Indian Institute of Technology Jodhpur

2nd year B.Tech Mechanical Engineering Curriculum Structure August 2020

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2nd year B.Tech Mechanical Engineering
Curriculum Structure

1. Introduction

Reckoned as one of the most versatile engineering disciplines, Mechanical Engineering virtually touches every aspect of modern life, from mobile phones and biomedical devices, to aircrafts and power plants. It is concerned with technological advancements through the development of products, processes, and power, at scales ranging from nano-scale to large and complex systems. Mechanical Engineering principles and skills are involved at some stage during the conception, design, development, and manufacture of every human-made object. While design and manufacturing involves design of mechanisms and the analysis of materials, thermo-fluid systems include methods of energy conversions, heat transfer and fluid flow. Future innovations crucial to the country's growth will always have their roots in the world of mass, motion, forces and energy- the world of mechanical engineers.

At IIT Jodhpur, mechanical engineers are therefore trained, educated and positioned, in a way not only to adapt, but to define direct change. This is reflected in the portfolio of current activities of the department. Our faculty are involved in a wide range of projects in the areas of Energy conversion and power systems, heat transfer and fluid mechanics, mechanics of solid, mechanical vibrations, robotics, autonomous unmanned vehicles, design optimization, acoustics and noise control, control systems, rotor dynamics, micro-nano materials and applications, biomechanics, bio inspired thermofluids, fluid structure interaction etc. to name a few. Additionally, efforts are being made to introduce advance concepts like smart manufacturing, Industry 4.O, computational techniques, high-performance computing, applications of artificial intelligence, machine learning algorithms, sensors and IoT as a part of solving mechanical engineering problems. Keeping a balance between theory and hands-on-experience, the department intends to provide its students a solid foundation in core as well as emerging areas of mechanical engineering by inspiring critical thinking and nurturing problem solving skills.

2. Objective of the program

The key objectives of this program are:

a. To enable students to have fundamental understanding of the core concepts of Mechanical Engineering
b. To integrate analytical and computational ability with experimental skills to create individuals competent in professional engineering practices
c. To stimulate critical thinking towards application of mechanical engineering concepts in interdisciplinary problem solving
d. To expose students to advanced concepts like AI & ML, Industry 4.0 and IoT for product and system design
e. To inculcate an attitude towards commitment to engineering ethics, leadership qualities and professional development.

3. Expected Graduate Attribute

Graduates of B.Tech program in Mechanical Engineering will have:

1. Strong understanding of fundamentals of Thermofluids, Mechanical Design and Manufacturing (Processes and Systems)
2. Ability to apply mechanical engineering principles to address challenges in real life problems through creative interdisciplinary thinking
3. Ability to use different simulation and computational tools for a better understanding and designing of mechanical processes/systems
4. Capability to appreciate the use of some of the advanced concepts like AI & ML, Robotics, Industry 4.0, IoT in Mechanical Engineering applications

5. Awareness of grassroots problems of the society and ability to provide technological solutions of sustainable nature.
6. Entrepreneurial spirit to undertake disruptive innovations
7. Skills to communicate engineering concepts and ideas to peers in written or oral forms
8. Commitment towards professional ethics and have humanitarian engineering skills.

4. Learning Outcome

Graduates of the B.Tech. program in Mechanical Engineering will:

1. Gain a strong understanding of mathematics, science and engineering fundamentals of mechanical engineering
2. Be able to design and conduct experiments as well as to analyze and interpret data
3. Be introduced to concepts including engineering design / optimization / sensors fabrication / computational methods / simulation tools /manufacturing systems and processes/ Industry 4.O/ thermal systems / fluid flow systems/ energy engineering/ micro-nano materials and applications/ AI/ IoT/ Smart Computing for various applications
4. Have the ability to design a mechanical system, component or process tailored to meet desired needs under socio-economic and environmental constraints
5. Be exposed to common problems that are prevalent in the domains of energy storage, systems and devices, clean energy, and micro-nano materials and applications, futuristic technology, and advanced scientific computation methods, allowing them to innovate and develop technological solutions for the same
6. Receive effective, hands-on laboratory training as a part of laboratory courses and short-term research projects
7. Develop their communication skills by participating in classroom presentations, seminars and workshops on manuscript / patent writing / presentation skills
8. Be taught the value of team work and group discussion in problem solving, and time management to continue co-curricular activities without compromising for academics.

5. New skillsets targeted

Multi and interdisciplinary approaches:

1. Design, develop and manufacturing of new or modified components for mechanical systems using computer-aided design/modelling software/additive manufacturing
2. Latest industrial pursuits, particularly in the areas of automation, robotics, and smart scientific computing, microfluidics etc.
3. Development of smart manufacturing capabilities for relevant industries
4. To play key roles in improving the range and performance of hybrid and electric automotive vehicles
5. Design of power-producing machines in the fields of alternative energies
6. Experimental validation of computational designs
7. Selection of materials based on engineering applications to ensure that it is safe, reliable and efficient
8. Advanced mechanical testing and characterization techniques
9. Familiarity with advanced and futuristic scientific computing techniques

6. Topic clouds and Mapping of Topic clouds with proposed courses

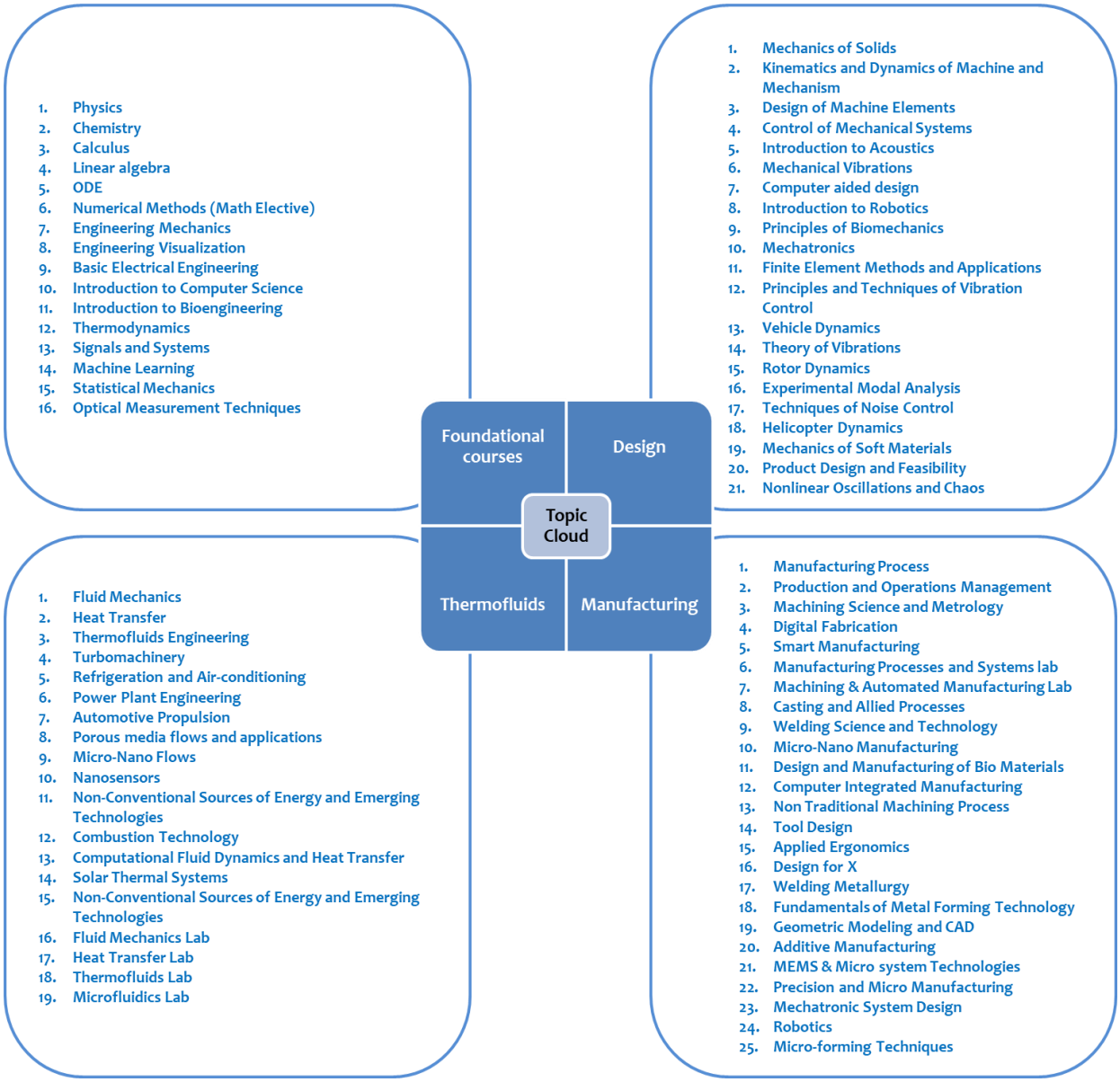

Table 1. Topics and Mapping of Topic with Courses

Area	**Topics**	**Category (Core/ Techniques Technology/Systems)**	**Course (PC/PE)**
Design	Stress, Strain, Bending & Torsion	Core	Mechanics of Solid (PC)

	Hydraulic and Pneumatic Systems, Mechatronic systems	Core and Techniques	Control of Mechanical Systems (PC)
	Geometric & Functional Requirements, Theory of Failures, Design and Selection of Machine Elements	Core and Techniques	Design of Machine Elements (PC)
	Mechanism Synthesis, Motion Analysis, Force Analysis, Gear Trains, Cams, Dynamics of Multi-Cylinder Engines	Core and Techniques	Kinematics & Dynamics of Machines (PC)
	Engineering Mechanics	Core	Engineering Mechanics (IE)
	Advanced concepts of stress analysis, analysis of systems such as rotating disks, thick cylinders etc.	Core	Advanced Mechanics of Solids (PE)
	Galerkin methods Finite element methods	Techniques	Finite element Methods and Applications (PE)
	Mechanical vibrations of one, two and multi degree of freedom systems, types of damping, vibration control	Core	Mechanical Vibrations (PE)
	Noise control of various engineering applications	Core and Techniques	Techniques of Noise Control (PE)
	Advanced Theories in Vibration	Core	Principles and Techniques of Vibration Control (PE)
	Theory of Helicopter Flight	Techniques and Technology	Helicopter Dynamics (PE)
	kinematics & kinetics of microsystem deformations	Core and Techniques	Micro-Nano Mechanics (PE)
	Non-linear mechanical behaviours displayed by	Core and Techniques	Mechanics of Soft Materials (PE)

	soft materials and tissues		
	Product life cycle, Product Design	Core and Techniques	Product Design and Feasibility
	Modal Analysis Measurement Techniques	Techniques	Experimental Modal Analysis (PE)
	Curves, Surfaces and Solid Modeling	Core, systems and Techniques	Computer aided Design (PE)
	Electro-Mechanical systems	Systems and Technology	Mechatronics (PE)
	Biomechanical systems	Systems and Techniques	Principles of Biomechanics (PE)
	Control system	Systems and Techniques	Control Systems (PE)
	Experimental Robotics	Systems and Techniques	Introduction to Robotics (PE)
	Dynamics of rotating machines	Core and Systems	Rotor Dynamics
	Links, mechanisms and dynamics in vehicles	Systems	Vehicle dynamics (PE)
	Nonlinear phenomena and solutions, bifurcation and stability, Chaos	Core and Techniques	Nonlinear Oscillations and Chaos (PE)
	Theory of sound generation, propagation and reception.	Systems	Introduction to Acoustics (PE)
Manufacturing	Theory of Casting, Welding and Forming	Core and Techniques	Manufacturing Process
	Principles in Production & Operations Management	Core and Techniques	Production and Operations Management (PC)
	Techniques in Machining Science and Metrology	Core and Techniques	Machining Science and Inspection Technology (PC)
	Principles of Smart Manufacturing	Core and Techniques	Smart Manufacturing (PC)

	Principles of Digital fabrication	Core and Techniques	Digital Fabrication (PC)
	Manufacturing Lab	Core and Techniques	Manufacturing Process and Systems Lab (PC)
	Machining Lab	Core and Techniques	Machining and Automated Manufacturing Lab (PC)
	Casting and Allied Processes Technology	Core and Technology	Casting and Allied Processes (PE)
	Welding Science and Technology Technology	Core and Technology	Welding Science and Technology (PE)
	Micro-Nano Manufacturing Technology	Core and Technology	Micro-Nano Manufacturing (PE)
	Design and Manufacturing of Bio Materials	Core and Technology	Design and Manufacturing of Bio Materials (PE)
	Principles of Computer Integrated Manufacturing	Core and Technology	Computer Integrated Manufacturing (PE)
	Non Traditional Machining Process Technology	Core and Technology	Non Traditional Machining Process (PE)
	Tool Design Techniques	Core and Technique	Tool Design (PE)
	Modeling and CAD in Product Design	Technique and Technology	Geometric Modeling and CAD
	Modeling and Control of Robot Manipulators	Technique and Technology	Robotics (PE)
	CNC Technology in manufacturing	Technique and Technology	Computer-Aided Manufacturing (PE)
	Technologies for additive rapid manufacturing	Technique and Technology	Additive Manufacturing (PE)
	Micro systems and its manufacturing techniques	Technique and Technology	MEMS & Microsystem Technologies (PE)

	Modern methods of micro-forming technologies	Technique and Technology	Micro Forming Techniques (PE)
	Precision Micro/Nano Manufacturing	Mechatronic System Design	Precision and Micro Manufacturing(PE)
	Elements of Mechatronic System Design	Mechatronic System Design	Mechatronic System Design (PE)
	Applied Ergonomics	Core and Technology	Applied Ergonomics (PE)
	Design for Manufacturing	Core and Technology	Design for Manufacturing (PE)
	Welding metallurgy Technology	Core and Technology	Welding Metallurgy (PE)
	Forming Technology	Core and Technology	Fundamentals of Metal Forming Technology (PE)
Thermofluids	Fluid Statics, Kinetics, Inviscid and Viscous Flow, Turbulence and Compressible flows	Core and Techniques	Fluid Mechanics (PC)
	Conduction, Convection, Radiation, Boiling & Condensation	Core and Techniques	Heat Transfer (PC)
	Thermodynamics	Core	Thermodynamics (PC)
	Heat engines and Power Plant Cycles, Turbomachines, Refrigeration and Air-conditioning	Systems and Technique	Thermofluids Engineering (PC)
	Turbines, pumps & Compressors	Systems and Technique	Turbomachinery (PE)
	Combustion engines	Systems and Technique	Automotive Propulsion(PE)
	Refrigeration cycles and air-conditioning systems	Systems and Technique	Refrigeration and Air-conditioning(PE)

	Cycles in power plant and energy conversion systems	Systems and Technique	Power Plant Engineering(PE)
	Fluid dynamics in porous media	Core and Technique	Porous media flows and applications(PE)
	Computational techniques for heat and fluid flow	Core and Technique	Computational Fluid Dynamics and Heat Transfer (PE)
	Solar Energy systems	Technique and Technology	Solar Thermal Systems (PE)
	Liquid transport in micro-nano flows	Core and Techniques	Micro-Nano Flows (PE)
	Exposer to various sensors and equipments used in micro system analysis	Core and Techniques	Micro Fluidics Lab (PE)
	Characterizing of sensors based on nanomaterials	Technique and Technology	Nano Sensors (PE)
	Non-Conventional energy sources and Technologies	Technique and Technology	Non-Conventional Sources of Energy and Emerging Technologies (PE)
	Fuel Combustions, Premixed Flames	Core and Techniques	Combustion Technology (PE)
	Fluid Flow Measurement	Systems and Techniques	Fluid Mechanics Lab (PE)
	Heat Transfer Measurements	Systems and Techniques	Heat Transfer Lab (PE)
	Measurements in various Thermofluids equipment's	Systems and Techniques	Thermofluids Lab (PE)

7. Course Categories, credit distribution and Credit Structure of B.Tech. Programmes

Table 2. ProposedCourse Categories and credit distribution in the proposed B.Tech. Programmes

S.N.	Course Type	Course Category	Regular B.Tech.		Double B.Tech.	
			Credit	Total	Credit	Total
1	Institute Core (I)	Engineering (IE)	**34**	**69**	**34**	**59**
		Science (IS)	16		**16**	
		Humanities (IH)	12		9	
2	Programme Linked (L)	Science (LS)	7		0	
3	Programme Core (P)	Programme Compulsory (PC)	**52**	**71**	**52**	**71**
		Programme Electives (PE)	**16**		**16**	
		B.Tech. Project (PP)	3		3	
4	Open (O)	Open Electives (OE)	10	**10**	0	**0**
5	Engineering Science (E)	Engineering Science Core	0	**0**	**22**	**22**
		Engineering Science Elective (EE)	0	**0**	**8**	**8**
Total Graded				**150**		**160**
6	Non-Graded (N)	Humanities (NH)	6	**15**	6	**15**
		Engineering (NE)	3		3	
		Design/Practical Experience (ND)	6		6	
Total Graded + Non-Graded				**165**		**175**

8. Credit Structure of B.Tech. Programmes

Table 3. Credit Structure for B.Tech. Programmes

Type	L-T-P	Distribution of contact and beyond contact hours			Total Credits (TC=TH/3)
		Contact Hours (CH)	Beyond Contact Hours (BCH)	Total Hours (TH)	
1 hour of Lecture	1-0-0	1 hr	2 hr	3 hr	1
1 hour of Tutorial	0-1-0	1 hr	2 hr	3hr	1
1 hour of Lab/Project	0-0-1	1 hr	0.5 hr	1.5 hr	0.5

#Contact hour for projects refers to the involvement of students in the laboratory, discussion, etc.

9. List of Programme Compulsory Courses

Table 4. Distribution of courses under Thermofluids, Manufacturing and Design categories

Sr. No	Course Name	LTP	Contact Hours	Credit
1	Fluid Mechanics	3-1-0	4	4
2	Fluid Mechanics-Lab	0-0-2	2	1
3	Heat Transfer	3-0-0	3	3
4	Heat Transfer-Lab	0-0-2	2	1
5	Thermofluids Engineering	3-1-0	4	4
6	Thermofluids Engineering Lab	0-0-2	2	1
7	Thermodynamics	3-1-0	4	4
Total				**18**
1	Mechanics of Solids	3-1-0	4	4
2	Kinematics and Dynamics of Machines	3-0-2	5	4
3	Design of Machine elements	3-0-2	5	4
4	Engineering Visualization	0-0-2	2	1
5	Engineering Mechanics	2-1-0	3	3
6	Engineering Design I	0-0-2	2	1
7	Engineering Design II	0-0-2	2	1
Total				**18**
1	Manufacturing Process	3-0-0	3	3
2	Production & Operations Management	3-0-0	3	3
3	Machining Science and Metrology	3-0-0	3	3
4	Digital Fabrication	3-0-0	3	3
5	Smart Manufacturing	2-0-2	3	3
6	Manufacturing Processes and Systems lab	0-0-2	2	1

7	Machining and Automated Manufacturing Lab	0-0-2	2	1
8	Engineering Realization	0-0-2	2	1
Total				**18**
Total				53

Table 5.Programme Vertical Compulsory Courses

Sr. No	Course Name	LTP	Contact Hours	Credit
1	Fluid Mechanics	3-1-0	4	4
2	Fluid Mechanics-Lab	0-0-2	2	1
3	Heat Transfer	3-0-0	3	3
4	Heat Transfer-Lab	0-0-2	2	1
5	Thermofluids Engineering	3-1-0	4	4
6	Thermofluids Engineering Lab	0-0-2	2	1
7	Mechanics of Solids	3-1-0	4	4
8	Kinematics and Dynamics of Machines	3-0-2	5	4
9	Design of Machine elements	3-0-2	5	4
10	Manufacturing Process	3-0-0	3	3
11	Production & Operations Management	3-0-0	3	3
12	Machining Science and Metrology	3-0-0	3	3
13	Digital Fabrication	3-0-0	3	3
Total				38

Table 6. Programme Horizontal Compulsory Courses

Sr. No	Course Name	LTP	Contact Hours	Credit
1	Control of Mechanical Systems	3-0-4	7	5
2	Data Structure and Algorithm (CS)	3-0-2	5	4
3	Smart Manufacturing	2-0-2	3	3
4	Manufacturing Processes and Systems lab	0-0-2	2	1

5	Machining and Automated Manufacturing Lab	0-0-2	2	1
Total				14

10. Area-wise Programme Elective Courses

Table 7. Stream-wise Programme Electives Courses

Area	S.No	Courses	L-T-P	Credit	Course Level
Design	1	Introduction to Acoustics	3-0-0	3	400
	2	Mechanical Vibrations	3-0-0	3	400
	3	Computer Aided Design	3-0-2	4	400
	4	Principles of Biomechanics	3-0-0	3	400
	5	Mechatronics	2-0-2	3	600
	6	Finite Element Methods and Applications	3-0-0	3	600
	7	Introduction to Robotics (offered by IDRP on RM)	3-0-0	3	400
	8	Embedded Systems (offered by electrical)	3-0-2	4	300
Manufacturing	1	Tool Design	3-0-0	3	400
	2	Applied Ergonomics	3-0-0	3	400
	3	Micro-Nano Manufacturing	3-0-0	3	400
	4	Design and Manufacturing of Bio Materials	3-0-0	3	600
	5	Computer Integrated Manufacturing	3-0-0	3	600
	6	Design for Manufacturing	3-0-0	3	600

ThermoFluids	1	Turbomachinery	3-0-0	3	400
	2	Refrigeration and Air-conditioning	3-0-0	3	400
	3	Solar Thermal Systems	3-0-0	3	600
	4	Porous media flows and applications	3-0-0	3	600
	5	Power Plant Engineering	3-0-0	3	700
	6	Computational Fluid Dynamics and Heat Transfer	3-1-0	4	700

11. Specialization to be offered by the department

Table 8. Specializations List

S. No.	Name of Specializations	Credit requirement	
		Core	**Elective**
1	Micro-Nano Engineering	8 credits	12 credits
2	Energy Engineering	8 credits	12 credits
2	Design Engineering	8 credits	12 credits
3	Smart Manufacturing	8 credits	12 credits

