Department of
Mechanical Engineering

B.Tech. (Mechanical Engineering)

Semester Wise Course Structure
&
Evaluation Scheme

(This Course Structure & Evaluation Scheme is as per New Education Policy-2020 and has been approved by the Academic Council. It has been implemented for First year students admitted in Academic Session 2022-23.)

I SEMESTER

Sr. No.	Course Type	Subject Code	Course Title	Credits (L-T-P)	Sessional Marks				ESM	Total Marks
					MSE	TA	Lab	Total		
1.	BSC	NCY101	Engineering Chemistry	4(3-0-2)	15	20	15	50	50	100
2.	ESC	NCS101	Introduction to Computer Science & Engineering	4(3-1-0)	30	20	-	50	50	100
3.	ESC	NET101	Introduction to Electronics Engineering	4(3-1-0)	30	20	-	50	50	100
4.	ESC	NCE101	Introduction to Civil Engineering	4(3-1-0)	30	20	-	50	50	100
5.	ESC	NCT101	Introduction to Chemical Engineering & Chemical Technology	4(3-1-0)	30	20	-	50	50	100
6.	ESC	NWS101	Workshop Practice	2(0-0-4)	-	20	30	50	50	100
Total Credits				**22**						

II SEMESTER

Sr. No.	Course Type	Subject Code	Course Title	Credits (L-T-P)	Sessional Marks				ESM	Total Marks
					MSE	TA	Lab	Total		
1.	BSC	NPH102	Engineering Physics	4(3-0-2)	15	20	15	50	50	100
2.	BSC	NMA102	Engineering Mathematics-I	4(3-1-0)	30	20	-	50	50	100
3.	ESC	NEE102	Introduction to Electrical Engineering	4(3-0-2)	15	20	15	50	50	100
4.	ESC	NME 102	Introduction to Mechanical Engineering	4(3-1-0)	30	20	-	50	50	100
5.	HSMC	NHS102	Professional Communication	4(2-1-2)	15	20	15	50	50	100
6.	ESC	NCE104	Engineering Graphics	2(0-0-4)	30	20	-	50	50	100
Total Credits				**22**						

III SEMESTER

Sr. No.	Course Type	Subject Code	Course Title	Credits (L-T-P)	Sessional Marks				ESM	Total Marks
					MSE	TA	Lab	Total		
1.	BSC	NMA201	Maths II	4 (3-1-0)	30	20	-	50	50	100
2.	ESC	NME201	Strength of Material	4 (2-1-2)	15	20	15	50	50	100
3.	PCC	NME203	Material Science	4 (3-0-2)	15	20	15	50	50	100
4.	PCC	NME205	Engg. Thermodynamics	4 (3-0-2)	15	20	15	50	50	100
5	PCC	NME207	Kinematics of Machine	3 (3-0-0)	30	20	-	50	50	100
6.	PCC	NME209	Mechanical Measurement	3 (2-0-2)	15	20	15	50	50	100
7.	PCC	NME211	Machine Drawing	2 (0-0-4)	-	20	30	50	50	100
Total Credits				**24**						

IV SEMESTER

Sr. No.	Course Type	Subject Code	Course Title	Credits (L-T-P)	Sessional Marks				ESM	Total Marks
					MSE	TA	Lab	Total		
1.	BSC	NMA202	Maths III	4 (3-1-0)	30	20	-	50	50	100
2.	ESC	NME202	Fluid Mechanics	4 (3-0-2)	15	20	15	50	50	100
3.	PCC	NME204	Manufacturing Science I	4 (3-0-2)	15	20	15	50	50	100
4.	PCC	NME206	Heat & Mass Transfer	4 (3-0-2)	15	20	15	50	50	100
5.	PCC	NME208	Dynamics of Machine	3 (2-0-2)	15	20	15	50	50	100
6.	HSMC	NHS202	Economics & Management	3 (3-0-0)	30	20	-	50	50	100
7.	PCC	NME210	Engg. Materials	2 (2-0-0)	30	20	-	50	50	100
Total Credits				**24**						

V SEMESTER

Sr. No.	Course Type	Subject Code	Course Title	Credits (L-T-P)	Sessional Marks				ESM	Total Marks
					MSE	TA	Lab	Total		
1.	PCC	NME301	Machine Design I	4 (3-0-2)	15	20	15	50	50	100
2.	PCC	NME303	Manufacturing Science II	4 (3-0-2)	15	20	15	50	50	100
3.	PCC	NME305	I C Engine	4 (3-1-0)	30	20	-	50	50	100
4.	PCC	NME307	Fluid Machinery System	4 (3-0-2)	15	20	15	50	50	100
5.	PCC	NME309	CAD / CAM	4 (3-0-2)	15	20	15	50	50	100
6.	OEC-I		OEC I(as per list)	2 (2-0-0)	30	20	-	50	50	100
Total Credits				**22**						

Open Elective-I (OEC-I)

1.	OME 341	Solar Energy	2[2-0-0]
2.	OME 343	Indl. Engg. & Automation	2[2-0-0]

VI SEMESTER

Sr. No.	Course Type	Subject Code	Course Title	Credits (L-T-P)	Sessional Marks				ESM	Total Marks
					MSE	TA	Lab	Total		
1.	PCC	NME302	Machine Design II	4 (3-0-2)	15	20	15	50	50	100
2.	PCC	NME304	Robotics	4 (3-1-0)	30	20	-	50	50	100
3.	PCC	NME306	RAC	4 (3-0-2)	15	20	15	50	50	100
4.	PCC	NME308	PP & C	4 (3-1-0)	30	20	-	50	50	100
5.	PEC-I	NME	PEC I	4 (3-1-0)	30	20	-	50	50	100
6.	HSMC		Entrepreneurship	2 (2-0-0)	30	20	-	50	50	100
Total Credits				**22**						

Programme Elective-I (PEC-I)

1.	NME322	Mechanical Vibrations	4[3-1-0]
2.	NME324	Operation Research	4[3-1-0]
3.	NME326	Additive Manufacturing	4[3-1-0]
4.	NME328	Power Plant Engg.	4[3-1-0]
5.	NME330	Thermal Turbo Machines	4[3-1-0]
6.	NME332	Advance Mechanics of Solids	4[3-1-0]

VII SEMESTER

Sr. No.	Course Type	Subject Code	Course Title	Credits (L-T-P)	Sessional Marks				ESM	Total Marks
					MSE	TA	Lab	Total		
1.	PEC-II	NME	PEC II	4 (3-1-0)	30	20	-	50	50	100
2.	PEC-III	NME	PEC III	3 (3-0-0)	30	20	-	50	50	100
3.	PEC-IV	NME	PEC IV	3 (3-0-0)	30	20	-	50	50	100
4.	OEC-II		OEC II(as per list)	2 (2-0-0)	30	20	-	50	50	100
5.	Industrial Training	NME483	Industrial Training	2 (0-0-4)	-	50	-	50	50	100
6.	Seminar	NME481	Seminar	2 (0-0-4)	-	50	-	50	50	100
7.	Project Minor	NME497	Minor Project	6 (0-0-12)	-	50	-	50	50	100
Total Credits				**22**						

Programme Elective-II (PEC-II)

1.	NME421	Advance Welding Technology	4[3-1-0]
2.	NME423	Mechatronics	4[3-1-0]
3.	NME425	Renewable Energy Systems	4[3-1-0]
4.	NME427	Composite Materials	4[3-1-0]
5.	NME429	Total Quality Management	4[3-1-0]

Programme Elective-III (PEC-III)

1.	NME441	Advance Materials & Characterization	3[3-0-0]
2.	NME443	Advance Manufacturing Processes	3[3-0-0]
3.	NME445	Finite Element Method	3[3-0-0]
4.	NME447	Indl. Engg. & Automation	3[3-0-0]
5.	NME449	Cryogenics	3[3-0-0]

Programme Elective-IV (PEC-IV)

1.	NME461	Gas Dynamics & Jet Propulsion	3[3-0-0]
2.	NME463	Design & Analysis of Experiments	3[3-0-0]
3.	NME465	Non-Destructive Evaluation	3[3-0-0]
4.	NME467	Product Design & Development	3[3-0-0]
5.	NME469	Smart Materials & Structures	3[3-0-0]

Open Elective-II (OEC-II)

1.	OME471	Composite Materials.	2[2-0-0]
2.	OME473	Optimization Methods in Engg.	2[2-0-0]

VIII SEMESTER

Sr. No.	Course Type	Subject Code	Course Title	Credits (L-T-P)	Sessional Marks				ESM	Total Marks
					MSE	TA	Lab	Total		
1.	PEC-V	NME	PEC V	4 (3-1-0)	30	20	-	50	50	100
2.	OEC-III		OEC III	2 (2-0-0)	30	20	-	50	50	100
3.	Project	NME	Major Project	16 (0-0-32)	-	50	-	50	50	100
Total Credits				**22**						

Programme Elective-V (PEC-V)			
1.	NME472	Automobile Engg.	4[3-0-2]
2.	NME474	Optimization Methods in Engg.	4[3-1-0]
3.	NME476	Experimental Stress Analysis	4[3-1-0]
4.	NME478	Computational Fluid Dynamics	4[3-1-0]
5.	NME480	Machine Tool Design	4[3-1-0]

Open Elective-III (OEC-III)			
1.	OME482	Total Quality Management	2[2-0-0]
2.	OME484	3D Printing.	2[2-0-0]

Total Programme Credits: 180

Department Of Mechanical Engineering
List of Programme Elective Courses

Programme Elective-I (PEC-I)

1.	NME322	Mechanical Vibrations	4[3-1-0]
2.	NME324	Operation Research	4[3-1-0]
3.	NME326	Additive Manufacturing	4[3-1-0]
4.	NME328	Power Plant Engg.	4[3-1-0]
5.	NME330	Thermal Turbo Machines	4[3-1-0]
6.	NME332	Advance Mechanics of Solids	4[3-1-0]

Programme Elective-II (PEC-II)

1.	NME421	Advance Welding Technology	4[3-1-0]
2.	NME423	Mechatronics	4[3-1-0]
3.	NME425	Renewable Energy Systems	4[3-1-0]
4.	NME427	Composite Materials	4[3-1-0]
5.	NME429	Total Quality Managentnt	4[3-1-0]

Programme Elective-III (PEC-III)

1.	NME441	Advance Materials & Characterization	3[3-0-0]
2.	NME443	Advance Manufacturing Processes	3[3-0-0]
3.	NME445	Finite Element Method	3[3-0-0]
4.	NME447	Indl. Engg. & Automation	3[3-0-0]
5.	NME449	Cryogenics	3[3-0-0]

Programme Elective-IV (PEC-IV)

1.	NME461	Gas Dynamics & Jet Propulsion	3[3-0-0]
2.	NME463	Design & Analysis of Experiments	3[3-0-0]
3.	NME465	Non-Destructive Testing	3[3-0-0]
4.	NME467	Product Design & Development	3[3-0-0]
5.	NME469	Smart Materials & Structures	3[3-0-0]

Programme Elective-V (PEC-V)

1.	NME472	Automobile Engg.	4[3-0-2]
2.	NME474	Optimization Methods in Engg.	4[3-1-0]
3.	NME476	Experimental Stress Analysis	4[3-1-0]
4.	NME478	Computational Fluid Dynamics	4[3-1-0]
5.	NME480	Machine Tool Design	4[3-1-0]

Department of Mechanical Engineering
List of Open Electives offered (for other Departments)

Open Elective-I (OEC-I)

1.	OME341	Solar Energy	2[2-0-0]
2.	OME343	Indl. Engg. & Automation	2[2-0-0]

Open Elective-II (OEC-II)

1.	OME471	Composite Materials.	2[2-0-0]
2.	OME473	Optimization Methods in Engg.	2[2-0-0]

Open Elective-III (OEC-III)

1.	OME482	Total Quality Management	2[2-0-0]
2.	OME484	3D Printing.	2[2-0-0]

Department of Mechanical Engineering

B.Tech. (Hons.) Degree
in
Mechanical Engineering

A student of Mech. Engg. may opt for B Tech Honours degree by completing in 20 more credit courses from courses listed in the following modules (one course from each module) as part of regular B.Tech. Programme.

List of Courses

Module-1:

1.	NME322	Mechanical Vibrations	4[3-1-0]
2.	NME324	Operation Research	4[3-1-0]
3.	NME326	Additive Manufacturing	4[3-1-0]
4.	NME328	Power Plant Engg.	4[3-1-0]
5.	NME330	Thermal Turbo Machines	4[3-1-0]
6.	NME332	Advance Mechanics of Solids	4[3-1-0]

Module-2:

1.	NME421	Advance Welding Technology	4[3-1-0]
2.	NME423	Mechatronics	4[3-1-0]
3.	NME425	Renewable Energy Systems	4[3-1-0]
4.	NME427	Composite Materials	4[3-1-0]
5.	NME429	Total Quality Management	4[3-1-0]

Module-3:

1.	NME441	Advance Materials & Characterization	3[3-0-0]
2.	NME443	Advance Manufacturing Processes	3[3-0-0]
3.	NME445	Finite Element Method	3[3-0-0]
4.	NME447	Indl. Engg. & Automation	3[3-0-0]
5.	NME449	Cryogenics	3[3-0-0]

Module-4:

1.	NME461	Gas Dynamics & Jet Propulsion	3[3-0-0]
2.	NME463	Design & Analysis of Experiments	3[3-0-0]
3.	NME465	Non-Destructive Testing	3[3-0-0]
4.	NME467	Product Design & Development	3[3-0-0]
5.	NME469	Smart Materials & Structures	3[3-0-0]

Module-5:

1.	NME472	Automobile Engg.	4[3-0-2]
2.	NME474	Optimization Methods in Engg.	4[3-1-0]
3.	NME476	Experimental Stress Analysis	4[3-1-0]
4.	NME478	Computational Fluid Dynamics	4[3-1-0]
5.	NME480	Machine Tool Design	4[3-1-0]

Department of Mechanical Engineering
Minor Degree
in
Mechanical Engineering

B.Tech. students from other Departments may get a Minor degree in Mechanical Engineering by completing 20 credit courses from the list courses listed below.

List of Courses

Si.No.	Name of Course	Subject code	Credit [L-T-P]
1	Engineering Thermodynamics		4[3-0-2]
2	Kinematics of Machine		3[3-0-0]
3	Dynamics of Machine		3[2-0-2]
4	Strength of Materials		4[2-1-2]
5	Material Science		4[3-0-2]
6	Machine Design – I		4[3-0-2]
7	Machine Design – II		4[3-0-2]
8	Operation Research		4[3-1-0]
9	Manufacturing Science I		4[3-0-2]
10	Manufacturing Science II		4[3-0-2]
11	Heat & Mass Transfer		4[3-0-2]
12	Fluid Mechanics		4[3-0-2]
13	CAD /CAM		4[3-0-2]
14	Mechanical Vibrations		4[3-1-0]
15	Additive Manufacturing		4[3-1-0]
16	Robotics		4[3-1-0]
17	Mechatronics		4[3-1-0]
18	Composite Materials		4[3-1-0]
19	Automobile Engineering		4[3-0-2]
20	Non-Destructive Evaluation		3[3-0-0]
21	Product Design & Development		3[3-0-0]
22	3-D Printing		2[2-0-0]
23	Six Sigma		3[3-0-0]

Department of Mechanical Engineering
B.Tech. Mechanical Engineering

Semester Wise Course Structure
&
Evaluation Scheme

(As per New Education Policy effective from Session 2022-23)

I SEMESTER

No course from Department of Mechanical Engineering is offered to First year B.Tech Mechanical Engineering students.

II SEMESTER

NME-101 / 102: INTRODUCTION TO MECHANICAL ENGINEERING

C[L-T-P]:4[3-1-0]

Course Objectives

To explain the basic fundamentals of forces, moments, stresses, strains, fundamental of fluid and fluid flow application, fundamentals of thermodynamics and mode of heat transfers.

Course Outcomes (CO)

At the end of this course students should be able to:

CO1	Understand the basic laws concepts of mechanical systems.	K1, K2
CO2	Determine resultants and apply conditions of static equilibrium to plane force systems.	K1, K3
CO3	Analyze beam for shear force and bending moment along the span and analyze trusses for axial forces	K1, K4
CO4	Evaluate the structural properties centroid and moment of inertia	K1, K5
CO5	Stress analysis for one- and two-dimensional stress systems.	K1, K3

K1- Remember, K2- Understand, K3-Apply, K4-Analyse, K5- Evaluate, K6- Create

Course Articulation Matrix (CO-PO Matrix)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3			1	1	1	1	1		1
CO2	3	3	3									1
CO3	3	3	3									1
CO4		3	2	2								1
CO5		3	2	2								1

COURSE CONTENT

UNIT-1

Fundamental Concepts and Definitions:
Mechanical Engineering: Scope and expanse
Concept of machines and mechanisms, classification of machines.
Thermodynamic systems, Laws of thermodynamics. Introduction to modes of heat transfer, applications.
Materials, classification, selection of materials in design of components.
Manufacturing processes, mechanical working of metals.

UNIT-2

Two-Dimensional Force Systems: Basic concepts, laws of motion, Principle of transmissibility of forces, transfer of a force to parallel position, resultant of a force system, simplest resultant of two dimensional concurrent and non-concurrent force systems, distributed force system, free body diagrams, equilibrium and equations of equilibrium, applications.
Friction: Introduction, Laws of Coulomb friction, Equilibrium of bodies involving dry-friction, belt friction, applications.

UNIT-3

Beam: Introduction, Shear force and bending moment, differential equations for equilibrium, shear force and bending moment diagrams for statically determinate beams.
Trusses: Introduction, simple truss and solution of simple truss, Method of joints and method of sections.

UNIT-4

Centroid and Moment of Inertia: Centroid of plane, curve, area, volume and composite bodies, Moment of inertia of plane area, Parallel Axes theorem, Perpendicular axes theorems, Principal moment of inertia, mass moment of inertia of circular ring, disc, cylinder, sphere and cone about their axis of symmetry.

UNIT-5

Introduction to Strength of Materials: Introduction, normal and shear stresses, stress- strain diagrams for ductile and brittle material, elastic constants, One Dimensional loading of members of varying cross-sections, strain energy, 2D state of plane stress, Principal stresses and strains.

Text Books

1. Engineering Mechanics by Abhijit Chanda and Debabrata Nag, Wiley India Pvt. Ltd, 2018, Kindle -Edition, ISBN: 9788126570935.
2. Engineering Mechanics: Statics by J L Meriam. L G Kraige. Virginia Polytechnic Institute and State University, John Wiley & Sons, 2017.ISBN-978-8126564033.
3. Engineering Mechanics of Solids, Egor P. Popov, PHI Publications, 1990.
4. Theory of Machines and Mechanisms by J.E. Shigley, Oxford University Press, 5th Edition, 2017.
5. Engineering Thermodynamics by P K Nag, TMH Publication, 4th Edition, 2008.

Reference Books

1. Theory of Machines and Mechanisms by Amitabha Ghosh and Asok Kumar Mallick, Affiliated East-West Press, 3rd Edition, ISBN: 9788185938936.
2. Engineering Mechanics by Timoshenko S., McGraw-Hill Education – Europe, 5th Edition, 2013.

3. Engineering Mechanics by Nelson A, McGraw Hill Education India, 1st Edition, ISBN-978-0070146143, 2017
4. Materials and Manufacturing: An Introduction to How they Work and Why it Matters by Mark A Atwater McGraw-Hill Education, 1st Edition, ISBN: 9781260122312, 2018
5. Engineering Thermodynamics: Work and Heat Transfer by Rogers, Pearson Education India, 4th Edition, 2002.

Web Links

1- https://nptel.ac.in/courses/112106286 [IIT Madras, Prof. K. Ramesh]
2- https://nptel.ac.in/courses/112103108 [IIT Guwahati, Prof. US Dixit]
3- https://nptel.ac.in/courses/112103109 [IIT Guwahati, Prof. US Dixit]
4- https://eng.utq.edu.iq/wp-content/uploads/sites/4/2019/09/engineering-mechanics-lectures.pdf[Thi-Qar University, Prof. Haider]
5- https://www.youtube.com/watch?v=tisNUzd_f1M&t=96s [Dr. V. P. Singh, HBTU, Kanpur]
6- https://www.youtube.com/watch?v=a6RNss9kBuI&t=11s [Dr. V. P. Singh, HBTU, Kanpur]
7- https://www.youtube.com/watch?v=LE1Lc6_640U[Dr. V. P. Singh, HBTU, Kanpur]

Evaluation Scheme

S. No.	Course Type	Subject Code	Course title	Credits (L-T-P)	Sessional Marks				ESM	Total Marks
					MSE	TA	Lab	Total		
1	BSC	NME 101 /102	Introduction to Mechanical Engineering	4(3-1-0)	30	20	-	50	50	100

III SEMESTER

NME201 STRENGTH OF MATERIAL
C[L-T-P]: 4[2-1-2]

Prerequisite: Basic knowledge of Engineering physics and Mathematics.

Course Objectives:

The objective of this subject is to elaborate the knowledge of engineering mechanics (statics). Understanding the stresses and deformations developed in mechanical and structural elements under different loads.

Course Outcomes:

Student will be able to

CO1	To understand and apply basic concepts of stress and strain in solid mechanics.
CO2	To analyze and determine stress distribution and deflection in the beams of symmetrical and unsymmetrical condition.
CO3	To evaluate torsional behavior of structural members and deflection the springs subjected to different condition.
CO4	To determine stresses in columns and struts and understand different theory of failure.
CO5	To understand stress and strain distribution in thin cylinders, spheres and thick cylinders.

Unit I

Stress & Strain: Introduction to Stress & Strain, Hooke's Law, Stress-strain curves, Elastic Constants, Strain Energy, Thermal Effects, Biaxial stress and strain: Stress at a Point, Stress Transformation, Strain-displacement correlation, Strain transformation, Constitutive equations, Principal stresses and strain.

Unit II

Stresses in Beams: Introduction to pure Bending**.** Direct and shear stresses in beams due to transverse and axial loads, composite beams, bending of beams with large initial curvature, position of neutral axis. Properties of beam cross-section, slope of neutral axis, stress and deflection in unsymmetrical bending, shear center and flexural axis for I-section and channel section. Moment-Area Method, Conjugate-beam method, Macaulay's Method, Castigliano's Theorem.

Unit III

Torsion-Introduction, torsional stiffness, Torsion of Circular Shaft, Torsion of Thin Walled Tubes, Compound Shaft, Tapered Shaft, Power Transmitted by a Shaft, Strain Energy in Torsion, Combined Bending and Twisting, Open and Closed Coiled Springs, deflection of springs under axial load and twist moment.

Unit IV

Columns & failure theories: Combined bending and direct stress, middle third and middle quarter rules. Struts with different end conditions. Euler's theory, Rankine-Gordon equations. Maximum principal stress theory (Rankine's theory), Maximum shear stress theory (Tresca's theory), Strain energy theory (Haigh's theory), and maximum strain theory (St. Venant's theory), Maximum distortion energy theory (Von Mises theory),

Unit V

Thin cylinders & spheres: Introduction to pressure vessels, Hoop and axial stresses, volumetric strain.
Thick cylinders: Radial, axial and circumferential stresses in thick cylinders subjected to internal or external pressures, Compound cylindrical shell.

Text Books:
1. Strength of materials, U. C. Jindal, Pearson Education India.
2. Strength of Materials, G. H. Ryder, Macmillan India Limited.

Reference Books:
Mechanics of Materials, Gere and Timosheinko, CBS Publications.
Mechanics of Materials, E. P. Popov, Prentics Hall Publications.
Strength of materials, U. C. Jindal, Pearson Education India.
Strength of Materials, S.S. Rattan, Tata Mcgraw Hill Publications.
Mechanics of Materials, Pytel and Kiusalaas, Cengage Learning Publications.
An Introduction to the Mechanics of Solids, 3e, Stephen H. Crandall, Norman C. Dah, Tata Mcgraw Hill Publications.

Online resource
https://nptel.ac.in/courses/112107146
https://archive.nptel.ac.in/courses/112/107/112107147/
https://onlinecourses.nptel.ac.in/noc23_me140/preview
https://ocw.mit.edu/courses/3-11-mechanics-of-materials-fall-1999/
https://ocw.mit.edu/courses/1-050-solid-mechanics-fall-2004/

NME203 MATERIAL SCIENCE

C[L-T-P]: 4[3-0-2]

Course Objectives:

The objective of the subject is to develop understanding regarding structure-property relationship for different class of materials. Further, to gain ability to choose potential material options on the basis of mechanical and other properties.

Course Outcomes:

Student will be able to-

CO1	To understand crystal structure and structural defects affecting mechanical properties.
CO2	To develop understanding of various mechanical properties and testing.
CO3	Concept of equilibrium diagram leading to alloy formation and various heat treatment processes to improve mechanical properties.
CO4	To understand mechanical, electrical and super-conducting properties of materials.
CO5	To understand the structure and properties of polymer, ceramics and composites.

