibrations. Introduction to variational calculus: Euler-Lagrange equation, Hamilton's principle, Introductory problems in variational calculus, Analysis of simply supported beam with uniform load, Elementary vibration problems.

References:
[1] Shames, I. H, 2005, *Engineering Mechanics –Statics and Dynamics*, Prentice Hall of India.
[2] Beer, F. P., and Johnston, E. R., 2013, *Vector Mechanics for Engineers*, McGraw-Hill.
[3] Meriam, J. L., and Kraige, L. G., 2012, *Engineering Mechanics – Dynamics*, John Wiley & Sons.
[4] Meirovitch, L., 2007, *Elements of Vibration analysis*, McGraw-Hill.
[5] Nambudiripad, K. B. M., 2016, *Variational Methods in Engineering*, Narosa.
[6] Meirovitch, L., 1970, *Methods of Analytical Mechanics*, McGraw-Hill.
[7] Hildebrand, F. B., 1972, *Methods of Applied Mathematics*, Prentice Hall of India.

ME2423E ELEMENTS OF MECHANICAL VIBRATION

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Explain the fundamentals of vibrations and solve Single-DOF systems for free and forced vibrations.
CO2: Solve and analyze Two-DOF vibration problems.
CO3: Formulate and solve problems in vibration of continuous systems.
CO4: Determine approximate and numerical solutions of Two-DOF systems.
CO5: Simulate numerically the ODEs governing the vibrations of Single-DOF systems.

Introduction - Fundamentals of Vibration
Introduction to the Course, Basic Concepts of Vibrations, Classification of Vibration.
Vibration Analysis Procedure, Spring Elements; Mass or Inertia Elements, Damping Elements; Harmonic Motion.

Free Vibration of Single-Degree-Of-Freedom Systems
Free Vibration of Undamped Systems - Free Vibration of an Undamped Translational System; Free Vibration of an Undamped Torsional System, Response of First-Order Systems and Time Constant, Rayleigh's Energy Method; Free Vibration with Viscous Damping - Free Vibration with Viscous Damping; Logarithmic Decrement, Loss Coefficient; Graphical Representation of Characteristic Roots and Corresponding Solutions; Free Vibration with Coulomb Damping, Free Vibration with Hysteretic Damping.

Harmonically Excited Vibration
Response of an Undamped System Under Harmonic Force; Response of a Damped System Under Harmonic Force; Response of a Damped System Under the Harmonic Motion of the Base; Response of a Damped System Under Rotating Unbalance; Forced Vibration with Coulomb Damping; Forced Vibration with Hysteresis Damping; Frequency Transfer Functions, Bode Diagrams.

Vibration Under General Forcing Conditions
Response Under a General Periodic Force; Response Under a Nonperiodic Force: Convolution Integral – Impulse Response, Step Response; Response Under a Nonperiodic Force: Convolution Integral – Rectangular Pulse, Triangular Pulse, Response Spectrum; Response Under a Nonperiodic Force: Laplace Transforms; Response Under a Nonperiodic Force: Laplace Transforms.
Applications Using MATLAB: Preliminaries; Numerical Simulation Using ODE Solvers.

Two-Degrees-of-Freedom-Systems
Free-Vibration of Undamped Systems, Semidefinite Systems; Eigen Value Problem for Undamped-Free Vibration; Orthogonality, Expansion Theorem; Normal Modes and their Properties; Response to Initial Excitation; Two DOF: Forced Harmonic Vibration; Vibration absorber.

Vibration of Continuous Systems
The Boundary-Value Problem for Strings; Longitudinal Vibration of a Bar or Rod; Torsional Vibration of Shafts; Lateral Vibration of Beams; Lateral Vibration of Beams.
Determination of Natural Frequencies - Rayleigh's Method, Rayleigh-Ritz Method; Dunkerley's Formula.

References:
[1] Thomson, W. T., 2003, *Theory of Vibration with Applications*, Prentice Hall of India.
[2] Meirovitch, L., 1986, *Elements of Vibration Analysis*, McGraw-Hill.
[3] Rao, S. S., 2004, *Mechanical Vibrations*, Pearson.
[4] Hartog, D. J. P., 1956, *Mechanical Vibrations*, McGraw-Hill.

ME2424E LIFE CYCLE ASSESSMENT

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Understand the concept of a life cycle and its various stages.
CO2: Describe the types of costs that are included in a life cycle cost analysis and apply qualitative and quantitative analysis.
CO3: Describe the four major phases of the ISO LCA Standard and Perform an interpretation analysis and data acquisition for life cycle inventory analysis.
CO4: Select and justify Life Cycle Impact Assessment LCIA methods and illustrate the value of life cycle techniques in the development of more sustainable designs.

Integral Concepts in LCA: Introduction, course outline, course expectation, Overview of LCA, Life Cycle Overview; ISO Standards,

Life cycle inventory methods- Quantitative and Qualitative methods for LCA, Life cycle costing, Life cycle costing/case studies, The ISO LCA Standard -Goal and Scope.

Life cycle stages and databases - Data Acquisition and Management, Multi-function system and LCA - raw materials, energy, transportation, production, use, end of life, recycling Model process, Lightweighting/Biomaterial LCA, Economic Input-Output models, Advanced Life Cycle Models,

Life cycle impact assessment- Life cycle impact categories – carbon footprint, global warming, acidification, eutrophication, ozone, respiratory effects, ecotoxicity, land use, resource depletion, sensitivity analysis, Uncertainty Assessment in LCA, Consequential LCA (cLCA)

References:
[1] Matthews, H. S., Hendrickson, C. T., and Matthew, D. H., 2018, *Life Cycle Assessment: Quantitative Approaches for Decisions That Matter.*
[2] Allen, D. T., and Shonnard, D. R., 2012, *Sustainable Engineering: Concepts, Design & Case Studies* Prentice-Hall.
[3] Hendrickson, C. T., Lave, L. B., and Matthews, H. S., 2010, *Environmental Life Cycle Assessment of Goods and Services: An Input-Output Approach.*
[4] Schenck, R., and White, P., 2010, *Environmental Life Cycle Assessment: Measuring the Environmental Performance of Products*.
[5] Hejungs, R., and Sangwon, S., 2002, *The Computational Structure of Life Cycle Assessment.*

ME3421E INTRODUCTION TO FINITE ELEMENT METHOD

Pre-requisites: Knowledge of Theory of Elasticity and Heat Transfer

L	T	P	O	C
3	0	0	6	3

Total Lecture sessions: 39

Course Outcomes:
CO1**:** Describe the basics and significance of finite element method.
CO2: Develop formulations for various problems using finite element method.
CO3: Solve 1D and 2D field problems using finite element method.
CO4: Solve nonlinear and time dependent problems using finite element method.

Analysis of Discrete Systems
Introduction – formulation of spring and rod element matrices – assembly process – application of boundary conditions and solution – formulation of beam elements – assembly and boundary conditions for systems of beam elements.

