DEPARTMENT OF MECHANICAL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY(ISM) DHANABD

SYLLABUS OF M.TECH (MECHANICAL ENGINEERING)

SPECIALIZATION: MACHINE DESIGN

FIRST SEMESTER					
Course No.	**Course Name**	**L**	**T**	**P**	**CH**
DEPARTMENTAL CORE					
MEC500	Theory of Elasticity	3	0	0	9
MEC501	Mechanical Vibration	3	0	0	9
MEC502	Numerical Methods	3	0	0	9
MEC503	Finite Element Method	3	0	0	9
MEC504	Computer Aided Engineering Design	3	0	0	9
PRACTICALS					
MEC505	Vibration and Acoustics Lab	0	0	3	3
MEC506	Computational Lab 1	0	0	2	2
	Total	**15**	**0**	**5**	**50**

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	MEC500	Theory of Elasticity	3	0	0	9

Course Objective

- To make students understand the analysis of linear elastic solids under mechanical and thermal loads.
- To provide the foundation for pursuing other solid mechanics courses such as theory of plates and shells, elastic stability, composite structures and fracture mechanics.
- To expose students to two dimensional problems in Cartesian and polar coordinates. 4. To make students understand the principle of torsion of prismatic bars.

Learning Outcomes

Upon successful completion of this course, students will:

- Understand the basic concepts in continuum mechanics of solids, including of strain, internal force, stress and equilibrium in solids.
- Characterize materials with elastic constitutive relations.
- Use analytical techniques to predict deformation, internal force and failure of simple solids and structural components.
- Apply principles of continuum mechanics to design a structure or component to achieve desired performance under realistic constraints.

Module	Topics to be Covered	Lecture Hours	Learning Outcome
1	Introduction of Cartesian tensor analysis, Continuum concept of stress and strain fields, Concept of displacement field, Stress-strain-displacement relationship in polar coordinate system	10	Gives a comprehensive idea about the basic mechanics of elastic response.
2	Generalized Hook's law, Stress equilibrium equation, Compatibility condition, 3-D Mohr's circle and plan stress & strain Problem, Hydrostatic and deviatoric stress tensor, Lame's elastic constant, concept of Airy's stress function approach	10	Understanding the traction vector and stress tensor and Develop the equilibrium equation
3	Formulation and Solution Strategies, Energy Methods	6	Understanding the general formulation of boundary value problem
4	Bending analysis of a beam with shear effect, Effect of thickness ratio on the deflection of beam due to shear, estimation of bending stresses, Plastic analysis of beams	4	Understanding the stress and deflection of general cross-section beam
5	Torsion of circular and non-circular bar (Saint-Venantapproach), Flexural rigidity in an elliptical and triangular bar under torsion.	4	Understanding the behavior of general cross-section bar under Torion

6	Axi-symmetric Problem: Analysis of thick cylinder under internal, external and combined pressure, analysis of Rotating disk using Airy's stress function	5	Understanding the stress and deformation in Axi-symmetric structures

Text Books:

1. Advanced Mechanics of Solids, L. S. Srinath, 2nd Ed. TMH, 2003.

Reference Books:

1. Solid Mechanics, Kazimi, TMH

2. Theory of Elasticity, S. P. Timoshenko & J. N. Goodier, 2nd Ed. McGraw-Hill, 1951

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	MEC 501	Mechanical Vibration	3	0	0	9
Course Objective						
• To impart necessary fundamental knowledge to a student so that he can confidently cater to the needs of industry or R & D organizations • Fourier analysis has been added to understand and address practical problems.						

Learning Outcomes			
Upon successful completion of this course, students should be able to: • Understand the concept of vibration • Apply the concept in solving industrial problems • Develop software code for a proper mathematical modeling • Identify a suitable research topic to solve realistic industrial problem			
Module	Topics to be Covered	Lecture Hours	Learning Outcome
1	Free vibration of SDF system with and without damping, concept of phase plane, logarithmic decrement, quality factor.	5	Vibration fundamentals. Learning different fundamental concepts in connection with free vibration.
2	Response of single degree of freedom system to periodic and non-periodic excitation, rotating unbalance, whirling of rotating shafts	6	Forced vibration concepts of Single DOF system. Different ways of forcing and its response.
3	Vibration isolation, support motion, absorption and isolation, Measuring instruments.	6	Ways to mitigate vibration problem