Table 9. Specialization core and elective courses

S. No.	Name of Specialization	Specialization Core (8 credits)	Specialization Electives (12 credits)
1	Micro-Nano Engineering	1. Micro-Nano Flows *[3-0-0, Credit:3, 600 Level]* 2. MEMS and Microsystems Technology *[3-0-2, Credit:4, Level: 700]* 3. Microfluidics Lab *[0-0-2, Credit:1, 600 level]*	1. *Nanomaterials (MT)[3-0-0, Credit:3, Level: 400]* 2. Porous media flows & applications *[3-0-0, Credit:3, Level: 600]* 3. Precision and Micro-Manufacturing *[3-0-0, Credit:3, Level: 700]* 4. Nanosensors *[3-0-0, Credit:3, Level: 700]* 5. Microsystems Fabrication Technology (EE) *[3-0-0, Credit:3, Level: 700]* 6. Micro-Forming Techniques *[3-0-0, Credit:3, Level: 700]* 7. Micro-Nano Mechanics*[2-0-0, Credit:2, Level: 600]* 8. *Computational Fluid Dynamics and Heat Transfer [3-1-0, Credit:4, 700 Level]* 9. Computational Materials Science *(PH)[3-0-0, Credit:3, Level: 700]* 10. *Project (3 Credits)*
2	Energy Engineering	1. Solar Thermal Systems (ME) *[3-0-0, Credit:3, Level: 600]*	1. Non-Conventional Sources of Energy and Emerging Technologies (ME) *[3-0-0, Credit:3, Level: 700]* 2. Solar Energy and Applications (ME) *[3-0-2, Credit:4, Level: 700]*

		2. Power Plant Engineering *[3-0-0, Credit:3, Level: 700]* 3. Energy Storage Systems (ME fractals) *[2-0-0, Credit:2, Level: 700]*	3. Wind turbine and field design (Civil)*[3-0-0, Credit:3, Level: 700]* 4. Energy Harvesting *(PHY)[3-0-0, Credit:3, Level: 700]* 5. Biomass Energy Conversion(BIO) *[3-0-0, Credit:3, Level: 700]* 6. Hydropower (ME)*[3-0-0, Credit:3, Level: 700]* 7. Building services and Intelligent building (Civil)*[3-0-0, Credit:3, Level: 700]* 8. Smart Grid (EE) *[3-0-2, Credit:4, Level: 700]* 9. Computational Fluid Dynamics and Heat Transfer *[3-1-0, Credit:4, 700 Level]* 10. Renewable Energy Systems (EE) *[3-0-0, Credit:3, Level: 700]* 11. Automotive Propulsion *[3-0-2, Credit:4, Level: 700]* 12. Combustion Technology *[3-0-0, Credit:3, Level: 700]* 13. Materials for Energy Conversion and Storage *(MT)[3-0-0, Credit:3, Level: 400]* 14. Conduction and Radiation *[3-0-0, Credit:3, Level: 700]* 15. Convective Heat and Mass Transfer *[3-0-0, Credit:3, Level: 700]* 16. Porous media flows & applications *[3-0-0, Credit:3, Level: 600]* 17. *Project Credit:3*
2	Design Engineering	1. Advanced Mechanics of Solid *[3-0-0, Credit:3, 700 Level]* 2. Finite Element Methods and its Application *[3-0-0, Credit:3, 600 Level]* 3. Optimization *[1-0-0, Credit:1, 600 Level]* 4. Design Lab *[0-0-2, Credit:1, 600 Level]*	1. Mechanical Vibrations *[3-0-0, Credit:3, 700 Level]* 2. Introduction to Acoustics *[3-0-0, Credit:3, 600 level]* 3. Geometric Modeling & CAD *[2-0-2, Credit:3, 700 Level]* 4. Robotics *[3-0-2, Credit:4, 700 Level]* 5. Principles and Techniques of Vibration Control *[3-0-0, Credit:3, 600 level]* 6. Techniques of Noise Control*[3-0-0, Credit:3, 600 level]* 7. Mechanics of Soft Materials*[3-0-0, Credit:3, 600 level]* 8. Product Design & Feasibility*[3-0-0, Credit:3, 600 level]* 9. Nonlinear Oscillations and Chaos *[3-0-0, Credit:3, 600 Level]* 10. Experimental Modal Analysis *[3-0-2, Credit:4, 600 Level]* 11. Vehicle Dynamics *[3-0-0, Credit:3, 600 Level]*

			12. Theory of vibrations *[3-0-0, Credit:3, 700 Level]* 13. Rotor Dynamics *[3-0-0, Credit:3, 700 Level]* 14. Helicopter Dynamics *[3-0-0, Credit:3, 700 Level]* 15. *Project Credit:3*
3	Smart Manufacturing	1. Artificial Intelligence-1: CS [3-0-0, Credit:3] 2. Introduction to Cyber Physical Systems: CPS [3-0-0, credit:3] 3. Statistics 2: Data & Computational Science [2-0-0, credit:2]	1. Applied Ergonomics *[3-0-0, Credit:3, 400 Level]* 2. Casting and Allied Processes *[3-0-0, Credit:3, 400 Level]* 3. Welding Science & Technology *[3-0-2, Credit:4, 400 Level]* 4. Non Traditional Machining Process *[3-0-0, Credit:3, 400 Level]* 5. Design for Manufacturing *[3-0-0, Credit:3, 600 Level]* 6. Geometric Modelling & CAD *[2-0-2, Credit:3, 700 Level]* 7. Robotics *[3-0-2, Credit:4, 700 Level]* 8. Computer-Aided Manufacturing *[3-0-2, Credit:4, 700 Level]* 9. Additive Manufacturing *[3-0-0, Credit:3, 700 Level]* 10. MEMS & Microsystems Technology *[3-0-2, Credit:4, 700 Level]* 11. Precision and Micro Manufacturing *[3-0-0, Credit:3, 700 Level]* 12. Mechatronic Systems Design *[3-0-0, Credit:3, 700 Level]* 13. Computer Aided Inspection & Quality Control *[3-0-0, Credit:3, 700 Level]* 14. Welding Metallurgy *[3-0-0, Credit:3, 700 Level]* 15. Fundamentals of Metal Forming Technology*[3-0-0, Credit:3, 600 Level]* *16.* Micro-forming Techniques *[3-0-0, Credit:3, Level: 700]* 17. Project *Credit:3*

11. Curriculum of B.Tech. Mechanical Engineering (Regular)

Table 10. Curriculum of B.Tech. Mechanical Engineering

Cat	*Course*	*LTP*	*CH*	*NC*	*GC*	*Cat*	*Course*	*LTP*	*CH*	*NC*	*GC*
I Semester						**II Semester**					
IE	Engineering Mechanics	2-1-0	3	-	3	IE	Introduction to Electrical Engineering	3-0-2	5	-	4
IS	Chemistry	3-0-0	3	-	3	IE	Introduction to Computer Science	3-0-2	5	-	4
IS	Physics	3-0-0	3	-	3	IE	Introduction to Bioengineering	3-0-2	5	-	4
IS	Chemistry Lab	0-0-2	2	-	1						
IS	Physics Lab	0-0-2	2	-	1						
IS	Mathematics I	3-1-0	4	-	4	IS	Mathematics II	3-1-0	4	-	4
IE	Engineering Visualization	0-0-2	2	-	1	IE	Engineering Realization	0-0-2	1	-	1
NE	Engineering Design I	0-0-2	2	1	-	NE	Engineering Design II	0-0-2	2	1	-
NH	Communication Skill I	0-0-2	2	1	-	NH	Communication Skill II	0-0-2	2	1	-
NH	Social Connect and responsibilities I	0-0-1	1	0.5	-	NH	Social Connect and responsibilities II	0-0-1	1	0.5	-
NH	Performing Arts I /Sports I	0-0-1	1	0.5	-	NH	Performing Arts II/Sports II	0-0-1	1	0.5	-
	Total	**11-2-12**	**25**	**3**	**16**		**Total**	**12-1-14**	**27**	**3**	**17**
III Semester						**IV Semester**					

LS	Scientific Computations	3-1-0	4	-	4	IE	Materials Science & Engineering F1:Material Selection F2: Structure of Materials F3: Physical Metallurgy	3 × 1-0-0	3	-	3
IE	Thermodynamics	3-1-0	4	-	4	PC	Data Structure and Algorithm	3-0-2	5		4
PC	Mechanics of solids	3-1-0	4	-	4	IE	Signals and Systems	3-1-0	4	-	4
IE	Introduction to Machine Learning	3-0-2	5	-	4	PC	Fluid Mechanics	3-1-0	4	-	4
						PC	Fluid Mechanics-Lab	0-0-2	2		1
LS	Statistical Mechanics	2-0-0	2	-	2	PC	Manufacturing Process	3-0-0	3	-	3
	Optical Measurement Techniques	1-0-0	1		1	IH	Humanities I	3-0-0	3	-	3
NE	Intro. To Profession	0-1-0		1							
	Total	**15-3-2**	**20**	**1**	**19**		**Total**	**18-2-4**	**24**	**-**	**22**
V Semester						**VI Semester**					
PC	Production & Operations Management	3-0-0	3	-	3	PC	Design of Machine elements	3-0-2	5		4
PC	Manufacturing Processes and Systems lab (HC)	0-0-2	2	-	1	PC	Machining and Automated Manufacturing Lab (HC)	0-0-2	2		1
PC	Heat Transfer	3-0-0	3		3	PC	Smart Manufacturing(HC)	2-0-2	4		3
PC	Kinematics and Dynamics of Machines	3-0-2	5		4	PC	Thermofluids Engineering	3-1-0	4		4

PC	Machining Science and Metrology	3-0-0	3		3	PC	Control of Mechanical Systems –(HC)	3-0-4	7		5
PC	Digital Fabrication	3-0-0	3		3	PE	Programme Elective-1	3-0-0	3		3
PC	Heat Transfer Lab	0-0-2	2		1						
IH	Humanities II	3-0-0	3	-	3						
NH	Professional Ethics I	0-1-0		1	-	NH	Professional Ethics II	0-1-0		1	-
	Total	**18-0-6**	**24**	**1**	**21**		**Total**	**14-1-10**	**25**	**1**	**20**
VII Semester						**VIII Semester**					
PP	B. Tech. Project	0-0-6	6	-	3	IH	Humanities IV	3-0-0	3	-	3
PE	Programme Electives	6-0-0	6	-	6	PE	Programme Electives	7-0-0	7	-	7
PC	Thermofluids Lab	0-0-2	2		1	OE	Open Elective-2	3-1-0	4		4
OE	Open Elective-1	3-0-0	3		3	OE	Open Elective-3	3-0-0	3		3
IH	Humanities III	3-0-0	3	-	3						
IS	Environmental Science	2-0-0	2	-	2						
	Total	**14-0-8**	**22**	**-**	**18**		**Total**	**16-1-0**	**17**	**-**	**17**
										9	**150**
										6	**-**
										15	**165**

13. Curriculum of Double B.Tech. : B.Tech. Mechanical Engineering and Engineering Science

Table 11. Programme structure of Double B.Tech.

Cat	*Course*	*LTP*	*CH*	*NC*	*GC*	*Cat*	*Course*	*LTP*	*CH*	*NC*	*GC*
	I Semester						**II Semester**				
IE	Engineering Mechanics	2-1-0	3	-	3	IE	Introduction to Electrical Engineering	3-0-2	5	-	4
IS	Chemistry	3-0-0	3	-	3	IE	Introduction to Computer Science	3-0-2	5	-	4
IS	Physics	3-0-0	3	-	3	IE	Introduction to Bioengineering	3-0-2	5	-	4
IS	Chemistry Lab	0-0-2	2	-	1						
IS	Physics Lab	0-0-2	2	-	1						
IS	Mathematics I	3-1-0	4	-	4	IS	Mathematics II	3-1-0	4	-	4
IE	Engineering Visualization	0-0-2	2	-	1	IE	Engineering Realization	0-0-2	1	-	1
NE	Engineering Design I	0-0-2	2	1	-	NE	Engineering Design II	0-0-2	2	1	-
NH	Communication Skill I	0-0-2	2	1	-	NH	Communicatio n Skill II	0-0-2	2	1	-
NH	Social Connect and responsibilities I	0-0-1	1	0.5	-	NH	Social Connect and responsibilities II	0-0-1	1	0.5	-
NH	Performing Arts I /Sports I	0-0-1	1	0.5	-	NH	Performing Arts II/Sports II	0-0-1	1	0.5	-
	Total	**11-2-12**	**25**	**3**	**16**		**Total**	**12-1-14**	**27**	**3**	**17**

	III Semester						IV Semester				
ES	Probability and Statistics	3-1-0	4	-	4	IE	Materials Science & Engineering F1: Material Selection F2: Structure of Materials F3: Physical Metallurgy	3 × 1-0-0	3	-	3
ES	Modern Physics	3-0-0	3	-	3	ES	Embedded Systems and IoT	3-0-2	5	-	4
IE	Thermodynamics	3-1-0	4	-	4	ES	Data Structure and Algorithm	3-0-2	5	-	4
IE	Signals and Systems	3-1-0	4	-	4	ES	Design of Experiments	3-0-0	3		3
IE	Machine Learning	3-0-2	5	-	4	ES	Modelling and Simulation	3-0-2	5	-	4
NE	Intro. To Profession	0-0-2		2		IH	Humanities I	3-0-0	3	-	3
	Total	**15-3-2**	**20**	**2**	**19**		**Total**	**18-0-6**	**24**	**-**	**21**

	V Semester						VI Semester				
PC	Manufacturing Processes and Systems lab (H)	0-0-2	2	-	1	PC	Design of Machine elements	3-0-2	5		4
PC	Heat Transfer	3-0-0	3		3	PC	Fluid Mechanics-Lab	0-0-2	2		1
PC	Kinematics and Dynamics of Machines	3-0-2	5		4	PC	Machining and Automated Manufacturing Lab (HC)	0-0-2	2		1
PC	Machining Science and Metrology	3-0-0	3		3	PC	Smart Manufacturing(HC)	2-0-2	4		3

PC	Mechanics of solids	3-1-0	4	-	4	PC	Thermofluids Engineering	3-1-0	4		4
PC	Fluid Mechanics	3-1-0	4	-	4	PE/Es	Control of Mechanical Systems	3-0-4	7		5
PC	Heat Transfer Lab	0-0-2	2		1	PC	Manufacturing Process	3-0-0	3	-	3
IH	Humanities II	3-0-0	3	-	3	PE	Programme Electives-2	3-0-0	3		3
NH	Professional Ethics I	0-1-0	1	1	-	NH	Professional Ethics II	0-1-0	1	1	-
	Total	**18-2-6**	**26**	**1**	**23**		**Total**	**17-2-10**	**30**	**1**	**24**
	VII Semester						**VIII Semester**				
PP	B. Tech. Project	0-0-6	6	-	3	PE/ES	Programme/Engineering Science Electives	15-0-0	15	-	15
PC	Production & Operations Management	3-0-0	3	-	3	IH	Humanities III	3-0-0	3	-	3
PC	Digital Fabrication	3-0-0	3		3	PC					
ES	Scientific Computation	3-0-2	5		4						
PC	Thermofluids Lab	0-0-2	2		1						
PE/OE	Programme/Engineering Science Electives	6-0-0	6	-	6						
IS	Environmental Science	2-0-0	2	-	2						
	Total	**17-0-10**	**27**	**-**	**22**		**Total**	**18-0-0**	**18**	**-**	**18**
									Total of graded and Non-Graded Credit	**9**	**160**
									Non-Graded Design Credits	**6**	**-**

Grand Total	**15**	**170**

Note: 1. ES are proposed Engineering Science compulsory courses,
* Students will be required to take 4 extra credits under Engineering Science Elective in lieu of double counting of Embedded System and IOT

14. Detailed Course Content of Programme Compulsory Courses

Title	**Fluid Mechanics**	Number	MEL2XX0/ CHL2XX0
Department	Mechanical Engineering/ Chemical Engineering	L-T-P [C]	3–0–0[3]
Offered for	B.Tech (ME, CH)	Type	Program Compulsory (PC)
Prerequisite			

Objectives

The instructor will

1. To inculcate the fundamental laws governing fluid flow
2. Help the students to understand the importance and application of fluid mechanics.
3. To exemplify concepts of similarity and model testing

Learning Outcomes

The students are expected to have the ability to:

1. Apply fundamental knowledge in modelling and analysis of fluid flow problems in engineering
2. Interpret data from experiments of fluid flows and solve using differential equations and charts

Contents

Introduction [2 Lecture]: Definition and properties, continuum approach, types of fluids, basics of vector calculus and index notations.

Fluid statics [4 Lectures]: Basic equations, Manometry, hydrostatic force on submerged bodies, rigid body motion.

Integral analysis of fluid flow [4 Lectures]: Reynolds transport theorem, conservation equations.

Differential analysis [5 Lectures]: Kinematics of fluids - Deformations in fluid particle, strain rate, vorticity, stream function, potential function, streamlines, pathlines, streaklines, derivation of Navier-Stokes equations.

Incompressible Inviscid flow [6 Lectures]: Euler's equation, Bernoulli's equation, elementary potential flows, superposition of elementary flows. Vorticity and vortex flows

Internal Incompressible Viscous flow [4 Lectures]: Hagen-Poiseuille and *Couette* flows, skin friction and loss coefficients, venturimeter, orifice meter and Pitot tube.

External Incompressible Viscous flow [5 Lecture]: Boundary layer over flat plate, boundary layer thickness, Prandtl-boundary layer equations, momentum integral equation, adverse pressure gradient & separation, drag coefficients.

Dimensional analysis and similarity [2 Lectures]: Buckingham Pi theorem and examples.

Introduction to Turbulent flows [3 Lectures]: Decomposition of instantaneous velocities, time-averaged continuity and Navier-Stokes equations, Reynolds stresses, turbulent viscosity.
Basics of Compressible flow [3 Lectures]: Acoustic waves, isentropic equations, concept of shock waves
Few Industrial Applications [4 Lectures]: Pipe networks, Flow past immersed objects, Agitation and Mixing.

Text Book

1. Fox, R. W., Pitchard, P. J and McDonald, A. T., (2010), Introduction to Fluid Mechanics, 7thEdition, John Wiley & Sons Inc.
2. Munson, B. R., Rothmayer, A. P., Okiishi, T'H., and Huebsch, W. W. (2009),Fundamentals of Fluid Mechanics, 7th Edition, John Wiley and Sons
3. Kundu, P. K, Cohen, I. M and Dowling, D. R, (2014), Fluid Mechanics, 6th Edn., Associated Press.
4. McCabe, W.L., Smith, J.C., Harriott, P., (2005), Unit Operations of Chemical Engineering, 7th edition, McGraw-Hill International edition.

Reference Books

1. White, F. M.,(2003), Fluid Mechanics, 5thEdition, McGraw-Hil
2. Cimbala, J.M. and Cengel, Y.A., (2010),Fluid Mechanics: Fundamentals and Applications, McGraw-Hill
3. Bird. R. B., Stewart, W. E. and Lightfoot, E. N., 2006, Transport Phenomena, 2nd edition, John Wiley & Sons.
4. Panton, Ronald L - Incompressible flow, John Wiley & Sons, 2006. Third edition is available from Wiley Student Edition

Self-Learning Material

1. S. Chakrabarty, Introduction to Fluid Mechnics, NPTEL Course Material, Mechanical Engineering, IIT Kharagpur, https://nptel.ac.in/courses/112/105/112105269/
2. V.Shankar, Fluid Mechanics, NPTEL Course Material, Chemical Engineering, IIT Kanpur, https://nptel.ac.in/courses/103/104/103104044/#
3. Nishith Verma, Fluid Mechanics, NPTEL Course Material, Chemical Engineering, IIT Kanpur, https://nptel.ac.in/courses/103/104/103104043/

Title	**Heat Transfer**	Number	MEL3XX0
Department	Mechanical Engineering	L-T-P [C]	3–0–0 [3]
Offered for	B.Tech (ME)	Type	Program Compulsory (PC)
Prerequisite	Basics of Thermodynamics & Fluid Mechanics		

Objectives

1. To inculcate understanding, formulation, designing and solving problems with concepts in conduction, convection and radiation

2. To explain design concepts of fins, heat exchangers
3. To introduce physical background associated with empirical correlations for heat transfer coefficients using real world problems

Learning Outcomes

The students will have the ability to:

1. Analyze empirical situation of steady and transient conduction heat transfer
2. Evaluate transfer coefficients in natural and forced convection in and out of control areas
3. Assess performance of various heat exchangers
4. Solve numerical problems related to conduction and radiation heat transfer

Contents

Introduction (1 Lectures): Modes of heat transfer, Fourier's law, conductivity, diffusivity

Introduction to Heat conduction (3 Lectures): General heat conduction equations, 1D Heat conduction, Boundary and initial conditions, Heat generation

Steady heat conduction (4 Lectures): Heat conduction in plane wall, cylinder, sphere, network analysis, critical radius of insulation, heat transfer from fins

Transient heat conduction (4 Lectures): Lumped system analysis, transient heat conduction in large plane walls, long cylinders and sphere with spatial effect, Heisler and Grober charts

Introduction to convection (4 Lectures): Velocity and thermal boundary layer, laminar, turbulent flows, solution of boundary layer equations, Non-dimensional numbers

External heat transfer (3 Lectures): Drag and heat transfer, parallel flow over flat plates, flow across cylinders and spheres

Internal heat transfer (4 Lectures): Mean Velocity and Temperature, Critical Reynolds number, The entrance regions, Hydrodynamic and thermal entry lengths, fully developed flow

Natural/free convection (3 Lectures): Physical Mechanism, Natural convection over surfaces, Criteria for forced and natural convection

Boiling and condensation (3 Lectures): Boiling Curve, Nucleate boiling, film boiling, Dropwise and film condensation, Nusselt's theory of film condensation

Heat Exchangers (4 Lectures): Classifications, Overall Heat Transfer Coefficient, LMTD, Effectiveness-NTU method, Operation Issues, Introduction to Design of Heat Exchanger

Introduction to radiation (5 Lectures): Physical Mechanism, Radiations laws, Intensity of Radiation, gray body

View factors (4 Lectures): View Factor Integral for diffuse surfaces, Radiation exchange, Electric Circuit Analogy

Text Book

1. Incropera, F. P. & Dewitt, D. P.,(2011),Fundamental of Heat and Mass Transfer, John Wiley & Sons
2. Cengel, Y. A. & Ghajar, A. J.,(2008),Heat and Mass Transfer, McGraw Hill
3. Sukhatme S.P., (2005), A Text Book on Heat Transfer, Universities Press

Reference Books

1. Holman J.P., Heat Transfer, Tata McGraw-Hill Edition, New Delhi
2. Bejan A., Heat Transfer, Fourth Edition, John Wiley and Sons

Self-Learning Material

1. https://www.youtube.com/watch?v=qa-PQOjS3zA&list=PL5F4F46C1983C6785

Title	**Thermofluids Engineering**	Number	ME4XX
Department	Mechanical Engineering	L-T-P-Th [C]	3–1–0 [4]
Offered for	B.Tech (ME)	Type	Programme Compulsory (PC)
Prerequisite	Basics of Thermodynamics and Fluid Mechanics		

Objectives

1. Introduce various energy conversion devices using fluid and thermal energy
2. To analyses the performance of various energy conversion cycles and devices

Learning Outcomes

1. Fundamental understanding on the thermodynamics cycles used in various energy conversion systems
2. Performance analysis of various machines used in power plants, automobiles and refrigeration systems

Contents

Introduction [2 Lectures]: Basics of Fluid Mechanics and Thermodynamics Laws
Fuels and Combustion [3 Lectures]: Introduction to combustion, Reacting systems, Stoichiometry and exhaust gas composition, Heat of formation, Adiabatic Flame Temperature
IC Engines [5 Lectures]: Introduction to SI and CI engines, Air standard cycle analysis, 2-S and 4-S engines, SI & CI engine combustion, Performance and testing of SI and CI engines.
Emissions [2 Lectures]: IC engine emissions, after treatment systems, Low carbon propulsion techniques ; *Steam Power Plants [5 Lectures]:* Steam power plant cycle, reheating, regeneration, co-generation, Layout of a thermal power plant, classification of steam generators.
Gas Turbine Power Plants *[5 Lectures]*: Layout of gas turbine power plant, Brayton Cycle, with reheat, intercooling, regeneration.
Refrigeration Systems and Cycles [6 Lectures]: Performance parameters, Bell Coleman refrigeration cycle, Vapour compression refrigeration, Vapour absorption system.
Psychrometry and its applications [4 Lectures]
Turbines [4 Lectures]: Euler's equation, velocity triangle, similarity laws & specific speed**,** Hydraulic Turbines: Impulse and reaction machines, Pelton-Turbine, Francis Turbine, Kaplan Turbine.
Pumps [2 Lectures]: Centrifugal pump, Performance analysis, Pump Characteristics
Compressors and Gas Turbines [4 Lectures]: Centrifugal Compressors, Stalling and Surging, Axial flow compressors, stage velocity triangles, Axial Gas Turbines.