Continuous Systems and Function Approximation
Introduction to continuous systems – function approximation: point collocation method, least square approximation, weighted residual method – finite difference method and finite element method.

One-dimensional Finite Element Analysis
Shape functions – Galerkin weighted residual method – assembly and boundary conditions – continuity requirements and order of shape functions.

Two-dimensional Finite Element Analysis
Introduction – scalar-field problems: heat transfer, torsion and potential flow problems – shape functions for triangular elements – formulation, assembly and solution.

Vector-field Problems
Stress analysis problem – rectangular elements – Lagrangian interpolation polynomials – isoparametric formulation and higher order elements – formulation, assembly and solution – numerical Integration.

Computational Aspects
Mesh generation – element shape parameters – node numbering – storage and solution schemes – finite element analysis using commercial software.

Nonlinear Analysis
Convergence and tolerance – fixed-point iteration – Newton-Raphson and modified Newton-Raphson methods.

Time-dependent problems
Time-stepping schemes – explicit and implicit methods – stability and accuracy.

References:
[1] Zienkiewicz, O. C., Taylor, R. L., and Zhu, J. Z., 2013, *The Finite Element Method: Its Basis & Fundamentals*, 7th ed. Butterworth-Heinemann.
[2] Zienkiewicz, O. C., and Morgan, K., 2006, *Finite Elements and Approximation*, Dover Publications.
[3] Cook, R. D., Malkus, D. S., Plesha, M. E., and Witt, R. J., 2001, *Concepts and Applications of Finite Element Analysis*, 4th ed. Wiley.
[4] Bathe, K. J., 2007, *Finite Element Procedures*, Prentice-Hall of India.

ME3422E NONLINEAR DYNAMICS AND CHAOS

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course outcomes:

CO1: Explain the fundamental principles of nonlinear dynamics, including the behaviour of systems with nonlinear equations and how it differs from linear systems.
CO2: Comprehend and analyze the dynamics of nonlinear continuous-time dynamical systems.
CO3: Analyze chaotic systems.
CO4: Analyze nonlinear systems, through discrete time systems or maps.
CO5: Construct and generate various types of fractals and measure their fractal dimensions
CO6: Familiarize and develop computer programmes in nonlinear dynamical systems

One-Dimensional Flows

Flows on the Line: A Geometric Way of Thinking, Fixed Points and Stability, Linear Stability Analysis, Existence and Uniqueness; Potentials, Population Growth; Saddle-Node, Transcritical, Pitchfork Bifurcations; Imperfect Bifurcations and Catastrophes; Computer Based Exercises

Two-Dimensional Flows

Linear Systems: Definitions and Examples; Classification of Linear Systems; Analysis of Different Linear Systems; Phase Plane: Phase Portraits, Fixed Points and Linearization; Conservative Systems, Reversible Systems; Phase Diagram for the Pendulum Equation; Index Theory; Computer Based Exercises on Linear Systems and Phase Plane; Limit Cycles: Examples, Ruling Out Closed Orbits, Poincare-Bendixson Theorem; Different Systems Showing Limit Cycles Bifurcations: Saddle-Node, Transcritical and Pitchfork Bifurcations; Hopf Bifurcations; Examples on Different Types of Bifurcations; Computer Based Exercises on Limit Cycles and Bifurcations

Tools to Identify and Analyze Motions

Introduction to Quasiperiodic and Chaotic Motions; Fourier Spectra; Poincare' sections and maps; Lyapunov Exponents; Numerical Integration; Harmonic Balance; Averaging Method;

Discrete Time Systems and Fractals

One dimensional map; Fixed points of maps – stability, cobweb diagram, stability of periodic points, basin of attraction; Logistic map – Periodic orbits, stability, chaos, bifurcation diagram; P3 window, intermittency; Tent map, Shift map; Two-dimensional maps; Henon Map; Fractal and Dynamical Systems: Cantor Set, Koch Curve, etc.; Fractal dimensions; Introduction to Julia set, Mandelbrot set and iterative function system (IFS); Computer based exercises in discrete time dynamical systems.

References:

[1] Strogatz, S. H., 2015, *Nonlinear Dynamics and Chaos,* CRC Press.
[2] Jordan, D., and Smith, P., 2007, *Nonlinear Ordinary Differential Equations,* OUP Oxford.
[3] Nayfeh, A. H., and Balachandran, B., 2008, *Applied Nonlinear Dynamics: Analytical, Computational, and Experimental Methods,* John Wiley & Sons.
[4] Thomson, J. M. T., and Stewart, H. B., 2002, Nonlinear *Dynamics and Chaos,* John Wiley & Sons.
[5] Moon, F. C., 2008, *Chaotic and Fractal dynamics,* John Wiley & Sons.
[6] Lynch, S., 2009, *Dynamical System with Applications using MAPLE,* Springer.
[7] Mallik, A. K., and Bhattacharjee, J. K., 2005, *Stability Problems in Applied Mechanics,* Alpha Science Int'l Ltd.

ME3423E ENGINEERING FRACTURE MECHANICS

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39
Course Outcomes:
CO1: Familiarize with concepts of fracture mechanics and fatigue.
CO2: Estimate the safety of the components using Fracture mechanics concepts.
CO3: Estimate the safety of the components loaded with fatigue loads.
CO4: Familiarize with crack detecting systems and Structural health monitoring systems.

Linear Elastic Fracture Mechanics
Introduction: Historic over view of fracture mechanics, Atomistic calculation of material strength; Effect of flows on strength of a material; Griffith energy balance approach: Irwin's modification to the Griffith theory; R-curve approach; Stress intensity factor approach; I, II & III modes of fracture; Crack tip plasticity; Irvin approach; Strip yield model; Mixed mode problems. Propagation of angled crack; FAD diagrams, Testing of K_{IC}; ASTM E 399 standard; K-R curve testing,

Elasto Plastic Fracture Mechanics
Elasto-plastic fracture mechanics – J integral- Nonlinear energy release rate- path independence of J integral; J as stress intensity parameter; Crack tip opening displacement approach - relationship between J and CTOD, J integral testing of materials; CTOD testing of materials

Fatigue analysis and design
Design of components in fatigue loading, infinite life approach- S-N Curve, Factors affecting endurance limit, Theories of failure in fatigue
Finite Life approach- Low cycle fatigue and high cycle approach, Coffin-Manson rule, Cyclic stress strain curve. Basquin Equation
Fatigue crack propagation – Empirical fatigue crack growth equations- Paris law- Crack closure mechanisms – fatigue threshold, Testing of fatigue crack growth. Life prediction in fatigue
Crack detection methods: Ultrasound methods, eddy current methods, stiffness degradation methods, potential drop methods, Infrared thermography

Structural Health Monitoring Systems
Acoustic emission monitoring, Passive IRT systems
Fractography analysis of crack surface: Indefinable features of, creep, fatigue failure, ductile failure, brittle failure.

