Indian Institute of Technology Jodhpur

PG Course Booklet

Indian Institute of Technology Jodhpur

July 2019

॥ त्वं ज्ञानमयो विज्ञानमयोऽसि ॥

M Tech

in

Advanced Manufacturing and Design

Introduction

M. Tech program in Advanced Manufacturing and Design at IIT Jodhpur provides a strong interdisciplinary focus with the objective of providing the student technical leadership in design processes and manufacturing systems. The program aims to hone engineering problem-solving skills of the student through a rigorous training in modern computational and experimental tools required in the domain of mechanical design, manufacturing processes and systems with focus on product development. The core program will have courses in the areas of Engineering Mathematics, Solid Mechanics, Dynamics and Control, Product Design and Manufacturing with focus on recent industrial and research trends such as Smart Manufacturing and Industry 4.0. Through advanced electives in modern areas like Robotics, Mechatronics Systems Design, Additive Manufacturing, Composite Structure design and manufacturing the student can further specialize in different domains. The program plans to establish synergy with Department of Electrical Engineering and Computer Science and Engineering by incorporating electives in the areas of Cyber Physical Systems, Sensors, Bio-mimetics, MEMs and nano-device design and manufacturing IoT and Artificial Intelligence. The role of new and smart materials in product design and manufacturing will be accomplished through electives from Department of Metallurgical and Materials Engineering. The program will have strong emphasis on the thesis work involving interdisciplinary research activity in the emerging areas of design and manufacturing.

Objective of the Program:

To develop professionals in the domain of mechanical design and manufacturing by imparting analytical and computational skills that enables an individual to handle problems in thrust areas such as structural design, design of advanced electro-mechanical systems, robotics, mechatronic systems design, additive manufacturing and smart manufacturing.

Expected Graduate Attributes:

1) Ability to undertake academic and industrial research in the areas Advanced Manufacturing and Design using analytical, computational and experimental tools
2) Understanding about recent thrust areas in the domain such as advanced multi-functional structure design, mechanical behavior of modern materials, robotics, mechatronic systems design, additive manufacturing, smart manufacturing etc.
3) Ability to appreciate the need of multidisciplinary approach in solving problems in the domain
4) Ability to handle analytical and experimental tools in the areas related to the program
5) Ability to carry out critical, creative and innovative thinking
6) Ability to express ideas in the written and oral formats
7) Development of appreciation and commitment to professional ethics

Learning outcome:

1) Understanding of the fundamentals related to mechanical design, CAD and design optimization
2) Knowledge of engineering materials, manufacturing processes and systems in the context of product development
3) Developing awareness about recent industrial trends such as smart manufacturing, autonomous Systems, Industry 4.0 through courses such as Computer Aided Manufacturing and Industrial Robotics
4) Knowledge of interdisciplinary topics such as machine learning, artificial intelligence, autonomous systems, signal and image processing etc.
5) Demonstrate the skills in the above areas by using or developing computational and analytical tools
6) Demonstrate advanced skills to communicate scientific ideas and /or application systems.

Compulsory Topics/Skills:

<table>
<tr><th>Design</th><th>Advanced Manufacturing</th><th>Others</th></tr>
<tr><td>a) Mechanical Design, Advanced Mechanics of Solids, Introduction to Finite Element Analysis
b) Engineering optimization - classical and heuristics methods and tools
c) Computer Aided Design – theory and tools</td><td>a) Manufacturing processes and systems in the context of product development
b) CNC Machine tools
c) Fundamentals of smart manufacturing and Industry 4.0
d) Additive Manufacturing</td><td>a) Introductory Machine Learning
b) Sensor technology and its applications
c) Technical Writing Skills
d) Project Management using tools e.g. Microsoft Project
e) Practices related to professional ethics
f) Knowledge of IP</td></tr>
<tr><td colspan="2">a) Engineering Materials, Properties; Selection of engineering materials
b) Industrial Robotics</td><td></td></tr>
</table>

Elective Topics/Skills:

<table>
<tr><th>Design</th><th>Advanced Manufacturing</th><th>Inter disciplinary</th></tr>
<tr><td>a) Mechanical vibration
b) Structural Dynamics
c) Acoustics
d) Rotor Dynamics
e) Composite Structures
f) Finite Element Methods
g) Multibody Dynamics
h) Damage and Fracture Mechanics
i) Smart materials and structures
j) Experimental Mechanics; nonlinear dynamics;
k) MEMS and Nano-structures
l) Advanced Mechanisms
m) Noise, Vibration and Harshness</td><td>a) Computer Aided Manufacturing
b) Multi-scale manufacturing
c) Product Design and Development
d) Design for X
e) Process Engineering and Tool Design
f) Metrology for Engineers
g) Theory of Arc Welding Processes
h) Metallurgy of Joining Processes
i) Mechanical Metallurgy
j) Quality Control of Weldments</td><td>a) Digital signal processing
b) Machine Vision
c) Biomaterials
d) Introduction to IoT
e) Introduction to CPS
f) AI- theory and applications
g) Data Analysis</td></tr>
<tr><td colspan="2">a) Theory of plasticity
b) Mechatronic Systems Design
c) Autonomous Systems and Autonomous Vehicles
d) Feedback control</td><td></td></tr>
</table>

Course Structure:

Cat.	Course Number, Course Title	L-T-P	Cr		Cat.	Course Number, Course Title	L-T-P	Cr
I Semester					**II Semester**			
MC	MEL7XX0: Advanced Mechanics of Solids	3-0-0-0	3		MC	MEL7XX0: Materials & Manufacturing Processes	2-0-2-0	3
MC	EE: Introduction to Sensors (Fractal Course)	1-0-0-0	1		MC	MEL7XX0: Robotic MEL7XX1: Robot Modeling MEL7XX2: Robot Control MEL7XX3: Motion Planning and Programming	3-0-2-0 1-0-0-0 1-0-0-0 1-0-0-0	4 1 1 1
MC	CS: Introduction to Machine Learning (Fractal course)	1-0-0-0	1		MC	MEL7XX0: Industry 4.0 Applications in Manufacturing Systems	1-0-0-0	1
MC	MEP7XX0: Smart Manufacturing	1-0-2-0	2		ME	Program Elective	3-0-0-0	3
MC	MEL7XX0: Geometric Modeling & CAD	2-0-2-0	3		ME	Program Elective	3-0-0-0	3
MC	MA: Optimization (Fractal course)	1-0-0-0	1		NH	OAL7XX0: Innovation and IP Managment	1-0-0-0	1
ME	Program Elective	3-0-0-0	3					
NH	HSN7XX0: Technical Communication	1-0-0-0	1					
		Total	**15**				**Total**	**15**
III Semester					**IV Semester**			
ME	MED8XX0: Project	0-0-0-5	5		ME	MED8XX0: Project	0-0-0-11	11
ME	Program Elective	3-0-0-0	3		MO	Open Elective	3-0-0-0	3
ME	Program Elective	3-0-0-0	3		NH	HSN7XX0: Professional Ethics	1-0-0-0	1
MO	Open Elective	3-0-0-0	3					
NH	OAN7XX0: Systems Engineering and Project Management	1-0-0-0	1					
		Total	**15**				**Total**	**15**
							Grand Total	**60**

Summary of courses (category wise) for M. Tech (AMD) Program:

S. N.	Course Type	Credits
1	Program Core (MC)	19
2	Program Elective (ME)	15
3	Open Electives (MO)	6
4	Project (MP)	16
5	Non-Graded Humanities (NH)	04
	Total	60

Tentative Program Electives (ME):

Design Engineering Domain	MEL7XX0: Theory of Vibrations MEL7XX0: Mechanical Vibrations MEL7XX0: Helicopter Dynamics MEL7XX0: Modeling and Control of Mechanical Systems MEL7XX0: Multibody Dynamics MEL7XX0: Finite Element Methods in Engineering MEL7XX0: Rotor Dynamics AVL7XX0: Autonomous Mobile Robots BBXXX: Biomechanics
Advanced Manufacturing Domain	MEL7XX0: Computer Aided Manufacturing MEL7XX0: Mechanical Metallurgy MEL7XX0: Theory of Arc Welding MEL7XX0: Welding Metallurgy MEL7XX0: MEMS and Microsystems Technology MEL7XX0: Precision and Micro-Manufacturing MEL7XX0: Applied Ergonomics MEL7XX0: Mechatronic Systems Design MEL7XX0: Additive Manufacturing MEL7XX0: Design for X MEL7XX0: Computer Aided Inspection and Quality Control MEL7XX0: Welding: Metallurgy, Defects and Testing MEL7XX0: Non-Conventional Welding Processes MEL7XX0: Welding inspection and Quality Control MEL7XX0: Microfluidics Technology BBXXX: Medical Devices and Implants MTXXX: Solidification Processing MTXXX: Light Metals and Alloys MTXXX: Powder Metallurgy MTXXX: Thermo-Mechanical Processing MTXXX: Near-Net Forming MTXXX: Platic Deformation and Microstructure Evaluation MTXXX: Corrosion Engineering MAXXX: Statistics I MAXXX: Statistics II MAXXX: Reliability Theory CSXXX: Artificial Intelligence I CSXXX: Machine Learning I EEXXX: Introduction to CPS EEXXX: Analog and Interfacing Circits (fractal)

Program Core:

Title	**Advanced Mechanics of Solids**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3-0-0-0 [3]
Offered for		Type	Program Core
Prerequisite			

Objectives:

1. Enable students to learn advanced concepts of stress analysis
2. Apply concepts to analysis of mechanical systems such as rotating disks, thick cylinders etc.

Learning Outcomes:

1. Develop Ability to solve advanced stress analysis problems using analytical and numerical methods
2. Ability to formulate and solve 3D problems in stress analysis

Contents:

1. Introduction to Cartesian tensors, Stress: Normal and shear stress, Equilibrium equations (force and moment), Symmetry of shear tensor, Equilibrium at boundary (Cauchy Equation). 2-D problems Plane stress, Stress transformation, Principal stresses, maximum shear stress, Mohr's circle (7 Lectures)
2. Displacements and strains, Green's strain, Compatibility condition, Plane strain Problems, Strain transformation, Strain gage and rosette (5 Lectures)
3. Structural Approximations: Physical and mathematical. Structural elements-bars, beams, plates, membrane, shear panel, shells (1 Lectures)
4. Mechanical behavior of Engineering Materials, Effect of Temperature, Anisotropic, Isotropic, Orthotropic materials, Failure Criteria (Distortion strain energy, Octahedral shear stress) Maximum normal stress, Maximum Shear stress (Tresca), Maximum distortion energy (von-Mises and Hencky) (4 Lectures)
5. Theory of Elasticity, Plane Stress Problem with Stress formulation in 2-D, Plane Strain Problem with Stress Formulation in 2-D, Airy's stress function, stress, strain and equilibrium in polar coordinates, Displacement formulation with plane stress, St. Venant's Principle (4 Lectures)
6. Bending and extension of beams, stress-resultants, Equilibrium equations in terms of deformation with transverse and axial load (3 Lectures)
7. Torsion of slender bodies (beams), Prandtl stress function formulation, Membrane analogy, Closed form beam torsion analytical solution, Warping function formulation, Thin Walled open sections, Torsion constants for rolled and extruded beams, Thin walled closed sections, Shear flow (8 Lectures)
8. Beam shearing stresses due to shear forces, Shear Centre(3 Lectures)
9. Euler Buckling (3 Lectures)
10. Principle of virtual-work (4 Lectures)

Reference Books:

1. Srinath, L.S. (2009), Advanced Solid Mechanics, Tata McGraw-Hill
2. Timoshenko, S.P., and Goodier, J.N. (1980), Theory of Elasticity, Tata McGraw- Hill
3. Sadd, M. H. (2006), Elasticity: Theory, Applications and Numerics, Academic Press

Self Learning Material:

1. http://nptel.ac.in/courses/105106049/

Title	**Smart Manufacturing**	Number	MEP7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	1-0-2-0 [2]
Offered for		Type	Program Core
Prerequisite			

Objectives:

1. Introduce students to the fundamentals of smart manufacturing

Learning Outcomes:

1. appreciate concepts and basic framework necessary for smart manufacturing
2. develop understanding about harnessing smartness into manufacturing processes from the data

Contents:

1. Introduction: Industrial revolutions, Interplay between CS, ICT and manufacturing automation, Concept of Smart Machine tool (4 Lectures)
2. Concept of Cyber Physical Systems (CPS) and Cyber Physical Production System (CPPS), System Architecture for implementation of CPPS, Components for CPPS, Communication for CPPS (6 Lectures)
3. Case Studies: CPPS modules for machine tools, Plug-and-play systems, Clip-on systems (4 Lectures)

Laboratory Exercises:

a. Implementation of Sensors in manufacturing applications
b. Working with embedded hardware e.g. Arduino, Rasberry Pi etc.
c. Data acquisition mechanisms
d. Data interpretation techniques and tools
e. Development of feedback systems
f. Mini-projects aiming at development of smart manufacturing processes

Reference Books:

1. Tao F., Zhang M., and Nee A. Y. C. (2019), Digital Twin Driven Smart Manufacturing, Academic Press
2. Jeschke S., Brecher C., Song H., and Rawat D. B. (2017), Industrial Internet of Things – Cybermanufacturing Systems, Springer

Self-Learning Material:

1. https://nptel.ac.in/courses/106105195/10

Title	**Geometric Modeling and CAD**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	2-0-2-0 [3]
Offered for		Type	Program Core
Prerequisite			

Objectives:

1. To introduce the concepts of geometric modelling and its used 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 design

Contents:

1. Introduction to Computer Aided Design, Fundamentals of Computer Graphics (2 Lectures)
2. Two- and Three-dimensional transformations and projections (6 Lectures)
3. Geometric modelling of curves: Hermite, Bezier, B-spline, NURBS (8 Lectures)
4. Parametric representation of surfaces: Planar, Ruled, Surface of revolution, Generic Surfaces (8 Lectures)
5. Part modelling techniques: Wireframe, Surface and Solid Modelling (4 Lectures)
6. Data representation and exchange formats, geometry and topology (2 Lectures)

Reference Books:

1. Newman W., Sproull, R. (2001), Principles of interactive Computer Graphics, McGraw Hill
2. Mortenson M. (2006), Geometric modelling, Industrial Press
3. Rogers D.F, and Adams J. A., Mathematical elements of Computer Graphics, McGraw Hill

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	**Materials and Manufacturing Processes**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	2-0-2-0 [3]
Offered for		Type	Program Core
Prerequisite			

Objectives:
The course aims at imparting knowledge related to
1. mechanical behavior of materials and their manufacturability
2. various manufacturing processes

Learning Outcomes:
A student is expected to
1. understand the mechanical behavior of materials and their role in manufacturing
2. develop capability to understand various manufacturing processes

Contents:
Fractal I: Material Characterization (14 Lectures)
1. Mechanical behavior of materials, Materials and design (1 Lecture)
2. Evolution of Engineering Materials and their Properties, Materials selection charts, Selection of Engineering materials, Selection of Manufacturing Processes (7 Lectures)
3. In-situ testing and inspection of components, Non-destructive testing, Examples and Case studies (6 Lectures)