Course Content:

Unit I

Brief review of modern atomic concepts, Crystalline and non-crystalline structures, Bravis space lattices, Miller indices for crystallographic planes and directions, X-ray crystallography techniques. Micro structural

examination and grain size determination. Structure- property interrelationship.

Imperfections in solids: point, line, planer and volume defects. Dislocations in solids, energy of dislocations, Frank Reed source of dislocation, grain boundary defects.

Unit II

Mechanical properties of metals: stress- strain diagram, ductile v/s brittle materials, failure by fracture, fatigue and creep,
Important mechanical testing: tensile, compression, torsion, impact and hardness tests, impact test, fatigue and creep test, non-destructive evaluation.
Ferrous materials: Iron and steel, alloy steels and cast irons - their properties and uses. Al, Cu, Mg, Ni and Ti based non-ferrous alloys, Bearing materials.

Unit III

Phase diagram and equilibrium diagrams: Unary and binary diagrams, phase rules, types of equilibrium diagrams,

Diffusion in solids - Fick's first and second laws of diffusion.

Types of solid solution, Hume-Rothery criteria of solid solution formation, intermetallic compounds.
Iron carbon equilibrium diagram, time-temperature-transformation (T-T-T) curves.
Heat treatment processes- annealing, normalizing, quenching, tempering, important case hardening processes.

Unit IV

Magnetic Properties: magnetism, hysteresis, Soft and hard magnets, Electric properties: Energy Band concept of conductor, insulator and semi- conductors, Superconductivity and its applications, high temperature superconductors.

Unit V

Ceramics- structure, properties and applications of ceramics, Polymers- structure, properties and applications of polymers. Composite material and its use as structural materials.
Performance of materials in-service: fracture, fatigue, and creep behavior, corrosion and its control.

Text books:

1. Material Science & Engineering by W.D. Callister, Jr., Addison-Wesley Pub.Co.
2. Engineering Materials, Vol. I &II by Ashby & Jones, Pergemon Press.

Reference books:

1. Elements of Material Science & Engineering by Van Vlack, John Wiley & Sons
2. Material Science by V. Raghvan, Prentice Hall of India

MATERIAL SCIENCE & TESTING LAB

Any 8 experiments out of following:

1. To identify different kind of materials by observation also identify the metals of different types.

2. To prepare specimen for metallographic examination.

3. To perform Jominy end Quench test to determine hardenability of steel.

4. To determine Rockwell hardness, Brinell hardness and Vicker's hardness of given test specimens.

5. To perform Tensile Test/ Compression Test on given specimen using UTM.

6. To perform Izod & Charpy Impact test.

7. To perform Torsion test on given specimen.

8. To perform fatigue test on given specimen.

9. To perform Creep test.

10. To perform Bend (flexura) test on the given specimen.

NME205 ENGINEERING THERMODYNAMICS
C[L-T-P]: 4[3-0-2]

Prerequisite: Class XII Mathematics & Physics

Course Objectives:

The objective of this course is to understand and apply knowledge of Basic thermodynamics for the designand development of systems for thermal application

Course Outcomes:

Students will be able to

CO1	Understand fundamental thermodynamic concepts, including dimensions, systems, properties, equilibrium, and temperature measurement.
CO2	Apply the first law of thermodynamics to analyze processes, work, energy, and limitations. Understand its application to open and closed systems.
CO3	Explain the second law of thermodynamics, entropy, heat engines, efficiency, reversible and irreversible processes, and thermodynamic temperature scale.
CO4	Gain proficiency in steam properties, phase transformations, property diagrams, and analyze thermodynamic cycles.
CO5	Apply thermodynamic relations, including Maxwell relations, Clapeyron equation, and understand real gases and gas mixtures.

Course Content:

Unit – I:

Introduction and Review of fundamental concepts: Introduction and definition of thermodynamics, Dimensions and units, Microscopic and Macroscopic approaches, Systems, surroundings and universe, Control systemboundary, control volume and control surface, Properties and state, Thermodynamic properties, Pressure and its measurement, Thermodynamic path, process and cycle, Thermodynamic equilibrium, Reversibility and irreversibility, Quasi-static process.

Zeroth law of thermodynamics: Zeroth law of thermodynamics, Temperature and its measurement, Temperature scales.

Unit – II:

First law of thermodynamics: Thermodynamic definition of work, Thermodynamic processes, Calculation of work in various processes and sign convention, non-flow work and flow work, First law of thermodynamics, Internal energy and enthalpy, First law of thermodynamics applied to open systems, Steady flow systems and their analysis, Steady flow energy equation, Boilers, Condensers, Turbine, Throttling process, Pumps etc. First law analysis for closed system (nonflow processes), Analysis of unsteady processes such as filling and evacuation of vessels with and without heat transfer, Limitations of first law of thermodynamics, PMM-I.

Unit – III

Second law: Devices converting heat to work, Thermal reservoir, Heat Source, Heat Sink, Heat engines, Efficiency, Devices converting work to heat, Heat pump, refrigerator, Coefficient of Performance, Reversed heat engine, Kelvin Planck statement of second law of thermodynamics, Clausius statement of second law of thermodynamics, Equivalence of two statements of second law of thermodynamics, Reversible and irreversible processes, Carnot cycle and Carnot engine, Carnot theorem and it's corollaries, thermodynamic temperature scale, PMM-II.

Entropy: Clausius inequality, Concept of Entropy, Entropy change in different thermodynamic processes, Tds equation, Principle of entropy increase, T-S diagram, Statement of the third law of thermodynamics.

Availability and Irreversibility: Available and unavailable energy, Availability and Irreversibility, Secondlaw efficiency, Helmholtz & Gibb's function, Availability analysis.

Unit-IV

Properties of steam and thermodynamics cycles: Pure substance, Property of steam, Triple point, Critical point, Sub-cooled liquid, Saturation states, Superheated states, Phase transformation process of water, Graphical representation of pressure, volume and temperature, P-T & P-V diagrams, T-S and H-S diagrams, use of property diagram, Steam-Tables & Mollier charts, Dryness factor and it's measurement, processes involving steam in closed and open systems. Simple Rankine cycle, Brayton cycle.

Unit-V

Thermodynamic relations: Mathematical conditions for exact differentials. Maxwell Relations, Clapeyron Equation, Joule-Thompson coefficient and Inversion curve. Coefficient of volume expansion, Adiabatic & Isothermal compressibility; Real gas, Law of corresponding states, Dalton's law, Amagat's law, Property of mixture of gases.

Textbooks:

1. Fundamentals of Thermodynamics by Sonntag, Van Wylen, Borgnakke, JohnWiley &Sons
2. Thermodynamics: An engineering approach by Cengel & Boles, Mc GrawHill
3. Engineering Thermodynamics by Onkar Singh, New Age Publishers
4. A textbook of Engineering Thermodynamics, R K Rajput, Fifth edition, Laxmi Publications, 2019.

Reference books:

1. Engineering Thermodynamics by Jones and Dugans, PHI Learning Pvt.Ltd.
2. Thermodynamics by J.P. Holman, McGraw-Hill.
3. Applications of Thermodynamics, Dr V Kadambi and Dr T R Seetharam, Wiley Publications, 2018.
4. Fundamentals of Thermodynamics by Claus Borgnakke and Richard E Sonntag, 8th edition, Wiley India Edition, 2020

Online learning resources:

1. (272) Engineering Thermodynamics - YouTube
2. (272) NPTEL-NOC IITM - YouTube
3. thermo.pdf (mit.edu)
4. lecture notes (iitk.ac.in)

ENGINEERING THERMODYNAMICS LAB

List of Experiments

1. To determine the polytropic index of compression, 'n', for air, from the polytropic expression $PV^n = C$.
2. To study and determine the calorific value of fuel using a Bomb calorimeter.
3. To study different types of thermo-couples and their calibration.
4. Second law analysis of cooking stove.
5. To study and perform heat pump experiments.

6. To determine the dryness fraction of wet steam
7. Study of the steam engine and its performance.
8. Study of different types of boilers and their accessories.
9. To measure the specific latent heat of vaporization using the electric method.
10. Project-based instrument design and analysis.
11. To study the fire tube boilers, focusing on its key components, thermal efficiency, heat transfer mechanisms, and safety measures.
12. To study the water tube boilers, focusing on its key components, thermal efficiency, heat transfer mechanisms, and safety measures.
13. To enable the student to measure the specific latent heat of vaporization of water by an electric method.

NME207 KINEMATICS OF MACHINES
C[L-T-P]: 3[3-0-0]

Prerequisite: A course on Engineering Mechanics, Statics and Dynamics.

Course Objectives:

To provide knowledge of transfer of motions and conversion of motions using mechanisms.

Course Outcomes:

Student will be able to

CO1	Understand the principles of kinematic chains and its inversions.
CO2	To draw position, velocity and acceleration diagrams of kinematic chains.
CO3	Understand the concepts of power transfer through belts, ropes and chains.
CO4	Understand the profiles of cams and its effect on follower intermittent motion.
CO5	Understand the gear profiles, motion and power transfer using gear trains

Course Content:

UNIT 1: Introduction: Aims & scope of the course & Basic concepts of Mechanisms. Basic definitions, Difference between structure & Machine, Links & their types, Types of constrained motion, Kinematic pair & their classification, Grubler's mobility criteria, Inversion of a kinematic chain and applications,

UNIT 2: Graphical (vector) method for velocity and acceleration of various mechanisms e.g. slider crank and four bar, Coriolis component of acceleration, Klien's construction. Instantaneous centre method, Kennedy's theorem.

UNIT 3: Transmission drives: Belt, Rope and Chain drives: Types and materials, Fundamentals of Power transmission Phenomena of slip & creep, centrifugal and initial tensions, Tight side and slack side tensions, Conditions of max. Power transmission. Fundamental law of steering mechanism, Devis and Ackermann steering mechanism.

UNIT 4: Cam and follower: Types of follower motion, Design of Cam profile, High speed cams, Analytical Cam design, Practical considerations in Cam design.

UNIT 5: Theory of gearing: Classification of gears and terminology, Law of gearing, systems of gear teeth, gear profiles, path of contact of gears in meshing, Interference. Gears Train, epicyclical gear train, Compound gear train, Torque analysis and various applications of complex gear trains.

Textbooks:

1. Theory of Machines by S. S. Rattan
2. Theory of Machines by J. Lal and Shah
3. Theory of Mechanisms and Machines by Ballaney P L

4. Theory of Machines: Kinematics and Dynamics" by Sadhu Singh
5. Mechanisms and Machine Theory" by Rao J S and Dukkipatti R V

Reference books:

1. Theory of Machines by J E Shingley
2. Theory of Machines by Thomas Bevan
3. Kinematics by HN Tyson
4. Theory Of Mechanisms Machines" by A Ghosh
5. Mechanism and Machine Theory" by Ambekar A G

Web-link:

1. https://archive.nptel.ac.in/courses/112/104/112104121/
2. https://archive.nptel.ac.in/courses/112/105/112105268/
3. https://onlinecourses.nptel.ac.in/noc20_me21/preview

NME209 MECHANICAL MEASUREMENT
C[L-T-P]: 3[2-0-2]

Prerequisite: Basic knowledge of Engineering physics, Mathematics and Engg. Thermodynamics etc.

Course Objectives:

The objective of the subject is to understand and analyze the fundamentals of measurement, measuring instruments and controls.

Course Outcomes:

Student will be able to

CO1	To understand different source of errors and uncertainty in the metrology and measurements.
CO2	To get acquainted with concepts of sensor and actuator in measurements.
CO3	To develop competence in finding suitability of sensors for measurement of force, pressure, vibration, and surface temperatures.
CO4	To understand and apply advanced tools of measurement for characterization.
CO5	To understand the role of Limits, Fits &Tolerance and Surface roughness in Machine tool metrology.

Unit I

Measurement: basic definitions- accuracy, precision, repeatability, reproducibility, reliability, maintainability, sensitivity, span, zero drift, ageing etc.; Measurement system-basic components, types of measurement direct & indirect active and passive transducers, digital and analog systems, null and deflection type devices; Transducers- mechanical and electrical transducers, basic requirements for transducers; Calibration- steps in calibration; Standards -primary, secondary, reference and working standards; Errors: types of errors-application v/s operational errors, dynamic error, environmental error, absolute v/s relative errors, random errors, uncertainty and bias.

Unit II

Introduction to sensor and actuator, transducers, accelerometer, Hall Effect sensor, Optical Encoder, resolver, Pressure and Temperature devices, Displacement, force and torque Measurement devices, fluid flow measurement devices, friction measurement devices, Bourdon tube pressure gauge, LVDT (linear Variable Differential Transformer), Cathode Ray Oscilloscope, .

Unit III

Zero, first and second order systems, Electrical strain gauges-working principle, materials, transverse sensitivity, Wheatstone bridges full, half, and quarter bridge circuits, strain rosette; Optical methods in measurement: Laser Beam as light pointer, length and displacement measurement, Laser Doppler anemometer.

UNIT IV

Coordinate measuring machine (CMM): Need, constructional features and types, Metrology and Inspection: Standards of linear measurement, line and end standards. Interchange ability and standardization. Linear and angular measurements devices, Scanning Electron Microscopy (SEM), Transmission Electron Microscope (TEM). Comparators: Sigma, Johansson's Microkrator. Limit gauges classification, Taylor's Principle of Gauge Design.

UNIT V

Limits, Fits &Tolerance and Surface roughness: Introduction to Limits, Fits, Tolerances and IS standards, Limit-gauges, and surface-roughness. Measurement of geometric forms like straightness, flatness, roundness. Toolmakers microscope, profile projector, autocollimator. Interferometry: principle and use of interferometry, optical flat. Measurement of screw threads and gears. Surface texture: quantitative evaluation of surface roughness and its measurement.

Textbooks:

1. Instrumentation by Sarma, Rangam & Mani
2. Engineering Control System by K. Ogata
3. Metrology of Measurements by Bewoor and Kulkarni, MCGRAW HILL INDIA
4. Hume KJ, "Engineering Metrology", MacDonald and Co
5. Jain, RK, "Engineering Metrology" Khanna Publishers

Reference books:

1. Mechanical Measurements- System and Design by E O Deobelin
2. Mechanical Measurement by Buck & Beckwith
3. Control System Engineering by Nagrath & Gopal
4. Jain, R.K., "Mechanical Measurement" Khanna Publishers
5. Gupta SC, Engineering Metrology, Dhanpat Rai Publications

Online resource:

https://nptel.ac.in/courses/112106179
https://archive.nptel.ac.in/courses/112/106/112106139/
https://archive.nptel.ac.in/courses/112/104/112104250/

NME211 MACHINE DRAWING
C[L-T-P]: 2[0-0-4]

Prerequisite: Fundamental knowledge of Engineering Graphics.

Course Objectives:

The objective of this subject is to make student acquire knowledge of joints such as riveting, threaded joints etc. The student also is enabled to prepare the assembly of various machine or engine components and miscellaneous machine components.

Course Outcomes:

1. Student will be aware with fundamentals of machine drawing.
2. Student will be able to understand principles of orthographic projections for machine drawing.
3. To draw the projections of machine elements including keys, couplings, cotters, riveted joints.
4. To understand working and draw joints like Pipe joint, welded joint and bearings.
5. To draw the assembled view using drawings of machine components and Engines.

Course Content:

Introduction: Graphic language, Classification of drawings, Principles of drawing, IS codes for Machine drawing, Lines, Scales, Sections, Dimensioning, Standard abbreviations.

Orthographic Projections: Principles of first and third angle projections, drawing and sketching of machine elements in orthographic projections, spacing of views.

Screwed (Threaded) fasteners: Introduction, Screw thread nomenclature, forms of threads, Thread series, Thread designation, Representation of threads, Bolted joints, Locking arrangement for nuts, Foundation bolts.

Keys and cotters: Keys, Cotter joints.
Shaft couplings: Introduction, Rigid and flexible coupling.
Riveted Joints: Introduction, Rivets and riveting, Rivet heads, Classification of riveted joints.
Pipe Joints: Joints for Steam Pipes, Hydraulic Pipes, Special Pipe joints, Pipe fittings.
Welded Joints: Introduction, Welded joints and symbols, Dimensioning of welds.
Bearings: Introduction, Sliding contact bearings, Rolling contact bearings.
Assembly drawing Introduction, Engine parts, Stuffing box etc.

Text books:

1.Machine Drawing by N. Siddeshwar, P. Kannaiah, V V S Shastry, TMH, New Delhi
2.Machine Drawing by K L Narayana, P. Kannaiah, K Venkat Reddy, New Age Intl Publication
3.Machine Drawing by Ajeet Singh, McGraw Hill Education Pvt. Ltd.
4. Machine Drawing by Basudeb Bhattacharya, Oxford university Press

Reference books:

1. 1. Engineering Drawing Practice for Schools & Colleges, SP46-1998 (BIS)

Web Links:

2. 1. https://youtu.be/0hLe342TIOw
3. 2. https://youtu.be/ptJfomL1I7o
4. 3. https://youtu.be/5xQdrWly1ls

IV SEMESTER

NME202 FLUID MECHANICS
C[L-T-P]: 4[3-0-2]

Course Objectives/Outcomes:

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

1. Understand the stress-strain relationship in fluids, classify their behavior, and establish force balance in static systems.
2. Apply and analyze the kinematics of fluid
3. Apply the Bernoulli principle and compute pressure drop in flow systems of different configurations and determine the performance of flow-metering devices.
4. Apply and analyze fluid dynamics as well principle of dimensional analysis and model similitude.
5. Compute and analyze the boundary layer thickness and forces on submerged bodies.

Course Content:

UNIT-I

Introduction: Scope and importance of Fluid Mechanics, Physical properties of fluids (density, specific weight, specific volume, sp. gravity, viscosity-Newton's law of viscosity, Newtonian and non-Newtonian fluids, Compressibility, Surface tension and Capillarity, vapour pressure), Rheological classification of fluids, Ideal fluid, Real Fluid.

Fluid Statics: ~~Pressure,~~ ~~Pascal's Law,~~ Hydrostatic Law, Pressure measurement devices – Piezometer, manometers, Mechanical gauges, Forces on plane and curved surfaces, Centre of pressure and pressure diagram, Buoyancy, Metacentre, Stability of Submerged and floating bodies, Fluid masses subjected to accelerations.

UNIT-II

Fluid Kinematics: Concept of control volume, Velocity, and acceleration of fluid Particle, Lagrangian and Eulerian approach, Classification of fluid flow Streamlines, Path lines and Streak lines, Equipotential lines, Stream Function and Velocity Potential, Flow Net, Continuity equation, Rotation, Vorticity and Circulation, Free and Forced vortex motion.

UNIT-III

Fluid Dynamics: Concept of control volume and control surface, Forces acting on the fluid in motion, Euler's equation, Bernoulli's Theorem and applications, Momentum Equation and applications, Basics of Navier Stokes Equations, Concept of HGL & TEL.

Laminar flow: Reynold's Experiment, Couette flow & Hazen Poisulle's Equation for viscous flow between parallel plates and circular pipes, Darcy's Law.

Turbulent flow: Velocity distribution and Shear stresses in turbulent flow, Prandtl mixing length theory, Introduction to Moody's Chart.

UNIT-IV

Dimensional Analysis: Dimensional analysis, Rayleigh's method, Buckingham's Π theorem, non-dimensional numbers & their significance.

Hydraulic Similitude and Model Studies: Model and prototype; Similitude; Geometric, Kinematic, and Dynamic similarity.

Flow in pipes: Darcy - Wiesbach Equation, factors affecting friction, Minor Losses in pipes, Concept of the equivalent length of pipe for different pipe fittings, Equivalent diameter of pipes, Hydraulic Power, transmission by pipe, Pipe network, Pipes in parallel, Series, Syphon, two reservoir problems, Water hammer in pipes, ~~Surge tanks~~.

Free Surface Flow: Open Channel Flow, Hydraulic Jump.

Unit-V

Boundary layer theory: Concept, Boundary layer along thin plate- Characteristics, Laminar, Turbulent Boundary Layer, laminar sub layer, Various Thicknesses- Nominal, displacement, Momentum, Energy, hydraulically smooth and rough boundaries, Separation of Boundary layer, control of Separation.

Forces on submerged bodies: Introduction to Drag and Lift on submerged bodies ~~s~~tokes law, Drag and Lift coefficients.

List of Experiments

1. To determine the metacentric height of a ship model experimentally.
2. To study the transition from laminar to turbulent flow and to determine the lower critical Reynolds number.
3. To determine the coefficients of velocity, contraction, and discharge of an orifice (or a mouthpiece) of a given shape.
4. To find the velocity distribution in a pipe and compute the discharge by integrating the velocity profile obtained.
5. To verify Bernoulli's theorem.
6. To calibrate an orifice meter and venturi meter and to study the variation of the coefficient of discharge with the Reynolds number.
7. To verify Darcy's law and to find out the coefficient of permeability of the given medium.
8. To study the variation of friction factor, 'f' for turbulent flow in smooth and rough commercial pipes.
9. To determine the loss coefficients for the various pipe fittings.
10. Study of free and forced vortex flow.

Text Books

1. Fluid Mechanics – Hydraulic & Hydraulic Mechanics -Modi / Seth – Standard Book House, Delhi
2. Fluid Mechanics and Hydraulic Machines by R. K. Bansal, Laxmi Publications
3. Fluid Mechanics – Shames - McGraw-Hill International Book Co., Auckland
4. Introduction To Fluid Mechanics and Fluid Machines by S K Som, Gautam Biswas, S Chakraborty, McGraw Hill Education

Reference Books:

1. Fluid Mechanics – by Frank M. White, Henry Xue, McGraw Hill
2. Fluid Mechanics- by Yunus A. Cengel Dr. John M. Cimbala
3. Fluid Mechanics and Machinery – Ojha, Berndtsson and Chandramouli, Oxford University Press.
4. Introduction to Fluid Mechanics by Edward J. Shaughnessy Jr., Ira M. Katz, James P. Schaffer, Oxford University Press, 2005

Web Links:

1. https://www.youtube.com/watch?v=plkDAEx80bQ&list=PLfF--3o8i4r82vJ0kjCVYgqKgyVM5QwN0&ab_channel=KrishanGunarathna
2. https://www.youtube.com/watch?v=lZ7NG16XFGA&ab_channel=nptelhrd
3. https://www.youtube.com/watch?v=9GMBpZZtjXM&ab_channel=nptelhrd
4. https://archive.nptel.ac.in/courses/112/104/112104118/
5. https://archive.nptel.ac.in/courses/112/105/112105171/
6. https://archive.nptel.ac.in/courses/112/105/112105269/
7. https://ocw.mit.edu/courses/16-01-unified-engineering-i-ii-iii-iv-fall-2005-spring-2006/pages/fluid-mechanics/
8. https://oyc.yale.edu/physics/phys-200/lecture-20

NME204 MANUFACTURING SCIENCE I
C[L-T-P]: 4[3-0-2]

Prerequisite: Course on Workshop Technology, Strength of materials

Course Objectives:

The course aims at understanding of fundamental manufacturing process such as casting, forming, sheet metal forming and powder metallurgy.

Course Outcomes:

After completion of course, a student will be able to:

CO1	Understand processes required to manufacture a component
CO2	Understand the capability of casting process and components that can be manufactured using casting process
CO3	Understand and analyze basic concept of metal forming processes and their applications in engineering.
CO4	Understand sheet metal working process and their analysis.
CO5	Understand about concept of powder metallurgy and components that can be manufactured using powder metallurgy
CO6	Understand the practical aspects of various manufacturing process.

Course Content:

Unit-I

Importance of manufacturing towards technological and social economic development. Classification of manufacturing processes. Survey of manufacturing processes. Manufacturing processes for common items, Concepts of Manufacturing Systems. Production and production system, Type of production processes and layout.

Unit II:

Casting: Basic principle and survey of casting processes. Types of patterns and allowances. Types and properties of moulding sand. Elements of mould and design considerations, Gating, Riser, Runners Core. Solidification of casting, Sand casting, Lost foam casting, Precision casting, Die Casting, Centrifugal casting. Investment casting, CO_2 casting and Stir casting etc. Casting Defects: Causes, type and remedies, Non destructive testing: Methods for casting inspection.

Unit-III

Metal Forming Processes: Elastic & plastic deformation, yield criteria. Hot working vs cold working. Analysis (equilibrium equation method) of Forging process for load estimation with sliding friction sticking friction and mixed condition for slab and disc. Work required for forging, Hand, Power, Drop Forging. Analysis of Wire/strip drawing and maximum-reduction, Tube drawing, Extrusion and its application. Condition for Rolling force and power in rolling. Rolling mills & rolled-sections. Design, lubrication and defects in metal forming processes. Hydroforming and its applications in metal forming. Surface treatment in metal forming: Lubrication, coating and heat treatment processes for improved forming characteristics.