References:
[1] Anderson, T. L., 2005, *Fracture mechanics*, 3rd ed. Tylor & Fransis publication.
[2] Ewalds, H. L., and Wan hill, R. H., *Fracture Mechanics* –Edward Arnold Edition.
[3] Broek, D., *Elementary Engineering Fracture mechanics*, Sijthoff & Noordhoff International Publishers.
[4] Hellan, K., *Introduction to Fracture Mechanic*s, McGraw Hill Book company.
[5] Kumar, P., *Elements of Fracture Mechanics*, Wheeler Publishing.
[6] Stefen, R. I., Alifatemi, Robert R. S., and Fuchs, H. O., *Metal Fatigue in engineering* 2nd ed., John Wiley & Sons Inc.

ME3424E THEORY OF PLASTICITY

Pre-requisites: Knowledge of Theory of Elasticity and Finite Element Method

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Learn the fundamentals of Theory of Plasticity.
CO2: Develop general formulations of problems in plasticity.
CO3: Perform elastic-plastic analysis of structural elements like beams and shafts.
CO4: Analyze metal forming problems using the fundamentals of theory of plasticity.

Review of Theory of Elasticity
Mathematical preliminaries – stress and strain tensor – transformation laws – principal stress and strain – Mohr's circle – equilibrium equations – strain-displacement relations – compatibility conditions – stress-strain relation – general problem formulation and solution strategies.

Fundamentals of Theory of Plasticity
Experimental observations on behaviour of metals under uniaxial tension and compression – true stress-true strain relations – effect of work hardening – empirical stress-strain relations for work hardening materials.

Yield Criteria and Stress-strain Relations
Yield criterion: stress space representation of yield criterion, representation of Tresca and von Mises criterion, yield surface for work hardening materials – Stress-strain relations in the plastic range: Prandtl-Reuss, Levy-Mises and St. Venant's stress-strain relations, plastic potential – principle of maximum work dissipation – Unloading.

Computational Methods in Plasticity
Review of basics of FEM: shape functions, element types, formulation, boundary conditions, loading, solution and post-processing – analysis of nonlinear problems: Newton-Raphson and modified Newton-Raphson methods – material nonlinearity: yielding and elasto-plastic stress-strain relations – strain-hardening models – unloading – applications.

References:
[1] Sadd, M. H., 2014, *Elasticity: Theory, Applications and Numerics*, 3rd ed. Academic Press.
[2] Chakrabarty, J., 2011, *Theory of Plasticity*, 3rd ed. Butterworth-Heinemann.
[3] Hoffman, O., and Sachs, G., 1953, *Introduction to the theory of Plasticity for Engineers*. McGraw-Hill.
[4] Johnson, W., and Mellor, P. B., 1987, *Engineering Plasticity.* McGraw-Hill.
[5] Hill, R., 2009, *The Mathematical Theory of Plasticity*. Oxford University Press.
[6] Dieter, G. E., 1988, *Mechanical Metallurgy*, SI Metric ed. McGraw-Hill Book Company.
[7] Dunne, F. and Petrinic, N., 2005, *Introduction to Computational Plasticity*, Oxford University Press.
[8] Reddy, J.N., 2009, *An Introduction to Nonlinear Finite Element Analysis*, Oxford University Press.

ME3425E VEHICLE DYNAMICS

Pre-requisites: Knowledge of Solid Mechanics

L	T	P	O	C
3	0	0	6	3

Total Lecture sessions: 39

Course Outcomes:
CO1: Estimate the various forces acting on a vehicle.
CO2: Identify the various forces acting on the tyre.
CO3: Design the suspensions and steering for a vehicle for optimum dynamics.
CO4: Analyse the dynamic behaviour of two-wheelers.

Forces and Moments Affecting a Vehicle
Dynamic axle loads – equations of motion – transmission characteristics – vehicle performance – power limited and traction limited acceleration – braking performance, brake proportioning, braking efficiency.

Aerodynamics
Mechanics of air flow around a vehicle – pressure distribution on a vehicle – aerodynamic forces, drag components, aerodynamics aids.

Tire Mechanics
Tire construction – size and load rating – terminology and axis system – tractive properties, cornering properties, camber thrust, aligning moment, combined braking and cornering.

Suspensions
Suspension kinematics – suspension types: solid axles, independent suspensions, anti-squat and anti-pitch suspension geometry, anti-dive suspension geometry – roll center analysis – suspension dynamics – body and wheel hop modes.

Steering System
Steering linkages – steering system forces and moments – steering system models – steering geometry, understeer and oversteer – effect of tire camber and vehicle roll – transient handling and directional stability – effect of vehicle roll on transient handling – steady-state and transient handling of articulated vehicles.

Motorcycle dynamics
Kinematic structure of motorcycle: geometry of motorcycles, importance of trail – resistance forces acting on motorcycle (tire rolling resistance, aerodynamic resistance forces, resistance force caused by slope) – location and height of motor cycle's centre of gravity, moments of inertia of motor cycle – introduction to front and rear suspensions of motorcycle – self-stabilizing motorcycle – un-ridable bicycles.

References:
[1] Gillespie, T., 2021, *Fundamentals of vehicle dynamics*. SAE international.
[2] Wong, J. Y., 2022, *Theory of ground vehicles*. John Wiley and Sons.
[3] Pacejka, H., 2005, *Tire and vehicle dynamics*. Elsevier.
[4] Blundell, M., and Harty, D., 2004, *Multibody systems approach to vehicle dynamics*. Elsevier.
[5] Vittore, C., 2005, *Motorcycle Dynamics*. Lulu.com.

ME3426E INTRODUCTION TO ROBOTICS

Pre-requisites: Knowledge of Engineering Mechanics

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Explain the subsystems, types, applications and history of robots.
CO2: Model robots kinematically using geometrical and analytical methods.
CO3: Model robots statically and dynamically.
CO4: Describe trajectory planning, robot programming and controller.

Introduction to Robotics
Introduction to robotics: brief history, types and applications of robots, present status and future trends in robotics, overview of robot subsystems challenges in robotics, characteristics of robots, robot applications, robot configurations and concept of work space, types of actuators and sensors in robotics, types of grippers; wheeled, legged and tracked robots

Robot Kinematics and Statics
Introduction to manipulator kinematics: position and orientation of rigid bodies, planar and spatial mechanism description, homogenous transformations, Denavit-Hartenberg (DH) notation, forward and inverse kinematic analysis, examples, case studies of modeling on real robot mechanism; linear and rotational velocity of rigid bodies: velocity propagation from link to link, jacobian, singularities; static forces in manipulators: jacobians in force domain.

Robot Dynamics, Trajectory Planning and Programming
Dynamic modeling: Lagrangian formulation, examples, trajectory generation: general consideration in path description and generation, joint space schemes, collision free path planning; robot control; overview of robot motion planning; robot programming methods.