Textbook

1. Heywood, J. B. (2004), *Internal Combustion Engine Fundamentals,* MIT Press.
2. El-Wakil, M.M, (1985), *Power Plant Technology* – Mc -Graw Hill.

3. Stocker, W. F and Jones J. W, (1983), *Refrigeration & Air Conditioning*, McGraw-Hill
4. Dixon, S.L. (2005), *Fluid Mechanics & Thermodynamics of Turbomachinery*, 5th edition, Elsevier.

Reference Books

Cimbala, J. M. and Cengel, Y. A, (2010), *Fluid Mechanics: Fundamentals and Applications*, McGraw-Hill

Title	**Heat Transfer Lab**	Number	MEP3XX0
Department	Mechanical Engineering	L-T-P [C]	0–0–2[1]
Offered for	B. Tech (ME)	Type	Program Compulsory (PC)
Prerequisite	Heat Transfer		

Objectives

The instructor will:

1. Provide the practical knowledge with regard to the determination of rate of heat exchange in various modes of heat transfer
2. Provide practical exposure to various temperature measurement instruments and its working principle

Learning Outcomes

1. The students will have the ability to:
2. Compare the performance of different convection processes
3. Measure the heat transfer properties of various metals
4. Understand basic laws of radiation heat transfer
5. Measure the temperature of objects using different temperature measurement instruments

Contents (13-14 Classes)

1. Study on Temperature distribution during 1-D heat transfer in (a) Plain Wall (b) Cylinder.
2. Measurement of Thermal Conductivity of unknown material.
3. Effect of Size of Plain wall on Temperature distribution and contact resistance.
4. Demonstration of domestic solar water heating system (Time vs Temperature plots).
5. Investigation of the influence of solar luminous intensity, the water flow rate and the angle of incidence of the light on the efficiency and temperature difference.
6. Study on forced and free convection heat transfer for flow over flat plate, Tube bundle and Fins.
7. Testing the accuracy and time response of different temperature sensors (PT100, NTC, Thermocouple, Mercury Thermometer, Gas Pressure Thermometer, Bimetallic Thermometer).
8. Calibration of PT100 temperature sensor and derive equation of temperature as function of resistance.
9. Calibration of K-Type thermocouple temperature sensor and derive equation of temperature as function of voltage.
10. Study on validation of different radiation laws (a) Lambert's Distance Law (b) Lambert's Direction Law (Cosine Law) (C) Stefan Boltzmann's Law.
11. Study on Heat Exchangers (a) Parallel Flow and (b) Counter Flow
12. Lab Course Project

Reference Books

1. Incropera, F. P. & Dewitt, D. P.,(2011),*Fundamental of Heat and Mass Transfer*, John Wiley & Sons

2. Cengel, Y. A. & Ghajar, A. J.,(2008),*Heat and Mass Transfer*, McGraw Hill
3. Sukhatme S.P., (2005), A Text Book on Heat Transfer, Universities Press

Title	**Fluid Mechanics Lab**	Number	MEP3XX0
Department	Mechanical Engineering	L-T-P [C]	0–0–2[1]
Offered for	B. Tech (ME)	Type	Program Compulsory (PC)
Prerequisite	Fluid Mechanics		

Objectives

1. To introduce various forms of flow measuring devices and techniques
2. To provide hands on experience on in the area of experimental fluid mechanics

Learning Outcomes

The students will have:

1. Ability to design experimental methods for fluid flow problems
2. Ability to interpret data from experiments of fluid flows and usage of charts and hand books

Contents (13-14 Classes)

1. Determination of head loss in pipes having different diameters, different materials and different roughness
2. Determination of pressure drop at different types of bends and valves
3. Reynolds apparatus to measure critical Reynolds number for pipe flows
4. Measurement of Cp distribution on a cylinder
5. Wake survey experiments in a flow over a cylinder
6. Impact of jet on flat and curved plates
7. Wind tunnel calibration using Pitot static tube
8. Working principle of different flow meters (orifice plate, venture meter, turbine, Rota meter, electromagnetic flow meter)
9. Effect of change in cross section and application of the Bernoulli equation
10. Flow measurement around an object or blockage using PIV techniques
11. Class projects for designing and measurement of simple fluid mechanics experiments

Reference Books

1. Fox, R. W., Pitchard,P. J.,and McDonald, A. T., (2010), *Introduction to Fluid Mechanics*, 7thEdition, John Wiley & Sons Inc.
2. Cimbala, J.M., Cengel, Y. A. (2010),*Fluid Mechanics: Fundamentals and Applications*, McGraw-Hill

Title	**Thermofluids Lab**	Number	MEP4XX0
Department	Mechanical Engineering	L-T-P [C]	0–0–2[1]
Offered for	B. Tech (ME)	Type	Program Compulsory (PC)
Prerequisite	Fluid Mechanics		

Objectives

1. To provide hands on training on the operation of the different energy conversion devices
2. To enable practical visualization of complex energy conversion processes

Learning Outcomes

The students will have:

1. Ability to interpret data from experiments on energy conversion and usage of charts and hand books
2. To enable novel designs for new generation ThermoFluids technologies of hybrid and non-hybrid character

Contents (13-14 Classes)

1. Performance characteristics of Pelton turbine
2. Performance characteristics of Francis turbine
3. Performance characteristics of Centrifugal pump
4. Performance analysis of Pumps in series and parallel
5. Vapor absorption refrigeration
6. Vapor compression refrigeration
7. Ventilation experimentation facility and analysis
8. Compresses air vortex tube
9. Steam jet refrigeration Engine performance, Morse test
10. Emission measurements
11. Investigation of flames and spray structure

Reference Books

1. Heywood, J.B. (1988). *Internal Combustion Engine Fundamentals*.
2. Ei-Wakil,M.M, (1985),*Power Plant Technology*, Tata McGraw-Hill
3. Jordan, R. C. & Priester, G. B., (2003), *Refrigeration & Air conditioning*, Prentice Hall of India
4. Sheperd, D. G., (1983),*Principles of Turbomachinery*, Mac Millan

Title	**Mechanics of Solids**	Number	ME2XX
Department	Mechanical Engineering	L-T-P-Th [C]	3–1–0–0 [4]
Offered for	B.Tech (ME)	Type	Programme Compulsory (PC)
Prerequisite			

Objectives

1. To inculcate fundamental concepts of stress, strain and deformation of solids
2. Fundamental of applying equilibrium, compatibility and forced deformation relationships to structural elements

Learning Outcomes

1. Apply the fundamentals to analyze structural members
2. Physical insight into distribution of stresses and strains in structural members
3. Ability to design structural members using dimensions, force-displacement relationships, boundary conditions, loading and allowable stress

Contents

Stress and strain [10 Lectures]: Concept of stress at a point, Plane stress case: transformation of stresses at a point, principal stresses and Mohr's circle, Displacement field, Concept of strain at a point, Plane strain case: transformation of strain at a point, principal strains and Mohr's circle, Strain Rosette, Polar coordinates in stress and strain analysis. St. Venant's principles and stress concentrations

Mechanical behaviour [8 Lectures]: Concepts of elasticity, plasticity, strain hardening, failure (fracture/yielding), Generalized Hooke's law (without and with thermal strains) for isotropic materials, orthotropic and anisotropic materials, Force displacement relationship and geometric compatibility for axially loaded members and thin walled pressure vessels

Static Analysis[5 Lectures]: Complete equations of elasticity; Force analysis (axial force, shear force, bending moment, and twisting moment diagrams) of slender members

Elastic Bending[5 Lectures]: Moment curvature relationship for pure bending of beams with symmetric cross section, bending stress, shear stress; Cases of combined stresses, Deflection due to bending, Integration of the moment curvature relationship for simple boundary conditions, Stress concentrations

Elastic torsion[5 Lectures]: Torsion of circular shafts and thin walled tubes, Stress concentrations

Strain Energy[5 Lectures]: Concept of strain energy, strain energy for simple structural elements, Castigliano's theorems for deflection analysis and indeterminate problems;

Elastic Buckling [4 Lectures]: Concept of elastic instability, Introduction to column buckling, Euler's formula

Text books

1. Crandall, S.H., Dahl, N.C., and Lardner, T. J., (1978), *An Introduction to the Mechanics of Solids*, McGraw Hill, Second Ed. with SI Units.
2. Beer, F.P, Johnston, E.R. and De Wolf, J.T., (2004), *Mechanics of Materials*, Tata McGrawHill.
3. Popov, E.P., (1990),*Engineering Mechanics of Solids*, First Ed. Prentice Hall
4. Meriam, J.L. and Kraige, L.G., (1980), *Engineering Mechanics, Vol. 1: Statics*, 2nd Ed. John Wiley

5. Timoshenko, S.P. and Goodier, J.N. ``Theory of Elasticity``, McGraw-Hill, International Edition, 1970.

Self Learning Materials:

1. https://nptel.ac.in/courses/105/106/105106116/
2. https://nptel.ac.in/courses/105/102/105102090/
3. https://nptel.ac.in/courses/105/104/105104160/

Title	**Kinematics and Dynamics of Machines**	Number	MEL3XX0
Department	Mechanical Engineering	L-T-P [C]	3–0–2 [4]
Offered for	B.Tech (ME)	Type	Program Compulsory (PC)
Prerequisite	Engineering Mechanics		

Objectives

1. To cover the kinematics and dynamics of planar single degree freedom mechanisms
2. To develop skills for designing and analyzing linkages, cams, gears and other mechanisms
3. To teach students concepts of Newtonian dynamic analysis of mechanisms and machines

Learning Outcomes

1. To analyze position, velocity and acceleration kinematics of mechanisms
2. Evaluation of forces and torques in mechanism and machines in operation
3. To understand the implication of computed results to improve design of machines

Contents

Part I: Kinematics [21 Lectures]

*Kinematics and Mechanism [2 Lectures]: L*inks, Kinematic pairs, Kinematics diagram and inversion, mobility, range of movements, Equivalent linkage

Motion characteristics of Mechanism [5 Lectures]: Displacement analysis of planar mechanisms analytical methods, Plane motion of a rigid body, Velocity analysis: analytical and Instantaneous Centre of Velocity methods, Coriolis component of acceleration, Acceleration analysis

Mechanism Synthesis [4 Lectures]: Function, Path, and Motion Generation, Three Position Dimensional Synthesis

Cam follower mechanism [5 Lectures]: Classification of Cam and followers, nomenclature, description and analysis of follower motion, pressure angle, Determine of basic dimensions and synthesis of cam profiles

Gear and gear train *[5 Lectures]*: Spur gears and gear terminology, Fundamental law of gearing, Involute profile, Interference and undercutting, Minimum number of teeth, Contact ratio, Helical gears on parallel shafts, Bevel helical, Spiral and Worm gears. Simple, compound, epicyclic gear trains, planetary gear trains.

Part I: Dynamics [21 Lectures]

Introduction to Dynamics [2 Lectures]: Dynamics lumped-parameter models of mechanical systems, Newton's Law, Inertia and D Alembert Principle, Energy Method

Dynamics of Rigid bodies [6 Lectures]: Solution Methods: superposition and simultaneous equation solution, Newtonian Approach, Shaking force and Shaking Moments, Applications to Linkage and Single and Multi-cylinder engines, Controlling Input Torque - Flywheel Design

Balancing [5 Lectures]: Static unbalance, static balancing machines, dynamics balancing, applications to balancing of linkage, single and multi-cylinder engines

Vibration Analysis [4]: Introduction, Basic features of vibratory systems, single degree freedom systems

Dynamics of Cams [3 Lectures]: Rigid and elastic body cam system, analysis of eccentric cams, analysis of elastic cam systems, lumped models of cams and vibration analysis.

Gyroscope [1 Lecture]: Gyroscopic Torque

Laboratory Classes (12 Classes)
Experimental: Coriolis Acceleration, Gear Trains, Static and Dynamic Balancing, Vibration Analysis, Gyroscope, Cam Dynamics
Matlab-based: Analytical Position, Velocity and Acceleration Analyses, Synthesis of CAM, Force analysis using Newtonian solution approach - simultaneous equation solution

Reference Books

1. Ghosh, A. & Mallik, A. K., (2009), *Theory of Mechanisms, and Machines*, 3rd Edition, East West Press
2. Norton, R. L., (2009), *Kinematics and Dynamics of Machinery*, Tata McGraw Hill
3. Uicker, J. J., Pennock, G. R. and Shigley, J. E., (2009), *Theory of Machines and Mechanisms*, 3rd Edition, Oxford University Press
4. Waldron, K. J. & Kinzel, G. L., (2004), *Kinematics, Dynamics and Design of Machinery*, 2nd Edition, Wiley
5. Thomson, W. T., *Theory of Vibrations with Applications*, CBS Publishers & Distributors
6. Paul, B., Kinematics and Dynamics of Planar Mechanisms', Prentice Hall, 1979.

Self-Learning Material
1. Ashok K Mallik, Kinematics of Machines, NPTEL Course, Department of Mechanical Engineering, IIT Kanpur, Link: https://nptel.ac.in/courses/112104121/
2. Amitabh Ghosh, Dynamics of Machines, NPTEL Course, Department of Mechanical Engineering, IIT Kanpur, Link: https://nptel.ac.in/courses/112/104/112104114/

Title	**Design of Machine Elements**	Number	ME4XX
Department	Mechanical Engineering	L-T-P-Th [C]	3–0–2–0 [4]
Offered for	B.Tech (ME)	Type	Programme Compulsory (PC)
Prerequisite	Basic knowledge in Mechanics and kinematics		

Objectives

1. Understand the nomenclature and selection of machine elements
2. To be able to design machine components taking into consideration stress concentration, failure and fatigue.

Learning Outcomes

1. Understanding different types of failure modes of machine components and their role in engineering design
2. To compare the design options involving various machine elements used in the machine design process and to graphically represent them using computer aided design software

Contents

Introduction to Engineering Design[5 Lectures]: Life cycle approach to Design, Mechanical Engineering Design, Design Considerations, Design Methods, Engineering Materials and their Mechanical properties Use, types of codes & standards in Design, Selection of preferred sizes, Behavior of Ductile & Brittle material, Stress-Strain Diagram for various materials. Material selection in design

Design for strength [5 Lectures]: Failure Criteria such as Maximum Normal and Shear Stress theory, Distortion energy theory;

Stress Concentration [4 Lectures]: Stress concentration factor, Stresses in members subjected to axial, shear, Bending, Torsional & Eccentric loading, Fatigue Failure, Endurance Limit & Strength.

Design of members [5 Lectures]: Problems on design of members for finite & infinite life in members subjected to individual & combined loading.

Design of shaft and couplings [5 Lectures]: Types, Design of solid & hollow shaft on strength and rigidity basis with steady loading subjected to pure torsion. Design of shafts carrying pulleys & gears (Combined loading). ASME Code for shaft design. Selection and design of Keys, Cotter & Knuckle Joints and couplings. Classification and Selection of Bearings.

Design of Riveted, Bolted and Welded joints [5 Lectures]

Design of Helical springs [3 Lectures]

Classification and selection steps for main components of belt, rope and chain drives [4 Lectures]

Classification, application and design consideration of clutches and brakes [4 Lectures]

Laboratory Classes [12 Classes]

1. Experimental sessions on machine drawing exercises (sketching and on CAD software)
2. Design project

Textbook

1. Shigley, J. E., Mischke, C., Nisbett, K., and Richard, B., (2008), *Mechanical Engineering Design*, McGraw Hill Education
2. Spotts, M. F. & Shamp, T. E., (2003), *Design of Machine Elements*, Prentice Hall
3. Sidheswar, K. N, & Sastry, P. V. V. V., (1997), *Machine Drawing*, Tata McGraw Hill

4. Cencil Jensen, Jay D. Helsel, Dennis R. Short, (2012), *Engineering Drawing & Design*, 7th Edition, TATA McGRAW-HILL
5. Mahadevan, K., Reddy,K.B. (2013), *Design Data Handbook for Mechanical Engineers*, CBS Publishers & Distributors
6. Dieter, Engineering Design, 4th Ed., McGraw-Hill, 2013.

Title	**Control of Mechanical Systems**	Number	MEL3XX0
Department	Mechanical Engineering	L-T-P [C]	3–0–4 [5]
Offered for	B. Tech (ME)	Type	Program Compulsory (PC)
Prerequisite	Basic Knowledge of Systems		

Objectives

1. Familiarize with methods to characterize dynamical behaviour of a mechanical system using the models
2. Provide an understanding of the basic concepts of control theory.
3. Provide a basic understanding of implementing control laws.

Learning Outcomes

1. Develop necessary mathematical models from the knowledge of the mechanical engineering discipline, and become familiar with various strategies for their representation and solution
2. Ability to design control systems for LTI systems and implementation using embedded hardware.

Contents

Part I: System Modeling and Response [14]

Introduction to Modelling & Representation [5 Lectures]: Objective, basic modelling concepts & types of models, Models of simple mechanical systems, linearization of nonlinear models, Transfer Function Modeling of LTI systems, block diagram representation and manipulation, signal flow graphs.

Basic Characteristics of Feedback System [4 Lectures]: Properties of feedback systems, sensitivity analysis, effect of control gain on system performance, effect of disturbances on system performance.

Response & Stability Analyses [5 Lectures]: Test signals, response of 1st and 2nd order, as well as, higher-order systems, poles and zeros and its effect on system response, Stability criteria, BIBO stability, Routh's stability criterion.

Part II: Control of Mechanical Systems [14]

Introduction to Control [2 Lectures]: Control objectives, introduction to control problem, open/ closed-loop control and structures.

Root- Locus and Compensator Design [6 Lectures]: Concept of root locus; use of control gain to change pole locations, design of lag, lead and lag-lead compensators using root locus techniques, PI, PD and PID controller design

Applications of control to Mechanical Systems [4 Lectures]: Practical aspect of control implementation - Actuators, sensors; Temperature control, Flow control, Pressure and Force control, Vehicle Active Suspension Control, Robot control

Implementation of Control Law [2 Lecturer]: Discretization of control law, Difference equation, computational aspect of control law

Part III Embedded Hardware for Control Implementation [14 Lectures]

Introduction to Embedded Processors [08 Lectures]: Concept of Processors; Microprocessors and Microcontrollers, Architecture of ARM M0 processors, Memory Interfacing, Memory-mapped peripherals, peripherals like GPIOs, Timers, analog inputs.

Programming of Embedded Processor *[06 Lectures]*: Introduction to Arm Mbed development environment, use of Arm Mbed for programming Embedded processors, digital I/Os and analog I/Os interface. Implementing PI, PID controllers using embedded processors

Laboratory Classes (12 Classes)

1. Control simulation of different systems i.e. temperature control, robot control using MATLAB as a tool [3 Lab classes]
2. Experiments on DC servo position control, inverted pendulum, helicopter emulator system, Active suspension, robot control [6 Lab classes]
3. Controller implementation using embedded hardware, interfacing sensors and actuators and implementation of PI [3 Lab classes]

Textbook:

1. Nise, N.S. (2014), Control Systems Engineering, 6th Edition, John-Wiley India, 2014
2. G. F. Franklin, J. D. Powell and A. E. Emami-Naeini (2002), Feedback Control of Dynamic Systems; Prentice Hall Inc.,
3. Perry Xiao., (2018), Designing Embedded Systems and the Internet of Things (IoT) with the ARM® Mbed™, John Wiley & Sons Ltd.

Reference Books

1. Ogata, K. (2012), Modern Control Engineering, 5th Edition, Prentice-Hall India, 2012,
2. Gopal, M. (2000), Control Systems - Principles & Design, 3rdEdition, Tata McGraw-Hill, 2015
3. Dorf, R.C. & Bishop, R.H. (2008), Modern Control Systems, 11th Edition, Pearson, 200

Self-Learning Material

1. Gopal, M., Control Engineering, NPTEL Course Material, Department of Electrical Engineering, Indian Institute of Technology Delhi, https://nptel.ac.in/courses/108102043/
2. Ramkrishna Pasumarthy R., Control Engineering, NPTEL Course Material Department of Electrical Engineering, IIT Madras, Link: https://onlinecourses.nptel.ac.in/noc17_ee12/preview

Title	**Manufacturing Processes**	Number	MEL2XX0
Department	Mechanical Engineering	L-T-P [C]	3–0–0 [3]
Offered for	B. Tech (ME)	Type	Program Compulsory (PC)
Prerequisite	----		

Objectives

The Instructor will:

1. Impart fundamental understanding of various casting, welding and forming processes.
2. Discuss design methodology and process parameters involve in obtaining defect free component.
3. Discuss tools, techniques and equipment involved in casting, welding and forming processes.