4	Transient analysis and impulse response, arbitrary excitation, Laplace Transform formulation, response spectrum.	4	Learning response to various excitation and mathematical models to solve the same.
5	Multi degree of freedom system, normal mode vibration, co-ordinate coupling, modal analysis, orthogonal properties, modal matrix, Lagrange's equation.	6	Fundamental concepts of Multi Degree of Freedom problems and modal analysis.
6	Multi degree of freedom system – exact analysis and numerical methods, classical methods like Rayleigh, Dunkerley, Rayleigh-Ritz, Holzer etc.	5	Analysis of Multi degree of freedom system and learning various numerical techniques.
7	Vibration in continuous system like sting, shaft, bar, beam and membrane. Fourier analysis of signals, Presentation of the results of frequency analysis.	7	Vibration analysis of various continuous systems and Fourier analysis.

Text Book:

1. Theory of vibrations with applications – W. T. Thomson, M.D. Dahleh, C Padmanabhan, Pearson, 5th Edition. (2008)

Other References:

1. Vibration: Fundamentals and practices ,Clarence W.de Silva; CRC press,2nd Ed.2006.

2. Vibration and noise for engineers – K. Pujara; Dhanpat Rai and Co,2013.

3. Vibrations, Waves and Acoustics – D Chattopadhyay and P C Rakshit; Books and Allied(P) Ltd,2019.

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	MEC502	Numerical Methods	3	0	0	9

Course Objectives

The objective of the course is to study the numerical solution of linear and non-linear algebraic equations, solution of differentiation, integrations, PDEs and ODEs.

Learning Outcomes

Upon successful completion of this course, students will:

1. be able to solve actual problems by using different numerical methods.

2. be able to use FDM for discretization of governing equations to find the temperature distribution in the given geometry.

3. be able to understand the different types of PDEs.

4. be able to use the upwinding for solving the flow problems.

5. be able to write the computer programming based on learning of this course.

Modules	Topics	Lecture hours	Learning outcomes

1	Introduction to Numerical methods	1	Numerical methods are gradually becoming the substitute of experimental methods
2	Solution of linear algebraic systems: Non-iterative method, Gauss elimination method, LU-factorization method, Matrix inversion method. iterative method, Gauss Seidel iterative method, Jacobi method, ill -conditioning problems, Tridiagonalization, Hoseholder's method, QR-factorization	8	This unit will help students in understanding the numerical solution methodology for linear equations
3	Solution of non-linear algebraic systems: Solution of equations by iterations, Fixed point iterations, Newton's method, Secant method, Bi-section method	5	Understanding the methods for solution of non-linear equations
4	Numerical differentiation: Methods for first order ODEs, Euler method, Runge-Kutta methods, Methods for higher order and systems of ODEs, Euler method, Runge-Kutta methods, Stiff systems	5	This unit will help students in understanding the applications of Euler's Method, R-K2 and higher order R-K 4 methods
5	Numerical integration: Trapezoidal rule, Simpson's 1/3 rule, Simpson's 3/8 rule. Numerical double integration	5	Numerical integrations will be very useful for summation and averaging. Also, students will learn about best technique for integration.

6	Introduction to partial differential equations: 1ST Order PDEs, Mathematical classification second order PDEs, Characteristics	2	Understanding the behavior of PDE equations
7	Finite Difference Methods: Different discretization techniques of PDE equations, Backward, forward and central differencing discretization schemes, Euler’s explicit, implicit and semiimplicit methods, Truncation, Discretization, Round off errors. Consistency, stability and convergence. Fourier or von-Neumann stability analysis of Finite difference schemes	8	Understanding different types of errors, consistency, stability and convergence during solving the governing equations
8	Applications to model problems: Parabolic equations, heat equations, Elliptic equations, Laplace and Poisson’s equations. Dirichlet problems, ADI method, Neumann and Mixed problems, Hyperbolic equation, wave equation, Upwinding differencing scheme of advection terms	5	Students may use different methods for solving the actual heat/fluid flow and wave equations

Text Books:

1. Introductory Methods of Numerical Analysis: S. S. Sastry, 4th Edition, Prentice Hall of India Pvt Ltd.

References:

2. Numerical Solution of Partial Differential Equations: G. D. Smith, Oxford University Press, 1985.

3. Computational Fluid Mechanics and Heat Transfer: D. A. Anderson, J. C. Tannehill and R. H. Pletcher, Hemisphere Publishing Corporation.