References:

[1] Craig, J. J., 1999, *Introduction to Robotics, Mechanics and control*, Addison-Wesley.
[2] Mittal, R. K., and Nagarath, I. J., 2003, *Robotics and Control*. Tata McGraw Hill.
[3] Niku, S. B., 2011, *Introduction to Robotics, Analysis, Systems and applications*, Prentice Hall India.
[4] Spong, M. W., and Vidyasagar, M., 1989, *Robot Dynamics and Control*. John Wiley & Sons.
[5] Fu, K. S., Gonzales, R. C., and Lee, C. S. G., 1987, *Robotics Control, Sensing, Vision and Intelligence*, McGraw Hill.
[6] Mikell P.G., Mitchell W. N. N., Roger, and Nicholas, G. O., 1986, *Industrial Robotics: technology, programming, and applications., Fundamentals of Robotics, Analysis and Control*. Prentice Hall of India.
[7] Choset, H., 2005, *Principles of robot motion: Theory, Algorithms, and Implementations*. MIT press.

ME3427E INTRODUCTION TO TRIBOLOGY

Pre-requisites: Solid Mechanics and Fluid Mechanics.

L	T	P	O	C
3	0	0	6	3

Total Lecture sessions: 39

Course Outcomes:
CO1: Apply concepts of tribology for the Analysis and design a tribological system for optimal performance.
CO2: Analyze and design hydrodynamic, hydrostatic journal, slider bearings for a given application.
CO3: Select proper bearing materials and lubricants for a given tribological application.
CO4: Apply the principles of surface engineering for different applications of tribology.

Fundamentals
Historical background, practical importance, Interdisciplinary approach, Economic benefits. Lubricants: Types and specific field of applications. Properties of lubricants, viscosity, its measurement, effect of temperature and pressure on viscosity, lubrication types, standard grades of lubricants, additives and selection of lubricants. Friction: Origin, friction theories, measurement methods, friction of metals and non-metals, Friction Instability. Wear: Classification and mechanisms of wear, delamination theory, debris analysis, testing methods and standards. Related case studies.

Hydrodynamic journal bearings
Friction forces and power loss in a lightly loaded journal bearing, Petroff's equation, mechanism of pressure development in an oil film, and Reynold's equation in 2D. Introduction to idealized journal bearing, load carrying capacity, condition for equilibrium, Sommerfeld's number and its significance; partial bearings, end leakages in journal bearing, numerical examples on full journal bearings only.

Plane slider bearings with fixed/pivoted shoe
Pressure distribution, Load carrying capacity, coefficient of friction, frictional resistance in a fixed/pivoted shoe bearing, center of pressure, numerical examples. Hydrostatic lubrication:
Introduction to hydrostatic lubrication, hydrostatic step bearings, load carrying capacity and oil flow through the hydrostatic step bearing, numerical examples. Introduction to Hydrostatic journal bearings.

Bearing Materials
Commonly used bearings materials, and properties of typical bearing materials. Advantages and disadvantages of bearing materials. Introduction to Surface engineering: Concept and scope of surface engineering.
Surface modification: transformation hardening, surface melting, thermo-chemical processes. Surface Coating: plating, fusion processes, vapor phase processes. Selection of coating for wear and corrosion resistance. Introduction to Green Tribology, Bio Tribology, Nano and Micro Tribology, Gear Tribology and Engine Tribology

References:
[1] Stolarski, T. A., 2000, *Tribology in Machine Design*, Butterworth Henemann, Oxford.
[2] Williams, J. A., 2005, *Engineering Tribology*, Cambridge University Press.
[3] Stachowiak, G. W., 2014, *Engineering Tribology*, Bachelor Butterworth Henemann.
[4] Rabinowicz, E., 1995, *Friction and wear of Materials*, John Wiley and Sons.
[5] Cameron, A., 1991, *Basic Lubrication Theory*, Ellis Hardwoods Ltd. UK.
[6] Suh, N. P., 1986, *Tribophysics*, Englewood Cliffs, NJ Prentice Hall.
[7] Totten, G. E., 2006, *Handbook of Lubrication and Tribology*, Taylor and Francis, London.
[8] Jagadeesha, T., *Design of bearings and Tribology*, Data Hand book (Private Circulation only).

ME3428E PRACTICAL FINITE ELEMENT ANALYSIS

Pre-requisites: Knowledge of basics of finite element method

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1**:** Describe the significance of finite element analysis.
CO2: Select appropriate elements and meshing for an analysis.
CO3: Model the material behaviour using finite element analysis and apply the appropriate boundary conditions.
CO4: Conduct various analyses using FEA.
CO5: Read the results from contour plots.

Introduction
Brief review of different numerical methods – theoretical finite element analysis – software-based FEA – applications of FEM – Various types of analyses using FEM.

Elements
Library of elements – Element types – Degrees of freedom of elements – Element selection criteria – shear locking – hour glassing.

Meshing
Selection of element size – meshing of critical regions – mesh refinement – convergence study – mesh transitions – rules of 1D, 2D and 3D meshing.

Material Modelling
Setting the units – isotropic, orthotropic and fully anisotropic materials.

Boundary Conditions
Types – properly defining boundary conditions – rigid body elements and multipoint constraints.

Various Static Analyses
Linear static analysis – characteristics of a linear analysis – nonlinear analyses – geometric, material and boundary nonlinearities – choosing the right elements – general recommendations – common mistakes – contact analysis.

Dynamic Analysis
Free vibration – forced vibration – single DOF – transient response analysis.

Fatigue Analysis
Various approaches in fatigue analysis – stress life and strain life approach – multi-axial approach.

Modelling of Manufacturing Processes
Modelling of welding and additive manufacturing processes – machining processes – various damage criteria.

Post Processing
Understanding FEA outputs – standard outputs – post processing – contour plots – performance improvement in computing – parallel computing systems.

References:
[1] Madier, D., 2021, *Practical finite element analysis*, FEA Academy.
[2] Gokhale, N. S., Thite, A. N., Deshpande, S. S. and Bedekar S. V., 2008, *Practical Finite Element Analysis, Finite to Infinite*.
[3] MacDonald, B. J., 2020, *Practical stress analysis with finite elements*, 3rd ed. Machdohnil Ltd.

ME3429E CONTROL SYSTEMS ENGINEERING

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Model the system using block diagram reduction, transfer function and state space methods
CO2: Analyse the transient response of systems and perform stability analysis using Routh-Hurwitz criterion and root locus method.
CO3: Analyse the frequency response of systems using rectangular, polar, Bode, Nichols and Nyquist plots.
CO4: Design of simple controllers

Introduction to Control Systems and Mathematical Modelling
Introduction to control system engineering: history, representation of feedback control system by block diagrams, physical systems and their mathematical models; representation of linear time invariant systems; order of the system; classical method; transfer function approach; block diagram reduction; state space representation; mathematical models of mechanical, electrical, hydraulic and pneumatic elements and systems; conversion of state space to transfer function and transfer function to state space.