Fractal II: Advanced Manufacturing (14 Lectures)
1. Classification, operating parameters, and throughputs of manufacturing processes (1 Lecture)
2. Generative, Additive, and Removal Processes; Conventional and Non-conventional processes; Contact and Non-contact processes (6 Lectures)
3. Hybrid manufacturing processes (4 Lectures)
4. Scaling laws and multi-scale manufacturing (3 Lectures)

Reference Books:

1. Dieter G E, Mechanical Metallurgy, McGraw Hill
2. Ashby M F and Johnson K., Materials and Design, Butterworth-Heinemann
3. Ghosh A., and Mallick A. K., Manufacturing Science, EWP

Online Course Material:
1. https://nptel.ac.in/courses/112107144/#
2. https://nptel.ac.in/courses/112105127/
3. https://nptel.ac.in/courses/110106044/#
4. https://nptel.ac.in/noc17_me27

Title	**Robotics**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3-0-2-0 [4]
Offered for	B. Tech (ME), M. Tech(AMD) and PhD	Type	Program Core
Prerequisite			

Objectives

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

Learning Outcomes

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

Contents:

Fractal 1: Robot Modeling [MEL7XX1] [1-0-0]

1. Rotational Transformations, Composition of Rotations, Parameterizations of Rotations, Rigid Motions, Homogeneous Transformations (2 lectures)
2. Forward and Inverse Kinematics – Kinematic Chains, Forward Kinematics: The Denavit-Hartenberg Convention, Inverse Kinematics, Kinematic Decoupling (4 lectures)
3. Velocity Kinematics – The Jacobian: Angular and Linear Velocity: The General Case, Derivation of the Jacobian, Analytical Jacobian, Singularities, Inverse Velocity and Acceleration (4 lectures)
4. Robot Dynamics: Equations of Motion, Kinetic and Potential Energy, Euler-Lagrange Equations, Properties of Robot Dynamic Equations, Recursive Newton-Euler Formulation (4 lectures)

Fractal 2: Motion Planning and Programming [MEL7XX2] [1-0-0]

1. Path and Trajectory Planning: Path vs. Trajectory, The Configuration Space, Path Planning Using Configuration Space, Potential Fields, Trajectory Planning, Point To Point Motion, Paths Specified by Via Points, Probabilistic Roadmap Planner (5 lectures)
2. Vision-Based Control: The Geometry of Image Formation, Camera Calibration, Camera Motion and Interaction Matrix, Image-Based Control Laws, Relation between End Effector and Camera Motions, Partitioned Approaches (4 lectures)
3. Robot Operating System (ROS): Basic ROS concepts, Writing RoS Programs, Log Messages, Graph Resource Name, Launch Files, Parameters, Services, Recording and Replaying Services (5 lectures)

Fractal 3: **Robot Control[MEL7XX3] [1-0-0]**

1. Sensors and Actuators: Joint Actuating Systems, Drives, Proprioceptive Sensors, Exteroceptive Sensors (3 lectures)
2. Linear Control: 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, modeling and control of a single joint, architecture of an industrial-robot controller (3 lectures)
3. Nonlinear control: Nonlinear and time-varying systems, multi-input, multi-output control systems, control of manipulators, practical considerations, current industrial-robot control systems, lyapunov stability analysis, cartesian-based control systems, adaptive control (4 lectures)
4. Force Control: Interaction with Environment, Compliance Control, Impedance Control, Force Control, Hybrid Force/Motion control (4 lectures)

Laboratory Classes (12 exercises)

DH Parameters, Forward and Inverse Kinematics of Robot, Robot Trajectory Planning, Robot Operating System (ROS), Control of Robot through ROS, Path Planning, Vision Based control, Force Control

Reference Books

1. Saha S. K., Introduction to robotics. Tata McGraw-Hill Education
2. Spong M. W., Hutchinson, S., and Vidyasagar, M., Robot modeling and control. New York: Wiley.
3. O'Kane J. M., A Gentle Introduction to ROS, ISBN 978-1492143239
4. Craig J. J, Introduction to robotics: mechanics and control. Pearson/Prentice Hall.

Self Learning Material

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

Title	**Industry 4.0 Applications in Manufacturing Systems**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	1-0-0-0 [1]
Offered for		Type	Program Core
Prerequisite			

Objectives:

The Instructor will:

1. provide brief understanding about Industry 4.0 concepts in manufacturing systems

Learning Outcomes:

The students are expected to appreciate:

1. current trends at system level in manufacturing organizations
2. the importance of industry 4.0 concepts at manufacturing systems

Contents:

Introduction to Manufacturing systems (2 Lecture)

Automated Manufcturing Systems: Concept of Group Technology and cellular manufacturing, Flexible Manufacturing Systems, Lean Manufacturing, Agile Manufacturing (6 Lectures)

Industry 4.0 for Manufacturing Systems: Agent Based Manufacturing, Cloud Based Manufacturing (6 Lectures)

Reference Books:

1. Talavage J., and Hanman R. G, Flexible Manufacturing Systems in Practice, Taylor and Francis
2. Gunasekaran A., Agile Manufacturing: 21st Century Competitive Strategy, Elsevier
3. Wang L., and Vincent W. X., Cloud Based Cyber-Physical Systems in Manufacturing, Springer

Self-Learning Material:

1. https://nptel.ac.in/courses/106105195/10

Program Electives:

Title	**Computer-Aided Manufacturing**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3-0-2-0 [4]
Offered for		Type	Program Elective
Prerequisite			

Objectives:

The Instructor will:

1. introduce concepts of CNC Technology and its usefulness in manufacturing
2. provide brief understanding of CAPP, AM and CAI concepts

Learning Outcomes:

The students are expected to appreciate:

1. the benefits derived from computer applications in manufacturing
2. recent trends in the domain of advanced manufacturing

Contents:

1. Introduction: Introduction to Automation, Numerical Control (NC) Technology, Computer Numerical Control (CNC), Direct and Distributed Numerical Control (DNC), Importance of CNC machines in Flexible Manufacturing Systems (FMS) and Computer Integrated Manufacturing Systems (CIMS) (3 Lectures)
2. CNC Hardware: Components of CNC system, Classification of CNC machines, Axes Designation, CNC Hardware elements including drives, actuators, sensors, controllers and machine tool elements, CNC interpolators, Tooling and work-holding devices for CNC machines, Fixtures for CNC machine tools, Automatic tool changers and automatic pallet changers (5 Lectures)
3. CNC Programming: Axes designation in CNC machines, Fundamentals part programming, Programming formats, Programming for CNC Lathes and Milling machines, Use of advanced programming features such as subroutines, canned cycles, Automated Programmed Tools, Compensation in CNC machine tools (12 Lectures)
4. Machining of Freeform Surfaces: Analysis of geometric attributes of curves and surfaces, curves and surfaces for manufacturing applications, CNC program generation from CAD models, CNC Program verification and Virtual CNC (8 Lectures)
5. Additive Manufacturing: Introduction, Process flow in AM, Classification, Issues in RP (4 Lectures)
6. Computer Aided Process Planning (CAPP): General Concepts, Manual process planning, Framework for CAPP, Computer Aided Assembly Planning, Representation of assembly and assembly plans, Generation of assembly plans and sequence, Integration with CAD systems (4 Lectures)
7. Computer Aided Inspection: General Concepts, Contact and Non-contact inspection techniques, Coordinate Measuring Machine, Machine Vision, Reverse Engineering (6 Lectures)

Laboratory Experiments:

Manual part programming on CNC lathe and CNC milling machines using CNC simulation software; Application of various canned cycles in programming; Machine setting on CNC lathe and CNC vertical milling machine; Representing free form curves on CAD/CAM software; Generation of part programs from CAD/CAM software for CNC Lathe and milling machines; Computer Aided Inspection (CMM); On-machine inspection of components; Importance of data exchange formats such as IGES, STEP, DMIS etc.

Reference Books:

1) Smid P. (2008), CNC Programming Handbook, Industrial Press
2) Madison J (1996), CNC Machining Handbook: Basic Theory, Production Data and Machining Procedures, Industrial Press
3) Marciniak K. (1991), Geometric Modeling for Numerically Controlled Machining, Oxford University Press

Title	**Mechanical Metallurgy**	Course No.	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3-0-0-0 [3]
Offered for		Type	Program Elective
Pre-requisite			

Objectives

1. To impart Mechanical Metallurgy concepts and their applications in mechanics and manufacturing

Learning Outcomes

1. Understanding of the basic concepts of Mechanical Metallurgy with emphasis on micromechanics of deformation and structure of solids.
2. Imparting knowledge in two areas of material mechanical behavior: Elastic and plastic deformation.

Course Content

1. Review: Material Properties, Effect of structure on properties at different levels subatomic to Macroscopic, Tensile Response of Materials, Scaling issues, Effect of Temperature on Flow Properties Stress State (2D). (6 Lectures)
2. Selection of Materials: Selection strategy, selection procedure, structural index, Material selection case studies, Shape factors, efficiency of standard sections, Material limits for shape factors. (6 Lectures)
3. Stress Tensor, Stress State (3D), Description of Strain, Elasticity; Advanced Treatment Plasticity (Yield Criteria for Ductile Metals) (4 Lectures)
4. Plastic deformation, Dislocation Theory, Strengthening Mechanisms, Metalworking, Creep, Metal forming, casting and allied manufacturing processes (12 Lectures)
5. Basic fracture mechanics, ductile-brittle transition, Toughness, microstructure anisotropy, Optimizing microstructures for toughness Environmental assisted cracking (EAC) Variables affecting EAC, Introduction to Fatigue, Wear, Corrosion. (12 Lectures)

Textbook:

1. Dieter, G. E., (1986), Mechanical Metallurgy, McGraw Hill Book Company
2. Hertzberg, R.W., (2012), Deformation and Fracture Mechanics of Engineering Materials, John Wiley and Sons
3. Ashby, F., (1999), Materials Selection in Mechanical Design, Butterworth –Heinmann

Self Learning Material

1. http://nptel.ac.in/courses/113106032/

Title	**Theory of Arc Welding**	Course No.	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3-0-0-0 [3]
Offered for		Type	Program Elective
Pre-requisite			

Objectives

1. To impart knowledge and train students in area of arc welding processes

Learning Outcomes

1. Acquire fundamental understanding of the principles of arc welding
2. Develop detailed understanding of Arc welding processes and effect of their process parameters
3. Understand how arc welding processes are selected, controlled, and applied to the various joint design requirements and Diagnose faults in arc welding processes and acquire basic understanding of the heat flow and residual stresses in welds

Course Content

Physics of welding arc:- Welding arc, voltage distribution along the arc, thermionic and non-thermionic cathodes, arc characteristics and its relationship with power source, arc efficiency, heat generation, effect of shielding gases on arc, isotherms of arcs, Classification, forces acting on the drop, metal transfer mechanisms, transition current, melting rate, effect of polarity, deposition efficiency, current and voltage oscillograms, high speed films. (10 Lectures)

Consumable electrode welding processes:- Manual metal arc (MMA) welding: type composition and functions of flux covering, ISI and other international codes for electrodes, concepts of special electrodes, consumables, arc length control in pulsed MIG welding, selection of parameters, self-shielded and gas shielded flux cored wire welding.(6 Lectures)

Submerged Arc Welding: Specific features, process variables, types and composition of fluxes and their manufacturing, arc length control, significance of flux-metal combination; Non-Consumable Electrode Welding Processes:- Gas tungsten arc welding, electrodes, compositions, shielding gases, arc ignition and maintenance, selection of polarity, arc voltage rectification and remedy, cathode spot and normal mode operations. Plasma arc welding: transferred and non-transferred plasma arc welding, selection of gases, welding parameters, keyhole technique. (10 Lectures)

Heat flow and Residual Stresses in Welds:- Heat flow in welding, effect of welding parameters on heat distribution, Calculation of peak temperature, weld thermal cycle, cooling rate and solidification time, residual stress distribution, influence of residual stress in static and dynamic loading. (14 Lectures)

Reference Books

1. Messler R. W., (1999), Principles of Welding (Processes, Physics, Chemistry and Metallurgy), John Wiley
2. Metals Handbook, Vol. 6, (1993), ASM International Publication
3. Welding Handbook Vol. 1, 2 & 3, (1991), American Welding Society

Self Learning Material

1. http://nptel.ac.in/courses/112107089/

Title	**Welding Metallurgy**	Course No.	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3-0-0-0 [3]
Offered for		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

1. Application of physical metallurgy principles to non-equilibrium thermo-mechanical conditions associated with welding. (6 Lectures)
2. Heat flow in welding, chemical reactions in welding, Fluid flow and metal evaporation in welding. (10 Lectures)
3. Fusion zone, Partially melted zone, Heat affected zone, Weld solidification principles, Chemical Inhomogenities and cracking. (12 Lectures)
4. Welding of stainless steels, aluminum alloys, copper alloys and Nickel alloys, Joining of Dissimilar metal welds. (12 Lectures)

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/

Title	**MEMS & Microsystems Technology**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P [C]	3–0–2-0 [4]
Offered for		Type	Program Elective
Prerequisite			

Objectives

The instructor will :

1. cover fundamental understanding of miniaturization and related functional advantages in various engineering disciplines and corresponding systems/devices
2. teach overview/working principles, modeling, analysis, design, manufacture and packaging of Microsystems along with the state of the art awareness of this domain

Learning Outcomes

The students are expected to have :

1. practical and simulation exposure to understand the complexity in design and manufacturing of Microsystems.
2. basic Microsystems based research and training to develop Micro-systems modules for commercial and futuristic applications.

Contents:

1. Introduction : Fundamentals and applications to Microsystems (2 lectures)
2. Engineering Mechanics For Microsystems Design: Static Bending of Thin Plates, Mechanical Vibration, Thermo-mechanics, Thin-Film Mechanics, Stress Analysis Problems (4 lectures)
3. Fluid Mechanics at small scales: Viscosity of Fluids, Basic Equations in Continuum Fluid Dynamics, Incompressible Fluid Flow in Micro-conduits (3 lectures)
4. Heat Conduction in Solids: General Principle of Heat Conduction, Fourier law of Heat Conduction, Newton's Cooling Law, Solid-Fluid Interaction, Heat Conduction in Multilayered Thin Films (3 lectures)
5. Scaling Laws in Miniaturization (3 lectures)
6. Materials for MEMS and Microsystems: Silicon as Substrate Material, Silicon Compounds, Gallium Arsenide, Quartz, Polymers, Packaging Materials, polymer MEMS (4 lectures)
7. Microsystems Fabrication Processes: Photolithography, micro molding/replica molding process, 3D printing for polymer processing, Diffusion, Oxidation, Chemical/Physical Vapor Deposition, Deposition by Epitaxy, Etching, Bulk and Surface Micro manufacturing. (8 lectures)
8. Characterization techniques: Overview of various visualization techniques such as FESEM, TEM, Optical microscope etc. (3 lectures)
9. Working Principles of Microsystems Devices: Working Principles, Design, Manufacturing and Packaging of Micro-sensors, Actuators, Inertial Sensors and Fluidic devices (8 lectures)
10. Microsystems Design Considerations: Selection of Materials, Manufacturing Processes, Signal Transduction, processing with respect to microsystem Packaging, modeling & simulation aspects (4 lectures)

Laboratory Experiments:

Design and development of micro channel/features with soft lithography; Development of micro-features with the help of electrodeposition; Design and fabrication of micro system device; Design and testing of micro fluidics device through diffusion and capillary action; Silicon wafer handling, RCA cleaning and surface effect analysis with plasma treatment; Modeling and analysis of MEMS based Device such as Capacitive Pressure Sensor, Micro-Inertial Sensors, Micro actuators, Studies based on Fluid Structure Interaction (FSI); Simulation studies on Wet Etching in Anisotropic condition, Meshing and Analysis based on Process Simulation Result, Coupled Package-Device Modeling

Reference Books

Tai-Ran, H. (2002). MEMS & microsystems: design and manufacture. ME Series.
Madou, M. J. (2002). Fundamentals of Micro-fabrication: the science of miniaturization. CRC
Campbell, S. A. (2001). The Science and Engineering of Microelectronic Fabrication (The Oxford Series in Electrical and Computer Engineering).