Unit-IV

Sheet Metal working: Presses and their classification, Die & punch assembly and press work methods and processes. Cutting/Punching mechanism, Blanking vs Piercing. Compound vs Progressive die. Flat-face vs Inclined-face punch and Load(capacity) needed. Analysis of forming process like cup/deep

drawing. Bending & spring-back. Introduction to sheet metal cutting processes like laser cutting and water jet cutting, Sheet metal joining process: Spot welding, Clinching

Unit-V

Powder Metallurgy: Powder metallurgy manufacturing process. The need, process, advantage and applications. Sintering process and its influence on the properties of powder metallurgy components. Powder metallurgy materials: Metal powders, binders and additives. Manufacturing of Plastic components: Review of plastics, and its past, present & future uses. Injection moulding. Extrusion of plastic section. Welding of plastics. Applications of plastics.

MANUFACTURING SCIENCE - I LAB

Any 8 experiments out of following:

1. Design of pattern for a desired casting (containing hole)
2. Pattern making
3. Making a mould (with core) and casting.
4. Injection moulding with plastics
5. Hand forging processes
6. Forging - power hammer study & operation
7. Tube bending with the use of sand and on tube bending machine.
8. Press work experiment such as blanking/piercing, washer, making etc.
9. Bending & spring back.
10. Jigs & Fixture experiment

Text books:

1. Manufacturing Science by Ghosh and Mallik
2. Production Engg. Science by P.C. Pandey

Reference books:

1. Production Technology by R.K. Jain
2. Manufacturing Technology by P.N. Rao., TMH
3. Materials and Manufacturing by Paul Degarmo. Prentice Hall of India Pvt. Ltd.
4. Manufacturing Engineering & Technology by Kalpakjian, Pearson Pub.

NME206 HEAT AND MASS TRANSFER
C[L-T-P]: 4[3-0-2]

Prerequisite: Course on Engineering Thermodynamics.

Course Objectives:

To provide students with a comprehensive understanding of heat transfer principles and their applications, enabling them to effectively analyze and solve a wide range of heat transfer problems.

Course Outcomes:

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

CO1	Understand and apply fundamental concepts of thermodynamics and heat transfer, including heat transfer mechanisms, general heat conduction equation, and analysis of steady-state one-dimensional heat conduction in composite systems.
CO2	Analyze unsteady heat conduction, evaluate extended surface heat transfer, and apply numerical methods to solve one-dimensional and two-dimensional heat conduction problems.
CO3	Analyze forced convection scenarios, including boundary layers, and apply empirical heat transfer relations.
CO4	Describe the principles of thermal radiation, including radiation properties, laws, and radiation exchange between non-black bodies.
CO5	Analyze heat exchangers and make informed design decisions for efficient heat transfer.

Course Content:

UNIT-1

Introduction and Basic Concepts:

Thermodynamics and Heat Transfer, heat and other forms of energy, Heat Transfer Mechanism: Conduction, Convection and Radiation –fundamental equations, Simultaneous heat transfer mechanisms

Heat conduction equation:

General heat conduction equation – One dimensional steady state equation -boundary and initial conditions- Heat generation in solids- generalized thermal resistance network – critical radius of insulation, Variable thermal conductivity, thermal contact resistance

Steady State one-dimensional Heat conduction:

Composite Systems in rectangular, cylindrical and spherical coordinates with and without energy generation; Thermal resistance concept; Analogy between heat and electricity flow; Thermal contact resistance; Critical thickness of insulation.

UNIT-2

Unsteady heat conduction analysis:

Lumped mass analysis with temporal effects – Governing equations – Biot number significance. Heat Conduction in Large Plane Walls, Long Cylinders, and Spheres with both Spatialand temporal Effects –Governing equations – Graphical Solution – Fourier number significance.

Extended surface heat transfer (Fins):

Governing equation, boundary conditions, Performance of fins – efficiency and effectiveness, proper length of the fin, Types of fins: Pin fin, rectangular, Parabolic and annular fins

Numerical methods in heat conduction:

Finite difference formulation of differential equation, One-dimensional steady-state heat conduction, Solution methods for systems of algebraic equations, Two-dimensional heat conduction, Transient heat conduction.

UNIT-3

Forced Convection:

Basic concepts; Hydrodynamic boundary layer; Thermal boundary layer; Approximate integral boundary layer analysis; Analogy between momentum and heat transfer in turbulent flow over a flat surface; Mixed boundary layer; Flow over a flat plate; Flow across a single cylinder and a sphere; Flow inside ducts; Empirical heat transfer relations; Relation between fluid friction and heat transfer; Liquid metal heat transfer.

Natural Convection:

Physical mechanism of natural convection; Buoyant force; Empirical heat transfer relations for natural convection over vertical planes and cylinders, horizontal plates and cylinders, and sphere; Combined free and forced convection.

UNIT-4

Fundamental of Radiation:

Thermal radiation and basic laws of radiation: Stefan-Boltzmann Law, Wien's displacement law and Planck's Law, radiation intensity, solid angle, irradiation and radiosity, radiation properties emissivity, absorptivity, transmissivity and reflectivity, atmospheric and solar radiation: greenhouse effect.

Radiation Heat Transfer: Shape factor- diffuse and gray surfaces. Radiative heat transfer between two and three enclosures, Radiation shield

UNIT-5

Heat Exchanger:

Types of heat exchangers: parallel flow, counter flow, cross flow, shell and tube, and compact heat exchanger. Overall heat transfer coefficient, fouling factor, Analysis of Heat Exchanger: LMTD and ε-NTU methods.

Condensation and Boiling:

Introduction to condensation phenomena; Heat transfer relations for laminar film condensation on vertical surfaces and on outside & inside of a horizontal tube; Effect of non-condensable gases; Dropwise condensation; Heat pipes; Boiling modes, pool boiling; Hysteresis in boiling curve; Forced convective boiling.

Introduction to Mass Transfer:

Introduction; Fick's law of diffusion; Steady state equimolar counter diffusion; Steady state diffusion through a stagnant gas film.

Textbooks:

1. Heat Transfer By J.P. Holman, McGraw-Hill International edition.
2. Heat and Mass Transfer by Cengel & Ghazar, TMH
3. Fundamentals of Heat and Mass Transfer by C P Kothandaraman, New Age International Publishers, New Delhi, 2012.
4. Fundamentals of Engineering Heat and Mass Transfer, By R C Sachdeva, 6th Edition, New Age International Publications.

Reference books:

1. Elements of Heat transfer by Bayazitouglu & Ozisik, McGraw-Hill Book Company.

2. Schaum's outline of Heat Transfer by Pitts & Sisson McGraw-Hill International edition.
3. Principles of Heat Transfer by Frank Kreith, McGraw-Hill Book Co.
4. Fundamentals of Momentum, Heat and Mass Transfer by James R. Welty; John Wiley & Sons (Pvt). Ltd.

Online Study resources:

1. (272) Heat Transfer: Introduction to Heat Transfer (1 of 26) - YouTube
2. NPTEL
3. NPTEL :: Mechanical Engineering - Heat and Mass Transfer
4. (272) Heat Transfer IITB - YouTube

HEAT & MASS TRANSFER LAB

Any 8 experiments out of the following:

1. Conduction - Composite cylinder experiment
2. Convection - Pool Boiling experiment
3. Convection - Experiment on heat transfer from tube-natural convection.
4. Convection - Heat Pipe experiment.
5. Convection - Heat transfer through fin- natural convection.
6. Convection - Heat transfer through tube/fin- forced convection.
7. Experiment on Stefan's Law, on radiation determination of emissivity, etc.
8. Experiment on solar collectors.
9. Heat exchanger - Parallel flow experiment
10. Experiment on the Cooling tower
11. Experiment on critical insulation thickness.
12. Conduction - Determination of thermal conductivity of fluids.
13. Conduction - Thermal Contact Resistance Effect.

NME208 DYNAMICS OF MACHINE
C[L-T-P]: 3[2-0-2]

Prerequisite: A Course on Engineering Mechanics

Course Objectives: To provide knowledge of dynamic mechanical systems such as gyroscope, flywheel, governor and engines.

Course Outcomes:

Students will be able to

CO1	Understand the static and dynamic force analysis of engine components
CO2	To analyze the different types of governors and flywheels.
CO3	Understand the concept of gyroscopic couple for ships, aero planes and road vehicles.
CO4	Understand the friction based brakes and dynamometer systems.
CO5	To balancing of the reciprocation and rotatory systems and to understand free and forced vibrations of single degree freedom systems.

Course Content:

Unit 1: Static and dynamic force analysis: Velocity and acceleration of Slider crank mechanism, Analytical method for velocity and acceleration of the piston, angular velocity and acceleration of

connecting rod. Force analysis of reciprocating engine mechanism and inertia torque calculations.

Unit 2: Flywheels: Fluctuation of energy and speed, Application of flywheel to various operations and mechanisms of machine; Governor: Terminology, Classification of governors, function, analysis of various types of governors viz. Watt, Proel, Hartnell, characteristics of governors.

Unit 3: Gyroscope: Introduction to gyroscope, precisional motion and Gyroscopic couple, Effect of gyroscope couple on aero plane, effect of gyroscopic couple on naval ship during steering, pitching and rolling, Stability of Four wheel and two-wheel vehicle during turning.

Unit 4: Brakes and Dynamometer: Types of braking systems force and torque analysis for block, band and band and block brake, disc brakes. Dynamometer and its types, Prony brake dynamometer, Rope brake dynamometer, Belt transmission dynamometer, Bevis-Gibsion Torsion dynamometer.

Unit 5:

Balancing and Vibration: Balancing of rotating and reciprocating masses: methods of balancing the primary and secondary unbalanced forces, partial balancing of reciprocating masses, and effects of partial balancing in locomotives. Free, damped and forced vibrations. Vibration isolation, transmissibility, critical speed of shaft.

Text books:

1. Theory of Machines by S. S.Rattan
2. Mechanical Vibrations by Grover, G.K
3. Theory of Machines: Kinematics and Dynamics" by Sadhu Singh
4. Mechanisms and Machine Theory" by Rao J S and Dukkipatti R V
5. Theory of Machines by J. Lal and Shah

Reference books:

6. Theory of Machines by J E Shingley
7. Theory of Machines by Thomas Bevan
8. Kinematics by HN Tyson
9. Theory of Mechanisms Machines" by A Ghosh
10. Mechanism and Machine Theory" by Ambekar A G

Web Links

1- https://archive.nptel.ac.in/courses/112/104/112104114/
2- https://www.classcentral.com/course/youtube-mechanical-dynamics-of-machines-47685

DYNAMICS OF MACHINE LAB

Any 8 experiments out offollowing:

1. To draw the slider displacement v/s crank angle and time v/s velocity curves for a slider crank mechanism and compare with theoretical;values.

2. To determine the ratio of time and maximum velocities for quick return motionusing crank and levermechanism

3. To study various approximate line drawingmechanism.

4. To determine the ratio of angular speeds of shafts in a Hooke'sJoint.

5. To determine the coefficient of friction between flat belt andpulley.

6. To determine the Moment of Inertia of a plane disc by using agyroscope.

7. To study quick return mechanism to get ratio of angle for forward stroke to return stroke.

8. To determine the forces on a spring in a Hartnell Governor to determine the spring stiffness.

9. To study the motion of the follower with the given profile of the cam andto determine the displacement, velocity and acceleration at all the points.

10. To study the working of Oldham's coupling.

11. To determine the speed ratio of a spur gear.

12. Determination of critical speed of shaft.

13. Finding the damping ratio and natural frequency of a cantilever beam.

NME 210 ENGINEERING MATERIALS
C[L-T-P]: 2[2-0-0]

Course Objectives:

The objective of the subject is to develop understanding regarding material options available for different kind of applications. Further, to understand the structure property relationship for different class of material.

Course Outcomes:

Student will be able to

CO1	To introduce to materials and their important properties.
CO2	To understand important ferrous and non-ferrous metals and alloys.
CO3	To understand the structure, properties and applications of polymers and ceramics.
CO4	To understand composites and its application for structural uses.
CO5	Concept of advanced engineering materials and their usage.

Course Content:

Unit I
Important classes of materials: metals, ceramics, polymers and composites. Bio-materials and semi-conductors. Structure-property relationship in materials.
Mechanical testing and properties: Tensilet, Compression, Impact, Fatigue, Creep and Hardness tests.
Important physical properties: electrical, magnetic, optical and thermal properties.

Unit II
Metals and alloys: Ferrous and non-ferrous alloys. Iron and Steel, Alloy Steel, Cast Iron. Heat treatment processes, Non-ferrous alloys: Al, Cu, Mg, Ni and Ti based alloys.

Unit III
Ceramic and glasses: their structure, properties and applications. Processing of ceramics. Polymers: Structure oand properties of polymers, Degree of polymerization, Thermoplastics, thermosets and elastomers, Processing of Polymers.

Unit IV
Composite Materials: Classification of composites - Particulate reinforced, Fibre reinforced composites, Composite Laminates, Sandwich and Honeycomb structures, Wood composites, Concrete, Degradation and failure of materials, Scope of recycling.

Unit V
Advanced Engineering Materials: Materials for high temperature applications, Functionally graded materials, Concept of Smart and Intelligent materials.

Reference Books:
1.Engineering Materials Vol. I & II by Ashby & Jones, Pergemon Press
2.The Science & Engg. of Materials by Donald R Askeland PWS Engg.
3.W.Callister D. Jr., Material Science & Engineering, Addison-Wesley Pub. Co

V SEMESTER

NME301 MACHINE DESIGN–I
C[L-T-P]: 4[3-0-2]

Pre-requisite: Fundamental knowledge of strength of materials, Engineering Mechanics, material science and kinematics of machine.

Course Objectives:

The objective of this subject is to provide understanding of the basics of Engineering Design, selection of materials for Mechanical components and analysis of Machine Elements

Course Outcomes:

Student will be able to

CO1	Understand the design concept, process, and different considerations
CO2	Understand the importance of material selection in design
CO3	Understand component design subjected to different loads
CO4	Design of machine components like, shaft, keys, couplings and joints
CO5	Design of important machine components springs and screw jack

Course Content:

UNIT-I

Introduction to Design process: Definition, various definitions of design, standards in design, considerations in design, Design process, need based developments, need analysis, Design by evolution, Technology based developments, Brain-storming Examples, Case studies.

UNIT-II

Selection of materials: Importance, Classification of Engineering Materials, different kind of steels & cast irons, steel designation, Materials for components subjected to creep, static and fatigue loads, Importance of ceramics, plastics & rubbers for Engineering applications, ASTM testing methods.

UNIT-III

Design for static load: Review of Mechanics, Modes of failure, Factor of safety, stress-strain relationship, principal stresses, and theories of failure.

Design for dynamic loads: types, effect w.r.t. static loads, stress concentration, Fluctuating/ alternating stresses, fatigue failure, endurance limit, design for finite & infinite life, Soderberg & Goodman criteria, design for fatigue, creep and fracture, design for contact stresses and residual stresses

UNIT-IV

Joints: Riveted joints, failure of rivets, welded joint, screwed joints, eccentric loading of above joints, and design for fatigue loading.

Shaft, keys & coupling: Design against static and fatigue loads, strength & rigidity design, selection of square & flat keys & splines, rigid & flexible couplings.

UNIT-V

Mechanical springs: Design of Helical and leaf springs, against static & fatigue loading.

Design analysis of Power Screws: Form of threads, square threads, trapezoidal threads, stresses in screw, design of screw jack.

MACHINE DESIGN-I LAB

Any 8 experiments out of following:

1. Design & drawing of Riveted joints for given operating conditions.
2. Design of an eccentrically loaded welded, riveted of bolted joint.
3. Design of bolted joint for fluctuating loads.
4. Design & drawing of a simple screw jack.
5. Design of shaft for different loading conditions.
6. Design & drawing of rigid coupling (flanged type).
7. Design & drawing of a flexible coupling(pin-bush type)
8. Design & drawing of a leaf spring for an automobile.
9. Design & drawing of a helical spring for a given application.
10. Product Development Design problems/exercise

Note -

1. Students have to use design data book for design.

Text books:

1. Mechanical Engineering Design, J. Shigley, C. Mischke, R.G. Budynas, and J.K. Nisbett; 8th edition Mcgraw-Hill Publishing Co. Ltd.,2008.
2. Materials Selection in Mechanical Design, M.F. Ashby; 4th edition Elsevier, Butterworth Heinmann, 2017.
3. Design of Machine Elements, V. B. Bhandari, 5th edition,Tata McGraw-Hill, 2020.
4. Design Data Handbook for Mechanical Engineering in SI and Metric Units, 4th Edition, by K. Mahadevan and K Balaveera Reddy, 4th edition, CBS publishers, 2018.

Reference books:

1. Machine Design: An integrated approach, R.L. Norton; Pearson Education Inc. (India), 2ndedition, 2000.
2. Design of Machine Elements by M.F.Spots, Pearson Education, 8th edition, 2004.
3. Material Science & Engineering by William D. Callister, Jr., David G. Rethwisch, 10th edition, Wiley publisher,2020.
4. Machine Component Design by R.C. Juvinall and Kurt M. Marshek, 5th edition, Wiley Publishers, 2012.
5. Machine Design by Sadhu Singh, 1stedition, Khanna Publisher, 2019.
6. Design of Machine Elements (Vol I), by T. Krishna Rao, 3rd edition, Publisher Dreamtech Press, 2022.

Web Links:

1. https://www.youtube.com/watch?v=bu8rKSKXUTQ [IIT Bombay]
2. https://www.youtube.com/watch?v=Yd1PoJfWZE4
3. https://archive.nptel.ac.in/courses/112/105/112105125/[NPTEL, IIT Kharagpur]

NME 303 MANUFACTURING SCIENCE II
C[L-T-P]: 4[3-0-2]

Prerequisite: Basic course in Workshop Practice and strength of material

Course Objective:

The course aims at understanding basic manufacturing process viz. chip removal process, Grinding process, understanding of abrasive process, joining processes and chip less metal removal processes.

Course Outcomes:

After completion of course, a student will:

CO1	Understand basic importance of tools, cutting fluid, tool materials in order to have high quality of production
CO2	Understand the applications of grinding and super finishing processes, and its applications
CO3	Understand the various methods of welding and their applications,
CO4	Understand the capabilities of various machine tools and components that can be manufactured on a particular machine tool
CO5	Understand manufacturing processes and their capabilities.
CO6	Understand the working of various manufacturing machines.

Course Content:

Unit-I

Metal Cutting: Mechanics of metal cutting. Geometry of tool and nomenclature. ASA system orthogonal vs. oblique cutting. Mechanics of chip formation, types of chips. Shear angle relationship. Merchant's force circle diagram. Cutting forces, power required for turning, milling and drilling. Cutting fluids/lubricants. Tool materials. Tool wear and tool life. Machinability. Force measurement. Economics of metal cutting. Introduction to CNC machining and CNC operation.

Unit-II

Grinding &Super finishing

(i) Grinding: Grinding wheels, abrasive & bonds, cutting action. Grinding wheel specification. Grinding wheel wear - attritions wear, fracture wear. Dressing and Truing. Max chip thickness and grinding criteria. Surface and Cylindrical grinding. Centerless grinding.

(ii) Super finishing: Honing, lapping, polishing.

Unit-III

Joining Methods: Survey of welding and allied processes. Gas welding and cutting, process and equipment. Arc welding : Power sources and consumables. TIG & MIG processes and their parameters. Resistance welding - spot, seam, projection etc. Other welding processes such as atomic hydrogen, submerged arc, electroslag, friction welding. Soldering & Brazing. Shrinkage/residual stress in welds. Distortions & Defects in welds and remedies. Weld decay in HAZ. Joining of non-metallic components, Introduction to unconventional welding: Laser welding, Electron beam welding, friction stir welding. Nondestructive testing of joints: Overview of NDT techniques used for inspecting welded joints, Ultrasonic testing, Radiographic testing, Magnetic particle testing, Liquid penetrant testing. Discuss their principles, applications and limitations in ensuring the quality of welded components.

Unit-IV

Machine Tools: (i) Lathe: Principle, construction, types, operations, Turret / capstan, semi / Automatic, Tool layout ; (ii) Shaper, slotter, planer : Construction, operations & drives; (iii) Milling : Construction, Milling cutters, up & down milling. Dividing head & indexing. Various types of milling cutters; (iv) Drilling and boring: Drilling, boring, reaming tools. Geometry of twist drills. CNC machining:

Introduction to CNC programming, Tool path generation. Additive manufacturing in machine tools: Explore the integration of additive manufacturing techniques such as hybrid manufacturing, laser metal deposition and powder bed fusion in machine tool design and fabrication. Discuss the advantages, challenges and future prospects of combining additive manufacturing with traditional manufacturing processes.

Unit V:
Introduction to advanced manufacturing: Classification, Limitations of conventional manufacturing process and need of unconventional manufacturing processes. Processes such as Ultrasonic machining, Abrasive jet machining, Abrasive water jet machining; Electro chemical, Electro discharge, Laser and Electron beam machining. Working principles and their application.

Textbooks:

1. Manufacturing science by Ghosh and Mallik
2. Manufacturing science by Degarmo

Reference books:

1. Fundamentals of Metal Cutting and Machine tools by Boothroyd
2. Production Technology by R.K. Jain
3. Production Engineering Science by P.C. Pandey
4. Modern Machining Processes by P.C. Pandey& H.S. Shan
5. Fundamentals of metal cutting & machine tools – Juneja, Shekhon & Seth, New Age Publ.
6. Process & materials of manufacturing - Lindburg.
7. Metal Cutting Principles by M.C. Shaw, Oxford Univ. Press.

EME351: MANUFACTURING SCIENCE-II LAB

Any 8 experiments out of the following:

1. Shear-angle determination (using formula) with tube cutting (for orthogonal) on lathe Machine.
2. Taper turning operation on lathe.
3. Bolt (thread) making on Lathe machine.
4. Tool grinding (to provide tool angles) on tool- grinder machine.
5. Gear cutting on Milling machine.
6. Machining a block on shaper machine.
7. Finishing of a surface on surface- grinding machine.
8. Drilling holes on drilling machine and study of twist-drill.
9. Study of different types of tools and its angles & materials.
10. Experiment on tool wear and tool life.
11. Gas welding of a lap/butt joint.
12. Arc welding of a lap/butt joint.
13. Resistance spot welding of two thin metallic sheets.
14. Experiment on Electro discharge machining.
15. Experiment on Dynamometer for force measurement.
16. Experiment on CNC machines.

NME305 I C ENGINE
C[L-T-P]: 4[3-1-0]

Course Objectives:

This course provides an in-depth knowledge of the functioning of IC engines and non-conventional engines, combustion techniques used for various fuels, pollution testing & performance assessment. This course finds immense application in the automobile industry and power plants.

Course Outcomes:

Students will be able to

CO1	Understand and use different thermodynamic cycles for the performance evaluation of IC engines.
CO2	Demonstrate various phenomena in SI and CI engine.
CO3	Analyze the emission performance of an engine and effectively implement variousmethods studied towards control of vehicle pollution.
CO4	Interpret various subsystems in engines and the pollution perspective.
CO5	Explain the working of different compressors and carry out performance assessments.

Course Content:

Unit 1:

Introduction to I.C Engines and thermodynamic cycles: Engine classification, Air standard cycles, Otto cycle, Diesel cycle, Dual cycle, Comparison of Otto, Diesel and Dual cycles, Sterling cycle, Ericsson cycles, Actual cycle analysis, Two and four-stroke engines, SI and CI engines, Valve timing diagram, Stratified charge engine,

Fuels and Combustion: Combustion analysis, Heating Values and its measurement, Air requirement, Air/Fuel ratio, Standard heat of Reaction and effect of temperature on standard heat of reaction, heat of formation, Chemical Equilibrium, adiabatic flame temperature, Exhaust gas analysis.

Fuels: Fuels for SI and CI engine, Important qualities of SI and CI engine fuels, Rating of SI engine and CI engine fuels, Vegetable oils, Biodiesel, Gaseous fuels, LPG, CNG, Biogas, Producer gas, Dopes, Additives, Alternative fuels for IC engines.

Unit 2:

SI Engines: Combustion in SI engine, Flame speed, Ignition delay, Abnormal combustion and it's control, combustion chamber design for SI engines; Carburetion, Mixture requirements, Carburetor types, Theory of carburetor, MPFI; Ignition system requirements, Magneto and battery ignition systems, ignition timing and spark plug, electronic ignition.

Unit 3:

CI Engine: Combustion in CI engines, Ignition delay, Knock and its control, Combustion chamber design of CI engines; Fuel injection in CI engines, Requirements, Types of injection systems, Fuel pumps, Fuel injectors, Injection timings; Scavenging in 2 Stroke engines

Unit 4:

Engine Cooling: Different cooling systems, Radiators, and cooling fans.
Lubrication: Engine friction, Lubrication principle, Type of lubrication, Lubrication oils, Crankcase ventilation.
Supercharging: Effect of altitude on power output, Types of supercharging.
Testing and Performance: Basic measurements, Optical measurement techniques, Laser Doppler anemometry, Testing of SI and CI engines.

Unit 5:
Air Pollution from IC engine: IC engine emissions, Mufflers, Silencers, EGR, Effect of pollutants, Pollution measurement, Emission control in SI and CI engines
Dual fuel and Multi-fuel engine, Stirling engine, Wankel rotary engine, Free piston engine.