Transient Response Analysis and Stability
Introduction to transient response, solution of first order, second order and higher order systems, solution by Laplace transform, solution of states space equation, performance parameters of first order and second order systems; stability of systems, Routh-Hurwitz criterion, steady state error, error constants, improving time response and steady state error, root locus techniques.

Frequency Response Analysis and Controller Design
Introduction to Frequency response, plotting the frequency response, rectangular plots, polar plots, Bode plots and Nichols chart; stability analysis: Nyquist plots and Nyquist criterion, gain margin, phase margin. Design of control systems: design philosophy, proportional, integral, derivative and PID controllers using root locus; tuning of controllers and PID controller gain tuning techniques.

References:
[1] Ogata K., 2010, *Modern Control Engineering*, 5th ed.. Prentice Hall.
[2] Nagrath, I. J., and Gopal, M., 2017, *Control Systems Engineering*, New Age International.
[3] Ogata, K., *System Dynamics*, 2004, Pearson Education Inc.
[4] Chen, C. T., 1999, *Linear System Theory and Design*, Oxford University Press.
[5] Franklin, G. F., Powell, J. D., and Naeini, A. E., 2002, *Feedback Control of Dynamic Systems*, Prentice Hall.
[6] Dorf, R. C., and Bishop, R. H., 2008, *Modern Control Systems*, Pearson Education.
[7] Azzo, J. J. D., and Houpis, C. H., 1995, *Linear Control System Analysis and Design*, McGrawHill Publisher.

ME3430E VIBRATION WITH CONTROL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Explain basics of vibration response with system parameters.
CO2: Apply vibration control by structural design and use of viscoelastic material.
CO3: Analyze dynamic vibration absorbers and isolators for vibration attenuation.
CO4: Explain basics of feedback control and apply active feedback for vibration control.

Overview of Vibration
Quantitative Description of Vibration: Free Vibration of Single Degree of Freedom system, Forced Vibration, Resonance, Vibration analysis of Multi-Degree of Freedom Systems

Vibration Control by Structural Design
Detuning and Decoupling, Damping Models and Measures, Origin of Structural Damping, Damping-Stress Relationship, Selection Criteria for Linear Hysteretic Materials

Viscoelastic Materials for Vibration Damping
Standard Linear Solid - constitutive models, Stress-strain relationship, Free Layer Damping, Constrained Layer Damping

Dynamic Vibration Absorbers
Dynamic Vibration Neutralizers, Self-tuned Pendulum Neutralizer, Optimum Design of Damped Absorbers, Auxiliary Mass with Damper

Vibration Isolators
Isolators with Complex Stiffness, Isolators with Coulomb Damping, Suspension systems

Active Vibration Control
Review of control theory, Closed loop control, Transfer Function, Poles, Stability; Feedback Control, proportional, integral, derivative and PID controllers; Active Feedback Vibration Control, Advanced topics

References:
[1] Mallik, A. K., and Chatterjee, S., 2014, *Active and Passive Vibration Control*, Affiliated East-West Press.
[2] Hartog, J. P. D., 1984, *Mechanical Vibrations*, Dover Publications Inc.
[3] Meirovitch, L., 1990, *Dynamics and Control of Structures*, Wiley-Interscience.
[4] Preumont, A., 2018, *Vibration Control of Active Structures: An Introduction*, Kluwer Academic.
[5] Inman, D. J., 2017, *Vibration with Control*, Wiley.
[6] Reza Moheimani, S. O., and Fleming, A. J., 2016, *Piezoelectric Translators for Vibration Control and Damping*, Springer.

ME3431E MECHANICS OF COMPOSITE MATERIALS

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Distinguish and categorize the types of composite materials.
CO2: Identify and understand the basic mechanical behaviour of composite materials.
CO3: Estimate the properties of fibrous composites by applying micromechanics approach.
CO4: Estimate the properties of fibrous composites by applying macro-mechanics approach.
CO5: Apply the concepts of plate theory in solving composite structural problems.

Introduction to Composite Materials:
Introduction–classifications–terminologies of composites, properties of fiber, matrix and their role-advantage and limitation of composite material, application and use of composite materials in the present world- Basic concept of composite materials.

Behavior of composite lamina:
Analysis of continuous and discontinuous fiber composites–derivation for density, mass of composite, critical fiber volume fraction, minimum fiber volume fraction, theoretical evaluation of UD composite properties (elastic modulus, shear modulus, poison's ratio, etc.), fraction of load carried by fibers, longitudinal tensile strength.

Mechanical analysis of lamina:
Hooke's law for anisotropic, monoclinic, orthotropic, transversely isotropic and isotropic materials–2d unidirectional and angle ply lamina, stress-strain relations for general orthotropic lamina, compliance matrix and stiffness matrix.

Strength of Lamina and Failure Theories:
Tension and compression along longitudinal and transvers-In-plane shear, failure mode–failure mode under tensile–compressive–shear loading, criteria of failure for isotropic material von mises criterion for metals, criteria for failure in orthotropic material–maximum stress theory–maximum strain theory–Tsai Hill theory-hashin failure criterion.

Analysis of Laminate Composites:
Introduction to classical plate theory, equilibrium equations for analysis of composite laminate plates- basic assumptions, strain-displacement relationship, stress- strain relationships, determination of stresses and strains of lamina, equilibrium equations, laminates stiffness, types of laminate configuration, balanced laminate, anti-symmetric laminate, laminate engineering constants.

References:
[1] Agarwal, B. D., Broutman, L. J., and Chandrashekhara, K., 2017, *Analysis and performance of fiber composites*, 4th ed., John Wiley & Sons, Inc.
[2] Jones, R. M., 2019, *Mechanics of Composite Materials,* Mc-Graw Hill.
[3] Kaw A. K., 2005, *Mechanics of Composite Materials*, 2nd ed., CRC Taylor & Francis Group.
[4] Daniel, G., and Suong, V. H., 2007, *Composite Materials, Design and Applications*, 2nd ed., CRC Taylor & Francis Group.
[5] Daniel, I. M. and Ishai, O., 2007, *Engineering Mechanics of Composite Materials,* Oxford University Press.

ME3432E VEHICLE DYNAMICS AND CONTROL

Pre-requisites: Knowledge of Engineering Mechanics

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Explain the dynamic systems using state space approach.
CO2: Model the lateral dynamic behaviour of an automobile.
CO3: Design control systems for the steering control of the automobile.
CO4: Design control systems for the yaw control of automobiles.

Basics of control system
Intro to dynamical systems, linearization around fixed points, eigen values and eigen vectors of the dynamical system, need for feedback, Controllability, Cayley Hamiltan theorem, pole placement of inverted pendulum on a cart, Linear Quadratic Regulator, motivation for full state estimation, reference tracking full state feedback control.

Lateral dynamic modelling of Automobile
Kinematic model of lateral vehicle motion, bicycle model of lateral vehicle dynamics. The motion of a particle relative to a rotating frame, dynamic model in terms of error with respect to the road, dynamic model in terms of yaw rate and slip angle, from body fixed to global coordinates, road models.