Online Course Material:

1. https://nptel.ac.in/courses/117105082/

Title	**Precision and Micro Manufacturing**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3–0–0 [3]
Offered for		Type	Program Elective
Prerequisite			

Objectives

The instructor will :

1. teach important topics in precision, micro/nano manufacturing based on the fundamentals enabling technologies.

Learning Outcomes

The students are expected to have the ability to:

1. understand the design and process issues associated with precision machine tools and the fabrication of precision components
2. develop a conceptual design solution to a precision machine operating in the small scale range
3. understand various fabrication techniques in manufacturing micrometer scaled devices and systems of complicated geometry

Contents:

1. Introduction to Precision engineering and practices: definitions, sources of error (4 Lectures)
2. Basic concepts of machining and precision engineering: Machine tool variables- accuracy, repeatability, stiffness, spindle vibration, flatness, straightness, and smoothness of motion, 1-2 DOF systems, feedback variables, cutting tool variables, workpiece variables, environment effects and thermal errors. Machine design for precision manufacturing, principles of measurement mechanical errors. (5 Lectures)
3. Micro machining techniques: Diamond micromachining introduction, diamond as a tool material, compatible materials, diamond performance, diamond machining, micro-mechanical applications. Micro-ECM, micro-EDM, Micromilling: micro-milling tools, process results and micro-milling applications. Microdrilling: micro-drilling and macro-drilling techniques. Laser micromachining: laser optics, laser ablation, heat affected zone and laser polymerization. (16 Lecture)
4. Joining Processes: Joining processes in similar and dissimilar materials; welding processes like ultrasonic, electron beam, laser beam and associated applications. (5 Lectures)
5. Micro casting: casting processes like vacuum, semi-solid state; applications processing of integrated circuits, clean rooms, crystal growing and shaping of wafers, etching, photo and other lithography techniques, impurity introduction, thermal oxidation, CVD etc. (12 Lectures)

Reference Books

1. Murthy R. L., Precision engineering manufacturing, New Age International, 2005
2. Suryaprakash M. V., Precision Engineering, Narosa publications
3. Venkatesh V. C., Precision Engineering, McGraw Hill Publications
4. Nakazawa H., ”Principles of precision engineering”, Oxford University Press

Self-Learning Material:

1. http://library1.org/_ads/A893BCE522D62C29FFB1D4CED8405ED4
2. https://nptel.ac.in/syllabus/112104028/

Title	**Applied Ergonomics**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3–0–0-0 [3]
Offered for		Type	Program Elective
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 enhance 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:

1. Introduction : Overview of Ergonomics, Introduction to human-machine system (2 lectures)
2. Physical ergonomics : Work Physiology, Musculoskeletal system, Metabolism & digestive system, Cardiovascular system, Respiratory system (8 lectures)
3. Anthropometry: Design principles, Collection of data & statistical tools (8 lectures)
4. Cognitive ergonomics: Human Sensory system, Perception, Attention resources, Memory, Common Cognitive tasks (8 lectures)
5. Physical work environment: 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 (8 lectures)
6. Biomechanics aspect and work study : Anatomical sites important for occupational ergonomics, manual work system, tools and techniques for work systems design and assessment (4 lectures)
7. Industrial/organizational ergonomics : Occupational Safety & Health, Case studies over industrial problems (4 lectures)

Reference 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	**Mechatronics System Design**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3–0–0-0 [3]
Offered for		Type	Program Elective
Prerequisite			

Objectives

The instructor will:

1. focus on essential elements of Mechatronics System Design i.e. Physical Systems Modeling, Sensors and Actuators, Signals and Transducers, Logic Systems and Data Acquisition
2. train students in systems design from the functional capability point of view and also to provide fundamental understanding of blended functionality of the subsystems combined with system sizing

.

Learning Outcomes

The students are expected to have the ability to:

1. demonstrate various fundamental aspects of Mechatronics Systems Design having complexity of interdisciplinary technologies including electrical, mechanical, computer science, pneumatics, and thermodynamics engineering

Contents:

1. Introduction to Mechatronics : Mechatronics in manufacturing, products and in engineering design, System Interfacing, Instrumentation and Control Systems, Microprocessor-Based Controllers and Microelectronics. (8 lectures)
2. Physical System Modeling: Modeling Electromechanical Systems, Structures and Materials, Modeling of Mechanical Systems for Mechatronics Applications, Fluid Power Systems, Electrical Engineering, Engineering Thermodynamics, Numerical Simulation, Modeling and Simulation for MEMS, Rotational and Translational Microelectromechanical Systems: MEMS Synthesis, Microfabrication, Analysis, and Optimization, Physical Basis of Analogies in Physical System Models. (14 lectures)
3. Mechatronic Sensors and Actuators: Introduction to Sensors and Actuators, Fundamentals of Time and Frequency, Sensor and Actuator Characteristics, Sensors, Linear and Rotational Sensors, Acceleration Sensors, Force Measurement, Torque and Power Measurement, Flow Measurement, Temperature Measurements, Distance Measuring and Proximity Sensors, Light Detection, Image, and Vision Systems. Actuators : Electromechanical Actuators, Electrical Machines, Piezoelectric Actuators, Hydraulic and Pneumatic Actuation Systems. Discussion with research articles. Problem solving based on drives, mechanisms and other mechatronics systems. (20 lectures)

Reference Books

1. Shetty, D., and Kolk, R. A. (2010). *Mechatronics system design*, SI version. Cengage Learning
2. Bishop, R. H. (Ed.). (2008). *Mechatronic systems, sensors, and actuators*. CRC press
3. Bradley, D. (2018). *Mechatronics: electronics in products and processes*. Routledge

Online Course Material:

1. https://nptel.ac.in/courses/112103174/

Title	**Additive Manufacturing**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3–0–0-0 [3]
Offered for		Type	Program Elective
Prerequisite			

Objectives

The Instructor will:

1. cover scientific as well as technological aspects of various additive, subtractive and formative rapid manufacturing processes.
2. cover wide range of contemporary methodologies/technologies and tools for rapid manufacturing.

Learning Outcomes

The students are expected to have the ability to:

1. appreciate process flow and working principles for various additive manufacturing processes
2. deal with challenges faced during additive manufacturing of components

Contents

1. Introduction: Mass production and customization, Classification of processes, process chain for AM (4 Lectures)
2. Data Preparation: Data formats, data conversion, data validity checks, data repair (4 Lectures)
3. Process Planning Stage: Slicing Algorithms, Part Depositions and Orientation, Direct Slicing, STEP related details (6 Lectures)
4. AM Processes: FDM of polymers, metals and ceramics, Laminated Object manufacturing, Shaped Deposition manufacturing, Sterolithography and liquid based systems, Laser Sintering technologies, 3-D Printing, Direct Metal Deposition, Electron and Laser beam technologies, Subtractive and Formative Rapid manufacturing processes (14 Lectures)
5. Rapid Tooling (2 Lectures)
6. Hybrid Processes (4 Lectures)
7. Process Selection, Applications, Capabilities and Challenges (8 Lectures)

Reference Books

1. Gibson, I, Rosen, D W, and Stucker, B, Additive Manufacturing Methodologies: Rapid Prototyping to Direct Digital Manufacturing, Springer
2. Hopkinson, N, Haque, R, and Dickens, P, Rapid Manufacturing: An Industrial Revolution for a DigitalAge: An Industrial Revolution for the Digital Age, Wiley
3. Bartolo,P J (editor),Virtual and Rapid Manufacturing: Advanced Research in Virtual and Rapid Prototyping, Taylor and Francis
4. Chua, C K, Leong, K F, Lim C S, Rapid Prototyping, World Scientific

Online Course Material:

1. https://nptel.ac.in/syllabus/112104156/

Title	**Design for X**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3–0–0-0 [3]
Offered for		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

1. Introduction: Need identification and problem definition, Concept generation and evaluation, embodiment design (4 Lectures)
2. Selection of Materials and Shapes: Properties of engineering materials, Selection of materials (with examples and case studies), selection of shapes, Co-selection of materials and shapes (8 Lectures)
3. Selection of Manufacturing processes: Overview of manufacturing processes, Design for Casting, Design for bulk deformation and sheet metal processes, Design for Machining, Design for Polymer and powder processing, Case studies (16 Lectures)
4. Design for Assembly: Review of Assembly operations, Design for Welding, Soldering, Brazing and Adhesive joining, Design for heat treatment, Case Studies (8 Lectures)
5. Design for Reliability and Quality: Failure Mode and Effect Analysis, Design for Quality, Design for Reliability, Approach to robust design, Design for optimization (6 Lectures)

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	**Theory of Vibrations**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3–0–0-0 [3]
Offered for	B.Tech (ME), M.Tech (AMD) and PhD	Type	Program Elective
Prerequisite	Basic knowledge of mechanical vibrations		

Objectives

The Instructor will:

1. Provide the approach adopted for analyzing the structural dynamic characteristics and dynamic response of uniform and non-uniform structural elements, like beams.
2. The approach is applicable for structural dynamic analysis of any structure

Learning Outcomes

The students are expected to have the ability to:

1. Analyze the vibration characteristics of non-uniform beams
2. Thorough understanding of approximate methods used in the structural dynamic analysis

Contents

1. Introduction: Discrete and continuous systems, SDOF, Types of Damping, Frequency response, Time response, Beating phenomenon, Response to impulse loading, Convolution integral, Numerical integration, Newmark-β method, Wilson-θ method (9 Lectures)
2. Rayleigh's Method: Approximate evaluation of natural frequency, improved Rayleigh's method (4 Lectures)
3. Stiffness and flexibility influence coefficients, finite element stiffness of beam elements, Static condensation (5 Lectures)
4. Hamilton's principle, Lagrange's equations (3 Lectures)
5. Linear conservative natural systems: Symmetric eigenvalue problem, Modal analysis, Systems with proportional damping, structural damping (complex stiffness) (4 Lectures)
6. Continuous parameter systems: Longitudinal vibration of bars, bending vibration of beams, torsion vibration (4 Lectures)
7. Differential Eigenvalue Problem: Admissible function, Comparison function, Eigen function (2 Lectures)
8. Positive definite system, self adjoint property (2 Lectures)
9. Natural modes of vibration: Mode shapes and natural frequencies (2 Lectures)
10. Approximate methods: Transfer Matrix method, Rayleigh's quotient, Rayleigh-Ritz method, Galerkin method (5 Lectures)
11. Response to excitation: Mode summation, Mode acceleration (2 Lectures)

Reference Books:

1. Meirovitch, L., Principles and Techniques of Vibrations, 3rd Edition, Prentice Hall
2. Meirovitch, L., Analytical Methods in Vibration Analysis, Macmillan
3. Clough, R.W., and Penzien, J., Dynamics of Structures, McGraw Hill

Self Learning Material:

1) https://nptel.ac.in/courses/105101006/

Title	**Mechanical Vibrations**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3–0–0-0 [3]
Offered for		Type	Program Elective
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. Analyze the vibration characteristics of discrete systems
2. Thorough understanding of modeling of damping and their effects on system response

Contents

1. Introduction (1 Lecture)
2. Single degree of freedom systems: Undamped free and forced vibration, Types of damping, Viscous, Friction, Hysteretic damping (10 Lectures)
3. Damped single degree of freedom: Frequency response, resonance Beating phenomenon (5 Lectures)
4. Vibration under general forcing condition, Duhamel Integral (5 Lectures)
5. Vibration measuring instruments (5 Lectures)
6. Response spectrum or Shock spectrum (2 Lectures)
7. Two-degrees of freedom system (2 Lectures)
8. Free vibration of undamped systems: Normal modes, Orthogonality of modes, Expansion theorem (5 Lectures)
9. Modal analysis (2 Lectures)
10. Vibration control: Vibration isolation, vibration absorber (3 Lectures)
11. String vibration (2 Lectures)

Textbook

1. Thompson, W.T., Theory of Vibration with Applications, Prentice Hall
2. Rao, S.S., Mechanical Vibrations Prentice Hall
3. Meirovitch, L., Elements of vibration analysis, Prentice Hall

Self Learning Material:

1) nptel.ac.in/courses/112103112/

Title	**Helicopter Dynamics**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3–0–0-0 [3]
Offered for		Type	Program Elective
Prerequisite			

Objectives

1. Provide fundamentals of helicopter dynamics

Learning Outcomes

The students are expected to have the ability to:

1. Provide basic understanding of the helicopter modeling and flight dynamics

Contents:

1. Historical development (1 Lecture)
2. Configurations of helicopters, rotor system (1 Lecture)
3. Flight control mechanism (1 Lecture)
4. Momentum theory and blade element theory in hover, Vertical flight and forward flight (13 Lectures)
5. Idealization of rotor blades (2 Lecture)
6. Flap, lag and torsional dynamics of rotor blade (7 Lectures)
7. Flap-pitch, lag-pitch and flap-lag coupling (3 Lectures)
8. Trim and equilibrium analysis (3 Lectures)
9. Aero-elastic stability of rotor blades (4 Lectures)
10. Simple model of rotor fuselage dynamics (3 Lecture)
11. Longitudinal and lateral stability and control of helicopters (4 Lecture)

Reference Books

1. Venkatesan, C., Fundamentals of Helicopter Dynamics, Taylor and Francis, CRC Press
2. Johnson, W., Helicopter Theory, Princeton University Press
3. Leishman, G., Principles of Helicopter Aerodynamics, Cambridge University Press

Self Learning Material:

1. Venkatesan, C., http://nptel.ac.in/courses/101104017/

Title	**Modelling and Control of Mechanical Systems**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3–0–0-0 [3]
Offered for		Type	Program Elective
Prerequisite			

Objectives

The Instructor will:

1. Familiarize with methods to characterize dynamical behaviour of mechanical system using the models
2. Provide understanding of basic concepts of control theory, along with the various control structures&elements
3. Describe a few techniques for designing control systems

Learning Outcomes

The students will have the ability to:

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. Set up a suitable control structure and acquire clarity about various control tasks and the corresponding elements to achieve the tasks
3. Interpret the closed-loop control design requirements in terms of simpler quantitative attributes and apply the design procedures to arrive at the required control scheme