Learning Outcomes

The students will have the ability to:

1. Select appropriate primary manufacturing process and related parameters for obtaining initial shape and size of components.
2. Design and develop adequate tooling linked with casting, welding and forming operations.

Contents

Module 1: Metal Casting Processes [14 Lecture]:

Introduction to Casting [3 Lectures]: Casting Terminology, Types of pattern and allowances, Applications and Challenges.

Design of various parts [4 Lecture]: Riser and Gating system design, Design principles for mould cavity.

Solidification [3 Lecture]: Metal flow and solidification; solidification and cooling of casting.

Types of casting process and defects [4 Lecture]: Expendable and Permanent Mould Casting Processes, Die casting and centrifugal casting, Casting defects and inspection of castings.

Module 2: Welding [14 Lecture]:

Introduction to Joining Processes [3 Lecture]: Basic requirements and classification of welding processes; Arc Welding Processes, Arc welding principle, Welding power source and its characteristics.

Arc Welding Processes [4 Lecture]: TIG&MIG processes and their parameters; Introduction to other welding processes such as submerged arc welding (SAW), shielded metal arc welding (SMAW)

*Advance welding processes [3 Lecture]:*Resistance welding processes, friction stir welding (FSW).

Weldability and thermal aspects [3 Lecture]: Concept of weldability of materials; Thermal Effects in Welding (Distortion, shrinkage and residual stresses in welded structures); Welding defects and remedies.

Allied processes [1 Lecture]: Soldering and Brazing.

Module 3: Metal Forming Processes [14 lecture]:

Introduction of metal forming process [5 Lecture]: Mechanical behavior of metals in elastic and plastic deformation, stress-strain relationships, Yield criteria, Application to tensile testing, train rate and temperature in metal working; Hot deformation, Cold working and annealing.

Metal Working Processes [5 lecture]: Fundamentals of metal working, Analysis of bulk forming processes like forging, rolling, extrusion, wire drawing by slab method,

Other sheet metal processes [4 Lecture]: Sheet metal forming processes (Die and punch assembly, Blanking, piercing, bending etc., Compound and Progressive die), High Energy rate forming processes.

Text book:

1. Ghosh, A. and Mallik, A. K., (2017), *Manufacturing Science*, East-West Press.
2. Parmar R. S., (2007), *Welding Processes and Technology*, Khanna Publishers.

Reference Books

1. Heine, R. W., Loper, C. R., and Rosenthal, P. C., (2008), *Principles of Metal Casting*, Tata McGraw Hill.
2. Conne, L. P., (1989), *Welding Handbook- Welding Technology Part-1*, American Welding Society.
3. Black, S. C., Chiles, V, Lissaman, A. J., and Martin, S. J., (1996), *Principles of Engineering Manufacture*, Butterworth-Heinemann.
4. Groover, M. P., (2011), Introduction to Manufacturing Processes, Wiley.
5. Kalpakjian, S., and Schmid, S. R., (2001), Manufacturing Engineering and Technology, Pearson.
6. Riggs, J. L., (1976), Production System-Planning Analysis and Control, John Wiley.

Self-Learning Material

1. D. B. Karunakar, Metal Casting, NPTEL Course Department of Mechanical and Industrial Engineering, IIT Roorkee, Link: https://nptel.ac.in/courses/112107083/
2. P. Biswas, Fundamental of Welding Science and Technology, Department of Mechanical Engineering, IIT Guwahati, https://nptel.ac.in/courses/112107083/
3. P. K. Jha, Principles of Metal Forming Technology, Department of Mechanical and Industrial Engineering, IIT Roorkee, https://nptel.ac.in/courses/112107250/

Title	**Machining Science and Metrology**	Number	MEL3XX0
Department	Mechanical Engineering	L-T-P [C]	3–0–0 [3]
Offered for	B. Tech (ME)	Type	Program Compulsory (PC)
Prerequisite	----		

Objectives

1. Impart fundamental understanding of various conventional and non-conventional machining processes.
2. Discuss various measuring and gauging techniques used for inspection of machined components.
3. Discuss various techniques for improvement and assessment of the surface finish.

Learning Outcomes

1. Appreciate theories of material removal associated with conventional and non-conventional machining processes.
2. Understand various aspects related with finishing and super-finishing processes.
3. Apply different inspection techniques to assess the dimensional accuracy of machined components.

Contents

Module 1: Conventional Machining Processes [17 Lecture]:

Introduction [1 Lecture]: Machining Process; Basic working principle of conventional machining processes.

Tool and Chip formation [4 Lecture]: Configuration, Specification and Classification of machine tools; Mechanics of Metal Cutting: Geometry of single point cutting tools; Mechanism of chip formation; Orthogonal and oblique cutting.

Force and temperature analysis [5 Lecture]: Analysis of machining forces and power requirement; Causes, effects and control of cutting temperature; Application of cutting fluids.

Machinability and tool life [3 Lecture]: Machinability concept; Tool Wear; Failure of cutting tools and tool life; Cutting Tool Materials; Economics of metal cutting.

Finishing process [4 Lecture]: Finishing and Super-Finishing Processes: Purpose and application of grinding; Selection of grinding wheels and their conditioning methods; Specific energy and power requirement in grinding; Super-finishing processes such as Honing, Lapping etc.

Module 2: Advanced Machining Processes [15 Lecture]:

Introduction [2 Lecture]: Comparison of non-conventional and conventional methods of machining; Classification of the processes; Advantages, limitations and applications.

Mechanical Processes [7 Lecture]: Abrasive Jet Machining Process, process parameters effect on material removal rate, Water Jet Machining (WJM) process; Abrasive Water Jet Machining (AWJM) process; Ultrasonic Machining (USM), Material removal in USM.

Thermo-electric Processes [7 Lecture]: Electric Discharge Machining (EDM); Use of LASERs in machining and Laser Beam Machining, Electron Beam Machining (EBM) and Plasma Machining (PM).

Electrochemical Processes [2 Lecture]: Electroplating and reverse-electroplating; Electro Chemical Machining (ECM).

Module 3: Metrology [10 Lecture]:

Introduction [3 Lecture]: Introduction to metrology and its relevance; Standardization; Limits, fits and tolerances, tolerance grades.
Measurement [7 Lecture]: Measurement of linear and angular dimensions; Measurement of geometric error such as straightness, flatness, parallelism, squareness, circularity and roundness; Surface Metrology: Surface topography definitions, Measurement of surface texture, Methods for measurement.

Text book:

1. Shaw, M C, (2014), *Metal Cutting Principles*, Oxford University Press.
2. McGeough, J A, (1988), *Advanced Methods of Machining*, Springer.
3. Mitutoyo, (2015), *Metrology Handbook*, Mitutoyo.

Reference Books

1. Chattopadhyay, A B, (2013*), Machining and Machine Tools*, Wiley India.
2. Galyer, J F W, Shotbolt, C R, (1990), *Metrology for Engineers*, Cassell.
3. Boothroyd, G., and Knight, W. A., (1932), Fundamentals of Machining and MAchine Tools, CRC Press.

Self-Learning Material

1. V. K. Jain, Advanced Machining Processes, NPTEL Course Department of Mechanical Engineering, IIT Kanpur, Link: http://nptel.ac.in/courses/112104028/.
2. M. S. Shunmugam, Metrology, NPTEL Course Department of Mechanical Engineering, IIT Madras, Link: http://nptel.ac.in/courses/112106138/.
3. U. S. Dixit, Mechanics of Machining, NPTEL Course Department of Mechanical Engineering Guwahati, Link: http://nptel.ac.in/courses/112103248/.
4. A. B. Chattopadhyay, Manufacturing Processes II, NPTEL Course of Department of Mechanical Engineering, IIT Kharagpur, https://nptel.ac.in/courses/112/105/112105126/.

Title	**Productions and Operations Management**	Number	MEL3XX0
Department	Mechanical Engineering	L-T-P [C]	3–0–0 [3]
Offered for	B. Tech (ME)	Type	Program Compulsory (PC)
Prerequisite	----		

Objectives

The Instructor will:

1. Familiarize students with basic concepts, techniques and algorithms that help in optimizing the performance of manufacturing systems

Learning Outcomes

The students will have the ability to:

1. Appreciate the need of developing mathematical models of conflicting situations and analyze the same;
2. Select rational options in practical decision-making problems using various techniques and algorithms.

Contents

Module 1: Introduction (14 Lecture):

Introduction [2 Lecture]: System concept of manufacturing; Types of manufacturing systems; Concept of productivity.

Linear Programming [6 Lecture]: Introduction to Linear Programming Problem (LPP); Formulation of mathematical model; Applications of LPP; Solution techniques for LPP such as graphical method, simplex method and its variants; Special issues in LPP e.g. degeneracy, multiple optimum solutions, infeasibility, unbounded feasible region; Sensitivity analysis.

Transportation problem and Assignment Problem [6 Lecture]: Transportation problem and its applications; Solution methods for transportation problem; Transhipment problem; Assignment problem and its applications; Solution techniques for assignment problem; Traveling salesman problem.

Module 2: Inventory Management (14 Lecture):

Introduction [3 Lecture]: Basic concept and terminology; Inventory classification and inventory costs; Concept of Economic Order Quantity.

Deterministic inventory models [3 Lecture]: Probabilistic inventory models; ABC analysis.

Project Management [1 Lecture]: Introduction and terms used in project management; Construction of network diagram.

PERT/CPM [4 Lecture]:Deterministic network model - CPM; Probabilistic network model – PERT; Crashing of network; Resource leveling and smoothing techniques.

Waiting Line Models [3 Lecture]:Introduction and terms used in queuing models; Kendall's notations; Classification of queuing models; Mathematical analysis of queuing system using various models; Queuing costs

Module 3: Forecasting (14 Lecture):

Forecasting [4 Lecture]: Nature and use of forecast; various forecasting models; Measure of forecasting accuracy; Selection of forecasting techniques.

*Material Management [4 Lecture]:*Product design considerations, Product development, Detailing, Value Engineering and its role in product design and cost rationalization, IPR.
Maintenance Management [3 Lecture]: Objectives, Nature of maintenance problems, Maintenance strategies, Organization, Maintenance Information Systems, Spare Parts Management, Maintenance Cost Control, Introduction to Total Productive Maintenance.
*Work study [3 Lecture]:*Purpose and scope, Productivity and work-study, Method Study and Work Measurement; Engineering economy and costing:Fixed cost, variable cost, introduction to break even analysis.

Text book:

1. Buffa E S and Sarin R K, (1987), *Modern Production/Operations Management*, Wiley.
2. Taha H A, (2010), *Operations Research: An Introduction*, Pearson.

Reference Books:

1. Sen R, (2016), *Operations Research*, Prentice Hall.
2. Hiller F S and Liberman G J, (2005), *Introduction to Operations Research*, McGraw Hill.
3. Pai J K, (2010), *Operations Research*, Oxford University Press.

Self-Learning Material

1. G Srinivasan, Operations Research, NPTEL Course Department of Mechanical Engineering, IIT Madras, Link: http://nptel.ac.in/courses/112106134/1
2. A Kanda, Project and Production Management, NPTEL Course Department of Mechanical Engineering, IIT Delhi, Link: http://nptel.ac.in/courses/112102106/

Title	**Digital Fabrication**	Number	MEL3XX0
Department	Mechanical Engineering	L-T-P [C]	3–0–0[3]
Offered for	B.Tech (ME)	Type	Program Compulsory (PC)
Prerequisite	--		

Objectives

The instructor will:

1. discuss various techniques involved for the digital presentation of objects
2. cover fundamentals of various digital manufacturing processes (additive and subtractive) and inspection technologies to demonstrate its potential in modern manufacturing industries
3. introduce concepts of smart manufacturing and Industry 4.0 in manufacturing industries

Learning Outcomes

The students will have the ability to:

1. develop and manipulate digital models of physical objects
2. program and execute various operations on digital subtractive and additive manufacturing processes
3. appreciate the recent manufacturing trends related to Industry 4.0 and its implementation

Contents

Digital design (14 Lectures):

*Geometric design [7 Lectures]:*Geometric design of curves, surfaces and solids

Shape digitization[7 Lectures]: 3-D object scanning, solid reconstruction from point cloud and tessellated data

Digital manufacturing (14 lectures):

Subtractive manufacturing [5 Lectures]:

Basic programming architecture [5 Lectures]: Control hardware and software details, Tooling, sculptured surface machining.

Additive Manufacturing [4 Lectures]: Introduction to various processes, capabilities and limitations, various applications of AM

Introduction of Industry 4.0 (14 lectures):

Introduction to Smart Manufacturing [7 Lectures]: IoT applications in Manufacturing, Cloud applications in manufacturing.

Introduction to Computer Aided Process Planning (CAPP)[7 Lectures]: Algorithms for CAPP, CAD-CAM development, Industry 4.0 applications in Product Development

Text Book

1. Zeid, I and Subramanian R, (2010), *CAD/CAM Theory and Practice*, Tata McGraw Hill.
2. Smid P., (2005), *CNC Programming Handbook*, Industrial Press.
3. Gibson I, Rosen D W, Stucker B, (2015), *Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing*, Springer.

Reference Books

1. Chua C K, Leong K F, Lim C S, (2012), *Rapid Prototyping*, World Scientific.

2. Marciniak K, (2006), *Geometric Modeling for Numerically Controlled Machining*, Oxford University Press

Self-Learning Material

1. Asimava Roy Choudhury, CNC Machine Tools and Processes, NPTEL Course Material Department of Mechanical Engineering, IIT Guwahati, Link: https://nptel.ac.in/courses/112105211/
2. John Hart, Additive Manufacturing, MIT Online courseware, Link: https://www.youtube.com/watch?v=ICjQ0UzE2Ao

Title	**Manufacturing Processes and Systems Lab**	Number	MEP3XX0
Department	Mechanical Engineering	L-T-P [C]	0–0–2[1]
Offered for	B. Tech (ME)	Type	Program Compulsory (PC)
Prerequisite	Fundamentals of Manufacturing Processes and Systems		

Objectives

The instructor will:

1. demonstrate concepts related with primary manufacturing processes by conducting various practical exercises
2. familiarize students with various simulation tools involved in manufacturing processes and systems
3. explain the software tools and skills required for optimization of manufacturing systems

Learning Outcomes

The students will have the ability to:

1. Appreciate the effect of process parameters on quality of manufactured components
2. Use various simulation tools and software for designing manufacturing processes and systems

Contents (13-14 classes)

1. Studying the effect of the clay and moisture content on sand mold properties
2. Derivation of cooling curve and mold thermal gradient using thermocouple and data acquisition system
3. Studying the effect of welding process parameters on bead profile using image processing system
4. Analysing the problem of heat balance using resistance spot welding setup
5. Effect of interface lubrication and temperature on bulk deformation characteristics using hydraulic press
6. Sheet metal punch/die design and layout optimization
7. Solving linear programming problems using LINGO software
8. Demonstration of material flow and solidification simulation using Auto-Cast software
9. Derivation of isotherms and estimation of bead profile using Ansys Software
10. Development of computational tool using Microsoft excel for solving transportation/Assignment and Inventory management problem.

Reference Books

1. Laboratory manual of various equipment.
2. Reveillac J, (2017), *Operational research using the spread sheet*. Wiley.

Title	**Machining and Automated Manufacturing Lab**	Number	MEP4XX0
Departme nt	Mechanical Engineering	L-T-P [C]	0–0–2[1]
Offered for	B. Tech (ME)	Type	Program Compulsory (PC)
Prerequisi te	Fundamentals of Manufacturing Processes and Systems		

Objectives

The instructor will:

1. Demonstrate concepts related with conventional and non-conventional machining processes by conducting various practical exercises
2. Demonstrate various inspection technologies to examine dimensional control of components
3. Discuss manual and automated programming of CNC machine tools
4. Demonstrate steps related to additive manufacturing of components

Learning Outcomes

The students will have the ability to:

1. Appreciate the effect of process parameters on quality of machined components
2. Use various simulation tools and software related to machining processes
3. Build and inspect components fabricated using additive processes
4. Generate and execute part programs for CNC machine tools

Contents (13-14 classes)

1. Effect of process parameters on machinability and surface characteristics of machined components
2. Measurement of cutting forces and analysing effect of process parameters in machining operation
3. Analysing machining characteristic of hard materials using Laser Beam Machining
4. Demonstration of hybrid machining concept using Ultrasonic Machining set up
5. Study of machinability characteristics of various materials using DEFORM software
6. Manual part programming using CNC turning simulator
7. Manual part programming using CNC milling simulator
8. Generation of CNC part programs and CAD/CAM integration
9. Demonstration of process flow in Additive Manufacturing and discussion of case studies
10. Measurement of freeform geometries using contact and noncontact inspection systems

Reference Books

1. Shaw M C, (2015), *Metal Cutting Principles*, Oxford University Press.
2. Smid P., (2005), *CNC Programming Handbook*, Industrial Press.
3. Chua C K, Leong K F, Lim C S, (2012), *Rapid Prototyping*, World Scientific.

Title	**Smart Manufacturing**	Number	MEL4XX0
Department	Mechanical Engineering	L-T-P [C]	2–0–2 [2]
Offered for	B.Tech (ME)	Type	Program Compulsory (PC)
Prerequisite	--		

Objectives:
The instructor will:
1. Introduce students to the fundamentals of smart manufacturing and Industry 4.0

Learning Outcomes:
The students will have the ability to:
1. Appreciate concepts and basic framework necessary for smart manufacturing
2. Develop understanding about harnessing smartness into manufacturing processes from the data

Contents:
Introduction:
Introduction [5 Lecture]: Introduction to manufacturing processes and systems; Industrial revolutions, Background and concept of smart manufacturing.
Models and key technologies for smart technologies [3 Lecture]
Automated manufacturing processes [6 lectures]: Elements of smart manufacturing process; sensing elements and IoT technologies; data-driven models.
Decision making systems [4 Lecture]: Decision making systems, Case Studies.
Automated manufacturing systems:
Concept of mass production [5 Lecture]: Precision manufacturing, flexible manufacturing and agile manufacturing; Concept of edge, fog and cloud computing in manufacturing
Big data and services in smart manufacturing [5 Lecture]: AR, VR and Mixed Reality in Manufacturing, Case Studies

Text Book:
1. Wang L, and Vincent W X, (2019), *Cloud Based Cyber-Physical Systems in Manufacturing*, Springer.
2. Tao F, Zhang M, and Nee A Y C, (2019), *Digital Twin Driven Smart Manufacturing*, Academic Press.

Reference Books:
1. Jeschke S, Brecher C, Song H, and Rawat D B, (2017), *Industrial Internet of Things – Cyber manufacturing Systems*, Springer

Self-Learning Material
1. MIT Online Course on Smart Manufacturing: https://professional.mit.edu/course-catalog/smart-manufacturing-moving-static-dynamic-manufacturing-operations

Detailed Course Content of Programme Elective Courses

Title	**Turbomachinery**	Number	ME4XX
Department	Mechanical Engineering	L-T-P-Th [C]	3–0–0–0 [3]
Offered for	B.Tech (ME)	Type	Programme Elective (PE)
Prerequisite	Basics of Fluid Mechanics and Thermodynamics		

Objectives

1. To teach about different types of turbomachines used in energy transformations
2. To introduce basic principles and equation governing the steady and unsteady fluid flow associated with Turbomachinery
3. To impart knowledge of designing turbines vanes using velocity triangles

Learning Outcomes

1. To analyse the flow behaviour which depends on the geometric configuration of various turbomachines
2. Identify and analyse the thermal cycles related to turbomachines
3. Turbo-machine stage characterization using various design parameters

Contents

*Introduction [3 Lectures]:*Classifications, Eulers equation of Turbomachines, Concept of velocity triangles, Expression of Eulers equation showing the components of energy transfer

Dimensional analysis of incompressible Turbomachines [3 Lectures]: Similarity laws and model testing., concept of specific speed and specific diameter, affinity laws, unit quantities

*Hydraulics Turbines [5 Lectures]:*Impulse and reaction machines, Analysis of Pelton-Turbine, efficiencies, performance characteristics, Analysis of Francis Turbine, Analysis of Kaplan Turbine.

Centrifugal Pumps [5 Lectures]: Introduction to pumping systems, Centrifugal pumps working principle, Efficiencies, losses, operating characteristics, pumps in series and parallel, NPSH, priming and cavitation.

*Compressible flow Turbomachines [6 Lectures]:*Introduction to compressible flows, flow choking, review of T-S and H-S diagrams of gas turbines and compressors, efficiencies, effect of reheat and preheat. Dimensional analysis of compressible flow machines. Lift and drag, blade cascading concept

Centrifugal Compressors [5 Lectures]: Centrifugal compressors, construction, flow analysis, performance analysis, stalling and surging.

Axial Compressors and Turbines [5 Lectures]: Axial flow compressors, construction details, stage velocity triangles, degree of reaction, stage pressure rise, stage pressure coefficient, stage efficiency, Axial Turbines.

Steam turbines [4 Lectures]: Overview, impulse turbine, speed ratio, idea of velocity and pressure compounding. Reaction stages-50% and 100% reaction

Fans and blowers [4 Lectures]: Axial fans: velocity triangle, stage parameters, performance characteristics Centrifugal fan: velocity triangle, stage parameters and performance characteristics.

Turbomachines used in power transmission[2 Lectures]: Fluid coupling, Torque converter

Textbook

1. Dixon, S. L., (2005), *Fluid Mechanics & Thermodynamics of Turbomachinery*, 5th Edition, Elsevier Science

2. Cohen, H., Rogers, G. F. C., and Saravanamuttoo, H. I. H., *Gas Turbine Theory*, Longman Publishing Group

Reference Books

1. Sheperd, D. G., Principles of Turbomachinery, Mac Millan
2. Kearton, W. J., Steam Turbine Theory and Practice, CBS Publishers & Distributors

Title	**Refrigeration and Air-conditioning**	Number	ME4XX
Department	Mechanical Engineering	L-T-P-Th [C]	3–0–0–0 [3]
Offered for	B.Tech (ME)	Type	Programme Elective (PE)
Prerequisite	Basic Knowledge in Thermodynamics, Thermofluids Engineering		

Objectives

1.To study the characteristics and engineering design of heating, ventilating, air conditioning and refrigeration and to enable the students to achieve effective and efficient design solutions.