Control systems for steering controls
State feedback, steady state error from dynamic equations, understanding steady-state cornering, consideration of varying longitudinal velocity, output feedback, unity feedback loop system, loop analysis with a proportional Controller, simulation of closed-loop performance, performance variation with vehicle speed

Control systems for yaw stability control
Differential braking systems, control architecture, desired yaw rate and side-slip angle, upper bounded values of target yaw rate and slip angle, upper controller design, lower controller design, independent all-wheel drive torque distribution, traditional four-wheel drive systems, torque transfer between left and right wheels using a differential, active control of torque transfer to all wheels

References:
[1] Rajamani, R., 2011, Vehicle *dynamics and control*. Springer Science & Business Media.
[2] Chen, X., Hansong, C. X., Qidong, W., Linfeng, Z., and Maofei, Z., 2016, *Integrated vehicle dynamics and control*. John Wiley & Sons.
[3] Jazar, R. N., 2019, *Advanced vehicle dynamics*. Cham: Springer International Publishing.
[4] Gillespie, T., 2021, *Fundamentals of vehicle dynamics*. SAE international.
[5] Shahram, A., Reza, K., and Hamidreza, R. N., 2021, *Vehicle Dynamics and Control: Advanced Methodologies*. Elsevier.
[6] Sinha, A., 2007, *Linear systems: optimal and robust control*. CRC press.
[7] Ogata, K., 2010, *Modern control engineering,* 5th ed., Pearson.

ME3434E DESIGN OF MECHANICAL SYSTEMS

Pre-requisites: Knowledge of Machine Design

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Transform ordinary problems into engineering design problems that can then be readily solved.

CO2: Interpret poorly defined problems and determine the appropriate engineering knowledge and methods to solve those problems.

CO3: Apply professional engineering practices, including standards and codes of practice, on a design project to include safety, ethical, social, cultural and sustainable considerations.

CO4: Use design theory of developing a design and then documenting it.

Design Specifications development- Introduction to the mechanical design process, conceptual design, and product design process, identify factors that have an influence on the design and selection of different machine components, Integration of the mechanical engineering disciplines and systematic integrated approach to design of machine elements and systems, Tribological interaction, Functional plane, mechanical work plane, thermal plane and material plane

Design with standards, - Design of Pressure Vessels, Design a spring for given load and deflection conditions and selection using catalogs, bearing selections using catalogs by knowing the bearing loads (radial and thrust), bearing life and reliability, Design a gear reducer using AGMA code to determine the allowable load and selection using catalogs, Design for industrial noise control, Design for human factor.

Design for Material Selection and Life Cycle Design- Material selection for plane bearing, gear, brakes, clutches, Internal combustion engines, ceramics and special alloys, Design for functions, Structural Hierarchies, Function based failure approach, use of decision-making methods at conceptual design, Optimization, Design for Recycling, Life cycle management.

References:

[1] Ullman, D. G., 2018, *The Mechanical Design Process*, 6th ed.
[2] Norton, R. L., 2014, *Machine Design*, 5th Edition, Prentice Hall.
[3] Juvinall and Marshek, 2012, *Fundamentals of Machine Component Design*, 5th ed. Wiley.
[4] Shigley, Mischke, and Budynas, 2014, *Mechanical Engineering Design*, 10th ed. McGraw-Hill.
[5] Baumeister, A., *Marks Handbook for Mechanical Engineers*. *American Society for Metals, Metals Handbook*, Vols. 8 & 10.
[6] Young and Budynas, 2002, *Roark's Formulas for Stress and Strain*, 7th ed. McGraw Hill.
[7] Rolfe, B., 1977, *Fracture and Fatigue Control in Structure*, Prentice Hall.
[8] Dudley, W. D., 1984, *Practical Gear Design*, McGraw Hill.
[9] Atila, E., and Jesse, J., 1993, *The Engineering Design Process*, Wiley.

ME3435E APPLIED DATA DRIVEN TECHNIQUES IN ENGINEERING

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Analyze signal in both time and frequency domains and implement signal processing algorithms on acquired data using software tools.
CO2: Apply SVD-based algorithms to analyse data.
CO3: Implement parametric identification techniques to analyze experimental data.
CO4: Apply the DMD algorithm to analyze time-series data.
CO5: Implement various machine learning algorithms specifically designed for signal analysis tasks.

Signal Processing
Introduction to the course Signals and Systems; Classification of Signals; Discrete Time Signals and Systems; Classification of Discrete Time Systems; Correlation; Data acquisition from experiments; Discrete Fourier Transform and Computation; Application of DFT; Fast Fourier Transform (FFT); Design of Digital Filters, Filter Types; Interpolation; Curve Fitting; Signal Processing Software Tools: Introduction to Matlab/Python; Signal Processing Software Tools: Signal Processing Libraries and Functions.

Singular Value Decomposition (SVD)
Overview; Matrix Approximation; Mathematical Properties and Approximations; Pseudo-Inverse, Least-Squares, and Regression; Principle Component Analysis; Example Codes*.

Parametric Identification
Difference with Non-Parametric Identification; Important Techniques; Least Square Based Methods; Experimental Aspects: Experimental Schemes; Experimental Signal Processing.

Dynamic Mode Decomposition
Overview, Formulating the DMD Architecture; The DMD Algorithm; Example Code and Decomposition; Limitations of the DMD Methods; Modal analysis and identification of dominant frequencies and vibration modes.

Machine Learning for Signal Analysis
Introduction to machine learning algorithms for signal processing; Supervised Versus Unsupervised Learning; Unsupervised Learning Techniques; Feature Extraction and Selection; Classification Trees and Random Forest; Applications* of machine learning in signal processing; Example Codes*; Advanced topics.

***** Applications using MATLAB/PYTHON/MAPLE/MATHEMATICA/Any Other Software

References:
[1] Brunton, S. L., and Kutz, J. N., 2019, *Data-Driven Science and Engineering: Machine Learning, Dynamical Systems, and Control*, Cambridge University Press.
[2] Kutz, J. N., Brunton, S. L., Brunton, B. W., and Proctor, J. L., 2016, *Dynamic Mode Decomposition: Data-Driven Modeling of Complex Systems*, Society for Industrial and Applied Mathematics, Philadelphia.
[3] Keesman, K. J., 2011, *System identification - An introduction*, Springer.
[4] Proakis, J. G., and Dimitris, G. M., 2006, *Signal Processing: Principles and Applications*, Pearson.
[5] Lyons, R. G., 2010, *Understanding Digital Signal Processing*, Pearson.
[6] Little, M. A., 2019, *Machine Learning for Signal Processing: Data Science, Algorithms, and Computational Statistics*, OUP Oxford.
[7] Tanwar, S., Nayyar, A., and Rameshwar, R., 2021, *Machine Learning in Signal Processing: Applications, Challenges, and the Road Ahead*, Chapman and Hall/CRC.