Contents

1. *Introduction to Modelling & Representation:* Objective, basic modeling concepts & types of models, Models of simple physical systems, linearization of nonlinear models and role of Linear Time Invariant (LTI) forms, I/O form, block diagram representation and manipulation, signal flow graphs, Laplace transform and transfer function concept (8 Lectures)
2. *Response & Stability Analyses:*Test signals, response of 1st and 2nd order, as well as, higher order systems, Stability / its connection to response, asymptotic and BIBO stability, role of characteristic roots, Routh's stability criterion & procedure (6 Lectures)
3. *Introduction to Control:* Control objectives, open/ closed loop control and structures, unity negative feedback systems, and basic control actions, Transient & steady-state responses, tracking & transient response features (5 Lectures)
4. *Proportional Control as Basic Action:* Proportional control action, relative stability and response, concept of root locus and its application to proportional, PI, PD and PID control actions (6 Lectures)
5. *Concept of Frequency Response:* Frequency response & its representation using bode', Nyquist plots, Nyquist stability analysis, concepts of gain & phase crossover, gain and phase margins, bandwidth and resonant amplitude as closed-loop system attributes (8 Lectures)
6. *Design of Control Elements:* Design of P, PI, PD & PID control elements using both root locus and frequency response techniques, Design of lead, lag and lag-lead compensators using both root locus and frequency response techniques (9 Lectures)

Text Book

1. Ogata, K., *Modern Control Engineering*, 5th Edition, Prentice-Hall India, (EEE)

Reference Books

1. Nise, N.S., *Control Systems Engineering*, 6th Edition, John-Wiley India, (WSE)
2. Gopal,M., *Control Systems - Principles & Design*, 3rd Edition, Tata McGraw-Hill
3. Dorf, R.C. & Bishop, R.H., *Modern Control Systems*, 11th Edition, Pearson

Self Learning Maerial

1. https://onlinecourses.nptel.ac.in/noc17_ee12/preview

Course Title	**Multibody Dynamic Systems**	Course No.	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3–0–0-0 [3]
Offered for		Type	Program Elective
Pre-requisite			

Objectives

1. To understand various abstractions in dynamics of rigid bodies to model real-life problems in mechanisms, robotics and vehicles

Learning Outcomes

1. Understanding the basic concepts of classical rigid body dynamics and robotics
2. Formulation of equations of motion and their solution
3. Applications in the area of robotics and mechanisms and vehicles

Course Content

Multibody systems, reference frames, constrained motion, kinematics, Euler angles, Denavit-Hartenberg notation, Relationship among various conventions (8 Lectures)

Analytical techniques, generailized co-ordinates, generalized forces, Lagrangian dynamics, calculus of variations, Newton-Euler equations (10 Lectures)

Mechanics of deformable bodies, formulation of equation of motion for multibody systems with deformable components, compliant mechanisms (12 Lectures)

Finite element method, variational formulation, discretization procedures, element shape functions, formulation of mass, stiffness matrices and their assembly for various boundary conditions and solution methodologies (12 Lectures)

Text Books

1. Shabana., A. A., *Dynamics of Multibody Systems,* Cambridge University Press, 4th Edition
2. *Reddy.,* J. N., *An Introduction to the Finite Element Method, Tata McGraw Hill, 3rd Edition*

Self Learning Maerial

1. http://real.uwaterloo.ca/~mbody/

Course Title	**Finite Element Methods in Engineering**	Course No.	**MEL7XX0**
Department	Mechanical Engineering	L-T-P-Th [C]	3–0–0-0 [3]
Offered for		Type	Program Elective
Pre-requisite			

Objectives

1. Understand the fundamental ideas and concepts of the FEM
2. Understand and perform engineering analysis of mechanical systems & civil structures, fluid mechanics and heat transfer
3. Understand the need in design for the Finite Element Method

Learning Outcomes

1. To achieve an understanding of the fundamentals of the FEA
2. Ability to develop the governing FE equations for systems (Mechanical, Civil, and Aerospace)
3. Ability to successfully use of the basic finite elements for structural applications using truss, beam, frame, and plane elements;
4. Ability to use FEA for fluid mechanics and heat transfer problems.
5. Ability to formulate two-dimensional and three-dimensional elements in FEA design process

Course Content

1. Historical background: General procedure for finite element analysis; Comparison between FEM solution and exact solution; Stiffness matrix, Spring and bar elements; Finite element formulation of axial rod and beam problems (6 lectures)
2. Stiffness Method Introduction, Element Transformation, Boundary conditions, Constraint forces, Global stiffness matrix, Element strain and stress, Three Dimensional Trusses and Frames (6 lectures)
3. Elementary beam theory, Flexure element stiffness matrix, Boundary conditions, constraint forces, Global stiffness matrix, General three dimensional beam element (5 lectures)
4. 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 (5 lectures)
5. One dimensional Conduction with and without convection; Heat transfer in 2D dimensions; Heat Transfer with mass transport; Heat Transfer in 3D dimensions; Time-dependent Heat Transfer (5 lectures)
6. Governing equations for incompressible flow; Fluid mechanics in 2-D flow, Incompressible viscous flow (5 lectures)
7. Basic Equations; Boundary Conditions; FEM Formulation; Shape Functions; Numerical Evaluation of Elements Matrices and Vectors; Global matrices; Boundary conditions and solutions; General 3D stress element (5 lectures)
8. Thin plate formulation; Various thin plate elements; Thick plate formulation (5 lectures)
9. Vibration of a rod; Vibration of a beam; Classification of partial differential equations; Time response of parabolic equations; Forced vibration problems (6 lectures)

Reference Books

1. Cook R. D., Concepts and Applications of Finite Element Analysis, John Wiley
2. Bathe K. J., Finite Element Procedures in Engineering Analysis, Prentice-Hall
3. Moaveni S., Finite Element Analysis - Theory and Application with ANSYS, Prentice Hall
4. Hutton D., Fundamental of Finite Element Analysis, McGraw-Hill

Self Learning Material

1. https://nptel.ac.in/courses/112104205/
2. https://nptel.ac.in/courses/105105041/

Course Title	**Rotor Dynamics**	Course No.	**ME7XX0**
Department	Mechanical Engineering	L-T-P-Th [C]	3–0–0-0 [3]
Offered for		Type	Program Elective
Pre-requisite			

Objectives

1. To impart the concepts, principles and fundamental understanding of the rotor dynamics phenomena
2. To understand the modeling and analysis of rotors for the transverse and torsional vibrations.
3. To study the condition monitoring of rotor bearing system for analyzing the performance of rotating machinery

Learning Outcomes

1. The students become familiar with the fundamental aspect of the dynamics of rotating machines
2. Ability to identify and detect the rotor bearing system parameters
3. Ability to use in futuristic model-based condition monitoring and fault diagnostic and prognostics
4. Be acquainted with the different techniques used in the industry for the analysis of rotor-dynamic problems.

Course Content

1. Review of dynamic principles using matrix algebra; Critical speeds and dynamic response; Stability of rotating components; Gyroscopic effects; Balancing of rotating machinery (10 lectures)
2. Torsional and transverse vibrations; Bearing dynamics and it's coefficient measurements (8 lectures)
3. Hydrodynamic Bearing Instabilities; Sub-Critical Phenomenon in Rotors (8 lectures)
4. Numerical and experimental studies employing a Jeffcott rotor; Fault Detection and analysis; Transducers and monitoring; Condition monitoring and signature analysis of Rotating Machines (10 lectures)
5. Development of complex rotor-dynamic models (8 lectures)

Reference Books

1. Vance J.M., Rotordynamics of Turbomachinery, John Wiley & Sons
2. Lee C.-W., Vibration Analysis of Rotors, Kluwer Academic Publishers
3. Goodwin M.J., Dynamics of Rotor-Bearing Systems, Unwin Hyman
4. Krämer E., Dynamics of Rotors and Foundations, Springer-Verlag

Self Learning Material

1. https://nptel.ac.in/syllabus/112103024/

Title	**Autonomous Mobile Robots**	Number	AVL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3-0-2-0 [4]
Offered for		Type	Program Core
Prerequisite			

Objectives:

1. To provide the basics required to develop autonomous mobile robots and systems
2. Introduce mobile robot locomotion and kinematics, environment perception and modeling, localization, mapping and navigation

Learning Outcomes

1. The course will equip students with theoretical and practical knowledge of Autonomous Mobile Robot.

Contents

2. Mobile Robots: Introduction, Wheeled robots, Aerial Robots, Legged robots (2 lectures)
3. Robot Kinematics: Kinematic Model and Constraints, Maneuverability, Workspace, Motion control (6 lectures)
4. Perception: Sensors for mobile robots, wheel, Heading, Accelerometers, IMU, Ground beacons, Fundamental of Computer Vision, Image Processing, Feature Extraction, Place Recognition, Extraction based on Range Data (11 lectures)
5. Robot Localization: Noise and Aliasing, Belief Representation, Map Representations, Probabilistic Map based localization, Autonomous Map Building (11 lectures)
6. Planning and Navigation: Planning and Reacting, Path Planning, Obstacle Avoidance, Navigation Architectures (8 lectures)
7. Application to Industry 4.0: Role of Internet of Things, Autonomous Transport, Material Handling and Logistics (3 Lectures)

Laboratory Experiments

Kinematics, Motion Control, Sensor Integration, Localization, Autonomous Map building, Path Planning, Obstacle Avoidance, Navigation

Text Books

1. Siegwart, R., Nourbakhsh, I. R., Scaramuzza, D., & Arkin, R. C. (2011). Introduction to autonomous mobile robots. MIT press.

Reference Books

1. Kelly, A. (2013). Mobile robotics: mathematics, models, and methods. Cambridge University Press.
2. Choset, H. M., Hutchinson, S., Lynch, K. M., Kantor, G., Burgard, W., Kavraki, L. E., & Thrun, S. (2005). Principles of robot motion: theory, algorithms, and implementation. MIT press.
3. Thrun, S., Burgard, W., & Fox, D. (2005). Probabilistic robotics. MIT press.

Self Learning Material

1. https://www.edx.org/course/autonomous-mobile-robots

Title	**Microfluidics Technology**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3–0–0 [3]
Offered for		Type	Program Elective
Prerequisite			

Objectives

The Instructor will:
1. teach topics based on the fundamentals of microfluidics enabling technologies.
2. cover state of the art work performed in the microfluidics domain.

Learning Outcomes

The students are expected to have the ability to:
1. explain the fundamental of micro fluidics and associated applications.
2. demonstrate knowledge of designing, fabricating and characterizing a) microfluidics components and sensors/actuators, and b) micro total analysis systems.
3. solve problems related to the fluid transport phenomena at the microscopic length scale.

Contents:
1. Basics to Micro fluidics: Fundamentals to Microfluidics, its commercial and scientific aspects, Device and Technology development, Theory of fluid mechanics at miniaturized length scales: Intermolecular forces, continuum mechanics at small scales, electrokinetics (electro-osmosis, electrophoresis, dielectrophoresis), Navier strokes equation and non dimensionalization, diffusion, mixing, separation in microsystems (14 Lectures)
2. Fabrication and Characterization of Microfluidic Devices: Design Considerations, Vacuum science and plasmas, Materials for microfluidics technology, Basic fabrication processes for polymers, bulk and surface micromachining, replication technologies, laser machining, micro-stereo lithography, micro-molding, Assembly and packaging of micro-systems, Flow characterization: Fundamental physics consideration of Micro-PIV, Special processing methods for Micro-PIV recordings, Micro-PIV examples (14 Lectures)
3. Microfluidics Technology (14 Lectures)
   (a) Microfluidics Sensors: Description about various microfluidics sensors (thermal flow sensors, velocity sensors etc.), design considerations etc.
   (b) Microfluidics Actuators : Micro-valves (Design considerations, Pneumatic valves, Thermo-pneumatic valves, Thermo-mechanical valves, Piezoelectric valves, Electrostatic valves, Electromagnetic valves, Electrochemical valves, Capillary force valves etc.) Mechanical Micro-pumps (design considerations, check valve pumps, peristaltic pumps, valveless rectification pumps, rotary pumps, centrifugal pumps, ultrasonic pumps). Non-mechanical pumps (Electrical pumps, Surface tension driven pumps, Chemical pumps, Magnetic pumps) etc.
   (c) Microfluidics in healthcare and diagnostics: Lab on chip devices, Micro total analysis systems, Micro-mixers (design considerations, building and testing).

Reference Books:

1. Nguyen N. T., Wereley S. T. and Shaegh S. A., (2019), Fundamentals and applications of microfluidics, Artech house
2. Campbell, S. A., (2001), The Science and Engineering of Microelectronic Fabrication, The Oxford Series in Electrical and Computer Engineering
3. Karniadakis, G., Beşkök, A. (2001), Microflows: Fundamentals and Simulation, Springer

Self Learning Material:
1. https://nptel.ac.in/courses/112105187/
2. https://freevideolectures.com/course/3495/microfluidics

Title	**Computer Aided Inspection and Quality Control**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3-0-0-0
Offered for		Type	Program Elective
Prerequisite			

Objectives:
The instructor will
1. introduce contact and non-contact techniques for the inspection of components
2. provide brief understanding about concepts of computer aided quality control

Learning Outcomes:
The students are expected to
1. appreciate fundamentals of contact and non-contact inspection techniques along with quality control techniques for its implementation in various measurement applications

Contents
1. Contact Inspection Techniques: Fundamentals, Coordinate Measuring Machine, Programming of CMM, Compensation, DMIS file components, Computer Aided Inspection Planning, Automatic Feature and GD&T extraction, Integration of CAD and Inspection Planning (14 lectures)
2. Non-contact Inspection Techniques: Introduction to Machine Vision and its applications, Image Acquisition and Digitization techniques, Image Proessing and Analysis Techniques, Interpretation of the image data, Optical inspection methods – Comparators, Laser Scanners and Linear Arrays, Non-optical methods – Radiation Techniques, Ultrasonic methods (14 lectures)
3. Computer Aided Quality Control: Quality in Design and Manufacturing, Traditional vs Computer Aided Quality control, Process variability and capability, Statistical process control, Six Sigma and DMAIC, Taguchi Methods in Quality Engineering, International Standards (14 lectures)

Reference Books

1. Al-Ahmari A., Nasr E. A., and Abdulhameed O., (2016), Computer Aided Inspection Planning: Theory and Practice, CRC Press
2. Demant C., Streicher-Abel B., and Waszkewitz P., Industrial Image Processing – Visual Quality Control in Manufacturing, Springer
3. Montgomery D., (2005), Introduction to Statistical Quality Control, John Wiley

Title	**Welding: Metallurgy, Defects and Testing**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3-0-0-0 [3]
Offered for		Type	Program Elective
Prerequisite			

Objectives:

1. The aim of the course is to provide fundamental principles of metallurgy related with welding. Knowledge about the welding defects and their testing.

Learning Outcomes:

1. Understanding about welding Metallurgy
2. Imparting knowledge about the welding defects and factors responsible for it.
3. Role of diffusible hydrogen content and residual stresses on mechanical performance of the welded joint.
4. Knowledge about the non-destructive testing of welded joint.
5. Imparting knowledge about the heat treatment of the welded joint.