Learning Outcomes

1. The students will learn to explain and analyze the refrigeration systems, their various components, and to apply them in real system analysis.
2. They will demonstrate the knowledge of basic principles of refrigeration cycle and psychometry.

Contents

Introduction [2 Lectures]: Definition, Necessity, Methods of refrigeration, Coefficient of performance (COP), Fundamentals of air-conditioning systems,

Air Refrigeration Systems [5 Lectures]: Carnot refrigeration cycle, Brayton refrigeration or the Bell Coleman air refrigeration cycle, Air craft refrigeration system, Simple cooling and simple evaporative types, Regenerative type, Comparison of different systems;

Vapour Compression (VC) Refrigeration Systems [5 Lectures]: Simple VC refrigeration system - Limitations of reversed Carnot cycle with vapor as the refrigerant, Analysis of VC cycle considering degrees of sub cooling and super heating, Multistage and cascade refrigeration systems

Refrigerants [4 lectures]: Definition, Classification, Nomenclature, Desirable properties, Comparative study, Introduction to eco-friendly Refrigerants, binary and azeotropic mixtures, alternate refrigerants.

Other Refrigeration Systems [5 Lectures]: Vapour Absorption Refrigeration System Basic Systems, Actual COP of the system, Performance, Relative merits and demerits, Electrolux refrigeration, Steam jet refrigerating system - Introduction, Analysis, Relative merits and demerits, Performance applications,

Psychrometry of Air & Air Conditioning Processes [5 Lectures]: Properties of moist Air-Gibbs Dalton law, Specific humidity, Dew point temperature, Degree of saturation, Relative humidity, Enthalpy, Wet bulb temperature, Thermodynamics wet bulb temperature, Psychometric chart, Psychometry of air-conditioning processes, Mixing process, Basic processes in conditioning of air.

Load Calculations [4 Lectures]: Outside and inside design conditions, Sources of heating and cooling load, Heat transfer through structure, Solar radiation, Electrical applications, Infiltration and ventilation, Heat generation inside conditioned space, Human physiology, Comfort chart.

Controls & Accessories [4 Lectures]: Classifications, Layout of plants, Equipment selection, Air distribution system, Duct system design, Filters, Refrigerant piping, Design of summer air-conditioning and Winter air conditioning systems, Temperature sensors, Pressure sensors, Humidity sensors, Actuators, Safety controls, Accessories;

Equipment design and selection [4 Lectures]: Type of compressors and their performance curves, Types of condensers, Heat transfer in condensers, Types of expansion devices, Types of evaporators, Cooling and dehumidifying coils.

HVAC design for buildings [4 lectures]: Design considerations, Ductwork, Cooling towers, Enclosed stairwells and elevator shafts, Smoke exhaust, Noise and vibration considerations, Mechanical equipment rooms, Ventilation requirements, Water piping, airflow requirements.

Textbook

1. Jordan, R. C. & Priester, G. B., (2003), *Refrigeration & Air conditioning*, Prentice Hall of India
2. Arora, C. P., (2008), *Refrigeration & Air conditioning*, Tata McGraw Hill
3. Stocker, W. F. & Jones, J. W., (2000), *Refrigeration & Air conditioning*, Tata McGraw Hill
4. Prasad, M., (1999), *Refrigeration & Air conditioning*, Wiley Eastern Limited
5. Arora, C. P. & Domkundwar, S., (1985), *A course in Refrigeration & Air Conditioning*, Dhanpat Rai & Sons

Title	**Power Plant Engineering**	Number	ME7XX
Department	Mechanical Engineering	L-T-P-Th [C]	3–0–0–0 [3]
Offered for	B.Tech (ME)	Type	Programme Elective (PE)
Prerequisite	Basic Knowledge in Thermodynamics		

Objectives

1. To introduce fundamental technologies related to the conversion of energy resources into electrical power generation

Learning Outcomes

1. Introduction to power plant components, operation and engineering.
2. Ability to select an appropriate type of power plant for given requirements under different situations
3. Optimization of energy efficiency of plant with respect to available resources and energy requirement

Contents

Introduction to power plant Engineering [2 Lectures]: National and International status on power generation and use

Thermal Power Plant [5 Lectures]: Plant layout, Thermal power plant equipment, Types of boilers, performance of boilers, super critical steam generator,

Condenser and steam turbines [3 Lectures]: Performance of condensers, types of steam turbines, draught system, Latest development in thermal power plants.

Gas Turbine Power Plant [4 Lectures]: Plant layout, Power cycles, Combustion chamber and gas turbines

Combine cycle power plants [5 Lectures]: Load type and calculation, Load variation, Use of internal combustion engine plant, plant layout and design calculation, combine cycle efficiency

Nuclear power plant [4 Lectures]: Principles of nuclear energy, Elements of nuclear power plants, Types of nuclear fuel, nuclear reactor, Fast breeder reactors, Next generation nuclear plant,

Hydroelectric power plant [3 Lectures]: Site selection, plant layout, types of plants, water turbine, plant operation, water storage and flow duration

Solar thermal power plant [5 Lectures]: Introduction to solar thermal power generation, type of solar collectors and receivers, daily and yearly load variation, Energy storage, Recent advances in solar power plants

Wind Turbine [3 Lectures]: Wind energy, types of wind turbine, site selection, turbine efficiency

Other Non-convectional power plants [3 Lectures]: Introduction to fuel cell, gasification, Ocean thermal energy, Tidal energy, geothermal energy, challenges and recent developments,

Hybrid power system [3 Lectures]: Power system selection, design of hybrid power system, power optimization, load distribution, plant efficiency

Selection of power plant [2 Lectures]: Environmental impact, different types of pollutions, fuel availability, Economic aspect

Textbook

1. Ei-Wakil, M.M, (1985), *Power Plant Technology*, Tata McGraw-Hill
2. P. K. Nag, *Power Plant Engineering*, Tata McGraw-Hill,
3. F. T. Morse, *Power Plant Engineering*, D. Van Nostran, New York,

Self-Learning
https://nptel.ac.in/courses/112107291/

Title	**Solar Thermal Systems**	Number	ME6XX
Department	Mechanical Engineering	L-T-P [C]	3–0–0 [3]
Offered for	B.Tech (ME)	Type	Programme Elective (PE)
Prerequisite			

Objectives

1. To deliver knowledge of fundamental principles of solar energy and their utilization.
2. To make students familiar with the potential of solar energy to meet the growing energy demands of society in a sustainable way.
3. To introduce solar thermal systems and related technologies.

Learning Outcomes

1. Knowledge to explain the technical and physical principles of solar collectors and solar thermal systems.
2. Ability to perform measurements on a wide variety of solar thermal systems and to evaluate their performance.
3. Ability to design solar thermal systems from energy requirements.

Contents

Introduction[2 Lectures]: Energy demand and supply, energy crisis, conventional and non-conventional energy resources, solar energy applications.

Solar Radiation [4 Lectures]: Solar radiation, attenuation by atmosphere, solar radiation on earth, measurement, utilization of data.

Flat Plate Solar Collector [5 Lectures]: General description of flat plate collectors, general characteristics, performance, short term and long term performance, design.

Concentrating Solar Collector [5 Lectures]: General description of focusing solar collectors, concentrators, receivers and orienting systems, general characteristics, performance, materials, design.

Energy Storage [5 Lectures]: Energy storage in a solar process system, different types of storages, characteristics, and capacity of storage medium, solar pond.

Solar Cooling and Heating [4 Lectures]: Passive heating and cooling, nocturnal radiation, Solar Cooking, Solar Desalination, Solar drying, Solar greenhouse.

Solar Cooling and Heating [4 Lectures]: Active heating and cooling, solar water/air heaters, absorption cooling, combined solar heating and cooling systems, performance, economics of solar heating and cooling.

Solar Thermal Power and Process heat [5 Lectures]: Solar thermal power, Examples: Rankine solar thermal power plant, Stirling Cycle, Solar industrial process heat.

Solar Thermal Design[4 Lectures]: Concept of system design, performance index, Simulation of Process, System performance, Design methods.

Economics and policies for Solar Energy [4 Lectures]: Definitions, Life cycle Costing, Economic Analysis, Payback period, current policies, clean development.

Textbook

1. John A. Duffie, William A. Beckman. John, (2013), *Solar Engineering of Thermal Processes*, Fourth Edition, Wiley & Sons, Inc.

2. Garg, H.P and Prakash, J, (2012) *Solar Energy: Fundamentals and Applications*, Tata McGraw – Hill Education
3. Tiwari, G.N. (2002), *Solar Energy Fundamentals, Design, Modelling and Applications*. Narosa publishing House, Delhi
4. Sukhatme, P, K and Nayak, J.K. (2008), *Solar Energy*, Tata McGraw-Hill Education, 3rd Ed.

Self-Learning Material

1. https://nptel.ac.in/courses/112/105/112105051/ (video course)
2. Excerpts, references, reading material, examples, problems & their solutions will be made available at the time of the course.

Title	**Non-Conventional Sources of Energy and Emerging Technologies**	Number	ME7XX
Department	Mechanical Engineering	L-T-P [C]	3–0–0 [3]
Offered for	B.Tech/M.Sc./M.Tech/M.Tech-Ph.D./Ph.D.	Type	Programme Elective (PE)
Prerequisite			

Objectives

The Instructor will:

1. Deliver knowledge of fundamental principles of non-conventional sources of energy and their utilization.
2. Teach important technologies of producing power from non-conventional and alternative energy sources.

Learning Outcomes

The students are expected to have the ability to:

1. Understand various energy sources such as solar, wind, hydropower, biomass, geothermal, and emerging technologies.
2. Utilize the potential of non-conventional energy sources and their applications.

Contents

(Fractal 1) *ME7XX1 Principles of Non-Conventional Sources and Solar Energy (1-0-0)*

Introduction to non-conventional energy sources [4 Lectures]: Availability and form of delivery; Energy consumption and conservation; Sustainable development; Standards and Regulations.

Solar radiation [5 Lectures]: Distribution, measurement and data; Solar energy collectors; Photovoltaic cell; Parabolic trough; Parabolic dish; Central receiver system; Solar energy storage.

Applications of solar energy [5 Lectures]: Solar distillation, Solar cooker, Solar drying, Solar greenhouse, Solar water heating, Solar heating and cooling of buildings.

(Fractal 2) *ME7XX2 Wind and Hydro Energy (1-0-0)*

Wind Energy [5 Lectures]: Wind data, Estimation and site selection; Principle of wind energy conversion- system and its components; Wind turbine and estimation of power output; Energy storage.

Application of wind energy [2 Lectures]: Applications and Environmental Aspects.

Hydro-electric power [5 Lectures]: Introduction and its classification; Typical components of micro/mini hydropower station; Water turbine; Pelton wheel turbine; Working principle, Performance and limitations.

Ocean wave energy [2 Lectures]: Working principle, Performance and limitations.

(Fractal 3) *ME7XX3 Geothermal, Biomass and Emerging Technologies (1-0-0)*

Geothermal Energy [4 Lectures]: Geothermal sources;Geothermal system and technologies; Ground-source heat pumps; Social and environmental aspects; Applications.

Biomass Energy conversion [4 Lectures]: Biomass conversion technologies, Classification, Advantages, and disadvantages; Production of biomass, Photosynthesis; Biogas generation; Properties of biogas and its purification; Applications.

Fuel cell [4 Lectures]: Working principle, Performance and limitations; Hydrogen Energy, Production methods, Storage and Transportation.

Hydrogen as an alternative fuel for vehicles [2 Lectures]

Textbook

1. J. Twidell, T. Weir, Renewable Energy Resources. 3rd Ed., Taylor & Francis Group, London, 2015.
2. J. A. Duffie, W. A. Beckman, Solar Engineering of Thermal Processes. 4th Ed., Wiley & Sons, Inc., 2013.
3. B.H.Khan, Non-Conventional Energy Resources. Tata McGraw-Hill Education, New Delhi, 2009.

Self-Learning Material

1. Dr. P. Haridoss, Non-Conventional Energy Resources, NPTEL Course Material, IIT Madras. https://nptel.ac.in/courses/121/106/121106014/

Title	**Porous Media Flows and Applications**	Number	ME6XX
Department	Mechanical Engineering	L-T-P-Th [C]	3–0–0–0 [3]
Offered for	B.Tech (ME)	Type	Programme Elective (PE)
Prerequisite	Basic knowledge in Fluid Mechanics		

Objectives

1. To impart the basic dynamic phenomena that occurs in within porous media from a mathematical and numerical perspective.
2. To apply different flow based equation to model porous flows in different media such as biomaterials, contaminant separation media, soils, etc.

Learning Outcomes

1. To exemplify how different porous processes occur in different multi-physical settings.
2. To apply empirical and deterministic porous media equations to model and design processes occurring in distinct phases.
3. To understand and identify different porous flow phenomena in biological, material transport, chemical as well as soil related contexts.

Contents

Basic concepts [6 Lectures]: Basics of porous materials, porosity, tortuosity, percolation, infiltration, soils, permeability, porous materials, biomaterials and their classifications, flow types, fluid types, nature of different fluids in different setting such a bio-fluid flows, ground water flows, water percolation and so on.

Visualizing and Experimental observation [6lectures] Understanding the porous nature, imaging techniques, microscopy and advanced methods, tomography methods, Hydrostatic- permeability measurements, Pressure variation. porosity measurement, capillary diaphragm methods, CT-scan and spectrometer method,

Modelling Basics [6 Lectures]: , Darcy's thought, Random walks and the advection diffusion equation, Network Models, Unit cells, volume averaging, elemental volumes, Statistical Descriptors Fractal Models, Effective Medium, Mixture Theories, Double Porosity Models,

Types of Media [5 lectures] Homogenous porous media, Stokes Thought, Karmen-Kozeny and Ergun's thought, Hazen-Dupuit-Darcy (HDD) models, Percolation Wettability, Klinkenberg effects, heterogeneous porous media, Mass and Momentum transport [6 Lectures]: Brinkman and Generalized Momentum aspects, Hydrodynamic boundary layers, Wall Channelling, Viscous fingering (application of box-counting for fractal dimension),

Thermal Aspects: [6lectures] Thermal properties and applications, Thermal dispersion, thermal conductivity measurement, lumped capacitance models, local thermal Non-equilibrium models, thermodynamics of Interface Energy Perspective [6 Lectures]: Forced convection thought, Nusselt numbers, energy equation appended with flows viscous dissipation, porous media as heat exchangers, pipes and channels with porous media fillings, Non Darcy flows, Heat Generation, Boundary layer calculations.

Textbook

1. Nield Donald A and Bejan Adrian, Convection in Porous Media, Fifth Edition, Springer Verlag
2. M. Kaviany, Principles of heat transfer in porous media, Second Edition, Springer Verlag
3. Arunn Narasimhan, Essentials of Heat and Fluid Flow in Porous Media, Ane Books Pvt Ltd.

4. Caffarelli L.A., Karakhanyan A.L. (2010) Lectures on Gas Flow in Porous Media. In: Cabrelli C., Torrea J. (eds) Recent Developments in Real and Harmonic Analysis. Applied and Numerical Harmonic Analysis. Birkhäuser, Boston, MA
5. Dullien, F.A.L. (1979), Porous Media, Academic Press
6. Scheidegger, Adrian E. (1974). The Physics of Flow Through Porous Media, 3rd Edition. University of Toronto Press

Reference Books

1. J. Bear, Dynamics of Fluids in Porous Media, Dover, 1972.
2. J. Cushman, The Physics of Fluids in Hierarchical Porous Media: Angstroms to Miles, Springer, 1997.
3. M. Beran, Statistical Continuum Theories, Wiley Interscience,1968.
4. S. Torquato, Random Heterogeneous Materials, Springer, 2002.

Title	**Micro-Nano Flows**	Number	MEL6XX0
Department	Mechanical Engineering	L-T-P [C]	3–0–0 [3]
Offered for	B.Tech (ME)	Type	Program Elective (PE)
Prerequisite	Fluid Mechanics & Heat Transfer		

Objectives

1. To inculcate the physics of liquid transport in micro-nano fabricated systems.
2. To introduce theory and physical principles of fluid mechanics on the microscale

Learning Outcomes

The students will have the ability to:

1. Understand physics involved in fluid flow in micro-nano fabricated systems
2. Solve problems of fluid flows in microchannels

Contents

Hydrodynamics Review [3 Lectures]: Continuum assumption, Conservation equations at Continuum level, Low Reynolds's no. flows-creeping flows, Physics of miniaturization, Scaling laws.

Fluid mechanics at Micro-scale [4 Lectures]: Intermolecular forces, States of matter, Governing equations, Constitutive relations, Gas and liquid flows, Boundary conditions, Slip theory-first order and higher order models, Transition to turbulence.

Shear driven Flows [6 Lectures]: Couette Flow- Slip flow regime, Transition and Free molecular, Oscillatory Couette Flow, Cavity Flow

Pressure driven Flows [6 Lectures]: Micro channel flows- Slip flow regime, Transition and Free molecular, Entrance flows, Effects of Roughness, compressible micro channel flows

Thermal Effects in Microscales [6 Lectures]: Thermal Creep, Heat Transfer in Poiseuille Microflows- Pressure-Driven Flows, Force-Driven Flows, Heat Transfer in Couette Microflows

Surface Tension-Driven Flows [5 Lectures]: Surface tension and interfacial energy, Different forms of Young's Equation, Thin Films, Capillary flows.

Electrokinetic Flows *[6 Lectures]:*Electrokinetic Effects, Electric Double Layer, Governing Equations, Electroosmotic Flows, Electrophoresis, Dielectrophoresis, Electrocapillary, Continuous electro-wetting, Direct
electro-wetting, Electro-wetting on dielectric.

Microfluidic devices [6 Lectures]: Micropumps,, Microvalves, Microflow sensors, Micromixers, Micropropulsion and Micronozzle Flows

Text Book

1. Karniadakis, G. M, Beskok, A, Aluru, N, (2005),*Microflows and Nanoflows: Fundamentals and Simulation*, Springer
2. Nguyen, N. T., Werely, S. T., (2002), *Fundamentals and applications of Microfluidics*, Artech house Inc.
3. Kirby, B.J., (2010), *Micro- and Nanoscale Fluid Mechanics: Transport in Microfluidic Devices*, Cambridge University Press.

Reference Books

1. Tabeling, P., (2005), *Introduction to microfluidics*, Oxford University Press Inc.
2. Colin, S., (2009), *Microfluidics*, John Wiley & Sons.

Self-Learning Material

1. https://nptel.ac.in/courses/112105187/
2. https://nptel.ac.in/courses/112106169/

Title	**Microfluidics Lab**	Number	MEL6XX0
Department	Mechanical Engineering	L-T-P [C]	0–0–2 [1]
Offered for	B.Tech (ME)	Type	Program Elective (PC)
Prerequisite	Fluid Mechanics & Heat Transfer		

Objectives

The instructor will:

1. Provide the practical knowledge with regard to the fluid flows in micro-nano fabricated systems
2. Provide practical exposer to various sensors and equipment use in micro system analysis

Learning Outcomes

1. The students will have the ability to:
2. Design microfluidic systems
3. Plan experiments to evaluate key performance characteristics of a micro-nano system

Contents

1. Visualisation of different micro-nano systems
2. Study of capillary action in conventional, mini and micro channels
3. Analysis of Laminar Flow and Diffusion in a Microchannel
4. Analysis of Turbulent Flow in Microchannel
5. Study of Droplet microfluidics
6. Electrophoretic Separation in a Microchannel
7. Demonstration of Paper Microfluidic Device for Blood-Plasma Separation
8. Measurement of Heat Transfer Coefficient during Flow Through Microchannel
9. Flow Simulation for micro-nano systems
10. Demonstration of ELectrokinetic Flows

Reference Books

1. Karniadakis, G. M, Beskok, A, Aluru, N, (2005), Microflows and Nanoflows: Fundamentals and Simulation, Springer
2. Nguyen, N. T., Werely, S. T., Fundamentals and applications of Microfluidics, Artech house Inc., 2002.
3. Kirby, B.J., Micro- and Nanoscale Fluid Mechanics: Transport in Microfluidic Devices,Cambridge University Press, 2010.

Title	**Tool Design**	Number	MEL4XX0
Department	Mechanical Engineering	L-T-P [C]	3–0–0 [3]
Offered for	B. Tech (ME)	Type	Program Elective (PE)
Prerequisite	----		

Objectives

The Instructor will:

1. discuss the fundamentals related to design of tools used during various manufacturing operations
2. principles of fixture design for various components

Learning Outcomes

The students will have the ability to:

1. design tooling and fixtures involved in manufacturing operations

Contents

Introduction To Tool Design [6 Lectures]: Tool engineering, Tool classifications, Tool design objectives, Tool design in manufacturing, Challenges and requirements, Standards in tool design, Tool drawings, Surface finish, Fits and tolerances, Tooling materials - Ferrous and nonferrous tooling materials - Carbides, Ceramics and Diamond - Non-metallic tool materials, Importance of tool design in PLM, Importance of tool design in process planning and selection of machine tool

Types of cutting tools [5 Lectures]: Single point cutting tools, Design of form tools, Design of drills, Reamers, Milling cutters, Broaching tools, Gear cutting tools, Thread cutting tools.

Cutting tools and tool holding [5 Lectures]: Tool holding methods for CNC machines, ISO standard for Inserts, 455 Tool holders, Selection of inserts and tool holders for specific applications, Automatic tool changers, Tool positioners and Tool presetting in CNC machines.

Design Of Jigs And Fixtures [8 Lectures]: Locating and supporting principles, Clamping and work holding principles, Drill bushes, Design of drill jigs and Milling fixtures, Turning fixtures, Welding fixtures, Modular fixtures.

Design Of Tools For Press Work [8 Lectures]: Study of power presses and accessories, Types of dies, Method of die operation, Clearance and cutting force calculations, Pilots, Strippers and pressure pads, Presswork materials, Strip layout, Design of blanking and piercing dies, Drawing dies, Bending dies, EDM for press tool making.

Mold elements [3 Lectures]: Mold Elements, Two plate and Three plate mold design,

Design of parts [4 Lectures]: Design of gates - runners - ejectors, under cut molds, hot runner mold.

Mold materials and manufacturing [3 Lectures]: Mold materials, mold manufacturing.

Text Book:

1. Donaldson C, Lecain G H and Goold V, (2012), *Tool Design*, Tata McGraw Hill.
2. Hoffman E. G, *Jigs and Fixtures Design*, Thomson Learning.