Textbooks:
1. A Course in International Combustion Engines, by Mathur & Sharma, Dhanpat Rai & Sons.
2. I.C Engine, by Ganeshan, McGraw Hill Publishers.
3. I.C Engine, by R. Yadav, Central Publishing House, Allahabad
4. Internal Combustion Engine Fundamentals by John B. Heywood, McGraw-Hill Education

Reference books:
1. Fundamentals of Internal Combustion Engine by Gill, Smith, Ziurs, Oxford IBH Publ. Co.
2. IC Engines, by Rogowsky, International Book Co.
3. I.C Engine Analysis & Practice by E.F Obert.
5. Internal-combustion engine in theory and practice by Taylor C.F., Cambridge University Press.
6. Internal combustion engines: Applied Thermosciences by Ferguson C.R., and Kirkpatrick A. T,John Wiley &Sons.

Web Links:
1. https://www.youtube.com/watch?v=CO2StedJtAc&list=PLwdnzlV3ogoXHbVNKWL1BYOo_8PpyNtnC&ab_channel=NPTELIITGuwahati
2. https://ocw.mit.edu/courses/2-61-internal-combustion-engines-spring-2017/
3. https://archive.nptel.ac.in/courses/112/103/112103262/

NME307 FLUID MACHINERY SYSTEM
C[L-T-P]: 4[3-0-2]

Prerequisite: Course on Fluid Mechanics.

Course Objectives:
This course aims at developing the capability to understand, mathematically model, and analyze different fluid machineries and processes involved in them.

Course Outcomes:
Upon successful completion of this course, the students will be able to:

CO1	Understand the hydrodynamics and capability of fluid in realizing different objectives of producing shaft work and fluid handling.
CO2	Understand the working of different hydraulic turbines and perform related calculations for their analysis.
CO3	Carry out elementary design and analyze centrifugal pumps and different positive displacement pumps.
CO4	Apply the principles of fluid mechanics in special-purpose hydraulic machines like accumulators, special duty pumps, press, lifts, cranes, couplings, torque converters and hydraulic ram.
CO5	Realize the requirements, usage, and limitation of hydraulic machines for different applications.

Course Content:

UNIT-I

Impact of jet: Introduction to the hydrodynamic thrust of jet on a fixed and moving surface (flat & curve), Effect of inclination of jet with the surface.

Hydraulic Turbines: Classification of turbines, Impulse turbines, Reaction turbines, Constructional details, Velocity triangles, Power and efficiency calculations, Governing of Pelton wheel.

UNIT-II

Reaction Turbines: Francis and Kaplan turbines, Constructional details, Velocity triangles, Power and efficiency calculations, Degree of reaction, Draft tube, Cavitation in turbines, Principles of similarity, Unit and specific speed, controls, Performance characteristics, Selection of water turbines,

UNIT-III

Centrifugal Pumps: Classifications of centrifugal pumps, net positive suction head (NPSH), Vector diagram, Work done by impellor, Efficiencies of centrifugal pumps, Specific speed, Model testing, Pumps in series and parallel, Cavitation and separation and their control, Performance characteristics.

UNIT-IV

Positive Displacement Pumps: Reciprocating pump theory, Slip and coefficient of discharges, Indicator diagram, Effect, and acceleration, Work saved by fitting air vessels, Comparison of centrifugal and reciprocating pumps, Positive rotary pumps, Gear and Vane pumps, Performance characteristics, diaphragm, and jet pumps.

UNIT-V

Principles of hydropower development: Types, layouts, and component work, surge tanks, types and choice, flow duration curves, and dependable flow, Storage and pondage, Pumped storage plants, Special types of hydel plants.

Other Machines: Submersible Pumps, Hydraulic accumulators, Special duty pumps, Intensifier, Hydraulic press, Lift and cranes, Theory of hydraulic coupling and torque converters, Performance characteristics. Water Lifting Devices: Hydraulic ram, Jet pumps, Airlift pumps.

Textbooks:

1. Fluid Mechanics & Hydraulic Machines by R.K. Bansal.
2. Hydraulic Machines by R K Rajput, S. Chand & Co. Ltd.
3. Hydraulic Machines by Banga & Sharma, Khanna Publishers.
4. Fluid Mechanics and Machinery by D. Rama Durgaiah, New Age International.

Reference books:

1. Fluid Mechanics & Fluid Machines; Dr. R.P. Saini, November, 2022 © AICTE, ISBN: 978-81-959863-6-1
2. Hydraulic Machines: Theory & Design, V.P. Vasandhani, Khanna Pub.
3. C.P. Kothandaraman, R. Rudramoorthy - Fluid Mechanics and Machinery-New Age Publications
4. Hydraulic Machines by D S Kumar, Kotaria & Sons
5. Fluid Mechanics, Fluid Machines & Hydraulics by V.P. Gupta, Alam Singh, Manish Gupta

Web Links:

1. https://nptel.ac.in/courses/112105206
2. https://www.youtube.com/watch?v=xFvPaQo9lds&list=PLiSPNzs4fD9sCyFlGXlVfkPuyrh0hKmsL&ab_channel=UnacademyGATE-ME%2CPI%2CXE
3. https://ocw.mit.edu/courses/2-000-how-and-why-machines-work-spring-2002/resources/lecture8_hydraulicsii/

NME302: FLUID MACHINERY LAB

1. To verify the momentum equation experimentally through the impact of the jet experiment.
2. To study and draw the characteristics curves of the Pelton turbine.
3. To study and draw the characteristic curves of the Francis turbine.
4. Determine the flow rate using the centrifugal pump and draw the characteristics curves.
5. Determine the flow rate of the reciprocating pump and draw the characteristics curves.
6. To study and draw the characteristics curves of the Gear oil pump.
7. To study and draw the characteristics curves of Hydraulic Ram.
8. To study the Hydraulic Brake.

NME309 CAD / CAM

C[L-T-P]: 4[3-0-2]

Course Objectives:

To introduce the student to concept and applications of CAD/CAM in view of industry 4.0.

Course Outcomes:

Student will be able to

CO1	Understand the role of computers for design & manufacturing, also understand the parametric mathematical formulation for geometric transformations
CO2	Understand the mathematical fundamentals for Geometrical Modelling.
CO3	Learning concepts of Finite Element Methods for Analysis.
CO4	Understand the fundamentals of Numeric Controlled Machine Tools and Computer Aided Manufacturing systems.
CO5	Understanding the roles of various types of manufacturing systems and strategies.

Unit 1: Introduction

Industry 4.0, CAD/CAM, CAD Hardwares, Plotting points & lines, Computer Graphics and its standards, CAD softwares, Reverse Engineering, CMM, 3D Scanners & its applications, classification.

Unit 2: Geometrical Modelling

Analytical and Parametric curves, Blending Functions, Curves types -Hermite, Bezier, B-Spline Curve, NURBS. Parametric continuity, Concepts of parametric surface design and its types, Surface of Revolution, Bezier Surface, B-Spline Surface. Geometric Transformations; Topology.

Unit 3: FEM

Background of mathematical modelling and its solution strategies; Fundamentals & applications of FEM for 1-D problems of stress & strain, Heat conduction. Concepts of FEM for 2-D and 2-D.O.F applications.

Unit 4: Numeric Controlled Manufacturing Systems

Concepts of NC M/c Tools; NC Part Programming for Turning, Drilling and Milling. (b) APT programming. Geometry, Motion and Additional statements, Macro- statement. Feedback Devices- Resolvers, Encoders, Actuation Systems- Hydraulic, Pneumatic and Electromechanical.

Unit 5 Manufacturing systems and strategies

Computer Control and Adaptive Control System-CNC and DNC. Flexible Manufacturing Systems, Types of Flexibility, work handling systems. AR/AS Systems, Manufacturing cell, Transfer lines, Group Technology, CIM, CAPP. Additive Manufacturing concept and methods. Digital manufacturing. Mechatronics, Robotics.

Textbooks:

1. CAD/CAM by M.P.Groover and E.W. Zimmer.
2. Computer Graphics by Hearn and Baker.
3. Finite Element Method with applications in Engg. by Desai, Eldho, Shah, Pearson.
4. Computer-Aided Design and Manufacturing by Justin Riggs, Willford Press.

Reference books:

1. CAD/CAM by Groover & Zimmers, PHI Ltd.
3. CAD by Tai-Ram Hsu &Dipendra K Sinha, West Publ. Co.
4. Finite Element Method Dhanraj & Prabhkaran, Oxford Higher Education

5. Finite Element in Engineering by Singiresu S. Rao, Elsevier
6. Computer control of manufacturing systems by Koren
7. Automation, Production System and Computer Integrated Manufacturing, M P Groover, PHI

CAD / CAM LABORATORY

1. To create the drawing environment by setting drawing template – name / drawing limits / units / naming & setting of layers / various file formats (.dxf, .stl and .dwg etc.) and perform 3D modelling of machine elements /assembly such as Nuts & Bolts (external and internal threading for ACME and Square threading standards).

2. To perform modelling and assembly of the Screw jack with given dimensions and also convert the 3D model into distinct views on CAD package.

3. To write FEM code for finding maximum deflection for the cantilever beam of given dimension and material properties.

4. To perform stress strain analysis for a beam under various types of flexural loads. Also find the temperature distribution in a composite wall using FEM package.

5. To build the manual part program for the part with given dimensions and perform Taper Turning & Grooving operations on CNC Lathe.

6. To develop the manual part program for the part with specified dimensions and execute on CNC Lathe to perform threading operation.

7. To prepare a 3D model of an object and human hand using 3D Scanner.

8. To perform experimental study of various features of 3D printing process on a FDM based 3D Printer by 3D printing an objects - part orientation & support structures, slicing effects, types of infill and its %, markers, connectors etc.

OME341: SOLAR ENERGY
C[L-T-P]: 2[2-0-0]

Prerequisite: Engineering Thermodynamics

Course Objectives:
This course on solar energy aims at developing understanding about availability of solar energy, its utilization and systems run on solar energy for power generation, cooling, heating and other applications.

Course Outcomes:

After completion of course, the students will have ability to,

CO1	Understand solar energy availability, associated geographical issues and its measurement.
CO2	Design, analyze and develop solar thermal systems for various applications.
CO3	Design, analyze and develop solar photovoltaic systems for different applications.
CO4	Understand and analyze solar energy economics.
CO5	Demonstrate holistic understanding of the various solar energy applications and think of certain modifications in them for better performance and utility.

Course Content:

UNIT-1

Introduction, Energy alternative, Devices for thermal collection and storage, Thermal applications; Solar radiation: Instruments for measuring solar radiation, Solar radiation geometry, Empirical equations for prediction of the availability of solar radiation, Solar radiation on tilted surfaces.

UNIT-2

Liquid flat-Plate Collectors: General performance analysis, Transmissivity absorptivity product and overall loss coefficient and heat transfer correlations, Collector efficiency factor, Analysis of collectors similar to the conventional collector. Testing procedures, Alternatives to the conventional collector,

UNIT-3

Solar Air Heaters: Performance analysis of a conventional air heater, Other types of air heaters. Concentrating Collectors: Flat plate collectors with plane reflectors, Cylindrical parabolic collector, Compound parabolic dish collector, Central receiver collector.

UNIT-4

Thermal energy storage: Sensible heat storage, Latent heat Storage, Thermo-chemical storage. Solar distillation: Introduction, working principal of solar distillation, Thermal efficiency of distiller unit, External heat transfer, Top loss coefficient, Bottom and side loss coefficient, Internal heat transfer, Radioactive loss coefficient, convective loss coefficient, Evaporative loss coefficient, Overall heat evaluation of distillation output, Passive solar stills, Conventional solar still, Basin construction, Thermal analysis of conventional solar still.

UNIT-5

Photovoltaic Systems: Introduction doping Fermi level, P-N junction characteristics, Photovoltaic effect, Photovoltaic material, Module, Cell temperature, Economic analysis: Introduction, cost analysis.

Text books:

1. Solar Energy, by S.P Sukhatme, Tata McGraw Hill.
2. Solar Enery Fundamentals and Applications by H P Garg,
3. Solar Energy and Non- Conventional Energy Resources by Domkundwar, Dhanpat rai & Co.
4. Solar Energy Fundamentals, Design, Modelling and Applications by G N Tiwari.

Reference books:

1. Solar Energy: Thermal Processes by Duffie John A, and Beckman W.A,, JohnWiley&Sons.

Web Links:

1. https://youtu.be/BWqjPHGM5D0
2. https://youtu.be/PFFoCx2WINY
3. https://youtu.be/27z-kOQzW2M

OME343: INDUSTRIAL ENGINEERING & AUTOMATION
C[L-T-P]: 2[2-0-0]

Prerequisite: Manufacturing science

Course Objectives:

The course considers Industrial productive concepts and automation. Principles of economy production planning and control.

Course Outcomes:

After completion of the course a students will be able to understand and apply fundamentals of Industrial engineering concepts:

CO1	Analyze and understand productivity concepts and automation concepts.
CO2	Explain various Industrial Layout and time study.
CO3	Exhibit skills towards program evaluation and review technique
CO4	Analyze and perform Break even analysis.
CO5	Analysis of Automated Flow lines for Reliability and Efficiency.

Course Content:

Unit 1

Introduction, engineering economy and costing, cost analysis, methods of depreciation, productivity concepts and measurements, job evaluation, Automation Concepts: SCADA, introduction to SCADA, software for SCADA systems, distributed control system (DCS), basics of PLC, Basic of robotic system.

Unit 2

Work measurement, time study, pre-determined motion and time study (PMTS), work sampling, method study, micro motion study, principles of motion economy.

Unit 3

Plant location, Types of Layout, Principles of Facility Layout, Objective Functions, Steps in PPC, Planning, Routing, Scheduling, Loading, Dispatching, Effectiveness of PPC.

Unit 4

PERT, CPM, Resource Allocation and GERT- Program Evaluation and Review Technique (PERT), Critical Path Method (CPM), Scheduling with Resource Constraints. Introduction to quality management, Ergonomics.

Unit 5

High Volume Production Systems- Transfer Devices, Feeder classification, Construction and Applications, Automated Flow lines, Analysis of Automated Flow lines for Reliability and Efficiency, Assembly Systems, Robot Technology, Flexible Manufacturing Systems (FMS)

Textbooks:

1. Industrial Engineering by M.S. Mahajan, DhanpatRai and Co. (P) Ltd.
2. Introduction to Robotics by S.K. Saha, Tata Magraw Hill

3. Mikell P. Groover, Mitchel Weiss, Roger N. Nagel, Nicholas G. Odrey and Ashish Dutta, “Industrial Robotics: Technology, Programming and Applications”, 2 nd Edition, Tata McGraw Hill, 2012

Reference Books:

1. Introduction to Industrial System Engineering by Turner w.c. et Al 1993, Prentice Hall
2. Motion and Time Study, Design and Measurement of Work by Ralph M. Barnes, Wiley Publishers
3. Project Management for Business and Technology by John M Nicholas, PHI
4. Robotics by John M Nicholas, Pearson Education

Online resources
https://nptel.ac.in/courses/108105063
https://nptel.ac.in/courses/112101098
https://archive.nptel.ac.in/courses/108/105/108105062/

VI SEMESTER

NME302 MACHINE DESIGN - II
C[L-T-P]: 4[3-0-2]

Prerequisite:
Fundamental knowledge of Machine Design-I, dynamics of machine and strength of materials.

Course Objectives:

The objective of this subject is to make student understand basic mechanical components like gears, bearings etc.

Course Outcomes:

Students will be able to

CO1	Design and selection of transmission machine components like belts and ropes
CO2	Design different types of gears such as spur, helical and bevel etc.
CO3	Analyze the pressure distribution and design of sliding bearings and ball bearing.
CO4	Design of thick and thin pressure vessels.
CO5	Analysis of IC engine parts such as cylinder, piston, crank shaft.

Course Content:

UNIT-1
Belt- pulley system:
Materials of construction of belts and pulleys, concept of slip and creep, initial tension, effect of centrifugal tension, maximum power condition. Selection of flat and V belts- length & cross section from manufacturers' catalogues. Design of pulleys.
UNIT-II
Spur and Helical Gears: Conjugate action, involute gears, gear cutting methods, gear materials, tooth relationship, tooth loads, strength of spur gears in bending and in wear. Design of helical gears, crossed helical gears, gear standards.
Worm and Bevel Gears: Analysis of loads and stresses, power rating, efficiency, Gear standard and proportions.
Unit -III
Bearing: Types of ball bearings, roller bearing, needle roller bearing, life of bearing, reliability considerations, Selection of ball, roller, tapered roller and thrust bearings,

Sliding Bearings: Hydrodynamic theory of lubrication, types of bearings, design of bearings using design charts, boundary lubrication, hydrostatic bearings, hydrodynamic thrust bearing.
Unit- IV
Design of Pressure Vessel: thick cylinder, thin cylinders, cylinder heads and cover plates, safety devices and standards of high-pressure vessels.
UNIT-V
Engine Parts: Design of engine parts such as connecting rod, crankshaft and cylinder & piston.
Web Links:

1. https://www.youtube.com/watch?v=bu8rKSKXUTQ [IIT Bombay]
2. https://www.youtube.com/watch?v=Yd1PoJfWZE4
3. https://archive.nptel.ac.in/courses/112/105/112105125/[NPTEL, IIT Kharagpur]
4. https://archive.nptel.ac.in/courses/112/106/112106137/ [IIT Madras]

MACHINE DESIGN-II LAB

I. Computer and Language:

Introduction to computer and languages such as C Input-output statements, control statements, if, for, while, switch statement etc., Function and its uses, Structures to make student able to write computer program in C. Preparation of library file for important design data e.g. material properties and relevant data.

II. WRITING COMPUTER PROGRAM FOR CONVENTIONAL DESIGN (Any 5)

1. Programfor designing circular shaft
2. Program for designing Helical gear
3. Program for designing Bevel gear
4. Program for designing Spur gear
5. Program for designing Sliding bearing
6. Program for flat belt- pulley system design
7. Program for designing thick & thin cylindrical pressure vessels.
8. Program for design of crankshaft.

III. Design Problem as a mini project

Student will be given a real life design problem and they have to complete design of it manually, using hand-book etc, they can also take help of computer & programming, if needed.

IV. 2D&3D modeling using drafting CAD Tool (viz. Creo2.0)

Text books:

1. Mechanical Engineering Design, J. Shigley, C. Mischke, R.G. Budynas, and J.K. Nisbett; 8th edition Mcgraw-Hill Publishing Co. Ltd., 2008.
2. Materials Selection in Mechanical Design, M.F. Ashby; 4th edition Elsevier, Butterworth Heinmann, 2017.
3. Machine Design by Paul Howard Black and Otto Eugene Adams, 2nd edition, McGraw-Hill, 1955.
4. Design of Machine Elements, V. B. Bhandari, 5th edition, Tata McGraw-Hill, 2020.
5. Design Data Handbook for Mechanical Engineering in SI and Metric Units, 4th Edition, by K. Mahadevan and K Balaveera Reddy, 4th edition, CBS publishers, 2018.

Reference books:

1. Machine Design: An integrated approach, R.L. Norton; Pearson Education Inc. (India), 2ndedition, 2000.
2. Design of Machine Elements by M.F.Spots, Pearson Education, 8th edition, 2004.
3. Material Science & Engineering by William D. Callister, Jr., David G. Rethwisch, 10th edition, Wiley publisher,2020.
4. Machine Component Design by R.C. Juvinall and Kurt M. Marshek, 5th edition, Wiley Publishers, 2012.
5. Machine Design by Sadhu Singh, 1stedition, Khanna Publisher, 2019.
6. Design of Machine Elements (Vol I), by T. Krishna Rao, 3rd edition, Publisher Dreamtech Press, 2022.
7. Machine Design by Alfred Hall et. al. adapted by S.K.Somani, Schaum's Outlines, Tata McGraw Hills, special edition, 2011.

NME304 ROBOTICS
[L-T-P]: 4[3-1-0]

Prerequisite: Background in Engineering mathematics, and basic physics.

Course Objectives:
The objectives of this course are to introduce the field of robotics to students, and also to get acquainted with aspects of mechanical design with kinematics, Trajectory planning, dynamics of robotic manipulators and control.

Course Outcomes:
Student will be able to

CO1	Develop the understanding of the various terminology associated with robotic system.
CO2	Develop the understanding of forward and inverse kinematics of robotic manipulators.
CO3	Develop the understanding of dynamics of robotic system and basics of control system for robotics.
CO4	Develop understanding of Robot work cell design and robot vision.
CO5	Understand Micro/Nano robotic systems and applications of robotic system.

UNIT I
INTRODUCTION
Introduction to robot, History and standard terminologies of Robotics, critical design specifications utilized in finding suitable robotic manipulators for different applications, example robots in biomedical field, robots in automated industries, and robots in non-industrial environments.
Robot joints and links, Robot Classifications, Architecture of robotic systems, Robot Drive Systems- Hydraulic, Pneumatic and Electric system.

UNIT II

Homogeneous co-ordinates and co-ordinate transformations, forward (D-H convention) and inverse kinematics for serial robotic manipulators. Robot kinematics- 2D, 3D Transformation-Scaling, Rotation, Translation, multiple transformation.

UNIT III
Basics of Lagrangian and Newton-Euler formulations for serial robotic manipulators, Point to point control, Continuous path control, Sensors and actuators, Intelligent Robot, Control system for robot joint, Feedback Devices, Encoder, Resolver, LVDT, Motion Interpolations, Adaptive control.

UNIT IV
Trajectory planning of robotic arm while considering velocity and acceleration. Robot work cell design and control, Operator interface, Safety monitoring devices in Robot, Mobile robot working principle, and basics of robot vision and image processing.

UNIT V
Micro/Nanorobotics system overview: scaling effect-Top down and bottom-up approach- Actuators of Micro/Nano robotics system, Wall climbing micro robot working principles, Biomimetic robot, Swarm robot, Nanorobot in targeted drug delivery system. Other applications- Material handling, Machine loading and unloading, assembly, Inspection, Welding, Spray painting and undersea robot.

Text books

1. S.K. Saha, Introduction to Robotics, Tata McGraw-Hill
2. Mark W. Spong, Seth Huchinson and M. Vidyasagar, "Robot Modeling and Contol", John Wiley and Sons, Inc.
3. Roland Siegwart, Illah R. Nourbakhsh, an d Davide Scaramuzza, "Introduction to Autonomous Mobile Robots", 2nd Edition, PHI, 2011.

Reference Books:

1. Deb .S.R, "Robotics Technology and flexible automation", Tata McGraw-Hill Education, 2009
2. Mikell P Groover & Nicholas G Odrey, Mitchel Weiss, Roger N Nagel, Ashish Dutta, Industrial Robotics, "Technology Programming and Applications", McGraw Hill, 2012.
3. Fu, K.S., Gonzalez, R.C. and Lee, C.S.G., Robotics: Control, Sensing, Vision, and Intelligence, McGraw Hill (1987).
4. Craig, J.J., Introduction to Robotics: Mechanics and Control, prentice Hall (2004).

Online resource

https://nptel.ac.in/courses/112105249
https://onlinecourses.nptel.ac.in/noc22_de11/preview
https://onlinecourses.nptel.ac.in/noc20_me03/preview
https://onlinecourses.nptel.ac.in/noc21_me32/preview

NME306 REFRIGERATION AND AIR-CONDITIONING
C[L-T-P] : 4[3-0-2]

Prerequisite: Course on Engineering Thermodynamics

Course Objectives:
This course aims to develop an understanding of different refrigeration and air conditioning methods along with their design and analysis for different applications of cooling, heating, ventilation, and air conditioning.

Course Outcomes:
After completion of this course, students will have ability to

CO1	Demonstrate an understanding of the need and importance of refrigeration and air conditioning.
CO2	Understand and analyze different refrigeration cycles and systems used for it.
CO3	Design and analyze air conditioning for human comfort conditions concerningtemperature and humidity and its impact on human comfort, productivity, and health.
CO4	Understand psychometrics and its application in HVAC engineering and carry out designalong with performing psychometric measurements.
CO5	Understand and analyze contemporary issues of ozone depletion, global warming, and other environmental adversities created by refrigeration and air conditioning systems to evolveenvironment-friendly systems.

Course Content:

Unit-1

Refrigeration:
Introduction to the refrigeration system, refrigeration methods, Carnot refrigeration cycle, Unit of refrigeration, Refrigeration effect, and C.O.P.

Air Refrigeration cycle:
Open and closed air refrigeration cycles, Reversed Carnot cycle, Bell Coleman or Reversed Joule air

refrigeration cycle, Aircraft refrigeration system, Classification of the aircraft refrigeration system. Bootstrap refrigeration, Regenerative, Reduced ambient, Dry air rated temperature (DART).

Unit-2

Vapour Compression System:

Single stage system, Analysis of vapour compression cycle, Use of T-S and P-H charts, Effect of change in suction and discharge pressures on C.O.P, Effect of subcooling of condensate and superheating of refrigerant vapour on C.O.P of the cycle, Actual vapour compression refrigeration cycle, Multistage vapour compression system requirement, Removal of flash gas, Intercooling, Different configuration of multistage system, Cascade system.