ME3436E PRODUCT DESIGN

Total sessions: 26L + 26P

L	T	P	O	C
2	0	2	5	3

Course Outcomes:
CO1**:** Describe the engineering product design
CO2: Conceptualize a product from the design
CO3: Prototype the designs using suitable method
CO4: Evaluate the prototypes to validate the design specifications

Engineering Design Process: Product life cycle – phases in product life cycle – generic product development – the product development process - degree of novelty of a product.
Selection of Material and Process: Properties of engineering materials – Ashby property charts – derivation of material index – material selection process – material selection with single and multiple objectives – shape factors – systematic process selection – effect of scale of production – estimation of material and process costs - economic batch size.
Opportunity Identification: Identification of customer needs – steps in identifying customer needs – market research and consumer insights – user interviews/surveys: best practices, when to use which technique – LEAN and Agile methodologies
Product specifications: Establishing target specifications – need-metric matrix – setting the final specifications – functional decomposition – FAST method – functional structure
Concept generation, selection and testing: Activity of concept generation – steps in concept generation process – concept selection – concept screening – prepare the selection metrics – concept scoring – evaluation of concepts – concept testing – rate the concepts – rank the concepts – combine and improve the concepts – select one or more concepts – concept testing – communicate and measure the customer response.
Product architecture: Types of modularity – implications of architecture – product change – variety – component standardization – product performance – manufacturability – product development management – establishing the architecture – developing function structures – development of working structures – selection and combination of working structures to concepts.
Prototyping Process: Purpose of prototyping – low and high-fidelity prototypes – minimum viable prototype – digital prototyping methods – physical prototyping methods – concept of digital twin.

Course Project (26 hours)
Initially some sessions may be conducted with case studies and industry examples before starting the course project. The objective of project is to develop a product from the conceived market need. The following steps are expected in the group project.

- Identify a problem for a set of users
- Conceptualize a solution
- Validate the solution concept
- Develop a low fidelity prototype keeping in mind LEAN and Agile development methodologies
- Come up with ways to validate the demand using the prototype

References:
[1] Ultrich, Karl T. and Eppinger, Steven D., 2016, *Product Design and Development*, 6th edition, Mc Graw Hill publication, 2016
[2] Otto, Kevin and Krisitn, *Product Design*, Pearson Education
[3] Ashby, Michael F., 2011, *Material Selection in Mechanical Design*, 4th edition, Elsevier publication.
[4] Ullan, David G, 2015, *The Mechanical Design Process*, 4th edition, McGraw Hill publication.
[5] McElroy, Kathryn, 2017, *Prototyping for Designers: Developing the Best Digital and Physical Products*, Oreilly publications.
[6] Jamnia, Ali, 2018, *Introduction to Product Design and Development for Engineers*, CRC Press publication.
[7] Pahl, G. and Beitz, W., 2007, *Engineering Design – A Systematic Approach*, Springer.

ME4421E EXPERIMENTAL STRESS ANALYSIS

Pre-requisites: Knowledge of Solid Mechanics

L	T	P	O	C
3	0	0	6	3

Total Lecture sessions: 39

Course Outcomes:
CO1: Analyze measuring circuits for strains of different strain gauge rosettes and their mountings.
CO2: Analyze and design various techniques for measurement of strain and stress.
CO3: Select proper experimental techniques for a given static and dynamic conditions.
CO4: Apply the principles of experimental stress analysis methods for different applications.

Fundamentals
Review of Stress and Strain Analysis: Introduction: Stress, strain, Plane stress and plane strain conditions, Compatibility conditions. stress functions, Mohr’s circle for stress strain, Three-dimensional stress strain relations.

Strain Measuring Devices
Principle of operation and requirements of Various types of strain gauges, Electrical resistance strain gauges: gauge factor, types, gauge materials, backing materials, adhesives, protective coatings, bonding of strain gauges, lead wires and connections, Semiconductor strain gauges, Performance of Strain Gauges: Temperature compensation, transverse sensitivity, gauge length, response, excitation level, stability; Strain gauge circuits, Calibration and temperature compensation, cross sensitivity, Wheatstone bridge and potentiometer circuits for static and dynamic strain measurements, strain indicators, Two element, three element rectangular and delta rosettes, Correction for transverse strain effects, Stress gage, Plane shear gage, Stress intensity factor gage. stress gauges, load cells, Data acquisition, six component balance, dynamic recording at high and low frequencies, telemetry systems. Optical displacement and strain sensors Linear voltage differential transducer and capacitance-based displacement sensors.

Photo elasticity
Nature of light, Wave theory of light - optical interference, Stress optic law – effect of stressed model in plane and circular polariscopes. Jones Calculus, Isoclinics & Isochromatics, Fringe order determination Fringe multiplication techniques, Calibration photo elastic model materials. 2D Photo elasticity: Separation methods: Shear difference method, Analytical separation methods, Model to prototype scaling, Properties of 2D photo-elastic model materials, Materials for 2D photoelasticity. 3D photo elasticity Stress freezing method, scattered light photo-elasticity, Scattered light as an interior analyzer and polarizer, Scattered light polariscope and stress data Analyses.

Birefringence coating
stresses, Effects of coating thickness: Reinforcing effects, Poisson's, Stress separation techniques: Oblique incidence, Strip coatings. Brittle Coatings: Coatings stresses, Crack patterns, Refrigeration techniques, Load relaxation techniques, Crack detection methods, Types of brittle coatings, Calibration of coating. Advantages and brittle coating applications. Moire methods: Introduction, mechanism of formation of Moire fringes, the geometrical approach to Moire-Fringe analysis, the displacement field approach to Moire-Fringe analysis, out of plane displacement measurements, out of plane slope measurements, sharpening and multiplication of Moire- Fringes, experimental procedure and techniques.

Residual Stress Analysis
Analytical and numerical solution of residual stresses in metal working processes (autofrettage, welding etc.), Experimental methods for assessing residual stresses: Sachs boring, X-ray diffraction, neutron diffraction and hole drilling method, inference of residual stresses from microhardness test

References:
[1] Hendray, A. H., 1977, *Elements of Experimental Stress Analysis*, Pergamon Press Inc. USA.
[2] Dally, J. W., and Riley W. F., 1998, *Experimental Stress Analysis*, McGraw Hill Inc., New York.
[3] Freddi, A., Olmi, G., and Luca, C., 2016, *Experimental Stress Analysis for Materials & Structures*, Springer, UK.
[4] Mark., F. M., 1968, *Photoelasticity,* Wiley, New York.
[5] Love, A. E. H., 1892, *Mathematical treaty of elasticity*, University press, Cambridge.
[6] Srinath, L. S., and Raghava, M. R, 1984, *Experimental Stress Analysis*, Tata McGraw Hill, New Delhi.
[7] Hetenyi, M., 1972, *Hand book of Experimental Stress Analysis*, John Wiley and Sons Inc., New York.
[8] Shukla, A., and Dally, J. W., 2014, *Experimental solid mechanics*, College House Enterprises, USA.