Reference Books:

1. Joshi P H, (2010), *Jigs and Fixtures*, McGraw Hill.
2. Arshinov V and Alekseev G, (1979), *Metal Cutting Theory and Cutting Tool Design*, MIR Publication

Self-Learning Material

1. A B Chattopadhyay, Manufacturing Processes II, NPTEL Course Department of Mechanical Engineering, IIT Kharagpur, https://nptel.ac.in/courses/112105126/

Title	**Applied Ergonomics**	Number	MEL4XX0
Department	Mechanical Engineering	L-T-P [C]	3–0–0[3]
Offered for	B.Tech (ME)	Type	Program Elective (PE)
Prerequisite			

Objectives

The Instructor will:

1. Teach about Human-Machine system, work study, Physical Ergonomics, Cognitive Ergonomics, Biomechanics, Physical Work Environment and Occupational Safety & Health

Learning Outcomes

Students will be able to

1. Correlate the understanding of this subject with their day to day activities and will be aware of concepts related to enhancing human as well as overall system efficiency. The course syllabus is designed so as to cover work physiology, engineering aspect of product, improvement in the cognitive capabilities etc.
2. Analyze the factors responsible for decreasing the system performance and work on those aspects, thereby making an efficient system.

Contents

Introduction [2 Lectures]: Overview of Ergonomics, Introduction to human-machine system.

Physical ergonomics [8 Lectures]: Work Physiology, Musculoskeletal system, Metabolism & digestive system, Cardiovascular system, Respiratory system

Anthropometry [8 Lectures]: Design principles, Collection of data & statistical tools).

Cognitive ergonomics [8 lectures]: Human Sensory system, Perception, Attention resources, Memory, Common Cognitive tasks

Physical work environment [8 Lectures]: Visual environment, Physics of light, Visibility & visual performance Lighting system, Auditory environment, Effect noise & permissible noise, Noise control, Climate control, Thermoregulation, Heat stress & cold stress

Biomechanics aspect and work study [4 Lectures]: Anatomical sites important for occupational ergonomics, manual work system, tools and techniques for work systems design and assessment

Industrial/organizational ergonomics [4 Lectures]: Occupational Safety & Health, Case studies over industrial problems

Text Books:

1. Bridger R. S., (2008), *Introduction to Ergonomics*, 3rd edition, CRC Press
2. Wickens C. D., (2003), *An Introduction to Human Factors Engineering*, 2nd edition, Pearson
3. David C. A. (1986) *The practice and management of Industrial Ergonomics*, Prentice Hall

Online Course Material:

1. https://nptel.ac.in/courses/nptel_download.php?subjectid=112104222

Title	**Micro-Nano Manufacturing**	Number	MEL4XX0
Department	Mechanical Engineering	L-T-P [C]	3–0–0 [3]
Offered for	B. Tech (ME)	Type	Program Elective (PE)
Prerequisite	----		

Objectives

The Instructor will:

1. Provide exposure to students with emerging manufacturing techniques for producing micro- and nano-level products

Learning Outcomes

The students will have the ability to:

1. Able to appreciate the processes employed for the fabrication of miniaturized products.
2. Explain the physical description, modelling and experimentations for manufacturing at micro and nano scale.

Contents

An overview of micro and nano mechanical systems and their applications in Mechanical Engineering [5 Lectures]: Nano-machines, Nanomechanics, Nano-metrology, Nano-tribology, Nano-fluidics, Nano-manufacturing.
MEMS Micro fabrication [7 Lectures]: Science, modelling and experimental aspect of diffusion, thermal oxidation, ion implantation, rapid thermal processing, optical lithography, photoresists, non-optical photolithography, vacuum processes and plasmas, and etching processes, thin film manufacturing using physical vapor deposition, chemical vapor deposition, epitaxial growth processes.
Silicon Micromachining [5 Lectures]: anisotropic wet chemical etching, wafer bonding, dry plasma etching, surface micromachining
Laser Micromachining methods [2 Lectures]
Mechanical Micromachining [6 Lectures]: Abrasive micro grinding, micro milling, micro electro discharge machining, micro electro chemical machining, nano grinding.
Beam method [2 Lectures]: focused ion beam and electron beam machining.
Fabrication of nano materials and nano crystalline materials [7 Lectures]: Characterization techniques such as SEM, SPM,AFM,TEM
Micro- nano patterned surfaces for functional devices [6 Lectures]: application potential of micro and nano structured surfaces
Recent advances in micro & nanofabrication [2 lectures]

Reference Books:

1. Drexler K E, Nanosystem: *Molecular Machinery, Manufacturing and Computation*, John Wiley
2. Rai-Choudhuri P, *Handbook of Microlithography, Micromachining and Microfabrication*, SPIE Press
3. McGeough J A, *Micromachining of Engineering Materials*, Marcel Dekkar
4. Jain V K,(2011), *Introduction to micromachining*, Narosa Publications
5. Cabrini S and Hawata S, (2012), *Nano fabrication hand book* – CRC press

Self-Learning Material

1. K N Bhat, Micro- and Smart Systems, NPTEL Course Material Department of Electrical Engineering, IISc Bangalore, https://nptel.ac.in/courses/112108092/

Title	**Design and Manufacturing of Biomaterials**	Number	MEL6XX0
Department	Mechanical Engineering	L-T-P [C]	3–0–0 [3]
Offered for	B. Tech (ME)	Type	Program Elective (PE)
Prerequisite	----		

Objectives

The Instructor will:

1. Discuss the fundamental principle in biomedical engineering material science, chemistry.
2. Enable engineering skills to students needed to solve challenges in the biomaterials and tissue engineering domain.

Learning Outcomes

The students will have the ability to:

1. appreciate processes used in making of biocompatible materials

Contents

Classes of materials used in medicine and healthcare [5 Lectures]: Metals, polymers, FRPs, fabrics, nanocomposites, ceramics, glasses etc

Bioresorbable and bio-erodable materials [3 Lectures]

Host reactions to biomaterials [5 Lectures]: biocompatibility, implant associated infection;

Testing of biomaterials [5 Lectures]: In vitro assessment, in vivo assessment, blood materials interactions.

Design of materials for biomedical application [4 Lectures]: Cardiovascular, dental implants, orthopaedic application, skin, ophthalmologic applications, wound healing, sutures,

Biomedical and biosensors [2 Lectures]

3-D printing of biomaterials [6 Lectures]: Fabrication of nanomaterials, tissue regenerations, laser assisted bio printing, scaffolding techniques,

3-D scaffold for organs, bone regeneration [2 Lectures]

Implantation techniques for soft tissue and hard tissue replacements [6 Lectures]: Problems and possible solutions in implant fixation;

Failure analysis of medical devices and implants [4 Lectures]

Text Book:

1. Ratner B D, Hoffman A, Schoen F, Lemons J, (2004), *Biomaterials Science: An Introduction to Materials in Medicine*, Academic Press
2. Park J.B. and Bronzino J.D., (2002), *Biomaterials: Principles and Applications*. CRC Press. ISBN: 0849314917

Reference Books:

1. Wright T M, and Goodman S B, (2001), *Implant Wear in Total Joint Replacement*: Clinical and Biologic Issues, Material and Design Considerations. American Academy of Orthopaedic Surgeons.
2. Ambrosio L, (2009), *Biomedical composites*, Woodhead Publishing Limited, UK.
3. Hin T.S., (2004), Engineering *Materials for Biomedical Applications*. World Scientific. ISBN 981-256-061-0

Self-Learning Material

1. M Doble, Medical Biomaterials, NPTEL Course Material Department of BioEngineering, IIT Madras, https://nptel.ac.in/courses/102106057/

Title	**Computer Integrated Manufacturing**	Number	MEL6XX0
Department	Mechanical Engineering	L-T-P [C]	3–0–0 [3]
Offered for	B. Tech (ME)	Type	Program Elective (PE)
Prerequisite	----		

Objectives

The Instructor will:

1. Understand the effect of manufacturing automation strategies and derive production metrics
2. Analyze automated flow lines and assembly systems, and balance the line.

Learning Outcomes

The students will have the ability to:

1. Design automated material handling and storage systems for a typical production system
2. Design a manufacturing cell and cellular manufacturing system
3. Develop CAPP systems for rotational and prismatic parts.

Contents

Manufacturing Automation [4 Lectures]: Automated Manufacturing Systems, Computerized Manufacturing Support Systems, Reasons for Automation, Automation Strategies-The USA Principle

Automated Flow lines [4 Lectures]: System Configurations, Workpart Transfer Mechanisms, Storage Buffers, Control of Production Line, Analysis of Transfer Lines-Transfer Lines with No Internal Parts Storage

Manual Assembly Lines [4 Lectures]: Assembly Workstations, Work Transport Systems, Line Pacing, Coping With Product Variety, Analysis of Single Model Assembly Lines-Repositioning Losses, The Line Balancing Problem, Line Balancing Algorithms-Largest Candiate Rule, Kilbridge and Wester Method, Ranked Positional Weights Method

Automated Assembly Systems [4 Lectures]: System Configurations, Parts Delivery at Workstations, Applications, Quantitative Analysis of Assembly Systems- Parts Delivery System at Workstations, Multi-station Assembly machines, Single Station Assembly Machines, Partial Automation

Automatic Material Handling and Storage systems [4 Lectures]: Design Considerations in Material Handling, Material Transport Equipment-Industrial Trucks, Automated Guided Vehicles, Monorails and Other Rail-Guided Vehicles, Conveyors, Cranes and Hoists, Analysis of Vehicle Based Systems, Conveyor Analysis. Automated Storage/Retrieval Systems, Carousel Storage Systems

Automated Inspection systems [4 Lectures]: Overview of Automated Identification Methods, Bar Code Technology, Radio Frequency Identification, Other AIDC Technologies-Mangnetic Stripes, Optical Character Recognition, and Machine Vision

Cellular Manufacturing Systems [4 Lectures]: Part Families, Parts Classification and Coding, Features of Parts Classification and Coding Systems, Opitz of Parts Classification and Coding Systems, Production Flow Analysis, Composite Part Concept, Machine Cell Design, Quantitative analysis of Cellular Manufacturing, Grouping of parts and Machines by Rank Order Clustering, Arranging Machines in a GT Cell

Flexible Manufacturing Systems [4 Lectures]: Flexibility, Types Of FMS-A Dedicated FMS, A Random Order FMS, FMS Components-Workstations, Material Handling and Storage Systems, Computer Control System, Human Recourses, FMS Applications and Benefits

Agile Manufacturing and Lean Manufacturing [2 Lectures]

Text Book:

1. Groover M. P., (2007), *Automation, production Systems and Computer Integrated Manufacturing*, 3 rd Edition, Prentice Hall Inc., New Delhi.
2. Singh N., (2006), *System Approach to Computer Integrated Manufacturing*, Wiley & Sons Inc.
3. Kusiak A, (2002), *Intelligent Manufacturing System*, Prentice Hall Inc., New Jersey.

Self-Learning Material

1. J Ramkumar, Computer Integrated Manufacturing, NPTEL Course Department of Mechanical Engineering, IIT Kanpur, https://nptel.ac.in/courses/112104289/

Title	**Design for Manufacturing**	Number	MEL6XX0
Department	Mechanical Engineering	L-T-P[C]	3–0–0 [3]
Offered for	B.Tech (ME)	Type	Program Elective
Prerequisite			

Objectives

The Instructor will:

1. Demonstrate the importance of integrating design and manufacturing to optimize production cost, quality and flexibility
2. Discuss topics related to design for quality and reliability along with approaches towards robust design

Learning Outcomes

The students are expected to have the ability to:

1. Understand the impact of manufacturing constraints on product design and process planning
2. Understand factors controlling production rate and influence the quality, cost and flexibility of manufacturing processes and systems.

Contents

Introduction [4 Lectures]: Need identification and problem definition, Concept generation and evaluation, embodiment design

Selection of Materials and Shapes [8 Lectures]: Properties of engineering materials, Selection of materials (with examples and case studies), selection of shapes, Co-selection of materials and shapes.

Selection of Manufacturing processes [8 Lectures]: Overview of manufacturing processes, Design for Casting, Design for bulk deformation and sheet metal processes,

Processing of polymer [8 Lecture]: Design for Machining, Design for Polymer and powder processing, Case studies.

Design for Assembly [8 lectures]: Review of Assembly operations, Design for Welding, Soldering, Brazing and Adhesive joining, Design for heat treatment, Case Studies

Design for Reliability and Quality [6 Lectures]: Failure Mode and Effect Analysis, Design for Quality, Design for Reliability, Approach to robust design, Design for optimization

Reference Books:

1. Dieter G., *Engineering Design - a materials and processing approach*, McGraw Hill
2. Ashby M. F., *Material Selection in Mechanical Design*, Butterworth-Heinemann
3. Boothroyd G., Dewhurst P., and Knight W., *Product Design for Manufacture and Assembly*, John Wiley
4. Bralla J. G., *Handbook for Product Design for Manufacture*, McGraw Hill

Online Course Material:

1. https://nptel.ac.in/courses/107103012/
2. https://ocw.mit.edu/courses/mechanical-engineering/2-008-design-and-manufacturing-ii-spring-2004/

Title	**Casting and Allied Processes**	Number	MEL4XX0
Department	Mechanical Engineering	L-T-P [C]	3–0–0 [3]
Offered for	B. Tech (ME)	Type	Program Elective (PE)
Prerequisite	----		

Objectives

The Instructor will:

1. Impart fundamental understanding of various casting processes.
2. Discuss fundamentals of solidification, design principles, melting techniques etc.

Learning Outcomes

The students will have the ability to:

1. Appreciate various casting processes and its selection for different materials
2. Design systems and components necessary for obtaining cast components.

Contents

Casting Processes [8 Lectures]: classification, characteristics of sand casting processes, metal mould casting processes and casting processes using other mould/core materials, Pattern materials, types of patterns, Mould and core making materials and their characteristics

Technology of Selected Casting Processes [6 Lectures]: clay bonded, oil bonded, synthetic resin bonded, and inorganic material bonded mould and core making processes. Sand additives and mould coatings. Metal mould casting processes, centrifugal and continuous casting processes

Casting for heterogeneous materials [6 Lectures]: FRP, quick casting , full mould casting, evaporative pattern casting

Solidification [7 Lectures]: Nucleation and grain growth, Solidification of pure metals, short and long freezing range alloys. Rate of solidification, Solidification contraction.

Microstructure study and testing [5 Lecture]: macrostructure and microstructure Fluidity and its measurement. Mould-metal interface reactions.

Design of the casting system [4 Lecture]: Gating and Risering design & analysis.

Melting and quality control of various steels and non-ferrous alloys [6 Lectures]: Casting defects - fettling, inspection and testing of castings

Reference Books:

1. Serope Kalpakjian, (1997), *Manufacturing processes for Engineering Materials*, Addison Wesley.
2. Mukherjee, P. C. *Fundamentals of metal casting technology*, Oxford and IBH.
3. Dieter G, *Mechanical Metallurgy*, Me Graw Hill, Kogakusha
4. Korolkove, V.*Casting properties of metals and alloys*

Self-Learning Material

P K Jha, Principles of Metal Casting, NPTEL Course Material Department of Mechanical Engineering, IIT Roorkee https://nptel.ac.in/courses/112107215/

Title	**Non-Traditional Machining Processes**	Number	MEL4XX0
Department	Mechanical Engineering	L-T-P [C]	3–0–0 [3]
Offered for	B. Tech (ME)	Type	Program Elective (PE)
Prerequisite	----		

Objectives

The Instructor will:

1. Discuss the fundamentals of non-conventional machining processes.
2. Appreciate the effect of process parameters on quality of machined components

Learning Outcomes

1. Students will learn new class of machining techniques used in industries
2. Students will learn about process parameters involved in non-traditional techniques and their effects on process performance
3. Students will be aware of distinct class of materials along with their industrial applications

Contents

Introduction [2 Lectures]: Technological and commercial need, classification, performance constraints, selection of NTM, advanced processes

Mechanical Machining Process [7 Lectures]: Abrasive jet machining, water jet cutting, abrasive water jet machining, abrasive flow machining, magnetic abrasive finishing - process variables, material removal rate, mechanism of material removal, process capabilities, abrasive particle size, limitations and applications.

Ultrasonic Machining [4 Lectures]: Ultrasonic machining system, mechanics of cutting, process parameters, analysis, capability, grain growing model, grain hammering model, applications and limitations.

Electro Discharge Machining (Edm) [7 Lectures]: Working principle, process parameters, process capabilities, components of system and its functions, analysis of RC circuit, power delivered to discharging circuit, current in discharge circuit, parametric relation for material removal rate and surface finish, gap cleaning, process characteristics, effect of various parameters on material removal rate, application and limitations,, wire EDM machine, stratified wire, process characteristics, applications and limitations.

Laser Beam Machining (LBM) [4 Lectures]: Production of lasers, types of lasers, process characteristics, working principle, process parameters, process capabilities, components of system and its functions, limitations, application in drilling, cutting, marking and miscellaneous applications.

Plasma Arc Machining (PAM) [4 Lectures]: Working principle, process parameters, process capabilities, elements of PAM system and their functions, various plasma arc torches, process capabilities, comparison with oxy fuel cutting, applications and limitations.

Electron Beam Machining (EBM) [2 Lectures]: Working principle, process parameters, process capabilities, elements of EBM system and their functions, applications and limitations.

Introduction to ElectroChemical And Chemical Machining Processes [2 Lectures]: Working principle components and functions, process parameters, limitations and applications.

Mechanism of MRR [3 Lectures]: Electro chemical machining, material removal rate and mechanism.

Parametric study [7 Lectures]: inter electrode gap, zero feed rate, finite feed rate, maximum permissible feed rate, self-regulation feature, effect of Joule's heating, effect of hydrogen bubbles generation, anode shape prediction.

Application, Advantages and limitations [2 Lectures]: Tool design - Chemical machining, masks, etchants, advantages and limitations.

Text Book:

1. Jain V K, (2012), *Advanced Machining Processes*, Allied Publications Private Limited.
2. McGeough J A, (2011), *Advanced Methods of Machining*, Springer.
3. Benedict G F, (2011), *Non Traditional Manufacturing Process*, Taylor and Francis.

Reference Books:

1. Pandey P C and Shan H S, (2011), *Modern Machining Process*, Tata McGraw Hill Publications.
2. Ghosh A and Mallik A K, (2006), *Manufacturing Science*, East West Press Private Limited.
3. Abdel H and El-Hofy G, (2005), *Advanced Machining Processes*, McGraw Hill Publications.
4. Sommer C, (2000), *Non-traditional Machining Handbook*, Advance Publishing Inc.

Self-Learning Material

1. V K Jain, Advanced Machining Processes, NPTEL Course Department of Mechanical Engineering, IIT Kanpur, https://nptel.ac.in/courses/112104028/

Title	**Welding Science and Technology**	Number	MEL4XX0
Department	Mechanical Engineering	L-T-P [C]	3–0–2 [4]
Offered for	B. Tech (ME)	Type	Program Elective (PE)
Prerequisite	----		

Objectives

The Instructor will:

1. Impart fundamental understanding of various conventional and non-conventional welding processes
2. Discuss various metallurgical aspects related with welding
3. Discuss heat transfer and associated issues with the welding operation

Learning Outcomes

The students will have the ability to:

1. Appreciate the physics of welding operation and allied processes and select the process
2. Model heat transfer and cooling characteristics of welding

Contents

Introduction and classification of welding [7 Lectures]: Design principles of welded structures; Physics of welding arc – characteristics of arc, mode of metal transfer, forces acting on a molten droplet.
*Shielded metal arc welding, Submerged arc welding (SAW) [3 Lecture]:*Gas tungsten arc welding, Gas metal arc welding,
*Arc welding [6 Lectures]:*Flux cored arc welding, Plasma arc welding, Electroslag welding, Electrogas welding, Arc stud welding, Synergic and pulsed welding.
Diffusion welding [2 Lecture].
Friction welding, resistance welding, brazing, soldering [8 Lectures]:
Power source [4 Lecture]: Types of power source and their characteristics.
Flux and coating [4 Lecture]: Welding fluxes and coatings - type and classification.
Welding thermal cycle [2 Lecture]: Cooling rates, models for welding heat sources.
Testing of the welded joint [4 Lecture]: Non-destructive Testing of welds, fracture and fatigue of welded structures.
Role of heat treatment and alloying elements on performance [4 Lecture]: Welding metallurgy, heat treatment of welds, effect of alloying materials.
Welding symbol for process and position [2 Lecture]: Welding symbols, standards and codes.

Laboratory Classes (12 Classes):

Study of temperature distribution during weld thermal cycle.
Study of residual deformation in arc welded joint.
Distortion study for the welded joint.
Effect of the welding parameters on bead profile.
Study on effect of welding parameters on mechanical performance of the welded joint.
Study of the heat input on microstructure of bulk weld metal and HAZ.
Non-destructive testing of the welded joint (Liquid penetrant testing).

Text book:

1. Brien, O., (2004), *Welding Handbook: Welding Processes, Part 1, Vol. 2*, AWS.
2. Lancaster J. F., (1986), *The Physics of welding*, Pergamon,.
3. Messler, R. W., (1999), *Principles of Welding*, John Wiley and Sons.

Reference book:

1. Grong O., (1997), *Metallurgical modelling of welding*, 2nd Ed, IOM Publication.
2. Radhakrishnan V M, (2002), Welding technology and design, New age.
3. Goldak A, (2005), *Computational welding mechanics*, Springer.
4. Lindgren L E, (2007), *Computational welding mechanics*, Woodhead Publishing Limited.

Self-Learning Material

1. G Phanikumar, Analysis and Modeling of Welding, NPTEL Course Material Department of Metallurgical Engineering, IIT Madras, https://nptel.ac.in/courses/113106067/

Title	**Welding Metallurgy**	Course No.	MEL6XX0
Department	Mechanical Engineering	L-T-P[C]	3-0-0[3]
Offered for	B. Tech (ME)	Type	Program Elective
Pre-requisite			

Objectives

1. To provide students understanding of the metallurgical principles involved in welding of ferrous and non-ferrous metals and alloys and to provide knowledge on dissimilar metal welding.

Learning Outcomes

1. To enable understanding and effective application of physical metallurgy principles to non-equilibrium thermo-mechanical conditions associated with welding.
2. Facilitate understanding and familiarity of the joining of dissimilar metal welds.
3. Understanding of the basic fundamentals, techniques and processes suitable for welding non-ferrous alloys.

Course Content

Metallurgy principles for welding [6 Lectures]: Application of physical metallurgy principles to non-equilibrium thermo-mechanical conditions associated with welding.

Heat and Fluid Flow in Welding [10 Lectures]:

Fluid flow in welding [5 Lecture]: fluid flow at flow in welding, Fluid flow and metal evaporation in welding.