Unit-3

Vapour Absorption system:

Working Principal of vapour absorption refrigeration system, Comparison between absorption, and compression systems, Elementary idea of refrigerant absorbent mixtures, Temperature–concentration diagram and Enthalpy – concentration diagram, Adiabatic mixing of two streams, Ammonia – Water vapour absorption system, Lithium- Bromide water vapour absorption system.

Refrigerants:

Classifications of refrigerants, Nomenclature, Desirable properties of refrigerants, Common refrigerants, Secondary refrigerants and CFC-free refrigerants, Anti-freeze solutions, Environmental impact of refrigerants. Manufacturing of Dry Ice, Leak Detection, and Charging of Refrigerants.

Unit-4

Air Conditioning:

Introduction to air conditioning, Psychometric properties and their definitions, Psychometric chart, Different Psychometric processes, Thermal analysis of the human body, Effective temperature and comfort chart, Cooling and heating load calculations, Selection of inside and outside design conditions, Heat transfer through walls and roofs, Infiltration, and ventilation, Internal heat gain, Sensible heat factor (SHF), Bypass factor, Grand Sensible heat factor (GSHF), Apparatus dew point (ADP).

Load Calculation: Solar radiation, Heat gain through glass- Calculation of solar heat gain through ordinary glass tables-shading devices- effect of shading devices. Fabric heat gain, overall heat transfer coefficient, Periodic heat transfer through walls and roofs. Empirical methods to calculate the heat transfer through walls and roofs using decrement factor and time lag method. Infiltration - stack effect, wind effect, infiltration load.

Unit-5

Refrigeration Equipment and Application:

Compressors, condensers, evaporators and expansion devices, Air washers, Cooling, towers, and humidifying efficiency, Elementary knowledge of transmission and distribution of air through ducts and fans.

Applications: Food Preservation, transport refrigeration, cold storage, refrigerates freezers, Ice plants, water coolers, comfort, and air conditioning refrigeration.

Other systems: Cryogenic liquefaction and refrigeration system, thermoelectric refrigeration system, steam jet refrigeration system, vortex tube refrigeration system, Magnetic refrigeration system.

Textbooks*:*

1. Refrigeration and Air conditioning, by Manohar Prasad, New Age Intnl. (P) Ltd.Pub.
2. Refrigeration and Air conditioning by Arora and Domkundwar.
3. Refrigeration and Air conditioning by Ballaney.

4. Refrigeration and Air conditioning by C.PArora.

Reference books:

1. Refrigeration and Air conditioning by Stoecker and Jones.
2. Refrigeration and Air conditioning by Roy J.Dossat.
3. Thermal Environment Engg. By Kuhen, Ramsey and Thelked.
4. Refrigeration and Air conditioning by R.C. Arora,PHI

Web Links:

1. https://archive.nptel.ac.in/courses/112/105/112105129/
2. https://archive.nptel.ac.in/courses/112/107/112107208/
3. https://archive.nptel.ac.in/courses/112/105/112105128/
4. http://home.iitk.ac.in/~samkhan/ME340A.htm
5. https://ocw.mit.edu/courses/4-401-environmental-technologies-in-buildings-fall-2018/35b1bfdbe2b8d720f6aa5cde6caf3770_MIT4_401F18_lec17.pdf
6. https://ocw.mit.edu/courses/8-21-the-physics-of-energy-fall-2009/b172949e5728814eb3f2f1989e38d570_MIT8_21s09_lec10.pdf

REFRIGERATION and AIR CONDITIONING LAB

Any 8 experiments out of following:

1. Experiment on vapor compression refrigeration test rig and calculation of performance parameters.
2. Experiment on vapor absorption refrigerator and calculation of performance parameters.
3. To study different types of expansion devices used in refrigeration systems.
4. To study different types of evaporators used in refrigeration systems.
5. To study different types of condensers.
6. To study the basic components of the air-conditioning system.
7. Experiment on the air-conditioning test rig and calculation of performance parameters.
8. Study of the window air conditioner.
9. Experiment on Ice plant for its performance assessment.
10. Study of Hermetically sealed compressor.
11. Experiment on the Desert cooler and calculation of performance parameters.

NME308 PRODUCTION PLANNING & CONTROL
C[L-T-P] : 4[3-1-0]

Prerequisite: Course on Manufacturing Science-I & II

Course Objectives:

The course aims at understanding function of production, place of production, forecasting and market analysis, factory location and layout depending on final production requirement.

Course Outcomes:

A student after going through the course will be able to:

CO1	Understand production planning and control as system approach.
CO2	Make master production schedule, material planning.
CO3	Handle inventory control problems.
CO4	Understand productivity pattern and related measurement and
CO5	Determine capacity planning, analyse product cost.

Course Content:

Unit-I

Introduction: Types and characteristics of production systems Objective and functions of Production, Planning & Control, Place of production, planning in Engineering, manufactures organization; Preplanning: Forecasting & Market Analysis. Factory Location & Layout, Equipment policy and replacement. Preplanning production, capacity planning.

Unit-II

Production Planning: Aggregate Planning, Master Production Schedule, Material Resource Planning, Selection of material methods, machines & manpower. Routing, Scheduling and Dispatching and its sheets & charts, Production Line Balancing

Unit-III

Production and Inventory Control: Progress control through records and charts. Types of inventories, Inventory Classification. Inventory Control under constraints Economic lot (batch) size. Trends in purchasing and store keeping, JIT production MRP II, comparison of Push & Pull systems, ERP, CAPPC.

Unit-IV

Productivity: Importance, Productivity patterns, productivity measurements & ratios, improvement maintenance process; Human Factors & Ergonomics: Human abilities, Training & motivation safety programs, workplace design & working conditions.

Unit-V

System Economics & Operations Economy: System Economics: Life cycle analysis, Capacity planning, Decision support system; Operations Economy: Replacement Planning, Sensitivity Analysis, Capital rationing, Product cost analysis and estimation, Allocation of resources.

Textbooks:

1. Production Planning & Control by Jain and Agarwal
2. Operations Management by Buffa.
3. Elements of Production Planning and Control / Samuel Eilon / Macmillan Publishers
4. Modern Production and operation managements / Baffa & Rakesh Sarin / John Wiley Publishers

Reference books:

1. Elements of Production Planning & Control by Eilon
2. Production System by J.L. Riggs.
3. Reliability Engineering & Quality Engineering / Dr. C. Nadha Muni Reddy and Dr. K.Vijaya Kumar Reddy / Galgotia Publications, Pvt., Limited
4. Production Control A Quantitative Approach / John E. Biegel/ Prentice-Hall

Programme Elective – I (PEC-I)

PEC-I: NME322 MECHANICAL VIBRATION
C[L-T-P] : 4[3-1-0]

Prerequisite: Basic science and dynamics of machines

Course Objectives:

To provide theoretical knowledge to the concepts of causes and effects of vibration in mechanical systems.

Course Outcomes:

Students will be able to

CO1	Understand the basic concepts of free vibrations.
CO2	Understand the forced vibration systems.
CO3	To apply the concept of vibration in 2D problems.
CO4	Analyze the multi-degree of freedom using exact methods.
CO5	Analyze the multi-degree of freedom using numerical methods.

Course Content:

UNIT- I

Introduction & Free Vibration: Periodic motion, harmonic motion, superposition of simple harmonic motions, beats, Fourier analysis; *Single Degree Freedom System***:** Free vibration, Natural frequency, Equivalent Systems, Energy method for determining natural frequency, Response to an initial disturbance, Torsional vibrations, Damped vibrations, Damping models, Vibrations of system with viscous damping, Logarithmic decrement, Viscous dampers.

UNIT- II

Forced Vibration: Forced vibration, Harmonic Excitation with viscous damping, Steady state vibrations, forced vibrations with rotating and reciprocating unbalance, support excitation, Vibration isolation, Transmissibility, Vibration measuring instruments. Flow induced vibrations–High Rise Structures, Structures in rivers, Exhaust from aircraft etc.

UNIT- III

Two Degree of Freedom System: Introduction, Principal modes, Double pendulum, Torsional system with damping, Coupled System, Undamped dynamic, vibration absorbers, Centrifugal pendulum absorber, Dry friction damper, Untuned viscous damper.

UNIT- IV

Multi-degree Freedom System: Exact Analysis - Undamped free and forced vibrations of multi-degree system, Influence numbers, Reciprocal Theorem, Torsional vibration of multi rotor system, Vibration of geared system, Principal coordinates, Continuous systems- Longitudinal vibration of bars, Torsional vibrations of Circular shafts, Lateral vibration of beams.

UNIT- V

Multi-degree Freedom System: Numerical Analysis: Rayleigh's, Dunkerley's, Holzer's and Stodola's

methods, Rayleigh – Ritz method.
Critical Speed of Shafts: Shafts with one disc with and without damping, Multi-disc shafts, Secondary critical speed.

Textbooks:

1. Mechanical Vibrations by Rao S.S., Addison-Wesley
2. Mechanical Vibrations by Grover, G.K., Nem Chand Publishers, Roorkee

Reference books:

1. Mechanical Vibrations by Church A.H.
2. Vibration Theory and Applicationos by Thomson, W.T., Prentice Hall
3. Mechanical Vibrations by Tse, Morse and Hinkle, Prentice-Hall.

PEC-I: NME324 OPERATION RESEARCH
C[L-T-P]: 4[3-1-0]

Course Objective:
This course aims at developing understanding about taking decisions on Industrial problems by making analytical calculations from the given data.

Course Outcomes:

At the end of the course student will be able to

CO1	Understand basics of operations Research and solve linear programming problems
CO2	Understand and solve Transportation Problems and Assignment problems
CO3	Understand and solve Game Theory and Decision Theory and Game theory problems
CO4	Analyze and solve stochastic inventory problems and Understand Simulation
CO5	Analyze and solve Queuing theory problems and Dynamic Programming Problems

Course Content:

UNIT-1
Introduction: Basics of Operation Research, Origin & development of operation Research, applications.
Linear Programming: Introduction & Scope, Problem formulation, Graphical Method, Simplex method, primal and dual problem, sensitivity analysis.

UNIT-2
Transportation Problem: Methods of obtaining initial and optimum solution, degeneracy in transportation problems, unbalanced Transportation Problem.
Assignment Problem: Methods of obtaining optimum solution, Maximization problem, travelling salesman problem.

UNIT-3
Game Theory: Two-person Zero sum game, Solution with/without saddle point, dominance rule, Different methods like Algebraic, Graphical and game problem as a special case of Linear Programming.
Decision Theory and its applications Laplace, Hurwicz, Mini-max criteria

UNIT-4
Stochastic inventory models: Single & multi period models with continuous & discrete demands, Service level & reorder policy.
Simulation: Use, advantages & limitations, Discrete event Simulation.

UNIT-5
Queuing models: Characteristics of Queuing Model, M/M/1 and M/M/S system,
Dynamic Programming: Forward and Backward recursion, DP Applications.

Textbooks:

1. Operations Research by- Prem Kumar Gupta & D.S. Hira, S. Chand.
2. Introduction to Operation Research, by- Hillier, McGraw Hill.
3. Applied Operations Research, J.K.Sharma,Trinity.
4. Operations Research - An Introduction, by- Hamdy A. Taha, Pearson India.

Reference Books:

1. Operation Research, by- Wayne L. Winston, Thomsan Learning.
2. Operations Research: Principles and Practice, by- Ravindran, Phillips, Solberg, John Wiley & Sons.
3. Operations Research, by Vivek Kumar S.K. Kataria & Sons.
4. Operation Research, by Yadav& Malik Oxford University Press.

Web Links:

1. https://youtu.be/PwpjcUNRG0o
2. https://youtu.be/knZrhVkZ71Q
3. https://youtu.be/66aKgySf9vo

PEC-I: NME326 ADDITIVE MANUFACTURING
C[L-T-P]:4[3-1-0]

Prerequisite: Manufacturing and Material science

Course Outcome: Student will be able to	
CO 1	Understanding the basics of additive manufacturing / rapid prototyping and its advantages and disadvantages
CO 2	Understanding the role of additive manufacturing in the design process and the implications for design.
CO 3	Understanding the processes used in additive manufacturing for a range of materials and applications
CO 4	Understand the various software tools, processes and techniques that enable advanced/additive manufacturing and personal fabrication.
CO 5	Apply knowledge of additive manufacturing for various real-life applications

COURSE CONTENT:

UNIT I

Introduction: Rapid Prototyping, Customized products, Digital Subtractive & Additive Manufacturing (AM), AM Technologies, Direct and Indirect Processes; Layer Manufacturing Processes: Polymerization, Sintering and Melting, Extrusion, Powder Binder Bonding, Layer Laminate Manufacturing, Other Processes; Aerosol printing and Bio-plotter.

UNIT II

Development of Additive Manufacturing Technology: Computer Aided Design Technology, Other Associated Technology, Metal and Hybrid Systems. Generalized Additive Manufacturing Process Chain; The Eight Steps in Additive Manufacturing, Variation from one AM Machine to Another, Metal System, Maintenance of Equipment, Material Handling Issue, Design of AM.

UNIT III

Additive Manufacturing Processes: *Vat Photo polymerization*; Materials, Reaction Rates, Photo polymerization Process Modelling, Scan Patterns, Powder Bed Fusion Processes; Material, Powder Fusion Mechanism, Process Parameters and Modeling, powder Handling, *Extrusion Based System*; Basic principles, plotting and Path Control, Other Systems *Material Jetting*; Materials, Material Processing Fundamentals, Material Jetting Machines, Directed Energy Deposition Processes; General

DED Process Description, Material Delivery, DED systems, Process Parameters, Processing Structure Properties Relationships

UNIT IV:

Design & Software Issues: Additive Manufacturing Design and Strategies; Potentials and Resulting Perspectives, AM based New Strategies, Material Design and Quality Aspects for Additive Manufacturing; Material for AM, Engineering Design Rules for AM. Software Issue for Additive Manufacturing; Introduction, Preparation of CAD Models: The STL file, Problem with STL file, STL files Manipulation, Beyond the STL file, Additional Software to Assist AM

UNIT V

Material Design & Quality Aspects

Machines for Additive Manufacturing, Printers, Secondary Rapid Prototyping processes, Intellectual Property, Product Development, Commercialization, Trends and Future Directions in Additive Manufacturing, Business Opportunities. *Applications* - Aerospace, Automotive, Manufacturing, Architectural Engineering, Art, Jewellery, Toys, Medical, Biomedical, Dental, Bio-printing, Tissue & Organ Engineering and many others.

Text Books:

2. Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing, by Ian Gibson , DSavid W. Rosen , Brent Stucker, Springer.
3. Understanding Additive Manufacturing, by Andreas Gebhardt, Hanser.
4. Additive Manufacturing, by- AmitBandyopadhyay, Susmita Bose, CRC Press.
5. Rapid Prototyping: Principles and Applications, by Chee Kai Chua, Kah Fai Leong, Chu Sing Lim

Reference Books:

1. Additive ay, Susmita Bose, CRC Press.
2. Rapid Prototypiah Fai Leong, Chu Sing Lim

PEC-I: NME328 POWER PLANT ENGINEERING
C[L-T-P]: 4[3-1-0]

Prerequisite: Course on Applied Thermodynamics

Course Objectives: Develop a comprehensive understanding of different power plant types, including their requirements, design principles, analysis techniques, performance evaluation methods, and economic studies.

Course Outcomes:

Students will be able to

CO1	Understand power plant economics, selection, and current power generation status in India.
CO2	Familiarize with steam power plant layout, boilers, and condensers with cooling towers.
CO3	Gain knowledge about diesel and gas turbine power plants, their layouts, components, and site selection.
CO4	Learn about nuclear power plants, reactors, waste disposal, and hydroelectric power plants.
CO5	Understand electrical systems, instrumentation, and the impact of power generation on pollution.

COURSE CONTENT:

Unit-I

Power plant economics and selection: Power and energy, classification of sources of energy, review of thermodynamic cycles related to power plants, General layout of modern thermal power plant, Site selection, and Present status of power generation in India.

Economics of Power Generation: Load curves, Load duration curves, Connected load, Maximum load, Peak load, Base load and peak load power plants, Load factor, Plant capacity factor, Plant use factor, Demand factor, Diversity factor, Cost of power plant, Performance and operating characteristics of a power plant, Tariff for electric energy.

Unit-II

Steam power plant: General layout of steam power plant, Power plant boilers including critical and supercritical boilers. Fluidized bed boilers, boilers mountings, and accessories, Different systems such as coal handling systems, pulverizers and coal burners, combustion systems, draft, ash handling systems, Dust collection systems,

Condensers and Cooling Towers: Types of condensers, sources of air in condenser, Effects of air leakage, Methods of obtaining maximum vacuum in condenser, Dalton's law of partial pressure, vacuum & condenser efficiency, Mass of cooling water required, Air pump-Edwardair pump. Necessity of cooling ponds and cooling towers, Condenser water cooling systems, Types of cooling.

Unit-III

Diesel power plant: General layout, Components of Diesel power plant, Performance of diesel power plant, fuel system, lubrication system, air intake, and admission system, supercharging system, exhaust system, diesel plant operation and efficiency, heat balance, Site selection of diesel power plant, Comparative study of diesel power plant with steam power plant.

Gas turbine power plant: Layout of gas turbine power plant, Elements of gas turbine power plants, Gas turbine fuels, cogeneration, auxiliary systems such as fuel, controls and lubrication, operation and maintenance, Combined cycle power plants, Site selection of gas turbine power plant

Unit-IV

Nuclear power plant: Nuclear fusion and fission, Chain reaction, Nuclear fuels, Components of a nuclear reactor, Classification of reactors, Pressurized water reactor, Boiling water reactor, Gas-cooled reactor, CANDU reactor, Fast breeder reactor, Nuclear waste, and its disposal, Nuclear power plants in India.

Hydroelectric power plant: Hydrology, Principles of working, applications, site selection, classification and arrangements, hydroelectric plants, runoff size of plant and choice of units, operation, and maintenance, hydro systems, interconnected systems.

Unit-V

Electrical system: Generators and generator cooling, transformers and their cooling, bus bar, etc. Instrumentation Purpose, classification, selection and application, recorders and their use, listing of various control rooms.

Pollution: Pollution due to power generation

Textbooks:

1. Power Plant Engineering by P.K. Nag, Tata McGraw Hill.

2. Steam & Gas Turbines & Power Plant Engineering by R. Yadav, Central Pub. House.
3. Power Plant Technology, M.M. El-Wakil, McGraw-Hill Education.
4. A Textbook of Power Plant Engineering by R. K. Rajput, Laxmi Publications.

Reference books:

1. Power Plant Engineering by F.T. Morse, Affiliated East-West Press Pvt. Ltd, New Delhi/Madras.
2. Theory and Practice of Heat Engine by D. A. Rangham, Camb. Univ. Press
3. Power Generation, Operation, and Control by Allen J. Wood, Bruce F. Wollenberg, and Gerald B. Sheblé, John Wiley & Sons.
4. Combined Cycle Gas & Steam Turbine Power Plants by R. R. Peacock, Institution of Electrical Engineers.

Online study resources:

1. (272) Power Plant Engineering - YouTube
2. Free Power Engineering Tutorial - Basics of Power Plant Engineering | Udemy

PEC-I: NME330 THERMAL TURBO MACHINES
C[L-T-P]: 4[3-1-0]

Prerequisite: Course on Engineering Thermodynamics.

Course Objectives:

This course builds on applied thermodynamics and focuses on developing the ability to design and analyze thermal turbomachines. Students will gain enhanced skills to effectively tackle complex engineering challenges in this field.

Course Outcomes:

Student will be able to

CO1	Gain a comprehensive understanding of the fundamental principles underlying the operation of thermal turbomachines.
CO2	Develop the ability to design various work-absorbing turbomachines, including compressors and pumps.
CO3	Acquire the skills to design a range of work-producing turbomachines, such as gas and steam turbines.
CO4	Familiarize oneself with the functional parameters and components associated with different turbomachines.
CO5	Obtain in-depth knowledge of the working principles and performance characteristics specific to gas turbines.

Course Content:

UNIT-I

Brief history of turbomachinery, introduction to blowers, pumps, compressors, steam & gas turbines, turbojet, Review of laws of thermodynamics & SFEE in reference to turbo machinery, Energy transfer in turbo machines, Euler's equation, Definition of various efficiencies, Preheat factor, Reheat factor, Blade classification, Blade terminology, Cascade testing, Velocity diagrams for axial and radial turbomachinery and pumps.

UNIT-II

Centrifugal compressors - Principle of operation, work done and pressure rise, Velocity diagram for centrifugal compressor, Slip factor, Stage pressure rise, Loading coefficient, Diffuser, degree of reaction, Effect of impeller blade profile, Pre-whirl and inlet guide vanes, Centrifugal Compressor characteristic curves.

Axial flow compressor- Principle of operation and working, Energy transfer, Velocity diagram for axial compressor, Factors affecting stage pressure ratio, Blockage in compressor annulus, Degree of reaction, 3-D flow, Design process, blade design, calculation of stage performance, Axial compressor performance characteristic curves.

UNIT-III

Axial flow turbines: Elementary theory of axial flow turbine, Energy transfer, Velocity diagram, Types of blades, Vortex theory, Choice of blade profile, pitch and chord, Estimation of stage performance, Characteristic curves.

UNIT-IV

Steam turbines- Constructional details, working of steam turbine.

Pumps: Classification of Pumps, Main components, indicator diagram and modification due to piston acceleration, Performance characteristics, Cavitation and its control, Miscellaneous types of pumps.

Radial flow turbines: Elementary theory of radial flow turbines, Enthalpy- Entropy diagram, State losses,

Estimation of stage performance, Performance characteristics.

UNIT-V

Gas Turbine Starting & Control Systems : Starting ignition system, Combustion system types, Safety limits & control.
Turbine Blade coding: Different cooling techniques, Types of coolants, Comparative evaluation of different cooling techniques.
Mechanical Design consideration: Overall design choices, Material selection, Design with traditional materials.
CFD Applied to Turbomachinery Flows: Governing equations, numerical methods, and test cases illustrating flow and heat transfer related to turbo-machines.

Textbooks:

1. Thermal Turbomachines, Onkar Singh, Wiley India Pvt. Ltd.
2. Gas turbine theory: Cohen & Rogers, Addison Weslay Longman Ltd.
3. Turbomachinery: Design and Theory" by Rama S. R. Gorla and Aijaz Ahmed Khan Publisher: CRC Press
4. Principles of Turbomachinery" by Seppo A. Korpela Publisher: Wiley.

Reference books:

1. Design of high-efficiency turbomachinery and gas turbines, David Gordon Wilson, Theodosios Korakianitis, Prentice Hall International.
2. Turbine, Compressors and Fans, S.M. Yahya, Tata Mc Graw Hill.
3. Gas Turbine- Ganeshan, Tata Mc Graw Hill.
4. Axial Flow Compressors: Fluid Mechanics and Thermodynamics" by J.H. Horlock Publisher: Butterworth-Heinemann.

Online study resources:

1. (272) Intro - Introduction To Turbomachinery - YouTube
2. Thermal Turbomachines - Introduction - YouTube

PEC-I: NME332 ADVANCED MECHANICS OF SOLIDS
C[L-T-P]: 4[3-1-0]

Course Objectives:

CO1	To learn the concepts of 3D Stress
CO2	To learn the concepts of 3D , Strain and deformation.
CO3	To know the stresses developed during bending in curved beams.
CO4	To know the stresses developed in rotating components
CO5	To understand the failure mechanisms

UNIT 1: STRESSES IN THREE DIMENSIONS:

Concept of Continuum, Homogeneity and Isotropy, Types of forces on a body, State of stress at a point, Cauchy formula, principal stresses and planes, Stress invariants, Hydrostatic and deviatoric stress tensor, Mohr's circle for general state of stress, stress transformations, Octahedral stresses, Differential equation of equilibrium

UNIT 2: STRAINS IN THREE DIMENSIONS:

Types of strain, Strain displacement relationship, Shear strain, Rigid body rotation, Principle strain and axes, Strain deviator and invariants, Compatibility conditions, Concept of Plane stress and strain, Stress strain relationship

UNIT 3: ROTATIONAL STRESSES

Introduction, Rotational stresses in discs and rims of uniform thickness; discs of uniform Strength

UNIT 4: TORSION OF NON-CIRCULAR MEMBERS:

St. Venant's theory, approximate solution of rectangular and elliptical sections, rigorous solution, stress function approach, membrane analogy, torsion of thin hollow sections, Torsional of thin and open sections

UNIT 5: INTRODUCTION TO FRACTURE MECHANICS

Modes of failure, theories of failure and their Applications, Spectacular failures that triggered the birth of fracture mechanics, Modes of loading, classification as LEFM and EPFM, Crack growth and fracture mechanisms, Energy release rate, Resistance, Griffith theory of fracture,

TEXT BOOKS

1. Advanced Mechanics of Solids- L.S. Srinath, Tata McGraw Hill
2. Advanced Mechanics of Solids- S.M.A. Kazimi, Tata McGraw Hill
3. Elements of Fracture Mechanics- Prashant Kumar, McGraw Hill

REFERENCE BOOKS:

1-Mechanics of Materials by E.P.Popov, PHI
2- Strength of Materials by Ryder

VII SEMESTER

Programme Elective - II (PEC-II)

PEC-II: NME421 ADVANCE WELDING TECHNOLOGY
C[L-T-P]: 4[3-1-0]

Prerequisite:

Course Objectives: At the end of the course the students will learn various concepts related to welding, its application, along with practical purview of various welding process, welding standards, advanced welding process.