4. Computational Fluid Flow and Heat Transfer: K. Muralidhar and T. R. Sundararajan, Narosa Publishing House.

5. Computational Methods in Engineering: S. P. Venkateshan and P Swaminathan, Ane Books Pvt Ltd.

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	MEC503	Finite Element Methods	3	0	0	9

Course Objective
• To provide the fundamental concepts of the theory of the finite element method. • To understand the need of numerical method to solving complex problems
Learning Outcomes
Upon successful completion of this course, students will able: • To obtain an understanding of the fundamental theory of the FEA method;

- To develop the ability to generate the governing FE equations for systems governed by partial differential equations;
- To understand the use of the basic finite elements for structural applications using truss, beam, frame, and plane elements; and
- To understand the application and use of the FE method.

Module	Topics	Lecture Hours	Learning Outcome
1	Introduction: Fundamental concepts and matrix algebra.	2	Understanding the basic concept of FEM problem and its formulation. Recap of matrix algebra
2	Direct stiffness method: Spring, Truss-coordinate transformation; Shape function in 1D, Governing Differential Equations -strong form and weak form	5	Understand to solve the problem by Direct stiffness method ; And role and significance of shape functions in finite element formulations
3	Approximation Techniques: Potential energy, Rayleigh-Ritz method and Galerkin method. 1D elasticity using the Rayleigh-Ritz	4	Understand to solve the FE problem by different types of Approximate Method

	Principle		
4	Element Properties: Lagrange and Serendipity Elements. Isoparametric Formulation, Stiffness Matrix of Isoparametric Elements. Numerical Integration: 1D & 2D	6	Understand global, local, and natural coordinates. Types and propesries of Element
5	Beam & Frames: Stiffness of Beam Members, Analysis of Continuous Beam, Plane Frame Analysis, Analysis of Grid and Space Frame	7	Understanding the structural element & their FE Formulations
6	2D & 3D element : CST, LST, Rectangular Elements, Axisymmetric Element, 3 D Elements	7	Understanding the 2D and 3D Element & their Isoparametric formulation
7	Plate and shell element: Plane stress & plane strain problems, Introduction to Plate Bending Problems, FEM of Thin Plate & Thick Plate, Finite Element Analysis of Shell	6	Understanding the thin structural element with different Types of Boundary Conditions and Loads
8	FEM programming with MATLAB	2	Understanding how to develop the FEM coding

Text Books:

1. Daryl L. Logan, A first Course of FEM, 5th Edition, Cengage learning

Reference Books:

1. T.R .Chandrupatta and A.D.Belegundu, *Introduction to Finite Element in Engineering*, Pearson Education India; 4 edition (2015)
2. J.N. Reddy, *An Introduction to the Finite Element Method*, Tata McGraw-Hill edition.
3. The finite element method, T. J. R. Hughes, PRENTICE-HALL, INC, Englewood Cliffs, New Jersey.

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	MEC504	Computer Aided Engineering Design	3	0	0	9

Course Objective
To impart knowledge dealing with computation aspects of engineering drawing and geometric modeling. This course is essential for design automation. It is the first step in all engineering analysis
Learning Outcomes
Upon successful completion of this course, students will: • get basic knowledge of different transformations which will be very useful in robotic and

mechatronics

- get mathematic details of the projections used in mechanical Engineering for visualization
- learn the concepts of parametric curves and surface modeling
- learn the basic techniques of representation of solids.

Module	Topics	Lecture Hours	Learning Outcome
1.	Overview of computer graphics: Introduction to CAD and Geometric Modeling, advantages of CAD, computer graphics software.	2	Students will know the use of Computer Aided Design in engineering and other applications.
2.	2-D Transformations: Transformations of points and straight lines, midpoint transformation, transformation of parallel lines and intersecting lines, rotation, reflection, scaling, combined transformations, solid body transformations, translations and homogeneous coordinates, rotation about an arbitrary point, reflection through an arbitrary line, projection.	6	Basic knowledge of transformed geometry in 2D and 2D homogeneous coordinate system will be the output of this module.
3.	3-D Transformations: 3-D scaling, shearing, rotation, reflection and translation, rotation about an	6	3D transformation will be applied to any model