[9] Ramesh, K., 2000, *Digital Photoelasticity*, Springer, New York.
[10] Pollock A. A., 1993, *Acoustic Emission in Acoustics & Vibration Progress*, Chapman and Hall.

ME4422E DESIGN OF POWER TRANSMISSION ELEMENTS

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Design the clutches and brake based on design standards and practices.
CO2: Design the belt and gear drives for strength and durability, based on standards and practices.
CO3: Design of multistage gear box for various applications.
CO4: Design OF internal gear and power screw for various applications.

Design of clutches and brakes:
Friction clutches and brakes; uniform pressure and uniform wear assumptions; design of disc and cone types of clutches and brakes; design of external contracting and internal expanding elements; band brakes.

Design of Belts and chain drives:
Belt and chain drives of common types; design of flat and V-belt drives; selection of roller chains.

Spur gear design:
Fundamentals of toothed gearing - Principles of transmission and conjugate action of spur gears, Characteristics of involute and cycloidal gears, Force analysis on spur gears, Two cylindrical and elliptical bodies in contact, Lewis bending strength, tooth form factor, stress correction factor, Buckingham’s dynamic load, design of spur gear for bending, contact strengths and surface wear.

Helical gear design:
Helical gear terminology, Virtual number of teeth, Contact ratio of helical gear, Force analysis on helical gears, Design of helical gear-strength calculation of helical gears.

Bevel gear design:
Bevel gear terminology, Force analysis on bevel gears, Bending and contact stress calculations, efficiency.

Worm and wheel design:
Types of worms, basic parameters of worm and worm wheel, Force analysis of worm drive, Bending and contact stresses calculations, Effect of heat generation, Self-locking and Efficiency of the worm drive.

Multi speed Gearbox:
Internal gear terminology, kinematics of internal gear, contact ratio, design of internal gear for bending and contact strength. the train value, Characteristic of a stage in multi speed gear box, Kinematic arrangement and Ray diagram.

Power screw:
Forms of thread, Torque and Efficiency, Stresses in screws, Design of screws for wear, strength and stability.

References:
[1] Shigley, J. E., and Mischke, C. R., 2003, *Mechanical Engineering Design*, 6th ed. Tata McGraw-Hill.
[2] Richard, G. B., and Nisbett, J. K, 2011, Shigley’s *Mechanical Engineering Design*, 9th ed. Tata McGraw-Hill.
[3] Maitra, G. N., 2001, *Handbook of Gear Design*, 2nd ed. McGraw-Hill.
[4] Siegel, M. J., Maleev, V. L., and Hartman, J. B., 1965, *Mechanical Design of Machines*, 4th ed. International Textbook Company.
[5] Phelan, R. M., 2015, *Fundamentals of Mechanical Design*, 3rd ed. Tata McGraw-Hill.
[6] Juvinall, R. C., and Marshek, K. M., 2011, *Fundamentals of Machine Component design*, 5th ed. John Wiley & Sons.
[7] Norton, R. L., 2013, *Machine Design*, 5th ed. Pearson Education.
[8] Buckingham, E., 1988, *Analytical Mechanics of Gears*, Dover publications.

Data Hand Books (allowed for reference during examinations):
[1] P.S.G. Tech., 2015, *Machine Design Data Handbook*, Kalaikathir Achchagam.
[2] Mahadevan K., and Reddy, B., 2013, *Design Data Handbook for Mechanical Engineers*, 4th ed. CBS Publishers and Distributors.
[3] Bhandari, V. B., 2019, *Machine Design Data Book*, 2nd ed. McGraw Hill.

ME4423E MOBILE ROBOTICS

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Describe various types of mobile robots.
CO2: Model mobile robots kinematically and dynamically.
CO3: Implement mobile robot navigation and path planning.
CO4: Select sensor based on requirement.

Introduction to Mobile Robotics
Introduction to mobile robots and mobile manipulators; principle of locomotion and types of locomotion; types of mobile robots: ground robots (wheeled and legged robots), aerial robots, underwater robots and water surface robots, healthcare robotics; introduction to modern mobile robots: Swarm robots, cooperative and collaborative robots, mobile manipulators, autonomous mobile robots.

Kinematics and Dynamics of Mobile Robots
Kinematics of wheeled mobile robot: degree of freedom and maneuverability, generalized wheel model, different wheel configurations, holonomic and non-holonomic robots.
Dynamics of mobile robot: Lagrange-Euler and Newton-Euler methods; Computer based dynamic (numerical) simulation of different wheeled mobile robots.

Sensors for Robot Motion
Sensors for mobile robot navigation: magnetic and optical position sensor, gyroscope, accelerometer, magnetic compass, inclinometer, tactile and proximity sensors, ultrasound rangefinder, laser scanner, infrared rangefinder, visual and motion sensing systems.

Mobile Robot Motion Planning and Control
Robot navigation: localization, error propagation model, probabilistic map-based localization, autonomous map building, simultaneous localization and mapping (SLAM); Motion and path planning: collision free path planning and sensor-based obstacle avoidance; Motion control of mobile robots: Motion controlling methods, kinematic control, dynamic control and cascaded control.

References
[1] Siegwart, I., Nourbakhsh, I. R., and Scaramuzza, D., 2011, *Introduction to Autonomous Mobile Robots*, MIT Press, USA.
[2] Tzafestas, S. G., 2014, *Introduction to Mobile Robot Control*, Elsevier, USA.
[3] Kelly, A., 2013, *Mobile Robotics: Mathematics, Models, and Methods*, Cambridge University Press, USA.
[4] Thrun, S., Burgard, W., and Fox, D., 2005, *Probabilistic Robotics*, MIT Press, USA.
[5] Dudek, G., and Jenkin, M., 2010, *Computational Principles of Mobile Robotics*, Cambridge University Press, USA.

ELECTIVE COURSES: PROJECT

ME4099E PROJECT-PART-III

Total Hours of Own Effort: 234

L	T	P	O	C
0	0	0	18	6

Course Outcomes:

CO1: Develop an understanding of practical engineering problems in industry / R&D

CO2: Analyze the problem and develop a feasible solution methodology.

CO3: Build project management skills and achieve project goals in stipulated time.

CO4: Make oral presentations and written reports about the work carried out.

CO5: Demonstrate professional ethics and responsibility towards society.

This optional project work shall preferably be done at the individual level as an internship in Industry / R&D organizations /Start-ups/ other academic institutions of repute in India or abroad. In such cases, the students should have a main guide in the Department and a co-guide in the external organization. Students who do not get the opportunity to do external internship may work on a research / consultancy project at the Institute or in their own entrepreneurial venture. All students are required to present their work before an evaluation panel during the mid-semester and end-semester reviews. A final report describing the details of the entire project work is also to be submitted to the Department in the prescribed format.