Course Outcomes:

After completion of the course a student will be able to:

CO1	Understand the importance and application of welding, conventional welding, weld design and inspection/testing.
CO2	Understand the importance and application of welding, conventional welding, formation of arc and arc ignition.
CO3	Develop good knowledge about Thermal and Metallurgical consideration of welding, HAZ, automation and safety in welding.
CO4	Student will have through knowledge about plasma arc, laser beam, electron beam, ultrasonic and diffusion welding.
CO5	Develop good knowledge about explosive welding, underwater welding, metal spraying and surfacing.

Course Content:

Unit-I

Introduction

Importance and application of welding, problems and drawbacks associated with conventional welding processes, Selection of welding process, Brief review of conventional welding process.

Unit II

Weld Design

Welding machines/equipment's and its characteristics, Heat input and heat flow, Weld defects and distortion, Inspection/testing of welds, Life prediction. Advantages of welding joints over other joining processes

Unit – III

Thermal and Metallurgical considerations

Thermal considerations for welding, temperature distribution, Analytical/Empirical analysis/formulae, heating & cooling, curves. Metallurgical consideration of weld, HAZ and Parent metal, micro & macro structure. Solidification of weld and properties. Automation in welding, Economics of Welding, Safety in welding.

Unit IV

Advanced welding Techniques-1

Principle, equipment, working and applications of Plasma Arc welding, Laser beam welding, Electron beam welding, Ultrasonic welding, and Diffusion welding.

Unit V

Advanced welding Techniques-2

Principle, equipment's, working and applications of explosive welding/ cladding, underwater welding, metal spraying and surfacing.

Textbooks:

1. Welding Processes and Technology – Dr. R. S. Parmar (Khanna Publication)
2. Manufacturing technology – Foundry, Forming and Welding- P. N. Rao (Tata McGraw Hill).
3. Khanna O. P. – 'A Text Book on Welding Technology' – Dhanpat Rai and Sons, New Delhi – 2013
4. Kou S. – 'Welding Metallurgy' – John Wiley Publications, New York – 2003 – 2nd Edition.

Reference books:

1. Welding and Welding Technology – Richard L. Little (Tata McGraw Hill).
2. Workshop Technology Vol1-B. S. Raghuvanshi (Dhanpat Rai and Sons)
3. Little R. L. – 'Welding and Welding Technology' – Tata McGraw Hill Publishing Company Limited, New Delhi – 1989
4. Grong O. – 'Metallurgical Modelling of Welding' – The Institute of Materials – 1997 – 2nd Edition

PEC-II: NME423 MECHATRONICS
C[L-T-P]: 4[3-1-0]

Prerequisite: Knowledge of Engineering Mathematics and physics.

Course Objectives:

The main objective of mechatronics is to provide knowledge of integration of mechanical and electrical systems with computer which will provide the multidisciplinary exposure for product development.

Course Outcomes:

Student will be able

CO1	To understand various elements of mechatronics and transfer functions.
CO2	To understand the concept of sensors and actuators and their interface for different applications.
CO3	To understand basic concept of microcontroller and microprocessor interfacing.
CO4	To understand basic principle of digital converters.
CO5	To get acquainted with applications of mechatronic systems and their modeling.

Course Content:

Unit I

Introduction to mechatronics, Dynamic Systems Modelling and Simulation: Equations of motion,

transforming, Model linearization, Frequency response. Transfer functions, Controller types and their design using frequency domain and Laplace domain method.

Unit II

MEMS sensors and actuators, Direct Current Motors, Stepper and Servo Motors, Piezoelectric strain sensors, Accelerometers and Gyroscope, Hydraulic systems, Pneumatic systems, pumps and valves, designing of hydraulic circuits.

Unit III

Embedded electronics, Basics of Microcontroller & Microprocessors architecture and instruction set, PID control, machine cycles, interrupts, instruction set, memory and I/O interfacing, programming techniques, Timer/ Counters, Serial Interfacing and communications, Interfacing to keyboards and displays.

Unit IV

AD and DA converters, Op Amps, Digital signal processing, Logic Circuit Devices, Gates-
AND, OR, NAND etc. and combinations, PID control.

Unit V

Study of Some Mechatronics Devices: Hard disk drive, dot matrix printer, optical sensing and control mechanism in NC machine tools etc. Electro-Mechanical Modeling, Hydraulic, Thermal, and Pneumatic systems. System modelling with structured analysis, Modelling of Mechatronic System.

Text book:

1. Mechatronics: electronic control systems in mechanical and electrical
2. Engineering, Bolton, William, Pearson Education, 2003.

Reference Books:

1. Mechatronics Principles, Concepts and Applications by N.P. Mahalik, McGraw Hill
2. Education
3. Introduction to Mechatronics and Measurement Systems by Alciatore David G.and Histand Michael B., McGraw Hill Education.
4. Mechatronics by Hindustan Machine Tools Ltd., McGraw Hill Education
5. Mechatronics Principles, Concepts and Applications by N.P.Mahalik, McGraw Hill Education.

Online resource:

https://archive.nptel.ac.in/courses/112/107/112107298/
https://nptel.ac.in/courses/112103174

PEC-II: NME425 RENEWABLE ENERGY SYSTEMS
C[L-T-P]: 4[3-1-0]

Course Objectives: This course considers the background of depleting fossil fuel reserves and lays emphasis on the utilization of alternative energy sources for meeting Varying requirements and ensure sustainable development while assessing the impact of both conventional and non-conventional sources of energy on civilization.

Course Outcomes:

By the end of this course, student will be able to

CO1	Understand effect of fossil fuels on global warming and their relative impact on the environment.
CO2	Comprehend the energy scenario of world in general and India in particular along with assessment of potential of alternative sources of energy.
CO3	Design, analyze and develop theoretical framework for use of alternative sources of energy for different applications.
CO4	Evaluate the performance of the various non-conventional and renewable energy sources.
CO5	Understand and analyze recent advancements in energy generations like magneto hydro dynamic power generation, fuel cell technology, hydrogen energy etc. and develop energy management skills.

Course Content:

UNIT-1

Energy resources and their utilization:

Indian and global energy sources, Status of Energy generation from different sources, Energy planning, Energy parameters (energy intensity, energy-GDP elasticity), Introduction to various sources of energy, Solar thermal, Photovoltaic, Water power, Wind energy, Biomass, Ocean thermal, Tidal and wave energy, Geothermal energy, Hydrogen energy systems, Fuel cells, Decentralized and dispersed generation.

Solar radiations:

Extraterrestrial radiation, Spectral distribution, Solar constant, Solar radiations on earth, Measurement of solar radiations, Solar radiation geometry, Flux on a plane surface, Latitude, Declination angle, Surface azimuth angle, Hour angle, Zenith angle, Solar altitude angle expression for angle between incident beam and the normal to a plane surface (no derivation), Local apparent time, Apparent motion of sun, Day length, Solar radiation data for India.

UNIT-2

Solar energy:

Solar thermal power and conversion, Solar collectors, Flat plate, Performance analysis of flat plate collector, Solar concentrating collectors, Types of concentrating collectors, Thermodynamic limits to concentration, cylindrical collectors, Thermal analysis of solar collectors, Tracking CPC and solar swing. Solar thermal energy storage, Different systems.

Applications, Water heating, Space heating & cooling, Solar distillation, solar pumping, Solar pond, solar cooking, Greenhouses, Solar power plants.

UNIT-3

Biogas:

Photosynthesis, Bio gas production, Aerobic and anaerobic bio-conversion process, Raw materials, Properties of bio gas, Producer gas, Transportation of bio gas, bio gas plant technology & status, Community biogas plants, Problems involved in bio gas production, Bio gas applications, Biomass conversion techniques, Biomass gasification, Energy recovery from urban waste, Power generation

from liquid waste, Biomass cogeneration, Energy plantation, Fuel properties, Biomass resource development in India.

Wind energy:

Properties of wind, Availability of wind energy in India, wind velocity, Wind machine fundamentals, Types of wind machines and their characteristics, Horizontal and Vertical axis wind mills, Elementary design principles, Coefficient of performance of a wind mill rotor, Aerodynamic considerations in windmilldesign,Selectionofawindmill,Windenergyfarms,Economicissues,Recentdevelopment.

UNIT-4

Electrochemical effects and fuel cells:

Principle of operation of an acidic fuel cell, Reusable cells, Ideal fuel cells, other types of fuel cells, Comparison between acidic and alkaline hydrogen-oxygen fuel cells, Efficiency and EMF of fuel cells, Operating characteristics of fuel cells, Advantages of fuel cell power plants, Future potential of fuel cells.

Tidal power:

Tides and waves as sources of energy, Fundamentals of tidal power, Use of tidal energy Limitations of tidal energy conversion systems.

Geothermal energy:

Structure of earth's interior, Geothermal sites, earthquakes & volcanoes, Geothermal resources, Hot springs, Steam ejection, Principal of working, Types of geothermal station with schematic representation, Site selection for geothermal power plants. Advanced concepts, Problems associated with geothermal conversion.

UNIT-5

Ocean energy:

Principle of ocean thermal energy conversion, Wave energy conversion machines, Power plants based on ocean energy, Problems associated with ocean thermal energy conversion systems, Thermoelectric OTEC, Developments of OTEC, Economics.

Wave Energy:

Introduction, Wave energy Conversion Systems, advantages and disadvantages of Wave Energy, status of wave Energy in India.

Magneto Hydro Dynamics:

Working principle, MHD Generator, advantages disadvantage and requirement of MHD, losses on MHD generator.

Textbooks:

1. Rai G.D, "Non-Conventional energy Sources", Khanna Publishers.
2. S. K. Dubey," Non-Conventional energy Resources", Dhanpat Rai & Co.
3. B.H.Khan," Non- Conventional Energy Resources",McGraw Hill education (India) Private Limited.
4. Shobh Nath Singh," Non- Conventional Energy Resources", Pearson Education Private Limited.

Reference books:

1. Bansal Keemann, Meliss," Renewable energy sources and conversion technology", Tata McGraw Hill.

Web Links:

1. https://www.youtube.com/live/7Ry643d3deE
2. https://youtu.be/aoG6eY89rWI
3. https://youtu.be/yNiEJzFrqjE

PEC-II: NME427 COMPOSITE MATERIALS
C[L-T-P]: 4[3-1-0]

Prerequisite: Fundamental knowledge of material science and engineering materials.

Course Objective:

The objective of the subject is to know the fundamental science and engineering principles relevant to composite materials.

Course Outcomes:

Students will be able to

CO1	Understand the concepts of composite materials fabrications of composite and their properties.
CO2	Understanding fibrous and particulate composites, their stress strain behavior and important properties.
CO3	Analysis of laminated composites and understanding of orthotropic lamina and laminated theory.
CO4	Characterize composites by evaluating various mechanical properties.
CO5	Analyze and identify the damages in composite structures.

Course Content:

Unit I

Introduction: Definition, Characteristics classification Particulate and fibrous composites. **Fibers Matrices and Fabrication of Composites:** Advance fibers, Glass fibers carbon and graphite fibers Aramid fibers Boron Fibers and other fibers. Matrix materials: Polymer and Metals, Fabrication of composites.

Unit II

Behavior of unidirectional composites: Nomenclatures, volume and weight fractions, Longitudinal Strength and Stiffness, Transverse Stiffness and Strength, Prediction of shear and Poisson Ratio, Failure modes.

Short Fiber Composites Theories of stress transfer Modulus and Strength of Short fiber.

Unit III

Analysis of an orthotropic Lamina: Hooke's law for orthotropic Materials, Stress- strain Relations and engineering Constants, Strength of an Orthotropic Lamina.

Unit IV

Analysis of Laminated Composites: Strain and stress Variation in a laminate, Synthesis of Stiffness Matrix, Construction and Properties of Special Laminates, Determination of laminae stress and strains, Analysis of laminates after initial failure. Hygro-thermal stresses in Laminates.

Unit V

Experimental Characterization of Composites Uniaxial Tension test, Uniaxial Compression Test,

In plane Shear test, Uniaxial Bending Tests Determination of Interlaminar Shear Strength and Fracture toughness. Damage Identification Using Nondestructive Evaluation Techniques.

Textbooks:

1. Analysis and Performance of fiber composite by Agrawal, B.D., Broutman L.J., John Wiley & Sons
2. Introduction to composite Materials by Tsai S.W., Hahn H.T., Thechnomic West Port, Conn.

Reference books:

1. Primer on Composite Material Analyisis, Haplin J.C., Technomic Stanford, Conn.1984
2. Mechanics of composite materials, Jones R.M., Sripta Book Company Washington D.C.

PEC-II: NME429 TOTAL QUALITY MANAGEMENT
C[L-T-P]: 4[3-1-0]

Prerequisite:

Course Objectives: To eliminate waste and increase efficiencies by ensuring that the production process of the organization's product (or service) is done right the first time and improve product quality.

Course Outcomes:

After completion of the course a student will be able to:

CO1	The understanding of quality concepts, total quality management, development of sources, quality in sales and services, analysis of claims.
CO2	The knowledge of Organization structure and design, quality function deployment, quality cost, Attitude of top management, operator ‘s attitude and responsibility.
CO3	The understanding of mathematics of control charts, construction, and analysis of $\bar{X}$, R, p and C- charts and use of control charts.
CO4	The knowledge of Defects diagnosis and prevention, correcting measure, reliability control, maintainability, zero defects, quality circle, ISO-9000, Taguchi method and JIT in details.
CO5	Student will able to understand the quality management control toll and role of human factor and team work in the development of quality and productive manufacturing process.

Course Content:

Unit-I

Quality Concepts: Evolution of Quality concept, TQM concept, Quality concept in design. Control of purchased product, Evaluation of supplies, Capacity verification, Development of sources, Procurement procedure, Manufacturing Quality Methods and Techniques for manufacture. Control on Purchased Product: Procurement of various products, evaluation of supplies, capacity verification, Development of sources, procurement procedure.
Quality tool and techniques: Introduction to Six Sigma, Lean principles & continuous improvements
Quality concept in design: Design for six sigma (DFSS),Design for experiments(DOE) & Design for manufacturing(DFM)
Manufacturing Quality: Methods and Techniques for Inspection and control of product, Quality in sales and services, Guarantee, analysis of claims.

Unit II

Quality Management:

Organization structure and design, Quality function deployment, Economics of quality value and contribution, Quality cost: Prevention, appraisal, internal failure & external failure costs, optimizing quality & cost reduction programme, use of QM initiatives, tools, and techniques in an organization.

Human factor in quality:

Attitude of top management, co-operation of groups, operator 's attitude & responsibility causes of operator 's error and corrective methods.

Unit – III

Statistical process control (SPC):

Control charts:

Theory of control charts, construction and use of $\bar{x}$ & R charts, process capability study, use of control charts, Limitations of X bar and R charts.

Attribute control charts

Defects, construction, and analysis of using p-chart, effect of variable sample size, construction, and use of C-chart

Unit IV

Defects Diagnosis and Prevention:

Defect study, identification and analysis of defects, corrective measures, factors affecting reliability, MTTF, calculation of reliability, Building reliability in the product, evaluation of reliability, interpretation of test results, reliability control, maintainability.

Failure Mode & Effect Analysis (FMEA) : Introduction to FMEA, Risk assessment & prioritization of failure modes.

Reliability Engineering: Introduction to reliability concept, reliability prediction & reliability improvement technique.

Maintainability & Availability: Introduction to maintainability concept, Availability calculation & Preventive Maintenance Strategies

Unit V

Environmental management system: Introduction to ISO 14001 & Environmental Sustainability Practices

Lean manufacturing: Introduction to Lean Principles, Tool (eg.5 S, Kanban) & Waste Reduction Techniques.

Total productive maintenance (TPM): Introduction to TPM concept & strategies for improving equipment effectiveness.

IS0-9000 and its concept of Quality Management:

Introduction, characteristics of quality assurance system. ISO -9000: scope, application, terms & definitions, evolution of ISO-9000 series, ISO 14000 Taguchi method, JIT- advantages and disadvantages. zero defects, quality circle.

Textbooks:

1. TQM in New Product Manufacturing - Menon, H.G. (McGraw Hill)
2. Total Quality Management - Lt. Gen. H. LaI (Wiley Eastern Limited)
3. Beyond Total Quality Management - Greg Bounds (McGraw Hill)
4. The Management & Control of Quality - Evans & Lindsay (Thompson South-Western).
5. Total Quality Management: Text & Cases - Jankiraman& Gopal (PHI Learning New Delhi).

Reference books:

1. Total Quality Management: A Primer - S M Sundara Raju (Tata McGraw Hill, New Delhi).

2. Introduction to Quality Management and Engineering - Sower, Savoie& Renick (Pearson Education Asia).
3. Total Quality Management - Besterfield Dale H (Pearson Education Asia, Second Edition).
4. Total Quality Management: A Practical Approach - H Lal (New Age International)

Programme Elective – III (PEC-III)

PEC-III: NME441 ADVANCE MATERIALS & CHARACTERIZATION
C[L-T-P]: 3[3-0-0]

Course Objectives
The objective of this course is to make students learn the skills needed to characterize and analyze various engineering materials.

Course outcomes:
On the successful completion of the course, students will be able to

CO1	Interpret metallographic images of material obtained using Optical microscope
CO2	Understand different aspects of X-Ray diffraction technique.
CO3	Understand the construction, application and working of Electron Microscope
CO4	Understand the principles and application of different thermal characterisation techniques
CO5	Understand the principles and application of microanalysis equipments

Unit 1. Optical metallography:
Scope of optical metallographic studies: Image formation, resolving power, numerical aperture, empty magnification, depth of focus, components of Microscopes, important lens defects and their correction, principles of phase contrast, interference and polarized light microscopy, elements of quantitative metallography and image processing, sample preparation techniques.
Unit 2. X Ray diffraction (XRD):
XRD and their applications, Production and properties of X-ray, absorption of X-rays and filters, X-ray – diffraction directions, diffraction methods, X-ray diffraction intensities, factors affecting intensity, 'structure factor' calculations for simple, body centered, face centered, diamond, cubic and hexagonal crystal structures.
Working principles of diffractometer, counters and cameras, Indexing of XRD patterns. Precise lattice parameter determination, Chemical analysis by X-ray diffraction & fluorescence, determination of particle size and micro/macro strains.
Unit 3. Electron microscope:
Introduction to electron microscopes, Construction and working principles of transmission electron microscopes, Image formation, resolving power, magnification, depth of focus, elementary treatment of image contrasts, Bright field and dark field images, Formation of selected area diffraction patterns, reciprocal lattice and Ewald sphere construction, indexing of diffraction patterns, sample preparation techniques, Scanning electron microscope; construction, interaction of electrons with matter, modes of operation, image formation of plane and fractured surfaces. Chemical analysis using electron microscope.
Unit 4. Advanced chemical and thermal analysis techniques:
Basic principles, practice and applications of X-ray photoelectron spectrometry, Augur spectroscopy, Principles of differential scanning, calorimetry, differential thermal analysis and thermo gravimetric analysis.
Unit 5. Instrumental analysis:
Devices like electron probe microanalysis, atomic force microscopy etc.

Text Books:

1. Spencer, Michael, Fundamentals of Light Microscopy, Cambridge Univ Press, 1982.
2. David B. Wiliams, C.Barry Carter, "Transmission Electron Microscopy:A Textbook for
3. Materials Science", Springer Pub. 2009.
4. Joseph I Goldstein, Dale E Newbury, Patrick Echlin and David C Joy, "Scanning Electron
5. Microscopy and X-Ray Microanalysis", 3rd Edition, 2005.
6. B.D. Cullity and S.R. Stock, "Elements of X-Ray Diffraction" Third edition, Prentice Hall,NJ, 2001

Reference books:

1. Fundamentals of light microscopy and electronic imaging' Douglas B. Murphy, 2001, Wiley-Liss, Inc., USA.
2. 'Encyclopedia of Materials Characterization, Surfaces, Interfaces, Thin Films', Editors C. Richard Brundle, Charles A. Evans, Jr.., Shaun Wilson, Butterworth – Heinemann, Boston London, Oxford, Singapore Sydney, Toronto, Wellington.

Web Links:

1- https://onlinecourses.nptel.ac.in/noc22_mm14/preview [IIT Madras]
2- https://archive.nptel.ac.in/courses/113/106/113106034/ [IIT Madras]
3- https://archive.nptel.ac.in/courses/113/105/113105101/ [IIT Kharagpur]

PEC-III: NME443 ADVANCE MANUFACTURING PROCESSES
[L-T-P]: 3[3-0-0]

Course Outcomes:

After completion of the course a student will be able to:

CO1	Ability to understand the role of various manufacturing processes in Industries, understanding of basic phenomena of removal in advanced manufacturing processes
CO2	Proper understanding of the role various energy such as thermal, Electrical and Mechanical for material removal and its control.
CO3	Understanding of working principle, application and advantages of advanced manufacturing processes.
CO4	Ability to design and develop various components being used in advanced machining, welding and forming
CO5	Proper understanding of combination of various advanced manufacturing processes. Ability to develop Hybrid manufacturing processes.

Course Content:

UNIT-1
Introduction: Advanced Manufacturing Processes and its Industrial applications Limitations of Conventional machining processes, Need of advanced manufacturing processes and its classification.
Micromachining: Introduction to micromachining, Challenges and considerations in machining at microscale, Emerging trends in micromachining, Industrial applications of micromachining.

UNIT-2
Thermal Type Advance Machining Processes: Classification, General principles and applications of Electro discharge machining, Plasma arc machining, Ion beam machining, Laser beam machining, Electron beam machining, Mechanics of metal removal in EDM, selection of EDM pulse generator dielectric, machining accuracy, surface finish and surface damage in EDM, Generation and control of electron beam for machining applications, advantages and limitations

UNIT-3
Chemical and Electro-chemical Type Metal Removal Processes: Principle, working advantages, disadvantages and applications of Electro-chemical machining, Chemical machining, Economy aspects of ECM, Electro-chemical debarring and honing, ECM and allied processes.

UNIT-4
Mechanical Type Metal Removal Processes: Ultrasonic machining; Elements of the process; Tool design and economic considerations; Applications and limitations, Abrasive jet and Abrasive water jet machining principles; Mechanics of metal removal; Design of nozzles; applications, Abrasive finishing process, Magnetic abrasive finishing process.

UNIT-5
Advanced Welding Processes Advanced Forming Processes, Hybrid Advanced and Assisted Machining Processes: Classification of hybrid machining processes, Introduction to ECDM, ECAM and Abrasive EDM, Vibration assisted hybrid processes. Additive manufacturing: (3D printing) Principles, techniques and applications. Smart Manufacturing and Industry 4.0: Integration of advanced manufacturing with digital technologies and automated systems.

Textbooks:

1. V.K.Jain,Advance, “Machining Processes”, New Age
2. P.C. Pandey, “Modern Machining Processes”, New Age
3. Degarmo, “Manufacturing Processes”,
4. Kalpakjian, “Manufacturing Processes”, Tata McGraw-Hill International

Reference books:

1. Introduction to Advance Manufacturing Process by Gary F. Benedict.

PEC-III: NME445 FINITE ELEMENT METHOD
C[L-T-P]: 3[3-0-0]

Prerequisite: Strength of Material

Course Objectives:

Course Outcomes:

Students will be able to

CO1	To get the knowledge of classical methods used for approximate analysis.
CO2	To understand the FEM formulations for 1D Problems.
CO3	Apply the FEM for 2-Dimensional problems
CO4	Application of Higher order elements.
CO5	Application of FEM for Scalar field problems.

Course Content:

UNIT-1

Classical methods: Introduction, Geometrical aspects of differentiation and integration, Mathematical modelling - Classical methods - Rayleigh-Ritz-Method, Galerkin Method, FDM. Applications in bar and beam.

UNIT-2

1D-FEM formulations: FEM approach, Nodes, Types of Elements, approximation function, shape function, Coordinates, Potential Energy Approach, Galerkin Approach, Derivation of stiffness matrix, Assembly of the Global Stiffness Matrix and Load Vector. Pre-Post processing. Penalty and Elimination approaches.

UNIT-3

2D FEM: Finite Element Modeling, Constant Strain Triangle (CST), Problem Modeling and Boundary Conditions, Axisymmetric Solids subjected to Axisymmetric Loading: Axisymmetric Formulation. Role of Jacobian Matrix, 2D Integration by Gauss quadrature method.

UNIT-4

FEM with Higher Order Elements: FEM analysis of Beam, parametric elements, Lagrangian method, Pascal Triangle, Problem Modeling and Boundary, Conditions, 2D – Iso-parametric Elements: Four-Node Quadrilateral, Numerical, Integration, Higher - Order Elements.