	arbitrary axis in space, reflection through an arbitrary plane, affine and perspective geometry, orthographic and axonometric projections, techniques for generating perspective views, vanishing points, stereographic projection, reconstruction of 3-D images.		efficiently after completion of this module. Different projection used in engineering graphics will be learned after completion of this module.
4.	Plane curves: Introduction to geometrical modeling, representation of parametric curves, composite curves, rational curves, interpolation, intersection of curves	8	Basic knowledge of parametric curves can be used in Path/ trajectory planning for road, rail and well-paths after completion of this module
5.	Surface description and generation: Surfaces of revolution, sweep surfaces, quadratic surfaces, mapping parametric surfaces, Bilinear surface, ruled and developable surfaces, linear Coons surface, Coons bicubic surface, Bezier and B-spline surfaces, Gaussian curvature and surface fairness.	8	At end of this module students will be able to model different parametric surfaces.
6.	Solid Modeling and Programming: Introduction to solid modeling, feature based design,	7	At end of this module students will able to model different objects use in mechanical engineering.
7.	Introduction of object oriented programming, and	2	At end of this module students

	introduction to OpenGL...		will able to know the basic concepts of computer graphics and object oriented programming

Text Books:

1. Mathematical Elements of Computer Graphics, D. F. Roger and J. A. Adam, McGraw Hill Pub. 2017

Reference Books:

1. Geometric Modelling, M. E. Mortenson, Industrial Press In., New York. 2017
2. Introduction to Solid Modeling, M. Mantyla, Computer Science Press,1988.

Practical 1st Semester

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	MEC505	Vibration and Acoustics Lab	0	0	2	2

Sl. No.	Name of Experiment
1.	Free vibration of cantilever beam
2.	Forced vibration of cantilever beam
3.	Calculation of damping using simple pendulum
4.	Comparison of vibration signatures in bearing
5.	Comparison of vibration signatures in gearbox
6.	Cepstrum Analysis for Machine Fault Detection
7.	Envelope Analysis for Fault Detection
8.	Whirling of shaft
9.	Transmission Loss of an acoustic damper
10.	Absorption co-efficient of acoustic element

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	MEC506	Computational Lab- I	0	0	2	9

Sl. No.	Name of Experiment
1.	Introductory algebra and graph plotting in MATLAB
2.	Bisection method of root finding
3.	Newton-Raphson method of root finding
4.	Gauss Elimination, ill conditioned systems
5.	LU decomposition methods, matrix inversion
6.	Optimization using golden-section search
7.	Numerical integration: Trapezoidal rule
8.	Numerical differentiation: finite difference method
9.	Discrete Fourier Transform
10.	Numerical solution of Laplace equation

2nd Semester					
	DEPARTMENTAL ELECTIVES (ANY THREE)	**L**	**T**	**P**	**CH**
	Course Name				
	Basket 1				
MED525	Rotor Dynamics	3	0	0	9
MED526	Finite Element Method for Dynamics and Stability Analysis	3	0	0	9
MED527	Design of Tribological Components	3	0	0	9
MED528	Robotics	3	0	0	9
	Basket 2				
MED529	Composite Materials	3	0	0	9
MED530	Theory of Plates and Shells	3	0	0	9
MED531	Fracture Mechanics	3	0	0	9
MED532	Theory of Plasticity	3	0	0	9
	Basket 3				
MED533	Acoustics and Noise control	3	0	0	9
MED534	Automation and control	3	0	0	9
MED535	Vibration Control	3	0	0	9

	OPEN ELECTIVE (ANY TWO)				
MEO577	Structural dynamics and Aero-elasticity	3	0	0	9
MEO578	Bond Graphs in Modelling and Simulation	3	0	0	9
	PRACTICALS				
MEC536	Computational Lab 2	0	0	2	2
MEC537	Computer Aided Engineering Design Lab	0	0	3	3
	Total	**15**	**0**	**5**	**50**

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	MCD525	Rotor Dynamics	3	0	0	9

Course Objective
• The course aims to equip the students to the methods of modelling and analyzing rotating machines for their dynamic behavior.
Learning Outcomes
After completing the course, students will be able to • derive the equations of motion of rotors in absolute and rotating coordinate systems • calculate the critical speeds of rotors, • balance a rotor, • explain the gyro effect on critical speed