Chemical reaction during the welding process [5 Lecture].

Fusion zone [12 Lectures]:

Various zones of the welded joint [6 Lecture]: Fusion zone, Partially melted zone, Heat affected zone.

Solidification and cracking in welds [6 Lecture]: Weld solidification principles, Chemical Inhomogeneities and cracking.

Welding of various materials [12 Lectures]:

Welding of similar alloys [6 Lecture]: Welding of stainless steels, aluminum alloys, copper alloys and Nickel alloys.

Joining of Dissimilar metal welds [6 Lectures]: Ni/Cu with SS; different grade steels.

Reference Books

1. Sindo Kuo, (2002), *Welding Metallurgy*, Second Edition, Wiley
2. Easterling K.E., (1992), *Introduction to the physical metallurgy of welding*, Butterworths
3. Lippold J. C. and Kotecki D. J., (2005), *Welding Metallurgy and Weldability of Stainless steels*, Wiley

Self Learning Material

1. http://nptel.ac.in/courses/113106082/

Course Title	**Fundamentals of Metal Forming Technology**	Number	MEL6XXX
Department	Mechanical Engineering	L-T-P-Th [C]	3-0-0-0 [3]
Offered for	B.Tech (ME)	Type	Programme Elective (PE)
Prerequisite			

Objectives

1. To impart the basic knowledge and concepts used in the area of metal forming technology.
2. To understand the science and technology of different forming processes and analyze forming problems - both the mechanics of forming processes and how the properties of metals interact with the processes.

Learning Outcomes

1. The course will enable the students to be conversant with working principles so that they can use the knowledge gained towards increasing the productivity of manufacturing industries in the long run.
2. Enabling the students to understand the fundamentals of the formability of materials.

Contents

Introduction [4 Lectures]: Introduction to metal forming technology; Classification of metal forming processes; Cold, warm and hot working; Mechanical behavior of materials.
Mechanical properties of materials [5 Lectures]: Concepts of stress-strain; State of stress in three-dimension; Elastic and plastic stress-strain relationships; Tensile properties; Flow stress and flow curves.
Theory of plasticity[5 Lectures]: Introduction to the theory of plasticity; Yield criteria; Strain, strain rate and temperature effects on flow properties; Microstructure variable and residual stresses.
Bulk forming processes [6 Lectures]: Introduction and classification of forging, rolling, extrusion, wire and tube drawing processes; Defects in rolled and forged products.
Analysis of bulk forming processes [5 Lectures]:Analysis of forming processes by Slab method, Slipline field method, Upper and lower bound methods.
Factors affecting metal working *[2 Lectures]*: Friction and lubrication in metal working; Metallurgical parameters affecting metal working processes.
Sheet metal forming processes [4 Lectures]: Shearing, Punching/Blanking, Bending &Deep drawing, Stretch forming, etc.
Formability [5 Lectures]: Formability testing of sheet metals; Determination of forming limit diagrams (FLD) and their applications; Defects in sheet metal forming; Case studies on the evolution of stress-strain during the forming processes.
Special metal forming processes [6 Lectures]: High-energy rate forming such as explosive, electrohydraulic and magnetic forming processes; Powder metallurgy forming; Pilgering, Semi-solid forming, Forming by severe plastic deformation (SPD) processes; Hot isostatic pressing (HIP).

Text Books

1. Ghosh A. and Mallik A.K., Manufacturing Science, Pearson India, 2010.
2. Altan T. and Tekkaya A.E., Sheet Metal Forming: Processes and Applications, ASM International, 2012.
3. Harris J.N., Mechanical Working of Metals - Theory and Practice, Pergamon 1983.

Reference Books

1. Rowe G.W., An introduction to the Principles of Metalworking, Edward Arnold, 1968.
2. Dieter G.E., Mechanical Metallurgy (Third edition), McGraw Hill Education, 2017.

Self-Learning Material

1. https://nptel.ac.in/courses/112/107/112107250/
2. https://nptel.ac.in/courses/112/106/112106153/

Title	**Introduction to Acoustics**	Number	ME4XX
Department	Mechanical Engineering	L-T-P-Th [C]	3–0–0–0 [3]
Offered for	B.Tech (ME)	Type	Program Elective (PE)
Prerequisite	Linear Algebra and Calculus		

Objectives

1. This course aims to provide fundamental concepts of acoustics involving sound propagation, sound generation, sound radiation, sound reflection and transmission, and sound reception, and use of these concepts for studying and development of noise control methods

Learning Outcomes

The students are expected to have the ability to:

1. Understand characteristics of acoustic field for different scenarios like in a room, in a muffler, in a duct, in free field etc.
2. Identify different noise sources in a system and then, work to develop methods to reduce the noise.

Contents

Introduction and terminology used in acoustics [1 Lecture]
Acoustic wave equation and its simple solutions [4 Lectures]
Spherical waves [3 Lectures]: Inhomogeneous acoustic wave equation, concept of point source
Reflection and transmission [5 Lectures]: Plane waves under normal and oblique incidence, Sound transmission through a fluid layer and a thin panel
Radiation [5 Lectures]: Sound field of oscillating spheres (as elemental sources), Sound field due to monopole, dipole and quadrupole sources, their importance, and their relation with oscillating spheres, sound field from a plane circular piston, continuous line source, radiation impedance, directivity and directivity index
Acoustic field in a rectangular waveguide of constant cross section [3 Lectures]
Pipes, resonators and filters [4 Lectures]: Resonance in pipes, power radiation from open ended pipes, Helmholtz resonator, Mufflers, Acoustic barriers and enclosures
Sound absorption [5 Lectures]: A simple model for growth of sound in a room, Reverberation Time, Sound absorption and Sound absorption materials, direct and reverberant sound
Electro-mechanical-acoustic analogies [4 Lectures]: Lumped parameter modeling of a loudspeaker using these analogies
Hearing [2 Lectures]: Anatomy of human ear and function of different parts, Fundamental properties of hearing
Noise and sound measurement [3 Lectures]: Introduction to sound measurement and instrumentation, frequency analysis, octave analysis, Combining band levels, Loudness level and loudness, Pitch and frequency
Green's function and Kirchoff's formula [3 Lectures]: Introduction to generalized functions and Green's theory for solution of partial differential equations, as required in acoustics, Reciprocal theorem in linear acoustics, Kirchhoff's formula of linear acoustics in the presence of surfaces.

Textbook

1. Kinsler L. E., Frey A. R., Coppens A. B., Sanders J. V., (1999), *Fundamentals of Acoustics*, 4th Edition, Wiley
2. Beranek L., Mellow T. (2019), *Acoustics: Sound Fields, Transducers and Vibration*, 2nd Edition, Academic Press

3. Migeot J. L., Coyette J. P., Lielens G., (2016), *Acoustics: Essential concepts, theory and models of linear acoustics for engineers*, 1st Edition, IJK Numerics
4. Munjal M. L., (2013), *Noise and Vibration Control*, World Scientific Publishing Pte. Ltd.
5. Dowling and Ffowcs-Williams, (1983), *Sound and sources of sound*, Ellis Horwood Publishers.

Self Learning Material

1. https://nptel.ac.in/courses/112106225/
2. https://nptel.ac.in/courses/112104026/
3. http://teachingexcellence.mit.edu/category/inspiring-teachers/amar-g-bose-6-312-acoustics

Title	**Computer Aided Design**	Number	ME4XX
Department	Mechanical Engineering	L-T-P-Th [C]	3–0–2 [4]
Offered for	B.Tech (ME)	Type	Program Elective (PE)
Prerequisite	Linear Algebra and Calculus		

Objectives
To introduce the concepts of geometric modelling and its use in Computer Aided Design

Learning Outcomes:
1. Understanding fundamentals of geometric modelling techniques
2. Understand the application of geometric modelling and CAD techniques in creation of product desi

Contents
Transformations [6 Lectures]: 2D transformations, 3D transformations, Projections
Analytical Curves [2 Lectures]: Circle, Ellipse, Parabola, Hyperbola, General quadratic curve
*Synthetic Curves [4 Lectures]:*Cubic Curves (Hermite), Parabolically blended Curves, Bezier curves, *B-spline Curves, NURBS [4 Lectures]*
Surfaces [3 Lectures]: Surface of revolution, Sweep Surfaces, Quadratic Surfaces, Spherical Surfaces
Surfaces [6 Lectures]: Coon's linear and bicubic patches, Ruled and Developable Surfaces, *Bezier Surfaces,* B-spline Surfaces, Rational Surfaces
Curve and Surface intersections and relational properties [4 Lectures]
Solid Modelling [6 Lectures]: B-rep, CSG, Analytical solid modelling, Octree and Voxel representation, Euler's operators, Euler's formula, Euler-Poincare characteristics, Topology and Geometry
Optimum Design [4 Lectures]: Purpose and applications of optimum design, effect of manufacturing errors; Characteristics of mechanical systems; Selection of optimum configuration; Critical regions; Materials and dimensions; Primary and subsidiary design equations; Limit equations; Normal redundant and incompatible specifications;
Design techniques *[3 Lectures]:* Exact and iterative techniques. Optimal design of elements and systems; shafts, beams, gears, bearings, springs, high speed machinery, cams, intermittent motion devices.

Laboratory Classes [12-13 Classes]
Rotation of a 2D object about any arbitrary point (m, n) using 2D transformations , Reflection of a 2D object about any arbitrary line using 2D transformations, Rotation of a 3D object about any arbitrary line using 3D transformations, Reflection of a 3D object about any arbitrary plane using 3D transformations, Program for Oblique projection (Verify with cube with cut section), Program for Perspective projection (Verify with cube or cube with cut section), Program for translating the object, rotating the object and then performing perspective projection, program to find curve values { x(t), y(t), z(t) } for normalised cubic splines when initial and final points of the curve and tangents at initial and final points are given, Plot Bezier basis function or Bernstein basis functions or blending function for Bezier curves of various degree, MATLAB code to plot B-spline basis functions and B-spline curves. The code should facilitate choice of knot vector: Uniform knot vector, open uniform knot vector, non-uniform knot vector, non-uniform knot vector proportional to chord distances, MATLAB code to plot rational B-spline basis functions and rational B-spline curves, MATLAB code for generating Bezier

Surfaces, MATLAB code for generating B-spline surfaces, MATLAB code for generating rational B-spline surface

Textbook

1. Rogers D.F, and Adams J. A., *Mathematical elements of Computer Graphics*, McGraw Hill
2. Mortenson M. (2006), *Geometric modelling*, Industrial Press
3. Zeid, I., and Sivasubramanian, R., *Theory and Practice CAD/CAM*, McGraw Hill
4. Johnson,'Optimum Design of Mechanical Element', John Wiley and Sons, 1961.
5. Johnson, 'Mechanical Design Synthesis', Van Nostrand Reinhold, 1970.
6. Fox, 'Optimization Methods for Engineering Design', Addison-Wesley, 1971.

Self-Learning Material:

1. http://nptel.ac.in/courses/106108056/
2. https://nptel.ac.in/courses/112104031/
3. https://nptel.ac.in/courses/112102101/

Title	**Principle of Biomechanics**	Number	ME4XX
Department	Mechanical Engineering	L-T-P-Th [C]	3–0–0[3]
Offered for	B.Tech (ME, BS & BE)	Type	Programme Elective(PC)
Prerequisite	Engineering mechanics, linear algebra, differential equations, and mechanics of materials		

Objectives

1. To provide basic background in biomechanics for engineering students to understand the overview of musculoskeletal anatomy, mechanical and structural behavior of biological organs
2. To analysis the forces in human function and movement; energy and power in human activity
3. To apply the concept of stress and strain analysis in biological tissues and organs
4. To explore the concept of viscoelasticity in modeling of biological organs

Learning Outcomes

1. Ability to identify a given bone, ligament or muscle by name, anatomic location, or function
2. Ability to demonstrate the basic principles of mechanics to the analysis of human movement
3. Ability to analyze the forces at a skeletal joint for various static and dynamic human activities
4. Ability to calculate the stresses and strains in biological tissues given the loading conditions and material properties
5. Ability to identify the appropriate viscoelasticity model for the mechanical behavior of a given biological tissue.

Contents

Basic Terminologies [5 Lectures]: Skeletal System, Axial and Appendicular Skeleton, Bones in Human Body, Types of Joints, Movements about Joints, Levers in the Human Body

Principle of Statics and its application of Musculoskeletal System [5 Lectures]: Joint structures and function, Joint Forces and Moments, Muscle Forces, Structural Function/Analysis of Skeletal Body Element (Shoulder, Elbow And Forearm, Wrist And Hand, Trunk And Spine, Hip, Knee, Ankle, Patterns Of Movement

Review of Dynamics and its applications [5 Lectures]: Linear And Angular Kinematics of Human Motion, Kinetic of Human Motion, Examples In Biomechanics; Applications of Human Motion Analysis In Fluid Medium

Stress And Strain In Tissue [5 Lectures]: Bone, Tendon and Ligament, Muscle, Articular Cartilage, Hookian Constitutive Law (Homogeneous/Non Homogeneous, Isotropic/Anisotropic),

Linear/Nonlinear Behavior of Tissues and its degradation [7 Lectures]: Tensile, Compressive, And Shear Properties of Connective Tissues, Mechanical Properties of Bones, Degradation of Tissue

Anisotropic Behavior of Bone [5 Lectures]: Response Of Tissue to Different Loading Conditions (Overload Injuries And Conditioning),

Introduction to Viscoelasticity [Lecture 5]: Viscoelasticity of Soft Tissues, Models of Viscoelasticity (Maxwell, Voigt, Kelvin),

Viscoelastic Behavior of Tissues[Lecture 5]: Viscoelastic Behavior of Tendons, Tendon Interaction with Surrounding Tissues, Mechanical Properties of Muscles

Textbooks

1. Hall, S. J, *Basic biomechanics*.
2. Ozkaya and Nordin, *Fundamentals of biomechanics: equilibrium, motion, and deformation.*

3. Mow And Hayes, *Basic orthopedic biomechanics*
4. Nordin & Frankel, *Basic biomechanics of the musculoskeletal system*
5. *Duane Keaton, 'Fundamentals of Biomechanics', 2nd Ed, Springer, 2007*

Reference Books

1. Fung, *Biomechanics: mechanical properties of living tissues*
2. Winter, *Biomechanics and control of human movement*

Title	**Mechanical Vibrations**	Number	ME4XX
Department	Mechanical Engineering	L-T-P [C]	3–0–0 [3]
Offered for	B.Tech. (ME)	Type	Program Elective (PE)
Prerequisite			

Objectives
The Instructor will:
1. Provide the fundamentals of vibration of discrete systems, influence of damping

Learning Outcomes
The students are expected to have the ability to:
1. Analyse the vibration characteristics of discrete systems
2. Thorough understanding of modeling of damping and their effects on system response

Contents
Introduction [1 Lecture]
Single degree of freedom systems [5 Lectures]: Undamped free and forced vibration
Types of damping [2 Lectures]: Viscous, Friction, Hysteretic damping
Damped single degree of freedom [2 Lectures]: Frequency response, resonance
Beating phenomenon [1 Lecture]
Vibration under general forcing condition, Duhamel Integral [4 Lectures]
Vibration measuring instruments [4 Lectures]
Response spectrum or Shock spectrum [4 Lectures]
Two-degrees of freedom system *[5 Lectures]*
Multi degree of freedom systems [5 Lectures]
Free vibration of undamped systems [3 Lectures]: Normal modes ,Orthogonality of modes, Expansion theorem, Modal analysis
Vibration control [3 Lectures]: Vibration isolation, vibration absorber
String and beam vibration [2 Lectures]
Vibration of rotating shafts and critical speeds [1 lecture]

Textbook
1. Thompson, W.T., (1993), *Theory of Vibration with Applications*, Prentice Hall
2. Rao, S.S., (1990), *Mechanical Vibrations*, Prentice Hall
3. Meirovitch, L., (1986), *Elements of vibration analysis*,, Prentice Hall
4. Weaver, Timoshenko and Young, 'Vibration Problems in Engineering', 5th Ed. John-Wiley and Sons, 1990.
5. Clough and Penzien, 'Dynamics of Structures', 2nd Ed. McGraw-Hill,1993.
Online Course Material
nptel.ac.in/courses/112103112/

Title	**Introduction to Robotics**	Number	RM4XX0
Department/ IDRP	Robotics and Mobility Systems	L-T-P [C]	3-0-0 [3]
Offered for	B. Tech (All Branches)	Type	Specialization Core
Prerequisite			

Objectives

1.To introduce fundamental aspects of modelling and control of robot manipulators.
2.To provide a brief of results from geometry, kinematics, dynamics, motion planning and control

Learning Outcomes

The course will equip students with theoretical and practical knowledge of robot modelling, programming and control.

Contents

Part I: Robot Modelling [14 Lectures]

Position Kinematics [6 lectures]: Transformations, Rigid Motions, Forward Kinematics: Denavit-Hartenberg Convention, Inverse Kinematics
Velocity Kinematics [4 lectures]: The Jacobian: Angular and Linear Velocity: Singularities, Accelerations
Robot Dynamics [4 lectures]: Equations of Motion, Kinetic and Potential Energy, Euler-Lagrange Equations, Recursive Newton-Euler Formulation

Part II: Motion Planning and Vision based control [14 Lectures]

Path Planning [3 lectures]: The Configuration Space, Planning in Configuration Space, Potential Fields, RRTs
Trajectory Planning [5Lectures]: Point to Point Motion, Paths Specified by Via Points
Computer Vision [3 lectures]: Introduction to Computer Vision, The Geometry of Image Formation, Camera Calibration, Image Features, Segmentation
Vision-Based Control [3 lectures]: Relation between End Effector and Camera Motions, Camera Motion and Interaction Matrix, Image-Based Control Laws, Partitioned Approaches

Part III: **Robot Control [14 Lectures]**

Linear Control [6 lectures]: Feedback and closed-loop control, second-order linear systems, control of second-order systems, Control-law partitioning, trajectory-following control, disturbance rejection, Continuous vs. Discrete time control, modelling and control of a single joint, architecture of an industrial-robot controller
Nonlinear control [5 lectures]: Nonlinear and time-varying systems, multi-input, multi-output control systems, control of manipulators, practical considerations, Lyapunov stability analysis, cartesian-based control systems, adaptive control
Force Control [3 lectures]: Interaction with Environment, Force Control, Hybrid Force/Motion control

Text Books

1.Craig J. J (2008), Introduction to robotics: mechanics and control. Pearson 3rd Edition.
2.Spong M. W., Hutchinson, S., and Vidyasagar, M.(2020), Robot modeling and control. New York: Wiley 2nd Edition.
3.Saha S. K. (2017), Introduction to robotics. Tata McGraw-Hill Education, 2nd edition

Self-Learning Material

1.https://see.stanford.edu/Course/CS223A

Title	**Mechatronics**	Number	ME6XX
Department	Electrical Engineering	L-T-P-Th [C]	2–0–2–0 [3]
Offered for	B.Tech (ME)	Type	Programme Elective (PE)
Prerequisite	Basic knowledge in Mechanisms		

Objectives

1. Understanding basics of sensing and actuation (electrical, hydraulic and pneumatic with industrial applications).
2. Inculcate system design thinking among students
3. Impart Programming and interfacing techniques of embedded microcontrollers with sensors and actuators for internet of things applications in mechanical engineering

Learning Outcomes

1. Knowledge and understanding of Sensors, actuators and microcontrollers in the context of mechanisms and machines.
2. Power management of systems through modern technologies and system integration and design
3. IoT fundamentals and modern computing skills, and the role of programming within the mechanical engineering domain.

Contents

Introduction to Mechatronics systems [3 Lectures]: Mechatronics system components- Measurement Systems, Block diagram representation

Types of systems [5 Lectures]: First order systems, second order systems, Performance specifications in time and frequency domain, Open and Closed Loop Systems, PID Control of mechanical Systems

Introduction to sensors [5 lectures]: Basics of analog and digital electronic devices, Principles and working of typical sensors such as Resistive, capacitive, inductive and resonant transducers, encoders, piezoelectric accelerometers and pressure sensors, ultrasonic flow meters, GPS sensor etc.

Sampling rate selection for sensors [3 Lectures]: Signal to noise ratio, power requirements for wired and wireless sensors, Selection of D/A and A/D converters, quantization and measurement errors.

Introduction to actuators [5 Lectures]: Classification of actuators: Basic working principles of DC motors, Stepper Motors, Pulse width modulation, Hydraulic and pneumatic actuation, PLC based control of systems with solenoids and relays,

Microcontrollers [3 Lectures]: Basics of Microcontrollers and Interrupts and Low Power Features, interfacing of sensors and actuators with microcontrollers.

Internet of Things (IOT) [3 Lectures]: Fundamentals of IOT, basic communication Networks, Introduction to protocols such as Bluetooth Low Energy, ZigBee etc,

Connecting Things to the Cloud [3 Lectures]: Review of IOT platforms, Hands-on project of a sensor based Weather Station.

Laboratory Classes (12 Classes):

1. Dissection and assembly of consumer appliances
2. Programmable logic controller (PLC) and Pneumatic circuits
3. Programmable logic controller for material handling system (conveyor belt)
4. Quanser CUBE servo control design with QUARC real time interface
5. Sensors and Internet of things project
6. MATLAB SIMULINK simulations

Reference Books

1. Bolton, W., (2010), Mechatronics, 4th Edition, Addison Wesley
2. R. Kamal (2017), Internet of things, Architecture and Design Principles, McGrawhill, First edition
3. Fraden, J., (2004), *Handbook of Modern Sensors Physics, Designs and Applications,* 3rd Edition, Springer Verlag
4. Histand & Aciatore, Introduction to mechatronics and measurement systems, McGraw Hill, 1999.
5. Bradley, Dawson, Burd & Loader, 'Mechatronics', Chapman & Hall, 1993.

Online sources:

1. NPTEL IIT Kharagpur: https://nptel.ac.in/courses/106105166/
2. Stanford: https://online.stanford.edu/courses/xee100-introduction-internet-things
3. https://www.coursera.org/specializations/iot (basic raspberry pi and Arduino)
4. Curtin university Micromasters program in IOT. https://news.curtin.edu.au/media-releases/curtin-offer-new-internet-things-micromasters/

Title	**Finite Element Methods and Applications**	Number	ME6XX
Department	Mechanical Engineering	L-T-P [C]	3–0–0[3]
Offered for	B.Tech (ME and CI)	Type	Program Elective (PE)
Prerequisite			

Objectives

Understand the fundamental concepts and formulation of the finite element methods for solving differential equations arising in solid and fluid mechanics.