UNIT-5

FEM for Scalar Field Problems: Steady-State Heat Transfer, Torsion, Potential Flow, Dynamic Analysis: Formulation, Element Mass Matrices, Evaluation of Eigen values and Eigenvectors. Application of popular softwares for FEM. Computational Fluid Dynamics (CFD).

Textbooks:

1. Introduction to Finite Elements in Engineering by T.R. Chandrupatla and A.D. Belegundu, Prentice- Hall of India

2. An Introduction to the Finite Element Method by J.N. Reddy, McGraw-Hill
3. Introduction to the Finite Element Method by C.S. Desai and J.F. Abel, Van Nostrand Reinhold
4. The Finite Element Method in Engineering by S.S. Rao, Pergamon.

Reference Books:

1. Finite Element Procedures in Engineering Analysis by K.J. Bathe, Englewood Cliffs, Prentice Hall
2. Concepts and Applications of Finite Element Analysis by R.D. Cook, Wiley
3. The Finite Element Method - Linear Static and Dynamic Finite Element Analysis by T.J.R. Hughes, Englewood Cliffs, Prentice-Hall
4. The Finite Element Method by O.C, Zienkiewicz, McGraw-Hill

PEC-III: NME447 INDUSTRIAL ENGINEERING & AUTOMATION
C[L-T-P]: 3[3-0-0]

Prerequisite: Manufacturing science

Course Objectives:

The course considers Industrial productive concepts and automation. Principles of economy production planning and control.

Course Outcomes:

After completion of the course a student will be able to understand and apply fundamentals of Industrial engineering concepts:

CO1	Analyze and understand productivity concepts and automation concepts.
CO2	Explain various Industrial Layout and time study.
CO3	Exhibit skills towards program evaluation and review technique
CO4	Analyze and perform Break even analysis.
CO5	Analysis of Automated Flow lines for Reliability and Efficiency.

Course Content:

Unit I

Introduction, engineering economy and costing, cost analysis, methods of depreciation, productivity concepts and measurements, job evaluation, Automation Concepts: SCADA, introduction to SCADA, software for SCADA systems, distributed control system (DCS), basics of PLC, Basic of robotic system.

Unit II

Work measurement, time study, pre-determined motion and time study (PMTS), work sampling, method study, micro motion study, principles of motion economy.

Unit III

Plant location, Types of Layout, Principles of Facility Layout, Objective Functions, Steps in PPC, Planning, Routing, Scheduling, Loading, Dispatching, Effectiveness of PPC.

Unit IV

PERT, CPM, Resource Allocation and GERT- Program Evaluation and Review Technique (PERT), Critical Path Method (CPM), Scheduling with Resource Constraints. Introduction to quality

management, Ergonomics.

Unit V

High Volume Production Systems- Transfer Devices, Feeder classification, Construction and Applications, Automated Flow lines, Analysis of Automated Flow lines for Reliability and Efficiency, Assembly Systems, Robot Technology, Flexible Manufacturing Systems (FMS)

Textbooks:

4. Industrial Engineering by M.S. Mahajan, DhanpatRai and Co. (P) Ltd.
5. Introduction to Robotics by S.K. Saha, Tata Magraw Hill
6. Mikell P. Groover, Mitchel Weiss, Roger N. Nagel, Nicholas G. Odrey and Ashish Dutta, "Industrial Robotics: Technology, Programming and Applications", 2 nd Edition, Tata McGraw Hill, 2012

Reference Books:

5. Introduction to Industrial System Engineering by Turner w.c. et Al 1993, Prentice Hall
6. Motion and Time Study, Design and Measurement of Work by Ralph M. Barnes, Wiley Publishers
7. Project Management for Business and Technology by John M Nicholas, PHI
8. Robotics by John M Nicholas, Pearson Education

Online resources
https://nptel.ac.in/courses/108105063
https://nptel.ac.in/courses/112101098
https://archive.nptel.ac.in/courses/108/105/108105062/

PEC-III: NME449 CRYOGENICS
C[L-T-P]: 3[3-0-0]

Prerequisite: Knowledge of engineering thermodynamics and Refrigeration and air-conditioning.

Course Objective:

Gain a comprehensive understanding of cryogenic technology, including its principles, applications, and implementation, enabling analysis of cryogenic systems, application of thermodynamics to cryogenics plants, and informed specialization within the field.

Course Outcomes:

After completion of the course a student will be able to:

CO1	Demonstrate a comprehensive understanding of the core principles and applications of cryogenic technology through the synthesis and application of fundamental concepts.
CO2	Explore a wide range of engineering and technological fields where cryogenic technology finds diverse applications, illustrating its significance in various industries.
CO3	Gain in-depth knowledge of different cryogenic liquefaction and refrigeration methods, including their working principles and practical implementations.
CO4	Identify and analyze various avenues within cryogenics, enabling students to make informed decisions and select a specific area of interest for further specialization.
CO5	Develop a thorough comprehension of the thermodynamics and operational mechanisms governing cryogenic plants, emphasizing their efficiency and performance.

Unit I

Cryogenics Fluids & Materials: Properties of air, Oxygen, Nitrogen, Hydrogen, Helium and its isotopes. Study of material properties & their selection for cryogenic application.

Cryogenic Refrigeration Systems & Gas liquefaction systems: Recuperative & regenerative cycles, Joule Thomson cycle, Gifford, Mcmohan cycle, Stirling cycle, Pulse Tube refrigeration, Magneto caloric refrigeration, Vuilleumier refrigerator. Ideal systems, Linde, Linde dual pressure system, Claude, Heylandt, Kapitza systems, Cascade cycle.

Unit II

Cryogenic Insulation: Vacuum insulation, Multilayer insulation (MLI), Methods of measuring effective thermal conductivity of MLI, Liquid & vapour shield, evacuated porous insulation, Gas filled powders and fibrous materials, Solid foams.

Unit III

Cryogenic Instrumentation: Peculiarities of cryogenic strain measurement, Pressure, Flow, Density, Temperature and liquid level measurement for cryogenic application.

Unit IV

Purification and separation of gases, Liquefied natural gas: Separation by condensation & flashing, Separation by distillation. Air separation system: Linde single column system. Linde double, Column systems etc, Liquefaction of Natural Gas.

Unit V

Transfer, Storage & Handling systems: Transfer from storage, Un-insulated transfer lines, Insulated lines, Transfer system components. Dewar vessel design, Piping, Support systems, Vessel safety devices and storage systems, Industrial storage systems.

Textbook:

1. Fundamentals of Cryogenic Engineering by Mamata Mukhopadhyay, PHI. Learning Pvt. Ltd.
2. Cryogenic Systems by Randall F. Barron, McGraw-Hill, 1985.
3. Cryogenic Engineering, by R.B. Scott – D. Van Nostrand Company, 1959
4. Cryogenic Process Engineering, by K.D. Timmerhaus and T.M. Flynn, Plenum Press, New York,1989

References:

1. Cryogenic Fundamentals, by Haselden C.J. (Ed), Academic Press (1975)
2. Advanced cryogenics by Baily C.A., Plenum Press (1971) 17
3. Advances in Cryogenic Engineering by Timmerhaus K D Timmerhaus
4. High Vacuum Technology, by A. Guthree, New Age International Publication

Online study resources:

1. (272) Mod-01 Lec-01 Introduction to Cryogenic Engineering - YouTube
2. 'Cryogenic Engineering' Video Lectures from IIT Bombay by Prof. M.D. Atrey - Mechanical Engineering NPTEL Video Lectures (nptelvideos.com)

Programme Elective - IV (PEC-IV)

PEC-IV: NME461 GAS DYNAMICS & JET PROPULSION
C[L-T-P]: 3[3-0-0]

Prerequisite: A first course in fluid mechanics or aerodynamics is required. Additionally, students must have taken a course in thermodynamics, dynamics, calculus, ordinary differential equations, and partial differential equations.

Course Objectives:

To develop a comprehensive understanding of fluid dynamics, focusing on the differentiation between incompressible and compressible flows, the analysis of shock waves, and the principles of jet propulsion and rocket propulsion.

Course Outcomes:

After completion of the course a student will be able to:

CO1	Understand compressible flow, including Mach waves, stagnation states, and the equations governing one-dimensional flow.
CO2	Analyze isentropic flow in variable area ducts, including choked flow and the relationship between area and Mach number.
CO3	Apply non-isentropic flow principles, such as Rayleigh and Fano flows, to analyze shock relations and use isentropic and shock tables.
CO4	Gain knowledge of jet propulsion theory, including thrust equation, power, efficiency, and analysis of ramjet, turbojet, turbofan, and turboprop engines.
CO5	Explore rocket engines, propellants, ignition, combustion, and theory of rocket propulsion. Study performance, staging, terminal velocity, and characteristic velocity in space flights.

UNIT -I: Compressible flow, definition, Mach waves, and Mach cone, stagnation states, Mass, momentum, and energy equations of one-dimensional flow.

UNIT-II: Isentropic flow through variable area ducts, nozzles and diffusers, subsonic and supersonic flow variable area ducts, choked flow, Area-Mach number relations for isentropic flow.

UNIT -III: Non-isentropic flow in constant area ducts, Rayleigh and Fano flows, Normal shock relations, oblique shock relations, isentropic and shock tables.

UNIT -IV: Theory of jet propulsion, thrust equation, thrust power and propulsive efficiency, Operating principle and cycle analysis of ramjet, turbojet, turbofan and turboprop engines.

UNIT -V: Types of rocket engines, propellants & feeding systems, ignition and combustion, theory of rocket propulsion, performance study, staging, terminal and characteristic velocity, space flights.

TextBooks:

1. Fundamentals of Compressible Flow by S. M. Yahya, New Age International Pvt Ltd Publishers
2. Modern Compressible Flow, John Anderson, McGraw Hill Education
3. Mechanics & Thermodynamics of Propulsion by Hill P. and Peterson C., Addison Wesley,1992.
4. Rocket Propulsion Elements by Sutton G.P., John Wiley, New York, 1986

Reference Book:

1. Aircraft and Missile Propulsion by Zucrow N. J., Vol.I& II, John Wiley, 1975.
2. Introduction to Compressible Fluid Flow" by Patrick H. Oosthuizen and William E. Carscallen, Publisher: Butterworth-Heinemann.
3. Rocket Propulsion Elements by George P. Sutton and Oscar Biblarz, Publisher: Wiley.
4. Elements of Gas Dynamics by H.W. Liepmann and A. Roshko, Publisher: Dover Publications.

PEC-IV: NME463 DESIGN AND ANALYSIS OF EXPERIMENTS
C[L-T-P]: 3[3-0-0]

Prerequisite:

Course Objectives: The students are expected to be able to demonstrate the following knowledge, skills and attitudes after completing this course. Also, able to plan, design and conduct experiments efficiently and effectively, and analyse the resulting data to obtain objective conclusions. Both design and statistical analysis issues are discussed.

Course Outcomes:

After completion of the course a student will be able to:

CO1	Understanding of western and Taguchi quality philosophy and steps involved in robust design.
CO2	Understanding of classical and factorial experiments and experimental design.
CO3	Opportunities to use the principles taught in the course arise in all phases of engineering work, including new product design and development, process development, & manufacturing process improvement.
CO4	Ability to analyse and interpret the experimental data using ANOVA and regression analysis.
CO5	Understanding of Taguchi's orthogonal arrays and Signal to Noise ratio, parameter design and tolerance design

Course Content:

Unit-I

Quality Control and Experimental Design: Quality assurance & Total Quality control, Basic statistical concepts, Control of accuracy and precision, Quality Engineering System.
Western and Taguchi quality philosophy, Elements of cost, Noise factors causes of variation, Quadratic loss function and variation of quadratic loss functions.
Robust Design: Steps in robust design: parameter design and tolerance design, its application to control of processes with high variability reliability improvement through experiments, Illustration through numerical examples.
Software applications and case studies.

Unit-II

Taguchi's Orthogonal Arrays: Types orthogonal arrays, Selection of standard orthogonal arrays, Linear graphs and interaction assignment, dummy level technique, Compound factor method, modification of linear graphs, Strategies for constructing orthogonal arrays. Software applications and case studies.

Unit-III

Signal to Noise ratio (S-N Ratios): Evaluation of sensitivity to noise, Signal to noise ratios for static problems, STB, NTB, LTB – type criteria.
Parameter Design and Tolerance Design: Parameter and tolerance design concepts, Taguchi's arrays, Parameter and tolerance design strategy, Illustrations through numerical examples.

Unit-IV

Analysis and Interpretation of Experimental Data: Measures of variability, Ranking method, column effect method and plotting method, Analysis of variance (ANOVA), parameter optimization. Mathematical models from experimental data, illustration through numerical examples. Repeated measures design, analysis of covariance and its applications in comparing alternatives.

Unit-V

Experimental Design: Introduction and application of experimental design, single factor experiments, randomized blocks, Latin square designs and extensions.
Fractional factorial designs, two-level, three-level and mixed-level factorials and fractional factorials, applications to quality control problems., factor effects, factor interactions, Fractional factorial design, Saturated design, Central composite designs, Illustration through numerical examples.

Text books:

1. M. S. Phadake - Quality Engineering using Robust Design, Prentice Hall, Englewood Clifts, New Jersey, 1989.
2. Douglas Montgomery, Design and analysis of experiments, Willey India Pvt. Ltd., 5th Edition, 2007.
3. P. J. Ross, Taguchi, Techniques for Quality Engineering, 2nd Edition. McGraw Hill Int. Edition, 1996.
4. Sharma M K, Design and Analysis of Experiments, 2012, Prentice Hall India Learning Private Limited.
5. Winer BJ, 1962, Statistical Principles in Experimental Design, 2nd Edition, McGraw-Hill

Reference books:

1. T. B. Barker, M. Dekker, Quality by Experimental Design, Inc ASQC Quality Press, 1985
2. Quality Control and Applications - B.L. Hansen & P.M. Ghare (Prentice Hall of India)
3. C. F. Jeff Wu, Michael Hamada, Experiments planning, analysis and parameter design optimization, John Willey Ed., 2002.
4. W. L. Condra, Marcel Dekker, Reliability improvement by Experiments, Inc ASQC Quality Press, 1985. 5. Hinkelmann K and Kempthorne, O, 1994, Design and Analysis of Experiments (Vol I), Wiley.

PEC-IV: NME463 NON-DESTRUCTIVE EVALUATION
C[L-T-P]: 3[3-0-0]

Prerequisite: Basic Science courses

Course objectives:

To provide the knowledge of non-destructive techniques to identify the health of the mechanical components and systems.

Course Outcomes:

Students will be able to

CO1	Have concepts of basic technology of inspection and evaluation according to the material of the system and components.
CO2	Have specific knowledge of surface morphology, eddy current techniques.
CO3	Understanding of Eddy Current Testing, probes, methodology of current measuring.
CO4	Understanding of Ultrasonic Testing, transducers.
CO5	Understanding of Thermal testing, Thermography components.

CourseContent:

Unit I

Destructive vs Non-Destructive Evaluation, Factors to consider in selecting tests, Economics of testing, In service testing; Defect detection, Terminology for non-destructive evaluation – Discontinuity, Imperfections,

Flaw, Defects, Non-critical flaw, critical flaw, False vs. relevant indications. Interpretation and evaluation.

Unit II

Methods of Nondestructive evaluation, Visual Inspection, Surface Inspection Methods, Dye penetrant method, Eddy current testing, Magnetic testing methods, Ultrasonic testing, Acoustic Emission. Radiography, X-ray.

Unit III

Eddy Current Testing- Basics of Eddy current testing, factors affecting eddy current response. Magnetic testing methods- Magnetization curves and hysterises, Magnetic particle tests, scope of test, detection of flaws and cracks using magnetic flux leakage; Radiographic Testing Methods: Principle, equipment and methodology, X-ray images, radiographic film, properties of x-ray film.

Unit IV

Ultrasonic Testing: Generation of ultrasounds in materials, Transducers, Display and interpretation of ultrasonic data. Principle of operation, Ultrasonic probes, Advantages, Limitation and Typical applications.

Unit V

Acoustic Emission Technique– Introduction, Types of AE signal, Principle, Advantages & Limitations, Interpretation of Results, Applications.
Holography, Thermography– Introduction, Principle, advantages, limitations and application

Textbooks:

1. Introduction to the Principles of Material Evaluation by David C Jiles, CRCPress.
2. Evaluation of Material & Structures by Quantitative Ultrasonics, by J.D. Achenbach, Springer- Verlag, NewYork-1994
3. Practical Non-Destructive Testing Baldev Raj, T.Jayakumar, M.Thavasimuthu Narosa Publishing House 2009
4. Non-Destructive Testing Techniques Ravi Prakash New Age International Publishers 1st revised edition2010

Reference books:

1 ASM Metals Handbook,"NonDestructive Evaluation and Quality Control", Volume-17 American Society of Metals, Metals Park, Ohio, USA, 2000
2 Introduction to Nondestructive testing: a training guide Paul E Mix, Wiley 2nd Edition New Jersey, 2005
3 Handbook of Nondestructive evaluation Charles, J. Hellier McGraw Hill, New York 2001

PEC-IV: NME467 PRODUCT DESIGN & DEVELOPMENT
C[L-T-P]: 3[3-0-0]

Prerequisite: Manufacturing science

Course objective:

To provide the exposure to the real design issues of product development.

Course Outcomes:

Students will be able to

CO1	Understand the basic theory of process of product design and different phases of design.
CO2	Carry out cost and benefit analysis through various cost models.
CO3	Be familiar with the design protection and Intellectual Property.
CO4	Understand the Applications of Computers in product design.
CO5	Analyse the methodologies for product design, development and management.

Course Content:

Unit I:

Introduction to Product Design: Introduction to PDD, Applications, Relevance, Product Definition, Scope, Terminology. Design definitions, the role and nature of design, old and new design methods, Design by evolution. Examples such evolution of bicycle, safety razor etc. Need based development, technology-based developments. Physical reliability & Economic feasibility of design concepts.

Unit II:

Morphology of Design: Divergent, transformation and convergent phases of product design. Identification of need, Analysis of need. Design for what? Design criteria, functional aspects. Aesthetics, ergonomics, form (structure). Shape, size, color. Mental blocks, Removal of blocks, Ideation Techniques. Creativity, Checklist.

Unit III:

Transformations: Brainstorming & Synectics. Morphological techniques. Utility concept, Utility value, Utility index. Decision making under multiple criteria. Economic aspects of design. Fixed and variable costs. Break-even analysis.

Unit IV:

Reliability: Reliability considerations, Bath tub curve, Reliability of systems in series and parallel. Failure rate, MTTF and MTBF. Optimum spares from reliability consideration. Design of displays and controls, Man-Machine interface, Compatibility of displays and controls. Ergonomic aspects. Anthropometric data and its importance in design. Applications of Computers in product design.

Unit V:

Product Appraisal: Information and literature search, patents, standards and codes. Environment and safety considerations. Existing techniques such as work-study, SQC etc. which could be used to improve method & quality of product. Innovation versus Invention.

Text books:

1. Product Design & Manufacturing by A.K. Chitab & R. C. Gupta, PHI (EEE).
2. Product Design and Development by Karl T Ulrich, Steven D. Eppinger

3. Reliability Engineering, S.C. Sharma Khanna Book Publishing Co.
4. Product Design & Decision Theory by M.K. Starr, Prentice Hall

Reference books:

1. The Technology of Creation Thinking by R.P. Crewford, PrenticeHall
2. The Art of Thought by Grohem Walls, Bruce & Co., NewYork
3. Human Factor Engg. byMccormick E.J.,McGrawHill.
4. Engineering: An Introduction to Creative profession by G.C. Beakley, H.W. Leach,Macmillan.

PEC-IV: NME469 SMART MATERIALS & STRUCTURES
C[L-T-P]: 3[3-0-0]

UNIT-I

Introduction to Smart Materials, Principles of Piezoelectricity, Perovskyte Piezoceramic Materials, Single Crystals vs Polycrystalline Systems, Piezoelectric Polymers, Principles of Magnetostriction, Rare earth Magneto strictive materials, Giant Magnetostriction and Magneto-resistance Effect, Introduction to Electro-active Materials, Electronic Materials, Electro-active Polymers, Ionic Polymer Matrix Composite (IPMC), Shape Memory Effect, Shape Memory Alloys, Shape Memory Polymers, Electro-rheological Fluids, Magneto Rheological Fluids

UNIT-II

HIGH-BAND WIDTH, LOW STRAIN SMART SENSORS Piezoelectric Strain Sensors, In-plane and Out-of Plane Sensing, Shear Sensing, Accelerometers, Effect of Electrode Pattern, Active Fibre Sensing, Magneto strictive Sensing, Villari Effect, Matteuci Effect and Nagoka-Honda Effect, Magnetic Delay Line Sensing, Application of Smart Sensors for Structural Health Monitoring (SHM), System Identification using Smart Sensors

UNIT-III

SMART ACTUATORS Modelling Piezoelectric Actuators, Amplified Piezo Actuation – Internal and External Amplifications, Magneto strictive Actuation, Joule Effect, Wiedemann Effect, Magneto volume Effect, Magneto strictive Mini Actuators, IPMC and Polymeric Actuators, Shape Memory Actuators, Active Vibration Control, Active Shape Control, Passive Vibration Control, Hybrid Vibration Control

UNIT-IV

SMART COMPOSITES Review of Composite Materials, Micro and Macro-mechanics, Modelling Laminated Composites based on Classical Laminated Plate Theory, Effect of Shear Deformation, Dynamics of Smart Composite Beam, Governing Equation of Motion, Finite Element Modelling of Smart Composite Beams

UNIT-V

ADVANCES IN SMART STRUCTURES & MATERIALS Self-Sensing Piezoelectric Transducers, Energy Harvesting Materials, Artophagous Materials, Self- Healing Polymers, Intelligent System Design, Emergent System Design

Text Books:

1. Brian Culshaw, Smart Structures and Materials, Artech House, 2000
2. Gauenzi, P., Smart Structures, Wiley, 2009 (c) Cady,
3. W. G., “Piezoelectricity”, Dover Publication.

OEC-II: NME471 COMPOSITE MATERIALS
C[L-T-P]: 2[2-0-0]

Prerequisite: Fundamental knowledge of material science and engineering materials.

Course Objective:

Course Outcomes:

Students will be able to

CO1	Understand the concepts of composite materials fabrications of composite and their properties.
CO2	Understanding fibrous and particulate composites, their stress strain behavior and important properties.
CO3	Analysis of laminated composites and understanding of orthotropic lamina and laminated theory.
CO4	Characterize composites by evaluating various mechanical properties.
CO5	Analyze and identify the damages in composite structures.

Course Content:

Unit I:

Introduction: Definition, Characteristics classification Particulate and fibrous composites. **Fibers Matrices and Fabrication of Composites:** Advance fibers, Glass fibers carbon and graphite fibers Aramid fibers Boron Fibers and other fibers. Matrix materials: Polymer and Metals, Fabrication of composites.

Unit II:

Behavior of unidirectional composites : Nomenclatures, volume and weight fractions, Longitudinal Strength and Stiffness, Transverse Stiffness and Strength, Prediction of shear and Poisson Ratio, Failure modes.
Short Fiber Composites Theories of stress transfer Modulus and Strength of Short fiber.

Unit III:

Analysis of an orthotropic Lamina : Hooke's law for orthotropic Materials, Stress- strain Relations and engineering Constants, Strength of an Orthotropic Lamina.

Unit IV:

Analysis of Laminated Composites : Strain and stress Variation in a laminate, Synthesis of Stiffness Matrix, Construction and Properties of Special Laminates, Dtermination of laminae stress and strains, Analysis of laminates after initial failure. Hygro-thermal stresses in Laminates.

Unit V:

Experimental Characterization of Composites Uniaxial Tension test, Uniaxial Compression Test, Inplane Shear test, Uniaxial Bending Tests Determination of Interlaminar Shear Strength and Fracture toughness.Damage Identification Using Nondestructive Evaluation Techniques.

Textbooks:

3. Analysis and Performance of fiber composite by Agrawal,B.D., Broutman L.J., John Wiley & Sons
4. Introduction to composite Materials by Tsai S.W.,Hahn H.T., Thechnomic West Port, Conn.

Reference books:

3. Primer on Composite Material Analyisis, Haplin J.C., Technomic Stanford, Conn.1984
4. Mechanics of composite materials, Jones R.M., Sripta Book Company Washington D.C.

OEC-II: NME473 OPTIMIZATION METHODS IN ENGG.
C[L-T-P] : 2[2-0-0]

Course Objective: The course aims at development of understanding regarding optimization of non-linear functions

Course Outcomes:

After successful completion of this course students will be able to

CO1	Learn classical optimization techniques.
CO2	Learn one dimensional minimization methods.
CO3	Solve unconstrained optimization Problems.
CO4	Solve Constrained optimization Problems.
CO5	Apply Genetic Algorithm to Optimization Problems.