Module	Topics	Lecture Hours	Learning Outcome
1	Introduction: Rotating machine Components, Aspects of rotating machine behavior,	2	Understanding the significance of rotor

	examples of rotating machines: Electrical Machines, Turbo generators, Gas Turbines		dynamics.
2	Introduction to vibration analysis: Single degree of freedom systems, Multiple degrees of freedom systems, Discrete Fourier transform	2	Writing equations of motion of single and multiple degree of freedom system
3	Free lateral response of simple rotor models: Gyroscopic couples, Rigid rotors on flexible supports, Isotropic flexible supports, Simple model for flexible rotors	6	Students will be able to obtain equations of motion of simple rotors
4	Finite element modeling: Finite element modeling of discrete systems, Axial deflection of bar, Lateral deflection of bar, Elemental equations for bar and torsion element,	3	Students will be able to obtain response of continuous systems using finite element
5	Free lateral response of complex systems: Disk elements, Shaft elements, Bearings and seals, Foundation, Free response of complex systems	6	Students will be able to obtain elemental matrices for different rotor elements
6	Forced lateral response: Rotor models, Critical speeds, Mode shapes associated with critical speeds, Stresses in rotors, Asymmetric rotors and instability	5	Students will be able to calculate the critical speeds and mode shapes of rotors

7	Balancing: balancing rigid rotors at design stage, Field balancing of rigid rotors, Field balancing of flexible rotors	6	Students will be able to do calculations for balancing the rotors
8	Axial and Torsional vibration: Simple system models for axial vibration, Simple system models for torsional vibration, Finite element models	6	Students will be able do the axial and torsional vibration analysis of rotors
9	Condition Monitoring of rotating machines: Different faults in rotors and their signatures, Data acquisition, Basic signal processing	3	Understand the vibration signature of different rotor faults

Textbooks:

1. M. I. Friswell, J. E. T. Penny, S. D. Garvey, A. W. Lee, Dynamics of Rotating Machines, 1st edition, Cambridge University Press.

References:

1. Tiwari R., Rotor Systems: Analysis and Identification, 1st edition, CRC Press, Florida.

2. Rao J.S., Rotor Dynamics, 3rd edition, New Age, New Delhi.

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	MED526	Finite Element Method for Dynamics and Stability Analysis	3	0	0	9

Course Objective
• To learn and apply finite element solutions to structural dynamic problem • To develop the knowledge and skills needed to effectively evaluate finite element analyses for stability analysis.
Learning Outcomes
Upon successful completion of this course, students will able: • To obtain an understanding of the dynamics FE theories. • To develop the dynamics stiffness matrix; • To understand the modal reduction techniques and its use • To understand the Nonlinear Dynamics FE analysis.

Module	Topics	Lecture	Learning Outcome

		Hours	
1	Approximate methods and FEM: Hamilton's principle, Rayleigh's quotient,Rayleigh Ritz method and method of weighted residuals	4	Understand to solve the FE problem by different types of Approximate Method
2	Finite element analysis of dynamics of planar trusses and frames: Analysis of axially vibrating rods and Euler-Bernoulli beams, Assembly of matrices ,FE modelling of planar structures	5	Understanding the basic concept of FEM problem and its formulation
3	Analysis of equations of motion: FRF-s and damping models-, Material damping models. Dynamic stiffness and transfer matrices. Analysis of grids and 3D frames: Twisting of circular bars and rectangular bars. Analysis of grids 3D frames	6	Understanding to develop the dynamics stiffness matrix for different critical structure
4	Time integration of equation of motion: Euler's forward and backward difference methods, Central difference method, Energy conservation. Nonlinear systems.	7	Understanding the time integration techniques for dynamic and nonlinear problem
5	Model reduction and sub-structuring schemes; Analysis of 2 and 3 dimensional continua - Plane stress models, 3d Solid element, Axisymmetric models. Plate	7	Understanding the Modal reduction technique

	bending elements., Plate bending elements		
6	Structural stability analysis - Nonlinear dynamical systems, Energy methods in stability analysis, FEM for stability analysis. Dynamic analysis of stability and analysis of time varying systems, Dynamic analysis of stability and analysis of time varying systems., FE modelling of vehicle structure interactions	6	Understanding the Structural stability analysis & FEM for Structural stability analysis
7	FE model updating	4	Understanding the need of model updating & to create an appropriate practical FEM model

Text:

1. Introduction to finite element vibration analysis, Book by M. Petyt, Cambridge.

Reference

2. Vibration Analysis by Finite Element Method, Jong-Shyong Wu

3. Weaver & Johnston, Structural Dynamics by Finite Elements, Prentice Hall.

4. K J Bathe, Finite Element Procedure, Prentice Hall.

5. Shames & Dym, Energy and FEM in Structural Mechanics, Wiley.

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	MED527	Design of Tribological Components	3	0	0	9