Contents:

1. Fundamentals of physical metallurgy: Need, phase diagrams: Fe-C, Al-Cu, Cu-Zn system, Phase transformations in Fe-C system, TTT diagram and CCT diagram, Carbon equivalent, Schaffer diagram, relevance of above in welding, delta ferrite formation (8 Lectures)
2. Effect of welding parameters on heat distribution, calculation of peak temperature, Residual stresses and shrinkage stresses, influence of stress in static and dynamic loading (6 Lectures)
3. Welding defects (Hot cracking, cold cracking, solidification cracking, nonmetallic inclusions; lamellar tearing; hydrogen damage) and non-destructive testing (Visual inspection, Liquid penetrant, Magnetic particle, Eddy current, X-ray, Radiographic, Ultrasonic testing) (10 Lectures)
4. Diffusible hydrogen content in deposited metal their measurement, Role of diffusible hydrogen on hydrogen induced cracking (2 Lectures)
5. Metal strengthen approaches: introduction, solid solution strengthening, grain refinement, precipitation hardening, transformation hardening, dispersion hardening, work hardening, strain aging (4 Lecture)
6. Heat treatment of weld joint: Need, Annealing; Normalizing; Quenching; Tempering; Austempering; Martempering and stress relieving of steel, Precipitation hardening of Al and copper alloys, Solidification of weld metal: principle of solidification of weld metal, modes of solidification, effect of welding parameter on weld structure, grain refinement principle of weld metal, method of weld metal refinement (10 Lecture)

Reference Books:

1. Lancaster J F., Metallurgy of Welding, Allen & Unwin
2. Avner S D, Introduction to physical metallurgy, TMH
3. ASM Handbook Vol. 6, Welding, Brazing and soldering, ASM International
4. Kou S., Welding metallurgy, 2nd edition, Wiley

Title	**Non-Conventional Welding Processes**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3-0-0-0 [3]
Offered for		Type	Program Elective
Prerequisite			

Objectives:

1. The aim of the course is to provide theoretical and practical details of various non-conventional welding/ joining processes and techniques including high energy density welding processes

Learning Outcomes:

1. Understanding about the non-conventional high-energy density welding processes and their application.
2. Imparting knowledge about solid-state welding processes and safety measurement.

Contents:

1. High Power Density Welding Processes: Electron Beam welding (EBW) their advantages, disvantages, and applications; Laser Welding: Principles, Significance of laser welding variables; Laser welding of various materials (8 Lectures)
2. Solid State Welding Processes : Friction welding, Ultrasonic welding, Explosive welding, Induction welding, Forge welding, and Diffusion welding (8 Lectures)
3. Special Topics: Soldering; brazing, Thermit welding, and braze welding (5 Lectures)
4. Cutting and Surfacing : Plasma and thermal cutting and surfacing operations; parameters; consumables; and equipment; arc and gas gouging (5 Lectures)
5. Resistance Welding: Principle of contact resistance; calculation of current, time and voltage for spot welding, choice of electrode material; electrode shapes; shunt current; shop tests for soundness of spot welds, seam, projection, butt and flash welding; selection of welding and other process details; stud welding; power sources for resistance welding (10 Lectures)
6. Safety measurement for the conventional and non-conventional welding process (4 Lectures)

Reference Books:

1. Welding Handbook Vol. 2 & 3, American Welding Society
2. Metals Handbook, Vol. 6, American Society of Metals

Title	**Welding Inspection and Quality Control**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3-0-0-0 [3]
Offered for		Type	Program Elective
Prerequisite			

Objectives:

1. To provide knowledge of dimensional inspection, destructive testing, NDT methods, WPS and PQR requirements and welder qualification standards

Learning Outcomes:

1. Provide basic knowledge about the welding terminology.
2. Imparting knowledge about the ASME and AWS standards used for mechanical testing of the welded joint.
3. Imparting knowledge about the welding defects and NDT of welded joints.

Contents:

1. Introduction: Types and purposes of weldment testing, important welding terms, symbols for welding and testing (4 Lectures)
2. Weld Related Discontinuities: Classification of discontinuities in weldment, occurrence, causes and prevention of discontinuities, location, orientation and extent of discontinuities, method for testing weld and base metal imperfections (8 Lectures)
3. Destructive Testing of Welds: Chemical tests, metallographic tests, hardness tests, mechanical test for groove and fillet welds-full section, reduced section and all-weld-metal tensile tests, root, face and side bend tests, fillet weld break tests, fillet weld shear strength test (8 Lectures)
4. Non-Destructive Testing (NDT) of Weldments: Visual inspection, dyepenetrant inspection, magnetic particle inspection; Ultrasonic inspection principle of ultrasonic testing, types of ultrasonic probes, standard blocks for calibration; Radiographic inspection – principle of radiography, X-ray tubes, gamma-ray sources, interpretation of radiographs, defect discernibility, neutron radiography; Eddy current inspection; Proof test, leak tests: NDT AWS (American Welding Society) standards, safety in NDT (15 lectures)
5. Inspection of Weldments: Duties and requirement of an inspector before, during and after welding, codes governing welding inspection, ASME (American Society of Mechanical Engineers) Code (5 Lectures)

Reference Books:

1. Welding Inspection, American Welding Society
2. Welding Hand Book, Vol. 5, American Welding Society
3. ASME Code Section IX , ASME

M Tech & M Tech - PhD Dual Degree

in

Thermofluids Engineering

Introduction:

Thermo-fluids is the combined study of heat transfer, fluid dynamics, thermodynamics, and combustion. Thermofluids program at IIT Jodhpur plans to engage in a wide range of research activities in the areas such as solar energy, clean water, thermodynamics and fluid dynamics, heat transfer and combustion, with a strong emphasis on the application of computational modeling and experimental methods. The thermal sciences area involves studies in energy conversion, the flow of liquids and gases, and the transfer of heat by means of conduction, convection and radiation. The flow and heat transfer are involved in devices and systems for energy conversion. The program involves a mix of fundamental courses followed by electives to specialize in the chosen area. Further, the project component ensures hands-on problem solving skills to enable solving of industrial problems as well as undertake research in the different areas of thermofluids. The potential employers of graduates from this program will be government and academia, automotive OEMs and ancillary manufacturers, energy sector, chemical and processing industries and others.

Objective of the Program:

To develop professionals through analytical and computational skills that enables individual to handle research and industrial problems in the domain of Thermofluids engineering

Expected Graduate Attributes:

1) Ability to undertake academic and industrial research in the areas of Thermal and Fluids Engineering like automobiles, thermal power, nuclear energy, gas turbines, solar energy, space science, defence, environmental engineering etc.
2) Ability to solve problems in design of thermal and fluid equipment/systems using analytical, experimental and computational techniques
3) Equipped to contribute to the multi-physics and interdisciplinary research interfacing with thermal and fluid systems
4) Ability to express ideas in the written and oral formats
5) Development of appreciation and commitment to professional ethics

Learning Outcomes:

At the end of program, a student is expected to have,

1) Strong fundamentals in incompressible/compressible fluid flow, thermodynamics and heat transfer
2) Analytical, computational and experimental skills to solve problems in multi-scale heat and fluid flow
3) Skills to design, develop and integrate systems/equipment involving heat and fluid flow
4) Competence to identify and analyze interdisciplinary systems/devices involving thermofluids
5) Expertise in one of the application areas e.g. solar thermal, combustion, heat exchanger design, HVAC systems, aerodynamics, thermal management of electronic systems, high speed flows etc.
6) Skills to communicate technical and scientific ideas in the domain of Thermal and Fluids Engineering

Proposed Course Structure:

Cat.	Course Number, Course Title	L-T-P-Th	Cr		Cat.	Course Number, Course Title	L-T-P-Th	Cr
I Semester					**II Semester**			
MC	MEL7XX0; Incompressible Fluid Flow	3-0-0-0	3		MC	MA: Numerical Methods in ODE	1-0-0-0	1
MC	MEL7XX0: Classical And Statistical Thermodynamics MEL7XX1: Multi Phase Systems and Chemical Reactions MEL7XX2: Kinetic Theory MEL7XX3: Statistical Thermodynamics	3-0-0-0	3		MC	MA: Numerical Methods for PDE	1-0-0-0	1
MC	MEL7XX0: Applied Heat and Mass Transfer	3-0-0-0	3		MC	MEP7XX0: Thermal Engineering Lab	0-0-2-0	1
MC	MEL7XX0: Experimental Techniques in Thermofluids	3-0-0-0	3		MP	Program Elective	3-0-0-0	3
MC	MA: Matrix Computations	1-0-0-0	1		MP	Program Elective	3-1-0-0	4
NH	HSN7XX0: Technical Communication	1-0-0-0	1		MP	Program Elective	3-0-2-0	4
MC	MEP7XX0: Fluid Engineering Lab	0-0-2-0	1		NH	OAL7XX0: Innovation andIP Management	1-0-0-0	1
		Total	**15**				**Total**	**15**
III Semester					**IV Semester**			
MP	MED8XX0: Project	0-0-0-5	5		MP	MED8XX0: Project	0-0-0-11	11
ME	Program Elective	3-0-0-0	3		MO	Open Elective	3-0-0-0	3
ME	Program Elective	3-0-0-0	3		NH	HSN7XX0: Professional Ethics	1-0-0-0	1
MO	Open Elective	3-0-0-0	3					
NH	OAN7XX0: Systems Engineering and Project Management	1-0-0-0	1					
		Total	**15**				**Total**	**15**
							Grand Total	**60**

Summary of Course categories for M. Tech (TFE) Programs:

S.N.	Course Type	Credits
1	Program Core (MC)	17
2	Program Elective (ME)	17
3	Open Electives (MO)	6
4	Project (MP)	16
5	Non-Graded Humanities (NH)	4
	Total	60

Course requirements:

Core Courses:

MEL7XX0:Applied Heat and Mass Transfer
MEL7XX0:Applied Thermodynamics
MEL7XX0:Experimental Techniques in Thermofluids
MEL7XX0:Incompressible Fluid Flow
MEL7XX0:Matrix Computations
MEL7XX0:Numerical Methods for ODE
MEL7XX0:Numerical methods for PDE
MEP7XX0:Fluid Engineering Lab
MEP7XX0:Thermal Engineering Lab

Elective Courses:

Program Electives:

MEL7XX0: Conduction and Radiation
MEL7XX0: Convective Heat and Mass Transfer
MELXXX0: Combustion Technology
MEL7XX0: Turbulent Flows
MEL7XX0: Jet and Rocket Propulsion
MEL7XX0: Computational Fluid Dynamics and Heat Transfer
MEL7XX0: Two Phase Flow and Heat Transfer
MEL7XX0: Design of Heat Exchange Equipment
MEL7XX0: Compressible Fluid Flows
MEL7XX0: Optical and Laser Based Measurements in Thermofluids
MEL7XX0: Fluid dynamics and Acoustics of Turbulent Jets
MEL7XX0: Heating, Ventilation and Air-Conditioning

General Electives:

MEL7XX0: Microfluidics Technology
MEL7XX0: Fluid Flow in Biological Processes
MEL7XX0: Nanosensors
MEL7XX0: Water Energy Nexus
MEL7XX0: Soil and Water Conservation Engineering
MEL7XX0: Probabilistic Methods in Engineering Design

Core Courses:

Title	**Incompressible Fluid Flow**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3-0-0-0 [3]
Offered for		Type	Program Core
Prerequisite			

Objectives

1. To provide a deeper and more thorough grounding in principles and basic applications of fluid mechanics to Mechanical Engineering students.
2. Enhanced understanding of fluid dynamics, including the equations of motion in differential and integral form.
3. Through exposure to the concepts of Boundary layer, turbulence etc.

Learning Outcomes

1. Ability to predict and solve engineering problems using conservation of mass and momentum.
2. Enhanced analytical ability in solving multi-scale fluid mechanics problems
3. For an application involving fluid mechanics, be able to utilize a commercial CFD software program in the problem solution.

Contents:

1. Introduction: definition of compressibility, incompressible and compressible flows (2 Lectures) Review on vector calculus and tensors (2 Lectures)
2. Fluid kinematics; stress-deformation relation (2 Lectures), stream function, potential function, vorticity and circulation (2 Lectures); Equations of fluid motion: Integral and differential approaches (1 Lecture), Euler equation for inviscid flows and Bernoulli's equation (2 Lectures), Navier-Stokes equations for viscous flows (2 Lectures); Exact solutions: Couette flow (2 Lecture), Hagen-Poiseuille flow (1 Lecture), flow through circular pipes (2 Lectures)
3. Vorticity Dynamics: Kelvin's circulation theorem (2 Lectures), Vorticity transport equation (2 Lectures)
4. Irrotational flows: potential theory for elementary flows (3 Lectures), application of complex variables in Irrotational flows (2 Lectures)
5. Boundary layer theory: Von-Karman integral equation (2 Lectures), Blassius solution (1 Lecture), effect of pressure gradient, separation and control (1 Lecture)
6. Flow instability: concept of small-perturbations (1 Lecture), linearized stability of parallel viscous flows (2 Lectures), Orr-Sommerfeld equation (2 Lectures)
7. Introduction to turbulence: Reynolds averaged Navier-Stokes equation (1 Lecture), turbulent kinetic energy and dissipation (1 Lecture), fully developed turbulent flow through a pipe and channel, universal law of wall, effect of wall roughness (2 Lectures)
8. Introduction to compressible flows (3 Lectures)

Reference Books

1. Kundu P. K., Kohen I. M, and Dowling D. R (2014), Fluid Mechanics, Academic Press
2. White F. M. (2015), Fluid Mechanics, McGraw Hill
3. Karamchety K. (1980), Principles of Ideal-Fluid Aerodynamics, Krieger

Self-Learning Material

1. http://web.mit.edu/hml/ncfmf.html

Title	**Classical and Statistical Thermodynamics**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3-0-0-0 [3]
Offered for		Type	Program Core
Prerequisite			

Objectives

1. To enhance the understanding of thermodynamics principles and their relevance to the problems of humankind; provide the student with experience in applying thermodynamic principles to predict physical phenomena and to solve engineering problems.
2. Providing exposure to the fundamental of statistical thermodynamics and enhance the familiarity of the students with immerging statistical methods like Lattice-Boltzmann method, Molecular dynamics simulation to solve relevant engineering problems.

Learning Outcomes

1. Ability to solve engineering problems using energy and exergy based thermodynamics principles.
2. Ability to appreciate and use statistical tools for solving micro and meso-scale thermodynamic problems

Contents

1. **Multiphase Systems and Chemical Reactions** (fractal 1): **[MEL7XX1] [1-0-0]**
   Review of first and second law of thermodynamics, Maxwell relations, Joule-Thompson experiment, exergy analysis, Third law of thermodynamics (5 Lectures)
   Phase transition, types of equilibrium and stability, multi-component and multi-phase systems, equations of state (4 Lectures)
   chemical thermodynamics, combustion (5 Lectures)

2. **Kinetic Theory** (fractal 2): **[MEL7XX2] [1-0-0]**
   Kinetic theory of gases-introduction, basic assumption, molecular flux, equation of state for an ideal gas, collisions with a moving wall, principle of equipartition of energy, classical theory of specific heat capacity (8 lectures)
   Transport phenomena-intermolecular forces, The Van der Waals equation of state, collision cross section, mean free path (6 lectures)

3. **Statistical thermodynamics** (fractal 3): **[MEL7XX3] [1-0-0]**
   Introduction, energy states and energy levels, macro and micro-stares, thermodynamic probability (7 lectures)
   Distribution function, partition energy, statistical interpretation of entropy (7 Lectures)

Reference Books:

1. Van Wylen G. J., Sonntag R. E. and Borgnakke C. (1994), Fundamentals of Classical Thermodynamics, Wiley Eastern Limited
2. Wark, K. Advanced Thermodynamics for Engineers, Mc-Graw Hill
3. Sears F. W. and Salinger G. L. (1998), Thermodynamics, Kinetic Theory And Statistical Thermodynamics, Narosa Publishing House
4. Moran M. J., Shapiro H. N., Boettner D. D. and Bailey M. B., Fundamentals of Engineering Thermodynamics, John Wiley
5. Huang, K. Statistical Mechanics, Wiley

Title	**Applied Heat and Mass Transfer**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3-0-0-0 [3]
Offered for		Type	Program Core
Prerequisite			

Objectives

1. To learn the concepts and design methodologies involved in various types of heat and mass transfer applications
2. To apply the concept of heat and mass transfer to design the system

Learning Outcomes

1. Interpret solutions to heat and mass transfer problems.
2. Ability to analyze and select the heat and mass transfer devices.
3. Design the system related to heat and mass transfer application.