Learning Outcomes

1. The application of finite element algorithms for structural, fluid mechanics and thermal applications.
2. Be able to formulate and solve basic problems in heat transfer, solid mechanics and fluid mechanics

Contents

Introduction [8 Lectures]: Basic concept of a finite element technique, Role of discretization, General procedure for finite element analysis, Assumed functions, Comparison between FEM solution and exact solution; Stiffness matrix, spring and bar elements; Finite element formulation of axial rod and beam problems.

Truss and Frame Structures [5 Lectures]: Stiffness Method Introduction; Element Transformation; Boundary conditions, Constraint forces, Global Stiffness matrix; Element strain and stress; Three Dimensional Trusses and Frames

Finite Element Formulation of Beam Elements [5 Lectures]: Introduction; Elementary beam theory; Flexure element stiffness matrix; Boundary conditions, constraint forces, Global stiffness matrix; General three dimensional beam element

Method of Weighted Residuals and Interpolation Functions [6 Lectures]: Introduction; Completeness and compatibility; Concept of interpolation functions; Polynomial forms, geometric isotropic; Triangular, rectangular and three dimensional elements; Isoparametric formulation, axisymmetric elements; Numerical Integration: Gaussian Quadrature.

Finite Element Analysis for Plane Stress and Plane Strain Problems [8 Lectures]: Basic Equations; Boundary Conditions; FEM Formulation; Shape Functions; Numerical Evaluation of Elements Matrices and Vectors; Global matrices; Boundary conditions and solutions; Thin plate formulation; Various thin plate elements;

Finite Element Analysis in Free and Forced Vibration Problems [5 Lectures]: Vibration of a rod; Vibration of a beam; Classification of partial differential equations; Time response of parabolic equations; Forced vibration problems

Finite Element Analysis in Heat Transfer and Fluid Flows problems [5 Lectures) : Conduction, Convection and Radiation conditions, Incompressible flows, Navier-Stokes equations including heat transfer, Acoustic fluids coupled to structures, Navier-Stokes fluids coupled to structures

Reference Books:

1. R. D. Cook, (2008), *Concepts and Applications of Finite Element Analysis*, John Wiley & Sons.
2. K. J. Bathe, (2002), *Finite Element Procedures in Engineering Analysis*, Prentice-Hall
3. S. Moaveni, (2008), *Finite Element Analysis*, Theory & Application with ANSYS, 2nd Edition, Prentice Hall
4. D Hutton, (2009), *Fundamental of Finite Element Analysis*, McGraw-Hill,
5. J. N. Reddy, (2005), *An Introduction to the Finite Element Method*, 3rd edition , McGraw Hill Education;

6. Zienkiewicz and Taylor, 'Finite Element Method', 4th Edition, McGraw-Hill, UK, 1989.

Self-learning Materials:

1. https://nptel.ac.in/courses/112104116/#

2. https://nptel.ac.in/courses/112/106/112106135/

3. https://nptel.ac.in/courses/112/104/112104115/

Title	**Vehicle Dynamics**	Course No.	ME6XX0
Department	Mechanical Engineering	L-T-P[PE]	3-0-0[3]
Offered for	B.Tech (ME)	Type	Program Elective
Pre-requisite			

Objectives

1. To cover the fundamentals of vehicle dynamics
2. To appreciate the vehicle subsystem design issues

Learning Outcomes

1. To be able to model and simulate dynamics of vehicles
2. To be able to analyze vehicle sub-systems

Course Content

Introduction [2 Lectures]: History, vehicle classifications, fundamental approaches to vehicle dynamics modelling, motion analysis, force analysis

Acceleration Performance [6 Lectures]: Power train components; power-limited acceleration; traction limited acceleration; transverse weight shift; front wheel drive vs rear wheel drive vs. all-wheel drive vehicles;

Braking Performance [6 Lectures]: Braking force analysis; brake design and analysis; federal regulation on braking performance; anti-lock braking system; wheel lock-up; tire/road friction; safety and maintenance issues in braking.

Tire and Tire Dynamics [6 Lectures]: Tire specifications and constructions; tire motion analysis; tire force analysis; tire contact stress analysis;

Ride [6 Lectures]: Riding comfort; perception of vibration; vibration sources; vibration transmission to the passengers; vibration models; vibration isolation techniques.

Cornering/steering [6 Lectures]: Lower speed cornering; high speed corner; cornering bicycle model; steering angle; over-steering vs. under-steering;

Chassis and Suspension Systems[6 Lectures]: General kinematics; vehicle constraint analysis; practical designs;

Text Books:

1. Thomas Gillespie, *Fundamentals of Vehicle Dynamics*, SAE Publication.

Reference Books:

1. Mike Blundell and Damian Harty , (2004),The Multibody systems Approach to Vehicle Dynamics, , Elsevier
2. Vehicle Dynamics, (2009), Theory and Application, Reza N. Jazar, Springer,
3. Reimpell, Stoll and Betzler: *The Automotive Chassis*: Engineering Principles.

Title	**Experimental Modal Analysis**	Number	ME6XX
Department	Mechanical Engineering	L-T-P-Th [C]	3–0–2–0 [4]
Offered for	B.Tech (ME)	Type	Programme Elective (PE)
Prerequisite	Linear algebra, calculus and Mechanical Vibrations		

Objectives

The Instructor will:

1. To study theory and practice of experimental modal analysis for identification of dynamic characteristics of structures
2. To study application of experimental modal analysis results for assessing structural dynamic behaviour

Learning Outcomes

The students are expected to have the ability to:

1. Understand theory of experimental modal analysis (theory of modal analysis and signal processing techniques)
2. Understand complete system and methods required for experimental modal analysis of any real life systems (practical system like car etc.)

Contents

Overview [1 Lecture]: introduction of modal analysis
Theory of modal analysis [6 Lectures]: single degree of freedom (SDoF) system, Theory of modal analysis for undammed and damped multi degree of freedom (MDoF) system
Signal Processing related to experimental modal analysis [5 Lectures]: Fourier Transform, Digital Fourier Transform, Aliasing, Windowing, Leakage
Experimental Set-up for modal analysis [3 Lectures]: Excitation instruments, response measurements, types of excitation signals
Modal parameter extraction [6 Lectures]: frequency domain methods, SDoF Methods and MDoF methods
Modal parameter estimation [6 Lectures]: Time domain methods
Model Validation [3 Lectures]: Modal scale factor, modal assurance criteria, mode phase collinearity and mode phase deviation
Model Updating [4 Lectures]: Direct methods and Iterative methods
Multi-input multi-output modal analysis methods [5 Lectures]
Applications of EMA [3 Lectures]: structural dynamic modification, coupled structural analysis and response simulation

Laboratory Experiments

Obtaining modal parameters (natural frequencies and mode shapes) of a cantilever beam using impact hammer and accelerometer (Hammer roving and accelerometer roving case), Obtaining modal parameters (natural frequencies and mode shapes) of a simply supported plate using impact hammer and accelerometer (Hammer roving and accelerometer roving case), Obtaining modal parameters using Laser Doppler Vibrometer and impact hammer, Obtaining modal parameters (acoustic mode shapes) of rectangular cavity and a vibro-acoustic rectangular cavity, Using modal parameters identified from

experiment to update the models, Use of update model for desired structural dynamic modification of a cantilever beam

Textbook

1. Ewins, D. J., (1984), *Modal testing: Theory and Practice*, Research Studies Press Limited.
2. Avitabile, P. (2017), *Modal Testing: A Practitioner's Guide*, John Wiley & Sons.
3. Heylen, W., Lammens, S., Sas, P.(1998), *Modal analysis theory and testing,* Katholieke Universiteit Leuven, Faculty of Engineering, Department of Mechanical Engineering, Division of Production Engineering, Machine Design and Automation, 2nd edition.
4. He, J. and Fu, Z. F. (2001), *Modal Analysis*, Butterworth-Heinemann 1st edition.

Title	**Techniques of Noise Control**	Number	ME6XX
Department	Mechanical Engineering	L-T-P [C]	3–0–0 [3]
Offered for	B.Tech (ME, CI)	Type	Programme Elective (PE)
Prerequisite	Introduction to Acoustics		

Objectives
The Instructor will:
Provide background of feed forward and feedback control strategies for active control of sound

Learning Outcomes
The students are expected to have the ability to:
Understand theory and application of single channel and multi-channel feed forward and feedback control strategies for active control of sound

Contents
Introduction to acoustics [2 Lectures]

Frequency analysis [3 Lectures]

Linear systems and digital filters (FIR and IIR Filters) [5 Lectures]

Interference in plane wave sound fields [6 Lectures]: Sound fields in an infinite duct and enclosed fields, physical mechanisms behind active minimization of acoustic energy in enclosed sound fields

Single channel feed forward control system [4 Lectures]

Single channel feedback control system [4 Lectures]

Global control of enclosed sound fields [6 Lectures]

Local control of enclosed sound fields [4 Lectures]

Multichannel feed forward control systems [4 Lectures]

Active suppression of free field radiation by point sources [4 Lectures]

Textbook
1. Nelson, P. A., and Elliott, S. J. (1992). *Active Control of Sound*, Academic Press Limited, London.
2. Hansen, C. H. (2001). *Understanding active noise cancellation*, Spon Press, Taylor & Francis Group, London & New York.

Title	**Nonlinear Oscillations and Chaos**	Number	ME6XX
Department	Mechanical Engineering	L-T-P [C]	3–0–0 [3]
Offered for	B.Tech (ME, CI, EE, PH, MA)	Type	Programme Elective (PE)
Prerequisite	Differential equations and linear algebra, Engineering Mechanics, Mechanical vibrations		

Objectives

1. To provide the fundamental understanding about nonlinear phenomena and associated different types of responses
2. To provide different types of solution techniques of nonlinear equations
3. To provide basics of bifurcations and principle of stability
4. To enable different numerical techniques to solve nonlinear equations
5. To highlight various route to chaos phenomena and its significant in the stability analysis of physical systems

Learning Outcomes

1. Understand fundamentals of nonlinear phenomena and associated different types of responses, Solution techniques of nonlinear equations and
2. Understand different aspects of bifurcations and principle of stability
3. Get an idea of various route to chaos phenomena and its significant in the stability analysis of physical systems

Contents

Introduction [8 Lectures]: linear and nonlinear systems, conservative and non-conservative systems; potential well, Phase planes, types of forces and responses; Local and global stability; Nonlinear phenomena.

Nonlinear equation of motion [6 Lectures]: Linearization techniques, ordering techniques; Duffing equation, Van der Pol's oscillator, Mathieu's and Hill's equations.

Perturbation Solution techniques [6 Lectures]: Harmonic balance, Linstedt-Poincare', Method of Multiple Scales, Averaging, incremental harmonic balance, modified Lindstedt Poincare' techniques.

Stability and bifurcation analysis [8 Lectures]: static and dynamic bifurcations, different routes to chaotic response crisis.

Numerical techniques [8 Lectures]: time response, phase portrait, FFT, Poincare' maps, point attractors, limit cycles and their numerical computation, strange attractors and chaos; Lyapunov exponents and their determination, basin of attraction, fractal dimension.

Application [6 Lectures]: Single degree of freedom systems: Free vibration-Duffing's oscillator; primary-, secondary-and multiple- resonances; Forced oscillations: Van der Pol's oscillator; parametric excitation: Mathieu's and Hill's equations, Floquet theory; effects of damping and nonlinearity. Multi degree of freedom and continuous systems.

Text Book:

1. Nayfeh, A. H., and Mook, D. T., *Nonlinear Oscillations*, Wiley-Interscience,
2. Hayashi, C. (1964), *Nonlinear Oscillations in Physical Systems*, McGraw-Hill.
3. Nayfeh, A. H., and Balachandran, B. (1995), *Applied Nonlinear Dynamics*, Wiley.

Reference books:

1. Evan-Ivanowski, R. M., (1976), *Resonance Oscillations in Mechanical Systems*, Elsevier.
2. Seydel, R., (1988), *From Equilibrium to Chaos: Practical Bifurcation and Stability Analysis,* Elsevier.
3. Moon, F. C., (1992), *Chaotic & Fractal Dynamics: An Introduction for Applied Scientists and Engineers*, Wiley.
4. J. S., Advanced Theory of Vibration: Nonlinear Vibration and Onedimensional Structures, New Age International, 1992.

Title	**Micro-Nano Mechanics**	Number	ME 6XX
Department	Mechanical Engineering	L-T-P [C]	2–0–0 [2]
Offered for	B.Tech (ME, EE)	Type	Programme Elective (PE)
Prerequisite	Mathematics, Basic Sciences, Engineering Mechanics, Mechanical vibration, and Structural mechanics		

Objective

1. Provide the fundamentals of kinematics and kinetics of deformations of microsystem
2. Highlights the interactions among thermal, electrical and mechanical effects in MEMS design

Outcomes:

Students can able to

1. Gain equivalent continuum mechanics to model nano-structures as sensors/actuators and energy harvester
2. Develop MEMS/NEMS models and their solutions

Contents

Introduction [8 Lectures]: Kinematics of deformations (Deformation gradient, different strain tensors, strain-rate and rotation tensors, deformations of lines, surfaces and volumes); Kinetics of deformations; stress tensors; Coulomb force; Van der Waals force; Casimir force; Maxwell equations.

Small-scale Mechanics[10 Lectures]: Lumped parameters micro-models; Micro-beams; Micro-plates; Governing equations; Boundary Conditions; Elctromechanical instability; Thermal effect in MEMS design; Inertia Forces and time-dependent voltage in MEMS design

*Nanomechanics [10 Lectures]:*Equivalent continuum mechanics for nano structures; Nano-sensors; Nano-composites; Size dependency; Nonlocal continuum mechanics

Text Books:

1. Elements of Continuum Mechanics, R. C. Batra, AIAA
2. Fundamentals Of Continuum Mechanics, Stephen Bechtel & Robert Lowe, ELSEVIER
3. Nonlinear Differential Equations in Micro/nano Mechanics & Application in Micro/nano Structures and Electromechanical Systems, Ali Koochi & Mohamadreza Abadyan

Title	**Principle of Vibration Control**	Number	MT 7XX
Department	Mechanical Engineering	L-T-P [C]	3–0–0 [3]
Offered for	B.Tech (ME)	Type	Programme Elective (PE)
Prerequisite	Mathematics, Basic Sciences, Solid Mechanics, Mechanical vibration, and Structural mechanics		

Objective

This course has been developed with the objective of providing a broad overview of different passive, active and semi-active vibration control strategies applied in Engineering fields.

Learning Outcomes:

Students can able to gain enhanced understanding of the principles and earn the requisiteconfidence to address the new problems by themselves.

Contents

Introduction [5 Lectures]:Overview of mechanical vibration; methods and strategies of vibration control, Vibration reduction at sources; Affecting factors to vibration control

*Dynamics properties and selection of materials [5 Lectures]***.** Damping-stress relationships; selection of criteria of structural materials; Design for enhancing the damping capacity; Stress-strain relationship of viscoelastic material; Complex stiffness model; Viscoelastic laminate

Dynamic Vibration Absorbers [6 Lectures]:Introduction; Dynamic Vibration Neutralizers; Self-tuned Pendulum Neutralizer; Optimum Design of Damped Absorbers; Auxiliary Mass with Damper; Gyroscopic Absorber; Impact Absorber; Absorbers attached to Continuous Systems; Stability analysis

*Vibration Isolations[5 Lectures]***: I**solators with Complex Stiffness; Isolators with Coulomb Damping; Three Element Isolators; Two-stage Isolators; Velocity Shock and Shock force

*Active Vibration Control[6 Lectures]***:** Collocated and non-collocated control model; Lumped parameter models; State-space model; Distributed parameter models; Centralized and de-centralized control

*Vibration Damping and Absorption[5 Lectures]***:** Stability theorem of vibratory systems; Velocity, acceleration and position feedback control

*Actuators and Sensors[5 Lectures]***:** Electrodynamics actuators and sensors; Magnetostrictive materials, Smart fluids and actuators

*Piezoelectric Materials[5 Lectures]***:** Introduction; Electrically shunted piezoelectric materials; Piezoelectric actuators and sensors; Semi-active vibration control

Text/reference books:

1. Principle of Passive and Active Vibration Control, Mallik and Chatterjee, 2014
2. Mechanical Vibrations, S S Rao, 2012
3. Vibration Control of Active Structures : An Introduction, A. Preumont, Kluwer Academic
4. Vibration with Control, D. J. Inman, Wiley

Title	**Mechanics of Soft Materials**	Number	MT6XX
Department	Mechanical Engineering	L-T-P [C]	3–0–0 [3]
Offered for	B. Tech (ME, BS & BE)	Type	Programme Elective (PE)
Prerequisite	Mechanics of materials, Advanced mechanics of solids		

Objective

The objective of the course is to provide an overview of the wide range of non-linear mechanical behaviours displayed by soft materials and tissues together with a basic understanding of their physical origin, to familiarize students with appropriate mathematical concepts for their modelling, and to illustrate the application of these concepts in different fields in mechanics.

Learning Outcomes

The students are expected to have the ability to:

1. Understand fundamentals and mathematical concepts of modelling the nonlinear material behaviour.
2. Get an idea of various failure modes of soft materials and safe design of soft material based systems.

Contents

*Introduction [4 Lectures]:*Introduction to soft materials: rubber-like materials, gels, soft biological tissues, etc. *Mathematical preliminaries [4 Lectures]:* Physical quantities and their classification; scalars, vectors, and tensors; index notation, vector products (dot, cross, and dyadic), representation of partial differentiation using comma symbol, gradient, divergence, curl of tensors and their representation using index notation. *Non-linear continuum mechanics [5 Lectures]:* Configurations and motion of continuum bodies, deformation gradient, strain tensors, stress and the balance principles:
Conservation Equations [4 Lectures]: Conservation of mass, the momentum principles, the Cauchy stress tensor, stress measures for large deformations, the equations of motion and symmetry of stress, balance of mechanical energy, the principles of virtual work and power.
Hyperelastic materials [4 Lectures]: General remarks on constitutive modeling, isotropic hyperelastic materials, incompressible hyperelastic materials, compressible hyperelastic materials,
Different forms of strain energy density functions [5 Lectures]: neo-Hoboken, Mooney Rivlin, Ogden, Gent, Arruda Boyce models, etc. elasticity tensors, anisotropic hyperelastic materials, composite materials with one characteristic direction, materials with two characteristic directions, Fung's model of biological tissue.
Viscoelastic Materials [3 Lectures]: Coupling of elasticity and fluidity, kinematics, multiplicative decomposition of deformation gradient,
Rheological models [5 Lectures]: concept of internal variables, dissipation inequality, constitutive equations, evolution equations, incompressibility.
*Applications [4 Lectures]:*Homogeneous deformation of hyperelastic membranes under uniaxial and biaxial loading, balloon inflation, inflation of an artery under blood pressure, creep phenomena,
Instabilities of soft materials [4 Lectures]: snap through instability, morphological instabilities: wrinkles, creases, folds, and ridges. dielectric actuators.

Text/reference books

1. A. Freed, Soft solids, Birkhauser Verlag Ag, 2016.
2. K. Volokh, Mechanics of soft materials, Singapore, Springer, 2016.
3. G.A. Holzapfel, Nonlinear Solid Mechanics - A continuum approach for engineering, 2000
4. L.R.G. Treloar, The physics of rubber elasticity, 3rd ed., 2005
5. P. Haupt, Continuum Mechanics and Theory of Materials, 2nd ed., 2002

Title	**Product Design and Feasibility**	Number	MT6XX
Department	Mechanical Engineering	L-T-P [C]	3–0–0 [3]
Offered for	B. Tech (ME, BS & BE)	Type	Programme Elective (PE)
Prerequisite	Mechanics of materials, Advanced mechanics of solids		

Objectives

1. To provide understanding of need of a new product and product life cycle
2. To inculcate basic steps of visualizing product development
3. To enable understanding of user experience, product form, human factors, and marketplace realities.

Learning Outcomes

The students are expected to have the ability to:

1. Enable to develop an engineering viewpoint for a specific product of societal use.
2. Ability to design new products and processes
3. Able to predict and assess the impact of specific products and their performance.

Contents

*New Product [4 Lectures]:*User-Centric Requirement, identifying customer needs, Need of a new product, concept generation, symbols, semantics, syntax and usability, product life cycle, steps towards a successful product.

Design [7 Lectures]: Human use experience analysis, synthesis, sketching, analysis and selection of profitable products, basic engineering, concept generation, detailed design, prototype a physical product and/or service, product for an organization, product design and architecture.

Characteristics of a Design[7 Lectures]: Applications in product design, Problem identification and selection, feasibility, viability, and human values towards a product, Analysis of functional Anatomy of function. Primary versus secondary versus tertiary/unnecessary functions, Functional analysis: Functional Analysis System Technique.

Sketching [7 Lectures]: Sketching in 3D, Designing in 3D, hand sketch to digital rendering, quality function deployment, CAD based design and Ergonomics in product designs.

*Manufacture [8 Lectures]:*Design for Manufacture and Assembly, design guidelines for different processes. Ideation, Rapid prototyping and its application, design for manual assembly user testing, iteration, and storytelling.

Materials [5 Lectures]: Durable products, non durable products, package designs, families of materials and processes in this areas, Product prototyping and manufacturing technologies; Creativity and innovation in product design.

Specification and Final Product [5 Lectures]:- Product performance test; Cost models for product design, development and production; Marketing and product specification; Design protection and intellectual property rights.

Text Books

1. Baxter, M.,,Product design : a practical guide to systematic methods of new product development, London: Chapman & Hall, 1996

Reference Books

1. M.M Andereasen, Integrated Product Development, IFS Publications Ltd. / SpringerVerlag, Berlin, 1987.
2. Woodson, W. E. (1981). Human Factors Design Handbook. New York, McGraw-Hill Book Company.

3. Norman, D. (1989). The Design of Everday Things. New York, Doubleday Currency
4. Powell, D. (1985). Design Rendering Techniques. London, Orbis Publishing Limited
5. Asimow Morris; Introduction to Design, Prentice Hall, Englewood Cliffs, N.J., 1962.
6. Pulos, Arthur, The American Design Ethic, MIT, USA, 1983.
7. Roozenburg and Eekels, Product Design: Fundamentals and Methods, Publisher: JohnWiley & Sons Inc; New Ed edition, 1995

Self-learning Materials:

Product Design and Development, IIT Roorkee, https://nptel.ac.in/courses/112/107/112107217/#