Course Content:

Unit-I:

Introduction to Optimization: Introduction, Historical Development, Engineering application, Classification of Optimization Problems
Classical Optimization Techniques: Single variable Optimization, Multi variable optimization without constraint, with constraint and with inequality constraint.

Unit-II

One Dimensional Minimization Methods: Elimination methods- Unrestricted search, Exhaustive search, Dichotomous search, Interval Halving method, Fibonacci Method, Golden section method.

Unit-III

Unconstrained optimization Techniques:
Direct search methods- random search method, Grid search method, Univariate method, Pattern directions, Powell's method.
Indirect search Methods- Steepest Decent Method, Conjugate gradient Method, Newton's Method. Davidon-Fletcher-Powell method, BFGS Method.

Unit-IV:

C**onstrained optimization Techniques:**
Direct methods- Sequential Linear programming, Zoutendijk's Method of Feasible Directions.
Indirect methods-Interior penalty function method, Exterior penalty function Method.

Unit-V:

Modern Methods of Optimization:
Overview of Modern Methods of Optimization, Genetic Algorithm.

Text books:

1. Engineering Optimization Theory and Practice by Rao S.S.
2. Optimization Methods for Engineers by N.V.S. Raju, PHI.
3. Genetic Algorithms by Kalyanmoy Deb
4. Genetic Algorithms in search, optimization and machine learning by David E Goldberg, Pearson

Reference books:

1. Operations Research: Applications and Algorithms by Winston W L
2. Integer and Combinational Optimization by G.L.Nemhauser and L.A.Wolsey
3. Multi-objective evolutionary optimization for Product Design and Manufacturing by LihuiWang,
4. Methods of Optimization by Walsh G R.

Web Links:

1. https://youtu.be/_awAywLKuEQ
2. https://youtu.be/gY9c1ANeZrQ
3. https://youtu.be/84HOL_EiJ4M

VIII SEMESTER

Programme Elective -V (PEC-V)

PEC-V: NME472 AUTOMOBILE ENGG.
C[L-T-P]: 4[3-0-2]

Prerequisite: Course on I C Engine and Energy Conversion

Course Objectives:

This course aims at developing the understanding of different functional components of automobile and their use in automobile.

Course Outcomes:

After completion of this course, students will have ability to

CO1	Understand the basic requirements from automobile and technology used in them.
CO2	Understand working of different functional systems of automobile such as brakes, suspension system.
CO3	Understand working of different functional systems of automobile such as steering system and Gear Box..
CO4	Understand working of different functional systems of automobile such as Driveline system and Axles.
CO5	Understand working of different functional systems of automobile such as Vehicle Electrical systems and wheels and tyres.

Course Content:

Unit I

Introduction: Automobile and Automobile Engineering, history and development, classification of auto vehicles, status of modern auto vehicles, function and layout of automobiles, Automobile chassis, types of frames, design of frame, components, Design and working of I.C. Engine components, Rolling , Air, gradient resistance, terminologies associated with vehicles.

Unit II

Brakes: Principle of braking, weight transfer, types of brakes, factors influencing the braking effect, disc and drum brake, hydraulic brakes.

Suspension System: Introduction, types of suspension system, leaf springs, helically coiled spring, torsion bar, shock absorbers, independent front suspension system, independent rear suspension system.

Unit III

Steering Mechanism: Wheel alignment, principal of correct steering, layout of steering system, arrangement of steering linkage, steering gears.

Gear Box: Need of gear box, principle of gearing, types of gear boxes, constant mesh gear box, sliding mesh gear box, synchromesh gear box.

Unit IV

Driveline System: Propeller shaft, universal coupling, analysis and design of hooke's joint, differential assembly, automatic transmission system, torque converter, Overdrive.

Rear And Front Axle: Front Axle, rigid axle beam, stub axle, loads on rear axle and their mounting style, types of rear axle, types of drives, rear axle casing.

Unit V

Automotive Electrical System:

Starting system, Charging System, Ignition System, Lighting and Accessory system

Wheel and Tyre:

Wheel- requirement, construction, Types, Tyre- function characteristics, construction and types.

Textbooks:

1. Automobile Engineering by K.M. Gupta
2. Automobile engineering by R.K. Rajput
3. Automobile engineering by Kripal Singh
4. Automobile Mechanics by A. K. Babu, S.C. Sharma, T. R. Banga, Khanna Publishing.

Reference books:

1. The motor vehicle by Newton & W. Steeds
2. Automotive chassis &body by W.H. Crouse
3. Automotive Mechanics by Crouse and Anglin, McGraw Hill Education.
4. Automobile Engineering by P. S. Gill, Kataria & Sons.

Web Links:

1. https://youtu.be/hs7bABMtOMI
2. https://youtu.be/c3CalfdYZYw
3. https://youtu.be/ilh8bnzvm8Q

AUTOMOBILE ENGINEERING LAB

1. Study of braking systems & experiment on vacuum brake.

2. Study of steering systems & experiment on power steering.

3. Study on lubrication and cooling system.

4. Study on five speed gear box and differential gear box.

5.Study of cut section model of multi cylinder petrol and diesel engine.

6. Study of fuel supply system for petrol and diesel engine.

7. Study of front and rear axle assembly.

8. Comparative study of features of common small cars available in India.

9. Comparative study of technical features of common scooters & motorcycles available in India.

10. Comparative Study of Technical features of common heavy vehicles available in India.

11. Visit of an Automobile factory.

Note: - Other experiments can be taken up subject to availability of its experimental set ups. Minimum 8 experiments

PEC-V: NME474 OPTIMIZATION METHODS IN ENGG.
C[L-T-P] : 4[3-1-0]

Course Objective: The course aims at development of understanding regarding optimization of non-linear functions

Course Outcomes:

After successful completion of this course students will be able to

CO1	Learn classical optimization techniques.
CO2	Learn one dimensional minimization methods.
CO3	Solve unconstrained optimization Problems.
CO4	Solve Constrained optimization Problems.
CO5	Apply Genetic Algorithm to Optimization Problems.

Course Content:

Unit-I

Introduction to Optimization: Introduction, Historical Development, Engineering application, Classification of Optimization Problems

Classical Optimization Techniques: Single variable Optimization, Multi variable optimization without constraint, with constraint and with inequality constraint.

Unit-II

One Dimensional Minimization Methods: Elimination methods- Unrestricted search, Exhaustive search, Dichotomous search, Interval Halving method, Fibonacci Method, Golden section method.

Unit-III

Unconstrained optimization Techniques:
Direct search methods- random search method, Grid search method, Univariate method, Pattern directions, Powell's method.
Indirect search Methods- Steepest Decent Method, Conjugate gradient Method, Newton's Method. Davidon-Fletcher-Powell method, BFGS Method.

Unit-IV

C**onstrained optimization Techniques:**
Direct methods- Sequential Linear programming, Zoutendijk's Method of Feasible Directions.
Indirect methods-Interior penalty function method, Exterior penalty function Method.

Unit-V

Modern Methods of Optimization:
Overview of Modern Methods of Optimization, Genetic Algorithm.

Text books:

1. Engineering Optimization Theory and Practice by Rao S.S.
2. Optimization Methods for Engineers by N.V.S. Raju, PHI.
3. Genetic Algorithms by Kalyanmoy Deb

4. Genetic Algorithms in search, optimization and machine learning by David E Goldberg, Pearson

Reference books:

1. Operations Research: Applications and Algorithms by Winston W L
2. Integer and Combinational Optimization by G.L.Nemhauser and L.A.Wolsey
3. Multi-objective evolutionary optimization for Product Design and Manufacturing by LihuiWang,
4. Methods of Optimization by Walsh G R.

Web Links:

1. https://youtu.be/_awAywLKuEQ
2. https://youtu.be/gY9c1ANeZrQ
3. https://youtu.be/84HOL_EiJ4M

PEC-V: NME476 EXPERIMENTAL STRESS ANALYSIS
C[L-T-P]: 4[3-1-0]

Prerequisite: Knowledge of engineering mechanics and strength ofmaterials.

Course Objectives:

The objective of the subject is to make the student learn to apply modern experimental stress analysis techniques to measure strain and stresses in engineering components.

Course Outcomes:

Students will be able to

CO1	Analyse the 3-D state of stress in components with application of plane stress and plane strain conditions
CO2	Analyse 3D state of strain in the components. Understand various practical methods of analyzing strain in the components.
CO3	Understand the parameters, and practical applications of strain gages.
CO4	Understanding various aspects of photo elasticity and its application for stress analysis.
CO5	Understanding of two dimensional photoelasticity.

Course Content:

Unit I

Elementary Elasticity:

Stress: Introduction, Stress Equations of Equilibrium, Laws of Stress Transformations, principal Stresses, Two-Dimensional State of Stress, Stresses Relative to Principal Coordinate System, Special States of Stress.

Strain: Introduction, Displacement and Strain, Strain Transformation Equation, Principal Strains, Compatibility, Volume Dilation, Stress Strain Relations, Strain Transformation Equations and Stress Strain Relations for Two-Dimensional State of Stress.

Unit II

Strain Measurements: Introduction, Properties of Strain Gage Systems, Types of Strain Gages, Grid- Method of Strain Analysis.

Brittle Coating Method: Coating Stresses, Failure Theories, Brittle Coating Crack Patterns,

Resin and Ceramic Based Brittle Coating, Test Procedure, Analysis of Brittle CoatingData.

Unit III

Electrical Resistance Strain Gages: Introduction, Strain Sensitivity in Alloys, Strain Gage Adhesives, Gage Sensitivity and Gage Factor.

Strain Gage Circuit: Potentiometer and its Application, Wheat-Stone Bridge, Bridge Sensitivity, Null Balance Bridges.

Analysis of Strain Gage Data: Three Element Rectangular Rosette, Delta Rosette, Stress Gage, Plane Shear-Gage.

Unit IV

Theory of Photoelasticity: Introduction, Temporary Double Refraction, Stress Optic Law, Relative Retardation, Stressed Model in Plane Polariscope, Effect of Principal Directions, Effect of Principal Stress Difference, Stressed Model in Circular Polariscope, Light and Dark Field arrangements, Tardy Compensation, Fringe Sharpening and Multiplication by Partial Mirrors.

Unit V

Two Dimensional Photoelasticity: Introduction, Isochromatic Fringe Patterns, Isoclinic FringPatterns, Compensation Techniques, Calibration Methods, Separation Methods, Shear Difference Method, Electrical Analogy Method, Oblique Incidence Method, Materials for Two-Dimensional Photoelasticity.

Text Books:

1. Experiment Stress Analysis by James W. Dally and William F. Riley, International Student Edition, McGraw-Hill BookCompany.
2. Experimental Stress Analysis by L.S.Srinath et.al.

Reference books:

1. Experiment Stress Analysis by Dr. Sadhu Singh, Khanna Publishers.

PEC-V: NME478 COMPUTATIONAL FLUID DYNAMICS
C[L-T-P]: 4[3-1-0]

Pre-requisites: Module Fluid Mechanics, Theoretical Fluid Mechanics, Mathematics, Application of Software Tools

Course Objectives:

1. To briefly introduce Computational Fluid Dynamics, specifically, analysis of fluid mechanics and heat transfer.
2. To enhance the understanding of solid mechanics-related problems and to equip students with necessary engineering skills.
3. To enable the students to solve engineering problems using commercial software packages such as ANSYS Fluent and MATLAB.
4. To understand the students with data analysis and presentation, numerical simulations.
5. To enable the students to apply the CFD knowledge in the fluid flow problems.

Course Outcomes

Upon completion of this course, the students will be able to

CO1. Understand basic knowledge of computational methods in Fluid flow applications
CO2. Analyze Initial Boundary Value Problems and determine various quantities of Interest.
CO3. Apply the appropriate solution strategy and estimate the accuracy of the results for a given flow case
CO4. Select and formulate various CFD problems by considering appropriate boundary conditions.
CO5. Adapt to various commercial software for solving numerical problems

Unit 1.

Introduction: Need of CFD as a tool, role in R&D, Illustration of the CFD approach, Governing equations (Mass, momentum, and energy), Partial differential equations- Parabolic, Hyperbolic, and Elliptic equations.

Unit 2.

Different forms of Governing equations: Conservative, Non-conservative form and primitive variable forms of Governing equations. Decoupling of Governing equations, Characteristic variables. Relation between the two non-conservative forms.
Turbulence Modeling: Introduction Reynolds averaged Navier-Stokes equations, RANS modeling.

Unit 3.

Mesh generation: Overview of mesh generation, Structured and Unstructured mesh, Guideline on mesh quality and design, Mesh refinement and adaptation.
Solution Algorithms: Discretization schemes for pressure, momentum and energy equations – Explicit and implicit Schemes, First order upwind scheme, second order upwind scheme, QUICK scheme, SIMPLE, SIMPLER and MAC algorithm, pressure-velocity coupling algorithms, solution of Navier-Stokes equations.

Unit 4.

Overview of Numerical methods: Finite difference and Finite volume Methods, Convergence, Consistency, Error and Stability, Accuracy, Boundary conditions, CFD model formulation.

Unit 5.

CFD Solution Procedure and Case Studies: Problem setup – creation of geometry, mesh generation, selection of physics and fluid properties, initialization, solution control and convergence monitoring, results reports and visualization.
Case Studies: Benchmarking, validation, Simulation of CFD problems by use of general CFD software, Simulation of coupled heat, mass and momentum transfer problem.

Textbooks:

1. T.J. Chung, Computational Fluid Dynamics, , Cambridge University Press
2. P.S. Ghoshdastidar, Computational fluid dynamics and heat transfer, Cengage learning, 2017.
3. Charles Hirsch, Numerical Computation of Internal and External Flows: The Fundamentals of Computational Fluid Dynamics – Vol 1 &Vol 2, Butterworth- Heinemann, 2007

Reference Books:

1. Pletcher, R. H., Tannehill, j. C., Anderson, d., Computational fluid mechanics and heat transfer, 3rd ed., CRC press, 2011, ISBN 9781591690375.
2. H. K. Versteeg and W. Malalasekera, An Introduction to Computational Fluid Dynamics: The Finite Volume Method, Pearson, 2007, ISBN: 0131274988
3. Moin, P., Fundamentals of engineering numerical analysis, 2nd ed., Cambridge university press, 2010, ISBN 9780521805261 (e- book available).
4. Ferziger, J. H., Numerical methods for engineering application, 2nd ed., Wiley, 1998.
5. Ferziger, J. H., Peric, m., Computational methods for fluid dynamics, 3rd ed., Springer, 2002.

Web Links:

1. https://nptel.ac.in/courses/112105045
2. https://www.youtube.com/watch?v=t7jS7V_6TGQ&ab_channel=nptelhrd
3. https://onlinecourses.nptel.ac.in/noc23_ch10/preview
4. https://canes.mit.edu/computational-fluid-dynamics-cfd
5. https://www.cfd-online.com/

PEC-V: NME480 MACHINE TOOL DESIGN
C[L-T-P]: 4[3-1-0]

Prerequisite: Kinematics of Machines and Dynamics of Machines.

Course Objectives:

This course aims at developing capability to understand all about Machine Tools, Their fundamental aspects (Drives, speed and feed regulations), This This course aims at developing capability to understand all about Machine Tools, Their fundamental aspects (Drives, speed and feed regulations), components, design of components (bed, column, housing etc), working of elements, Dynamics of machine tools and its control.

Course Outcomes:

After successful completion of this course students will be able to

CO1	Understand classification of machine tools with their nomenclature, specification and uses.
CO2	Explain working of various drives mounted in machine tools.
CO3	Analyze the speed and feed box with the regulation of speed and feed rates.
CO4	Design components like structural bed, column, power screws etc.
CO5	Apply knowledge to study dynamics of machine tool and its control.

Course Content:

Unit-I

Introduction: Developments is machine tools, types of machine tools surface, profits and paths produced by machine tools. Features of construction and operations of basic machine tools e.g. lathe, drill, milling shapes and planers, grinding machine etc. General requirement of machine tool design. Machine tool design process. Tool wear, force Analysis.

Unit-II

Machine Tools Drives: Classification of machine tool drives, group Vs individual drives, Selection of electric motor, A brief review of the elements of mechanical transmission e.g. gear, belt and chain drives, Slider-crank mechanism, cam mechanism, nut & Screw transmission, Devices for intermittent motion, reversing & differential mechanisms. Couplings and clutches Elements of hydraulic transmission system. e.g.

pumps, cylinder, directional control valves, pressure valves etc., Fundamentals of Kinematics structure of machine tools.

Unit-III

Regulation of Speed and Feed rates: Laws of stepped regulation, selection of range ratio, standard progression ratio, selection of best possible structural diagram, speed chart, Design of feed box, Developing gearing diagrams. Stepless regulation of speed and feed in machine tool, speed and feed control.

Unit-IV

Design of Machine Tool Structure: Requirements and design criteria for machine tool structures, selection of material Basic design procedure for machine tool structures, design of bed, column and housing, Model technique in design.

Design of guide ways and power screws: Basic guide way profiles, designing guide way for stiffness a wear resistance, hydrostatic and antifriction grand ways. Design of sliding friction power Screws.

Unit-V

Design of spindle & spindle supports: Design of spindlier & spindle supports. Layout of bearings, selection of bearings for machine tools

Dynamics of machine tools: General procedure for assessing the dynamic stability of cutting process, closed loop system, chatter in machine tools.

Text books :

1. Machine Tools Design & Numerical Controls by N.K. Mehta, T.M.H. New Delhi.
2. Principles of Machine Tools by Bhattacharya A and Sen.G.C. New Central Book Agency.
3. Design of Machine Tools by S.K. Basu Allied Publishers.
4. **A Textbook of Machine Tools and Tool Design by P.C. Sharma, S. Chand Publication**

Reference books:

1. Machine Tool Handbook: Design and Operation by P.H. Joshi, McGraw Hill Education

2.Fundamentals of Metal Cutting and Machine Tools by Juneja, B.L.; Seth, Nitin and Sekhon, New age International Publishers.

3. Design of Machine Tools by **S.K. Basu , D.K. Pal ,** CBS Publishers & Distributors Pvt Ltd, India.

4. Fundamentals of Metal Machining and Machine Tools by **Geoffrey Boothroyd , Winston A. Knight .**

Web Links:

1. https://youtu.be/rHkbPcDgju0
2. https://youtu.be/dqMgVdNWnN0
3. https://youtu.be/A0dTvf_Q8BA

OPEN ELECTIVE-III (OEC-III)

OEC-III: OME482 TOTAL QUALITY MANAGEMENT
C[L-T-P]: 2[2-0-0]

Prerequisite:

Course Objectives: To eliminate waste and increase efficiencies by ensuring that the production process of the organization's product (or service) is done right the first time and improve product quality.

Course Outcomes:

After completion of the course a student will be able to:

CO1	The understanding of quality concepts, total quality management, development of sources, quality in sales and services, analysis of claims.
CO2	The knowledge of Organization structure and design, quality function deployment, quality cost, Attitude of top management, operator ‘s attitude and responsibility.
CO3	The understanding of mathematics of control charts, construction, and analysis of $\bar{X}$, R, p and C- charts and use of control charts.
CO4	The knowledge of Defects diagnosis and prevention, correcting measure, reliability control, maintainability, zero defects, quality circle, ISO-9000, Taguchi method and JIT in details.
CO5	Student will able to understand the quality management control toll and role of human factor and team work in the development of quality and productive manufacturing process.

Course Content:

Unit-I

Quality Concepts: Evolution of Quality concept, TQM concept, Quality concept in design. Control of purchased product, Evaluation of supplies, Capacity verification, Development of sources, Procurement procedure, Manufacturing Quality Methods and Techniques for manufacture. Control on Purchased Product: Procurement of various products, evaluation of supplies, capacity verification, Development of sources, procurement procedure.
Quality tool and techniques: Introduction to Six Sigma, Lean principles & continuous improvements
Quality concept in design: Design for six sigma(DFSS),Design for experiments(DOE) & Design for manufacturing(DFM)
Manufacturing Quality: Methods and Techniques for Inspection and control of product, Quality in sales and services, Guarantee, analysis of claims.

Unit II

Quality Management:
Organization structure and design, Quality function deployment, Economics of quality value and contribution, Quality cost: Prevention, appraisal, internal failure & external failure costs, optimizing quality & cost reduction programme, use of QM initiatives, tools, and techniques in an organization.
Human factor in quality:
Attitude of top management, co-operation of groups, operator ‘s attitude & responsibility causes of operator ‘s error and corrective methods.

Unit – III

Statistical process control(SPC):
Control charts:
Theory of control charts, construction and use of $\bar{x}$ & R charts, process capability study, use of control

charts, Limitations of X bar and R charts.

Attribute control charts

Defects, construction, and analysis of using p-chart, effect of variable sample size, construction, and use of C-chart

Unit IV

Defects Diagnosis and Prevention:

Defect study, identification and analysis of defects, corrective measures, factors affecting reliability, MTTF, calculation of reliability, Building reliability in the product, evaluation of reliability, interpretation of test results, reliability control, maintainability.

Failure Mode & Effect Analysis (FMEA): Introduction to FMEA, Risk assessment & prioritization of failure modes.

Reliability Engineering: Introduction to reliability concept, reliability prediction & reliability improvement technique.

Maintainability & Availability: Introduction to maintainability concept, Availability calculation & Preventive Maintenance Strategies

Unit V

Environmental management system: Introduction to ISO 14001 & Environmental Sustainability Practices

Lean manufacturing: Introduction to Lean Principles, Tool (eg.5S, Kanban) & Waste Reduction Techniques.

Total productive maintenance (TPM): Introduction to TPM concept & strategies for improving equipment effectiveness.

IS0-9000 and its concept of Quality Management:

Introduction, characteristics of quality assurance system. ISO -9000: scope, application, terms & definitions, evolution of ISO-9000 series, ISO 14000 Taguchi method, JIT- advantages and disadvantages. zero defects, quality circle.

Textbooks:

6. TQM in New Product Manufacturing - Menon, H.G. (McGraw Hill)
7. Total Quality Management - Lt. Gen. H. LaI (Wiley Eastern Limited)
8. Beyond Total Quality Management - Greg Bounds (McGraw Hill)
9. The Management & Control of Quality - Evans & Lindsay (Thompson South-Western).
10. Total Quality Management: Text & Cases - Jankiraman& Gopal (PHI Learning New Delhi).

Reference books:

5. Total Quality Management: A Primer - S M Sundara Raju (Tata McGraw Hill, New Delhi).
6. Introduction to Quality Management and Engineering - Sower, Savoie& Renick (Pearson Education Asia).
7. Total Quality Management - Besterfield Dale H (Pearson Education Asia, Second Edition).
8. Total Quality Management: A Practical Approach - H Lal (New Age International)

OEC-III: OME484 3D PRINTING
C[L-T-P]: 2[2-0-0]

Prerequisite: NIL

Course Outcome: Student will be able to	
CO 1	Understanding the basics of 3D printing and its application
CO 2	Understanding the various 3D Printing methods & Software
CO 3	Understanding the machine and process for metal 3D printing.
CO 4	Realizing the roles of 3D Printing for various common application such as fashion/ footwear/tools & Die/Drones etc.
CO 5	Implementation of 3D printing for health care and food industry.

COURSE CONTENT:

UNIT I: Introduction
Prototypes vs Product, Rapid prototyping vs Manufacturing, Historical background of AM, AM vs CNC Machining, Basic concept of AM process, steps in AM. Applications of AM for various industries. World scenario, growth rate of business.

UNIT II: Methods, Materials and Software
Preparation of CAD Models: The STL file /Problems / Manipulation, Brief discussion on AM Technologies based on mechanisms and materials for polymers, metals, ceramics – FDM/SLA/DLP/DIW/SLS/MJP. Multi Color and Multi-material 3D Printing; Lattice structure, Material for AM, Engineering Design Rules for AM. Material Handling, Software Issue for Additive Manufacturing;

UNIT III: Metal 3D Printing
Metal and Hybrid Systems. Metallic Powder based 3D printing, types of lasers; Metal-Polymer filament-based methods, Printing using direct printing of metallic wires. Metallic Porous structure, Applications Aerospace, Automotive, Manufacturing.

UNIT IV: Prototyping, Tools & Die applications
Development of 3D printed products for Tools & Die applications; Important areas of fashion and its utilities Fashion - Footwear& Jewelry and Toys; 3D printing for drones; Architectural application - Business opportunities, start-up stories

UNIT V: Health care and Food Industry.
3D scanning based models, intra oral scanners, CT Scan /MRI based models, 3D printing of Implants, prosthetics, dental applications; Bio-printing, Pharmaceutical applications; 4D Printing; Business opportunities, start-up stories. Food 3D Printers, application, start-up stories and business opportunities.

Text Books:
1. Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing, by Ian Gibson , D Savid W. Rosen , Brent Stucker, Springer.

Reference Book:
1. Understanding Additive Manufacturing, by Andreas Gebhardt, Hanser.
2. Additive Manufacturing, by- Amit Bandyopadhyay, Susmita Bose, CRC Press.
3. Rapid Prototyping: Principles and Applications, by Chee Kai Chua, Kah Fai Leong, Chu Sing Lim