Contents

1. Generalities and fundamentals: Heat transfer by conduction, convection and radiation (4 Lectures)
2. Heat Conduction: basic law, governing equations in differential form, solution methods, steady state, unsteady state problems-fins, moving boundaries. (6 Lectures)
3. Convective heat transfer - conservation equations, boundary layer approximations, Forced convective laminar and turbulent flow solutions, Natural convection solutions, correlations. (6 Lectures)
4. Boiling and Condensation: Basic definitions, Inception of Boiling in channel Flow, boiling map, Flow models, prediction of friction factor during flow boiling, Prediction of Heat transfer, Nusselt's theory of film condensation, condensation on tubes and tubes banks, In-tube condensation, drop wise condensation. (7 Lectures)
5. Heat Exchanger Design: Design of Tube-in-Tube Parallel and Counter Flow Heat Exchanger, Design of Shell and Tube Heat Exchanger, Introduction to Compact Heat Exchanger, Analysis of Compact heat exchanger. (5 Lectures)
6. Heat Transfer Enhancement: Modes of enhancement, Different methods of Enhancement, Introduction to different passive methods of heat transfer enhancement, Mechanism of heat transfer through surface enhancement, Mechanism of heat transfer through inserts, Introduction to different active methods of heat transfer enhancement. (6 Lectures)
7. Radiation heat transfer: mechanism, properties, exchange between black and nonblack surfaces. (4 Lectures)
8. Mass Transfer- governing laws, Mass transfer coefficients, applications. (4 Lectures)

Reference Books:

1. Ganapathy V. (1982), Applied heat transfer, PennWell Publishing
2. Eckerst E.R.G. and Drake R.M. (1972), Analysis of Heat Transfer, McGraw-Hill
3. Faghri A., Zhang Y. and Howell J. (2010), Advanced Heat and Mass Transfer, Global Digital Press

Self-Learning Material

1. https://nptel.ac.in/downloads/103105052/

Title	**Experimental Techniques for Thermo-fluids**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3-0-0-0 [3]
Offered for		Type	Program Core
Prerequisite			

Objectives

The Instructor will:

1. Provide understanding about measurements in thermal processes related to mass and heat transfer in optical/cryogenic/high temperature/plasma/transient environments with acceptable precision.
2. Enable digital and manual experimental data collection in simple as well as extreme thermal conditions with efficacy.

Learning Outcomes

The students are expected to have the ability to:

1. Work on measurement of thermal parameters in area of high temperature, low temperature, multi-phase fluid and distinct flow regimes.
2. Collect data with accuracy and precision, digitize measurements, simulate and analyze all the three types of errors in data collection.

Contents

Sensors and data analysis: Accuracy, Precision, Sensitivity, Calibration (3 lectures), Temporal response of probes & transducers (2 lectures), Measurement system model, zeroth, first, and second order systems (2 lectures), Probes and transducers (2 lectures), Errors and Error Distribution (2 lectures), Regression Analysis (1 lectures); Design of experiments (3 lectures), Time series analysis: time domain and frequency domain (2 lectures), Response to transient and periodic signals (1 lectures), Fourier series and Fast Fourier Transform (FFT) (2 lectures), Cross-Correlation and Auto Correlation (1 lectures).

Measurement Techniques in Thermo-Fluids: Thermal Measurement Techniques: Thermocouple thermometry, resistance thermometry, thin film sensors, Heat flux measurement (5 lectures); Pressure Measurement: U-Tube manometer, pitot probes, piezo electric and piezo resistive sensors, pressure sensitive paints, strain gauges (5 lectures); Force and Moment Measurement: load cells, accelerometers (2 lectures); Velocity Measurement: Hotwire anemometer, Laser Doppler Velocimetry (LDV), Particle image velocimetry (PIV) (3 lectures); Mass and volume flow measurement: Venturimeter, Rotameter, Coriolis mass flow meter (3 lectures); Data acquisition systems: Analog to digital converter, resolution, noise, signal conditioning (3 lectures).

Reference Books:

1. Holman, J. P., (2007), *Experimental Methods for Engineers*, 7th Edition, McGraw Hill.
2. Eckert, E. R. G., and Goldstein, R. J., (1970), *Measurement techniques in heat transfer,* Technical Press.
3. Doebelin, E. O., (2004), *Measurement Systems: Application and Design*, 5th Edition, McGraw Hill.

Self Learning Material

1. https://nptel.ac.in/courses/112106138/12
2. https://nptel.ac.in/courses/112104039/home

Title	**Fluid Engineering Laboratory**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	0–0–2-0 [1]
Offered for		Type	Program Core
Prerequisite			

Objectives

The course will:

1. Equip students with a variety of experimental skills in fluid mechanics
2. Provide knowledge to investigate numerically common fluid engineering problems

Learning Outcomes

The students are expected to have the ability to:

1. Use some experimental methods in Fluid Engineering
2. Solve problems related to the fluid flow through spreadsheet/MATLAB/Programming

Contents

Experimental techniques

1. Pressure drop in fluid flow system (2 Lab Session)
2. Drag and lift measurement of aerofoil (2 Lab Session)
3. Velocity and turbulence measurement using Hot wire anemometer (2 Lab Session)
4. Droplet size measurement using PDPA (2 Lab Session)

Computational Techniques:

1. Incompressible flow in a nozzle (2 Lab Session)
2. Fully developed laminar flow between parallel plates (2 Lab Session)
3. Power law profile for turbulent pipe flow (2 Lab Session)
4. Aerodynamic drag reduction (2 Lab Session)

Reference Books:

1. Fox R.W, McDonald A. T., Pritchard P. J., and Mitchell J. W., Introduction to Fluid Mechanics, John Wiley
2. Rathakrishnan E., Instrumentation, Measurements, and Experiments in Fluids

Self Learning Material : NACA videos on youtube

Title	**Thermal Engineering Lab**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	0-0-2-0 [1]
Offered for		Type	Program Core
Prerequisite			

Objectives

1. To provide hands on experience of experiments associated with applications of Thermodynamics and Heat Transfer
2. To inculcate understanding of the basic principles and concepts through experiments
3. To make the students familiar with the sensors, devise, software, and measurement techniques associated with Thermal Engineering Applications.

Learning Outcomes

1. Familiarity with measurement techniques, measurement errors, experimental repeatability and reproducibility
2. Relating theoretical knowledge with experimental measurements
3. Capability to appreciate empirical relations obtained from combining theoretical and experimental knowledge

Contents

1. Measurement of convective heat transfer coefficient during free convection over vertical flat surface and tube banks (2 Lab Session)
2. Heat exchanger performance characterization (4 lab sessions)
3. Performance characterization of Vapor compression refrigeration system (VCRS) and Vapor absorption refrigeration system (VARS) (4 lab sessions)
4. Performance Characterization of HVAC system (2 lab session)
5. CFD simulation of pure diffusion, forced and free convection (4 lab session)

Reference Books:

1. Beckwith T. G., Marangoni R. D., Lienhard J. H. V, Mechanical Measurements, Pearson
2. Patankar S. V., Numerical Heat Transfer and Fluid Flow
3. Kuo K.K., Principles of Combustion, Taylor & Francis

Program Electives:

Title	**Conduction and Radiation**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3-1-0-0 [4]
Offered for		Type	Program Elective
Prerequisite			

Objectives:

1. To provide a deeper and more thorough analytical background for 1-D, 2-D, 3-D steady and transient multi-scale heat conduction problems relevant to multi-disciplinary engineering applications.
2. Exposure to the concepts of solving different classes of partial differential equations (PDE) associated with heat conduction problems analytically and numerically.
3. To provide a deeper and more thorough analytical background for radiation heat transfer associated with opaque surfaces and participating media.

Learning Outcomes:

1. Enhanced analytical ability to solve PDEs associated with multidimensional conduction problems.
2. Ability to Identify types of boundary conditions.
3. Ability to produce codes to solve different classes of conduction problems and familiarity with analytical and empirical radiation models used in CFD tools.

Contents:

Conduction:

1. Recapitulation, 3-D conduction, isotropic, orthotropic and anisotropic solids, Mathematical formulation, analytical solutions, variation of parameters (8 Lectures)
2. integral method, periodic boundary conditions, Duhamel's theorem and Green's function, Stationary and moving heat sources and sinks, Moving boundary problems (8 Lectures)
3. Inverse heat conduction problems, Micro-scale heat transfer, Bio-heat transfer, Combined mode heat transfer, integro-differential equations, introduction to Monte Carlo technique (9 Lectures)

Radiation:

1. Recapitulation, Radiative properties of opaque surfaces, Configuration factors, (6 Lectures)
2. Enclosure analysis for diffuse-gray surfaces and non-diffuse non-gray surfaces, Radiation in absorbing, emitting and scattering media (6 Lectures)
3. Engineering treatment of gas radiation in enclosures, Radiation measurements (5 Lectures)

Reference Books:

1. Ã–zisik, Necati M., Necati Özısık M., and NecatiÖzışık, M., Heat conduction, John Wiley & Sons.
2. Howell, J. R., Menguc M. P., and Robert Siegel. Thermal radiation heat transfer. CRC press.

Title	**Convective Heat and Mass Transfer**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3-1-0-0 [4]
Offered for		Type	Program Elective
Prerequisite			

Objectives

1. To provide a deeper and more thorough analytical and numerical background for coupled heat and fluid flow problems relevant to multi-disciplinary engineering applications.
2. Exposure to the concept of thermal and hydrodynamic boundary layers and their interactions.
3. Exposure to solution techniques of solving system of coupled non-linier PDEs using analytical and numerical methods.

Learning Outcomes

1. Enhanced analytical and numerical ability to solve system of coupled non-linear PDEs associated with multidimensional convection problems.
2. Ability to Identify types of boundary conditions and coupling constraints.
3. Ability to produce codes to solve different classes of coupled heat and fluid flow problems.

Contents

1. Conservation equations for mass, momentum, energy and species. Boundary layer flows, similarity parameters, dimensionless numbers. (10 Lectures)
2. External laminar flow heat transfer. Internal laminar flow heat transfer, entrance region. (10 Lectures)
3. Turbulent flow heat transfer, turbulent Prandtl number, external and internal flows. (6 Lectures)
4. Natural convection in external and bounded flows. Rayleigh Benard Convection (6 Lectures)
5. Mixed convection. Boiling–pool boiling and forced convection boiling in tubes. Condensation over a plate, tube and tube banks. Mass transfer. Applications to engineering problems. (10 Lectures)

Reference Books:

1. Bejan, A., Convection heat transfer. John Wiley
2. Kakaç, S., Shah R. K., and Aung, W. Handbook of single-phase convective heat transfer
3. Kays, W. M., Convective heat and mass transfer, Tata McGraw-Hill

Title	**Combustion Technology**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3-0-0-0 [3]
Offered for		Type	Program Elective
Prerequisite			

Objectives

1. To introduce energy and combustion fundamentals for analyzing modern combustion systems
2. To develop understanding of the basic principles and concepts of advanced fuel combustion and control process
3. To be familiar with the fundamental physical and chemical principles regarding formation and control of air pollutants in industrial and technological processes.

Learning Outcomes

1. Understanding of thermodynamics and kinetics of combustion
2. Apply mathematical equations and solve the problems that are related to combustion

Contents

Importance of combustion, Combustion phenomena in gas turbines, IC engines and power plants; Review of thermodynamics, Chemical kinetics, Mass transfer definitions: Fick's law. Equations of conservation of species mass, momentum, and energy; multi-component diffusion equation, Schvab-Zel'dovich formulation, Rankine-Hugoniot relations (14 lectures)

Laminar premixed flames: Flame speed, adiabatic flame temperature, flammability limits, flame stabilization, ignition and quenching; Laminar diffusion flames: Burke-Schumann problem and droplet burning; Partially premixed flames (14 lectures)

Introduction to turbulent flames: premixed and diffusion flames; Detonations and Combustion instabilities (7 lectures)

Combustion of solids: solid propellant, drying, devolatilization and char combustion
Spray combustion (4 lectures)

Chemical Emission from combustion, Quantification of emission, Emission control methods, Introduction to combustion modeling (3 lectures)

Reference Books

1. Turns, S. R., An Introduction to Combustion: Concepts and Applications, McGraw-Hill
2. Mishra D. P., Fundamentals of Combustion, Prentice Hall of India, New Delhi
3. Kuo K.K., Principles of Combustion, John Wiley and Sons

Self-Learning Material

1. https://nptel.ac.in/syllabus/101106037/

Title	**Turbulent Flows**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3-0-0-0 [3]
Offered for		Type	Program Elective
Prerequisite			

Objectives

1. Introduce the basic properties of turbulence
2. Expose the students to theoretical and numerical techniques to describe and quantify the effects of turbulence

Learning Outcomes

1. Understand the underlying flow physics of turbulent flows and make a trade-off between different applicable models
2. Carry out effectively CFD simulation of an unsteady turbulent flow

Contents

Introduction to turbulence. Fundamental equations of turbulent flow. Statistical description of turbulence. Reynolds equations. (8 lectures)

Kolmogorov's theory, Scales of turbulence. Homogeneous or isotropic turbulence. Energy transfer, Spectral description (12 lectures)

Turbulent free-shear flows. Bounded flows. Boundary layers (6 lectures)

Simulating turbulent flows. Reynolds Averaged Navier-Stokes approach Introduction to Large Eddy Simulations and Direct Numerical Simulation. (10 lectures)

Application of AI in Turbulence modeling(4 lectures)

Reference Books

1. Pope, S. A., Turbulence, Cambridge
2. Davidson P. A., Turbulent Flows, Oxford
3. Durbin P. A., Reif B. A., Statistical Theory and Modeling for Turbulent Flows, John Wiley

Self-Learning Material

1. https://ocw.mit.edu/courses/mechanical-engineering/2-27-turbulent-flow-and-transport-spring-2002/

Title	**Jet and Rocket Propulsion**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3-0-0-0 [3]
Offered for		Type	Program Elective
Prerequisite			

Objectives
1. Familiarity with common types of aircraft and spacecraft propulsion systems
2. Preliminary cycle design and performance analysis of propulsion systems for both aircraft and spacecraft.
3. Use of thermodynamic cycle analysis, including the thermodynamic treatment of chemically reacting systems.

Learning Outcomes
1. Calculate energy release, e.g., adiabatic flame temperatures, and equilibrium composition of gases at known temperature and pressure
2. Analyze the thermodynamic performance of jet engine cycles and rocket cycles along with computation of relevant performance parameters
3. Career in the design, development, operation and maintenance of propulsion systems.

Contents

Air breathing and non-air breathing engines Thermodynamics Review, Equilibrium Chemical Thermodynamics, Thermodynamic Cycle Analysis, One-Dimensional Flow (8 lectures)

Air breathing Propulsion Systems: Engine Performance Parameters, Jet Engine Cycle Analysis and Performance; Cycle Design Optimization, Turbojet, Analysis, Design and Performance of Turbine Engine Components - intake, nozzle, combustor, turbomachinery (12 lectures)

Rocket Propulsion Systems: Overview, Performance Parameters, Chemical Rockets cycle analysis, Types of propellants and their properties, injectors, thrust chamber, burning rate, cryogenic propellant, combustion phenomena, thrust vector control, ignition and inhibitors, basics of Electrical and Nuclear propulsion. (10 lectures)

Ram Jet & Scramjet Engines Operating principle – sub critical, critical and supercritical operation. Combustion in ramjet engine, Ramjet performance. Turbo-ramjet engines. Introduction to scramjet, preliminary concepts in supersonic combustion, various types of supersonic combustors, integral ram rocket. Pulse jet engines- Construction details. Principles & operation. (12 lectures)

Reference Books

1. Hill, P. G., and Peterson C. R., Mechanics and Thermodynamics of Propulsion, Addison Wesley
2. Sutton, G. P. and Biblarz O., Rocket Propulsion Elements, John Wiley & Sons
3. Cumpsty N. A., Jet Propulsion, Cambridge University Press

Self-Learning Material
1. https://nptel.ac.in/courses/101104019/30#

Title	**Computational Fluid Dynamics and Heat Transfer**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3-1-0-0 [4]
Offered for			
Prerequisite			

Objectives

1. To provide a deeper and more thorough grounding in principles and basic applications of computational fluid mechanics
2. To provide basic knowledge of CFD to enable function competently in both an industrial setting and in further graduate studies involving CFD and its applications.

Learning Outcomes

1. Describe the major theories, approaches and methodologies used in CFD
2. Apply CFD methods in commercial CFD codes and describe the limitations on accuracy
3. Apply CFD analysis to real engineering designs

Contents

Introduction to Computational Fluid Dynamics, Review of governing equations for heat transfer and fluid flow; Classification of Partial Differential Equations and Physical Behaviour (6 lectures)

Finite Difference Method for heat transfer problems, Steady state heat conduction with heat source, Convective- diffusive system – Upwind scheme, Transient heat conduction – explicit, implicit and Crank – Nicolson methods, Handling variable thermo-physical properties, Finite Difference Method for fluid flow problems (10 lectures)

Stream function – vorticity based formulation,Finite Volume Method, Formulation, calculation of fluxes at faces of control volume, Source term linearization Discretization for convective terms – upwind, power law, QUICK schemes, staggered grid and solution of incompressible fluid flow, SIMPLE algorithm and extensions to SIMPLER, SIMPLEC and PISO , Introduction to Turbulence Modeling (14 lectures)

Handling various boundary conditions, External and internal flow simulations, Review of the solution procedure of system of linear equations (8 lectures)

Numerical methods for radiation–enclosures with gray gas, Hottel zone method.
Combined convection and radiation. Applications of Monte-Carlo method (4 lectures)

Reference Books:

1. Patankar, S. Numerical heat transfer and fluid flow. CRC press, 1980.
2. Versteeg, H. K., and Malalasekera, W. Computational fluid dynamics- The finite volume method
3. Ferziger, J H., and Peric, M., Computational methods for fluid dynamics. Springer

Self-Learning Material

1. https://nptel.ac.in/courses/112105045/

Title	**Two Phase Flow and Heat Transfer**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3-1-0-0 [4]
Offered for		Type	Program Elective
Prerequisite			

Objectives

1. To learn the concepts and design methodologies involved in various types of thermal energy conversion devices.
2. To gain a deeper understanding of fluid-dynamic mechanisms associated with phase change processes.

Learning Outcomes

1. Learn methods of analysis of two phase flows with and without phase change
2. Develop analytical tools for design and performance assessment of two-phase devices.
3. Design codes for solving two-phase heat transfer problems.

Contents

1. Definitions and basic concept - Review of 1-D conservation equations in single-phase flows, Mass flux, heat flux, mass quality, void fraction, liquid holdup, etc. (3 Lectures)
2. Various two-phase flow models - Governing equations for homogeneous, separated flow models and drift-flux models. (5 Lectures)
3. Flow pattern maps for horizontal and vertical systems - Bubbly, Slug, Annular and Stratified Flow, Measurement of Void Fraction, Measurement of Two-phase pressure drop, Lockhart-Martinelli Correlation, Simplified treatment of stratified, bubbly, slug and annular flows. (7 Lectures)
4. Thermodynamics of boiling, Nucleation at a single site, Hsu's model and concept of waiting period. (6 Lectures)
5. Pool boiling - Modes of pool boiling, inception of boiling, correlations for heat transfer coefficients, mechanisms of critical heat flux, prediction methods for critical heat flux,effect of sub-cooling. (7 Lectures)
6. Flow boiling - onset of nucleation in channel flow, Hysteresis effect, Flow Boiling Map, Subcooled flow boiling, Saturated flow boiling, Nucleate boiling, convective boiling, correlation for two-phase pressure drop inside tube flow, correlations for heat transfer coefficients. (7 Lectures)
7. Critical heat flux - Introduction, Types of Boiling Crisis and Mechanisms, Prediction of Critical Heat Flux, CHF Table, Correlation to predict dryout, Critical heat flux in horizontal and vertical systems. (7 Lectures)

Reference Books:

1. Whalley P.B., Two-Phase flow and Heat Transfer, Oxford University Press
2. Tong L. S. and Tang Y. S., Boiling Heat Transfer and Two-Phase Flow, Taylor and Francis
3. Collier J. B. and Thome J. R., Convective Boiling and Condensation, Oxford Science Publications

Self-Learning Material

1. https://nptel.ac.in/courses/103105058/1
2. https://nptel.ac.in/courses/112107207/

Title	**Design of Heat Exchange Equipment**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3-1-0-0 [4]
Offered for		Type	Program Elective
Prerequisite			

Objectives

1. To learn the concepts and design methodologies involved in various types of Heat exchange devices.
2. To gain a deeper understanding and design process associated with heat exchangers.

Learning Outcomes

1. Learn methods of heat transfer in heat exchange system
2. Develop ability to design and performance assessment of heat exchanger devices.
3. Develop codes for designing heat transfer systems.

Contents

Construction Details and Heat Transfer Analysis:

1. Types of Heat exchange equipment use in industries, General design consideration of heat exchangers, Double pipe heat exchanger, Shell and Tube Heat Exchangers, Regenerators and Recuperators, Industrial applications. (7 Lectures)
2. Temperature distribution and its implications, LMTD, Effectiveness. (4 Lectures)
3. Flow Distribution and Stress Analysis, Effect of Turbulence, Friction factor, Pressure loss, Channel divergence, Thermal Stress in tubes, Types of failures. (7 Lectures)

Design Aspects:

1. Calculation of Heat Transfer and pressure loss, Flow Configuration, Effect of Baffles, effect of Deviations from ideality, Design of Typical liquid, Gas-Gas-Liquid Heat Exchangers, Plate Heat Exchangers. (8 Lectures)
2. Condensers and Evaporators Design: Design of Surface and Evaporative Condensers, Design of Shell and Tube, Plate type evaporators. (6 Lectures)
3. Design aspect of Horizontal and Vertical Heat Exchange systems with phase change. (6 Lectures)
4. Cooling Towers Packings, Spray design, Selection of pumps, Fans and Pipes, Testing and Maintenance, Experimental Methods (6 Lectures)

Reference Books:

1. Hewuttm G. F., Shires G. L. and Bott T. R., Process Heat Transfer, CRC Press
2. Shah R. K., and Sekulic D. P., Fundamentals of Heat Exchanger Design, John Wiley
3. Smith E. M, Advances in Thermal Design of Heat Exchangers, John Wiley

Self-Learning Material

1. https://nptel.ac.in/syllabus/103106102/

Title	**Compressible Fluid Flows**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3-0-0-0 [3]
Offered for		Type	Program Elective
Prerequisite			

Objectives

1. to bring an in-depth understanding on the theory of compressible fluid flows, especially supersonic flows.
2. introduce shock waves in supersonic flows and its reflection, blast waves and various experimental techniques for high speed flow visualization.

Learning Outcomes

The students are expected to have the ability to:

1. Predict and solve fluid dynamics of engineering applications involving supersonic flows such as, flow over supersonic vehicles, nozzle flows, rocket plumes etc.
2. Predict flow properties across shock waves and to take up research in high speed flows and shock wave dynamics.
3. Conduct various high speed flow measurement experiments.

Contents

Review of thermodynamics; Governing equations for fluid flow (3 lectures); Introduction to compressible flows: sonic velocity and Mach number, wave propagation (3 lectures); Isentropic flows: static and stagnation condition, isentropic flows with area change, nozzle operation (4 lectures); Steady adiabatic compressible flows: normal shock, Rankine-Hugoniot equations, oblique shock; Prandtl-Meyer expansion flows (6 lectures); Adiabatic flow with area change: normal shock in c-d nozzles, oblique shocks in over expanded and under expanded nozzle flows, supersonic wind tunnel (6 lectures); Shock reflections: reasons for reflection, Regular and Mach reflections (3 lectures); Analytical approach for regular and Mach reflection: two shock and three shock theory, shock polar (5 lectures); Transition criteria: von-Neumann and detachment criteria (2 lectures); Compressible flow with friction: Fanno Flow (3 lectures); Compressible flow with heat transfer: Rayleigh flow (2 lectures); Unsteady compressible flows: 1-D wave motion: simple and finite waves, Riemann invariants, wave propagation in shock tube, blast waves; Method of characteristics (MOC) (3 lectures); Measurements in compressible flows: Schlieren and shadowgraph. (2 lectures)

Laboratory Experiments

1. Mach number prediction in supersonic flow using Pitot tube pressure measurement.
2. Prediction of choking point and mass flux variation in convergent nozzle with change in back pressure.
3. Evaluating convergent-divergent (c-d) nozzle flow pressure curve and finding critical pressure ratios.
4. Prediction of normal shock location in c-d nozzle for various pressure ratios.
5. Schlieren and Shadowgraph optical flow visualization techniques for shock wave visualization.
6. Shock diamonds in over and underexpanded nozzle jets and flow property evaluation across the first shock diamond.
7. Transition criteria for regular reflection to Mach reflection in wedge induced shock reflections.
8. Mach number prediction of moving shock in shock tubes using pressure measurements.

Reference Books:

1. Zucker R. D. and Biblarz O., Fundamentals of Gas Dynamics, Wiley
2. John J. E. A. and Keith T., Gas Dynamics, Prentice Hall
3. Anderson J. D., Modern Compressible Flow: With Historical Perspective, McGraw-Hill

Title	**Optical & Laser based Measurements in**	Number	MEL7XX0

	Thermo-Fluids		
Department	Mechanical Engineering	L-T-P-Th [C]	3-0-0-0 [3]
Offered for		Type	Program Elective
Prerequisite			

Objectives

1. To introduce students with various non-intrusive measurement tools using laser and optical methods.
2. To introduce students with various image processing techniques for thermo-fluidic measurements.

Learning Outcomes

1. Theoretical knowledge on conducting various laser and optical based experimental measurements.
2. Knowledge to use advanced measurement tools for combustion, spray and supersonic flow research.

Contents

Introduction to optics and high speed imaging; Flow visualization using light scattering and refraction: Mie scattering, Rayleigh scattering, Shadowgraph and Schlieren; Thermal imaging: I-R cameras; Image processing for thermo-fluids measurements: Background subtraction, Filtering, Flat Field Correction, Edge detection, Modal decomposition using Proper Orthogonal Decomposition (POD) and Dynamic Mode Decomposition (DMD). (14 Lectures)

Introduction to Lasers, Nonintrusive diagnostic techniques, Application areas and relevance; Measurement of concentration and gaseous flow mixing: Acetone Laser Induced Fluorescence (LIF); Measurement of Combustion species: LIF (OH, CH PLIF); Measurement of planar temperature: 2 Line Planar Laser Induced Fluorescence (PLIF), Coherent anti-Stokes Raman Spectroscopy (CARS) ; (14 Lectures)

Soot measurement: LII (laser induced incandescence); Spray measurements: direct laser sheet imaging, Phase Doppler Particle Analyzer (PDPA); Liquid LIF: spray characteristics, quantification of liquid film thickness impingement, jet break up characteristics; Flow Velocity and Turbulence: Laser Doppler Velocimetry (LDV), Particle Image Velocimetry (PIV). (14 Lectures)

Reference Books:

1. Schulz, C., Dreizler, A., Wolfrum J., Combustion Diagnostics, Springer Handbook of Experimental Fluid Mechanics
2. Leipertz A., Pfadler S., and Schiebl R., An Overview of Combustion Diagnostics, Handbook of Combustion Vol.2: Combustion Diagnostics and Pollutants.

Self-Learning Material:

1. M. Alde´n, J. Bood, Z. Li, M. Richter, Visualization and understanding of combustion processes using spatially and temporally resolved laser diagnostic techniques, Proceedings of the Combustion Institute 33 (2011) 69–97
2. R. K. Hanson, Combustion Diagnostics: Planar Imaging Techniques, Twenty-first Symposium (International) on Combustion/The Combustion Institute, 1986/pp. 1677-1691.
3. Dantec Dynamics, https://www.dantecdynamics.com/all-measurement-principles.

Title	**Fluid dynamics and Acoustics of Turbulent Jets**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3-0-0-0 [3]
Offered for		Type	Program Elective
Prerequisite			

Objectives

1. to bring an in-depth understanding on the theory of turbulent jets and its acoustics.
2. introduces students with various measurement techniques for noise prediction in turbulent jets.

Learning Outcomes:

The students are expected to have the ability to:

1. Sound and noise prediction of wide variety of engineering applications involving jet flows.
2. Data analysis from time series measurements.
3. Conduct various acoustic measurement experiments.

Contents:

Introduction to turbulent free jets: Structure of subsonic and supersonic jets, plane and circular jets, jet spreading (3 lectures);
Governing equations for plane turbulent free jet: Integral equations for momentum, moment of momentum and energy, similarity analysis, entrainment principle, Tollmien solution, experimental measurements in plane jets (6 lectures);
Governing equations for circular turbulent free jet: Integral equations for momentum, moment of momentum and energy, similarity analysis, entrainment principle, Tollmien solution (6 lectures);
Plane turbulent shear layers: Similarity analysis, shear layer growth, mixing layers, stream wise and span wise vortices, jet axis switching, introduction to shear layer instabilities (5 lectures);
Introduction to acoustics: unsteady wave equation, acoustic speed (4 lectures);
Jet acoustics: Sound Pressure Level (SPL), Overall Sound Pressure Level (OSPL), near field and far/free filed, sound intensity and power, sound intensity level (SIL), scaling laws in free field (6 lectures);
Sources of sound: monopole, dipole, quadrupole (2 lectures);
Jet Noise: broad band noise and tonal noise, feedback loop and screech tone (3 lectures);
Acoustic measurements: Anechoic chamber, microphones, SPL measurements (3 lectures);
Time series analysis: Time and frequency domain, Fast Fourier Transform (FFT), auto correlation and cross correlation functions, power spectrum, Linear spectral analysis (4 lectures).

Reference Books:

1. Rajaratnan N., Turbulent Jets, Elsevier
2. Mueller T. J., Allen C. S., Blake W. K., Dougherty R. P., Lynch D., Soderman P. T., and Underbrink J. R., Aeroacoustic Measurements, Springer
3. Raman G., Jet Aero Acoustics, Multi-science Publishing

Title	**Heating, Ventilation and Air-Conditioning**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3-0-0-0 [3]
Offered for		Type	Program Elective
Prerequisite			

Objectives

The Instructor will:

1. Teach applications of Psychrometrics in industry, residential, automotive and building design.
2. Inculcate design of air conditioning systems keeping in building design codes in mind.

Learning Outcomes

The students are expected to have the ability to:

1. Design spaces with appropriate thermal comfort specific to the requirements of the utility of the space.
2. To incorporate processes and refrigerants such that it adheres to national standards for energy conservation and building code.

Contents

Standards and Design Process (Lecture 1-10)

Introduction, Historical development of heating, ventilation, and air-conditioning engineering (HVAC). The design process. Standards and norms psychrometry of air-conditioning processes. HVAC technologies. Thermal comfort - factors influencing thermal comfort. Simulations can be performed for Cooling and Heating load calculations. Software such EQuest, Design Builder, HAP, Trace and Smart Energy.

Ventilation Aspects (Lecture 10-26)

Room air distribution principles. Design of air duct systems. System solutions for renewable energy production and heat storage; for ventilation and tempering of rooms; for domestic water supply, sewerage and preparation of domestic hot water. Selection of Refrigerants according to requirements and latest climate protocol standards; Sizing of systems for renewable energy production and heat storage; space heating and cooling. Natural ventilation, principles of air supply and tempering of rooms. Methods for selecting and sizing the supply air terminals. Sizing of hydronic heating systems.

Selection of components for air conditioning (Lecture 26-34)

Study on filters, dampers, fans, ducts, pumps, valves, piping, heat exchangers, sensors and control components Indoor air quality, Ventilation - need, principles. Various types of air conditioning systems. Cooling, dehumidification and humidification equipment. Temperature, pressure and humidity controllers. Various types of controls and control strategies for food preservation, storage and other industrial aspects.

Environment Design and Green Building Norms (Lecture 35-42)

Climatic factors, classification of tropical climates, site climate, microclimate of human settlements, ventilation requirements for health, solar tracking and building design, mechanisms and estimation of natural ventilation, airflow patterns in building. Thermal comfort factors, comfort indices, thermal quantities, heat exchange in buildings, periodic heat flow.

Mechanical and structural means of thermal control. Moisture control in buildings, Monitoring and control of air conditioning plants, building automation. Use of dynamic simulation program for the design and evaluation. Measures to meet LEED, BEE and GRIHA standards.

Reference Books:

1. Ameen A., Refrigeration and Air Conditioning, PHI, Learning
2. Stocker W. F. and Jones J. W., Refrigeration & Air conditioning, TMH
3. Ananthanarayanan P. N.,Basic Refrigeration and Air Conditioning, Tata McGraw-Hill

Self Learning Material :

1. https://www.asme.org/learning-development/find-course/heating-ventilation-air-conditioning
2. https://www.eit.edu.au/cms/courses/mechanical-engineering/professional-certificate/in-heating-ventilation-and-air-conditioning-hvac

Open Electives:

Title	**Fluid Flow in Biological Processes**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3-0-0-0 [3]
Offered for		Type	Open Elective
Prerequisite			

Objectives

The Instructor will:

1. Teach topics on the fundamentals of biological flows
2. Provide knowledge required to analyse and model biological flows

Learning Outcomes

The students are expected to have the ability to:

1. Explain the fundamentals of flows in biological processes.
2. Demonstrate knowledge of solving problems related to the fluid transport phenomena in the biological processes

Contents

Basics of biological flows (12 lectures)
Introduction to the course, Complexity of fluid properties,Fluid drag, Coefficient of viscosity Newton's law of viscosity, Molecular basis for viscosity,Fluid rheology, Navier-Stokes equation, Viscous-dominated flows, internal flows, Porous media, poroelasticity, Cellular fluid mechanics, Blood flow

Biological transport:(14 lectures)

Diffusional flux, Fourier, Fick and Newton,Steady-state diffusion,Concentration gradients,Unsteady diffusion equation, Convection-diffusion equation,Convection-diffusion equation, Relative importance of convection and diffusion,The Peclet number, Solute/solvent transport, Solving the convection-diffusion equation in flow channels

Fluid flow in Biological Processes and their modeling: (16 lectures)
Flow Through a Permeable Tube, Respiratory Airflow,, Hemodynamics in the Developing Cardiovascular System, Blood Flow in Stented Coronary Arteries, Fluid structure interaction in arteries, flow in renal arteries

Reference Books:

1. Truskey, G. A., Yuan F., and Katz D. F., Transport Phenomena in Biological Systems, Prentice Hall
2. Bird, R. B., Lightfoot E. N., and Stewart W. E., Transport Phenomena, Wiley

Self-Learning Material

1. https://ocw.mit.edu/courses/biological-engineering/20-330j-fields-forces-and-flows-in-biological-systems-spring-2007/index.htm

Title	**Nanosensors**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3-0-0-0 [3]
Offered for	B. Tech, M. Tech and PhD	Type	Open Elective
Prerequisite			

Objectives

The Instructor will:

1. Provide understanding about importance of nanoscale materials for sensing applications.
2. Teach approaches for fabrication and characterizing of sensors based on nanomaterials.
3. Enhance critical, creative and innovative thinking to tailor nanomaterials for specific application.

Learning Outcomes

The students are expected to have the ability to:

1. Design and fabricate nanomaterial based sensors.
2. Undertake interdisciplinary research and exploit nanomaterials for new sensing applications.

Contents

Sensor types: Displacement, position and proximity sensors (3 lectures); velocity, motion, force and pressure sensors (4 lectures); components and classification of sensors (1 lecture); parameters for sensor characterization (1 lecture); sensor arrays (1 lecture).

Nanostructures and Nanoparticles: Nanostructures (1 lectures); nanostructure fabrication (top down and bottom up approach) (3 lectures); characterization of nanostructures using different techniques (Atomic Force Microscopy, Scanning Electron Microscopy, Tunneling Electron Microscopy) (3 lectures); nanoparticles (types and shapes) (1 lecture); nanoparticle production, shape control, functionalization and application (2 lectures); nanowires (properties, sensing mechanism, fabrication, and devices) (4 lectures); quantum dots (1 lecture).

Carbon nanotubes/nanofibres (CNT/CNF) and other Nanosensors: CNT structure, properties, synthesis, functionalization (3 lectures); CNT/CNF based sensors (single layer/multi-layer) (2 lectures); nanostructure, nanoparticles, nanowire and nanofibre based metal oxide sensors (3 lectures); flexible sensors and electronic skin (2 lectures); Nanosensors in engineering applications: optical, chemical, mechanical, electrochemical, mass sensitive, biosensors, mechanical sensors in liquid solution, thin film sensors (7 lectures).

Reference Books:

1. Khanna, V. K., (2011), Nanosensors: Physical, Chemical, and Biological, CRC Press.
2. Atta, N. F., (2014), Nanosensors: Materials and Technologies. IFSA Publishing.
3. Meyyappan, M., (2004), Carbon Nanotubes: Science and Applications, 1st Edition, CRC Press.

Self Learning Material

1. https://nptel.ac.in/courses/112108092
2. https://www.coursera.org/learn/nanotechnology/home

Title	**Water Energy Nexus**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3-0-0-0 [3]
Offered for		Type	Open Elective
Prerequisite			

Objectives

1. to understand relation of energy of water use in our daily lives as well as water use for energy and food production
2. to enable plan pathways of water life cycle according the end-use requirements in municipal/ agriculture/ industrial environments

Learning Outcomes

1. Ability to design energy/cost optimized systems according to location specific end-use requirements and water availability
2. To have capability to locate correct locations where energy intensity as well as water efficiency measurements of the water transport within systems can be performed

Contents

1. Introduction to energy-water nexus: Hydro-electric power production, Water Life Cycle in the different economic sectors (4 Lectures)
2. Energy intensity (Joule/Litre etc.) definition, Equivalent electrical energy intensity [kWh/m3], Basic unit conversion, factors of energy conversion from thermal to electrical and vice versa (6 Lectures)
3. Water extraction from ground as well as surface. Pumping efficiency, effect of lift and other influencing parameters, Different modes of surface water transfer. (5 Lectures)
4. General overview of conventional water treatment energy use, Intro to thermal desalination, Membrane desalination systems, hybrid desalination systems .Renewable and non-renewable sources of energy and its influence of energy intensity (6 Lectures)
5. Discussion on water end-use based electrical and thermal energy consumption. Electricity consumption in Residential water use: Clothes Washing, doing dishes, heating water, cooking water based foods. Commercial buildings and Energy use; Do buildings consume energy or the people within, Human behavior and variation in energy consumption. (8 Lectures)
6. Waste water recycling: review, of equivalent electrical energy intensity and operation of waste water treatment plant equipment and technologies. (4 Lectures)
7. Agricultural water use and their energy intensity: Energy intensity of irrigation water use with change in crops; change in irrigation technology, subsidy in electricity, human behavior; with variation in geographic land scape. (5 Lectures)
8. Case study of water life cycle in various locations: USA, Ontario, Canada, China, Australia, India (4 Lectures)

Reference Books:

1. Sommariva C., Desalination Desalination and Advanced Water Treatment: Economics and Financing, Balaban Desalination Publications
2. Plappally A. K. and Lienhard J. H., Energy Requirements for Water Production, Treatment, End Use, Reclamation and Discharge, Renewable and sustainable energy reviews
3. WEF, Energy Conservation in Water and Waste Water Facilities, WEF Press, McGraw Hill

Self-Learning Material:

1. https://www.edx.org/course/sustainable-development-the-water-energy-food-nexus
2. https://www.water-energy-food.org/resources/resources-detail/university-of-california-water-energy-nexus-course-of-studies-at-irvine/
3. https://ce.uci.edu/areas/facilities/waternexus

Title	**Soil and water conservation Engineering**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3-0-0-0 [3]
Offered for		Type	Open Elective
Prerequisite			

Objectives:

1. to enable students to design irrigation systems, ponds, water ways and treatment wetlands
2. to enable to understand flow physics of water through soils, piping systems and lake systems in order to conserve water and treat soils.

Learning Outcomes:

1. Ability to design crop specific irrigation practices
2. To have capability to help treat soil contamination, enhance soil productivity and water use optimization.

Contents:

1. Precipitation, Infiltration, Evaporation and Transpiration (5 Lectures)
2. Run-off, water erosion and control practices, Wind erosion and Control practices (6 Lectures)
3. Vegetated waterways, Constructed Wetlands and Hydrodynamics (6 Lectures)
4. Open Channels flows and Subsurface Drainage Design (6 Lectures)
5. Pumps, Pumping, Water Supply and Quality (5 Lectures)
6. Balancing soil nutrients and Basics in Agronomy (4 Lectures)
7. Irrigation Principles (3 Lectures)
8. Soil Less Farming (3 Lectures)
9. Micro-irrigation and Sprinkler Irrigation Design (4 Lectures)

Reference Books

1. Schwab G. O., Fangmeier D. D., Elliot W. J. and Frevert R. K., Soil and Water Conservation Engineering, John Wiley & Sons
2. Micheal A. M, Irrigation theory and Practice, Vikas Publication House
3. Subramanya K., Environmental Hydrology, McGraw Hill Education

Self-Learning Material:

1. https://nptel.ac.in/courses/126105012/
2. https://icar.org.in/content/soil-and-water-conservation-engineering

Title	**Probabilistic Methods in Engineering Design**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3-0-0-0 [3]
Offered for		Type	Open Elective
Prerequisite			

Objectives

1. To provide a unified probabilistic approach to design aspects in transport phenomena, hydrology, climatic events, properties of materials and dealing with environmental and ecological variables.

Learning Outcomes

The students are expected to have the ability to:

1. Ability to model and predict phenomena such as development of strength in composite materials, size effect in failure theories, precipitation events, earth quake occurrences, and system behaviors etc.
2. To assess the reliability of engineering structures, to assess hazard rates of extreme climatic events, to assess the multi-parameter influences on flow, electro-kinetic parameters.

Contents

Data: Hydrologic Data, Big data, Overview of how data can be helpful in designing and planning urban spaces, social data, experimental data and specific nature of the data related to heat measurement, electricity, dielectric strength, porosity, particle size distribution, and other materials properties, stochastic data and its behavior, line diagram representation of linear and nonlinear data (8 lectures)

Prior and Post event categorization: Collective and exhaustive events, Total probability theorem, Bayes Theorem, Calculations of Probability Density Function, Cumulative Density Function when experimental data is provided (6 lectures)

Data Reduction: Descriptive statistics, Skewness, Moments, Kurtosis, Parameter Estimation, Chebyshev Inequality, Law of Large Numbers, Descriptive statistics introduction and training exercises in design of experiments and data compilation (6 lectures)

Presentation: Hydrographs, Distribution graph, flood frequency studies, normal annual precipitation events, lognormal models in fracture of materials and strength characterization, Gumbel Distribution, Log Pearson Type III Distribution, Extreme events type 1 distrbution, Raleigh Distribution (assessing errors in projectile motion), exponential distribution, Erlangs distribution and its variation the gamma distribution, Markov Processes. MINITAB 15/16 introduction and training exercises on transforming data as required by the software (8 lectures)

Analysis: Auto-correlation, hydrologic time series, spectral density functions, Regression, removing correlations between predictor variables, linear multi-parameter regression, Principal components, factor analysis, multi-variate regression analysis, Boot strapping and Jack Knife Procedures. Exercises to find correlation matrices from available experimental data, finding principal components using multi-variate analysis etc. Introduction to GEPHI and social network data analysis with intra-levels (10 lectures)

Testing: Sensitivity Analysis, Kolmogorov Smirnov Tests, Chi square Tests, Analysis of variance. Exercises to perform normality tests and variance analysis. (4 lectures)

Laboratory Experiments

MINITAB 15/16 introduction and MATLAB training exercises on transforming data as required by the software.

Reference Books

1. Benjamin J. R. and Cornell A. C., Probability, Statistics and Decision for Civil Engineers, McGraw Hill
2. Ang A. H. S. and Tang W. H., Probability Concepts in Engineering, Planning and Design Vol-1- Engineering and Design, John Wiley
3. Ang A. H. S. and Tang W. H., Probability Concepts in Engineering, Planning and Design Vol-2- Decision, Risk and Reliability, John Wiley

Online Course Material

1. https://nptel.ac.in/courses/105105045/