Course Objective
The main objective of this course is to promote a better appreciation of the increasingly important role played by tribology at design stage in engineering. It will help in implementing algorithms developed from the basic principles of tribology to a wide range of practical application.
Learning Outcomes
Upon successful completion of this course, students should be able to: • Implement the concept of tribology at the design stage of a mechanical components such as rolling element bearing, gears, seals, clutches , brakes and belt drive • solve industrial problem related to tribological components • Identify a suitable research topic to solve realistic industrial problem

Module	Topics	Lecture Hours	Learning Outcome
1	Introduction: Tribological consideration in design, Conceptual design, Classification of tribological components, Mechanisms of tribological failures in machines, Zero wear concept, Computational techniques in design	3	Concept of tribology at the design stage
2	Rolling Element Bearings: Selecting bearing types and size, Principles and operating limits, Friction and Elastohydrodynamic Lubrication	9	Ability to Select of rolling element bearing for a particular application
3	Dry and Starved Bearings: Dry and semi lubricated bearings, analysis of partially starved bearings, minimum oil supply and temperature of starved bearings	5	Ability to analyse the bearing under different operating situation
4	Gas Lubricated Bearings: Thrust Bearing, Journal bearings, porous bearing	6	Concept of gas lubricated bearing
5	Seal Fundamentals: Classification of seals, Clearance seals, Visco seals, Radial contact seals, Mechanical face seals	5	Ability to design a seal
6	Tribology of Gears: Spur gears, friction and wear of spur gears, contact stresses,	4	ability to design a gear for a particular application

	lubrication of spur gears, surface failures		
7	Design of Dry Frictional Elements: Dry friction concepts, Brakes and Clutches, Friction belts and Dry rubbing bearing	7	Ability to analyse and design clutches brakes and belt drives

Textbooks

1. M M Khonsari and E R Booser,,Applied Tribology: Bearing Design and Lubrication, John Wiley & Sons, 3rd Ed.2017.
2. H Hirani, Fundamentals of Engineering Tribology with Applications, Cambridge University press, 1st Ed.2016.

References

1. G W Stachowiak and A W Batchelor, Engineering Tribology, Butter Worth & Heinemann Publication, 3rd Ed.2005.
2. Ghosh , Mazumdar, and Sarangi, Theory of Lubrication, Tata McGraw Hill Education, 1st Ed.2013.

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	MED 528	Robotics	3	0	0	9

Course Objective

• To expose the students in both the aspects of analyses and applications of robotics.
Learning Outcomes
Upon successful completion of this course, students will: • have a broad understanding of classification of robots and robotic manipulators used in automation industry. • have an understanding about basics of robot dynamics and control.

Module	Topics	Lecture Hours	Learning Outcome
1	Introduction: Robot definition, application, robot anatomy; robot classifications and specifications, serial robots.	3	Understanding robot classifications and general applications
2	Actuators: Pneumatic, hydraulic and electric actuators, Stepper motors, DC and AC motors, Selection of motors, Robot end-effectors	4	Learning the actuator sizing procedure and different types of end-effectors
3	Robot sensors: Contact and non-contact sensors; position, velocity, acceleration and force sensors; Robot vision and their interfaces.	4	This unit provides an overview of robotic sensors, vision and interfaces
4	Transformations: Grubler-Kutzbach Criterion; DOF of a Robot Manipulator; Pose or Configuration; Denavit-	4	Understanding the analytical procedure involved in motion transformation from

	Hartenberg (DH) Parameters; Homogeneous transformation.		fixed base to the end-effector
5	Robot kinematics: forward and inverse kinematics, link velocity and acceleration analysis: Jacobian matrix; Singularity.	4	This unit demonstrates the kinematic analysis of serial chain robots
6	Statics: Link forces and moments; Recursive formulas; force and moment recursion at different joints, Role of Jacobian; Force ellipsoid.	5	Learning the relationships between the joint torques/forces, and the Cartesian moments and forces at the end-effector
7	Dynamics: Inertial properties, Euler-Lagrange formulation, Generalized coordinates; Kinetic and potential energy; Newton-Euler equations; recursive robot dynamics- forward and inverse.	6	Analyzing forces and moments causing the motion of different parts of serial chain robotic manipulator
8	Control: Transfer function and state-space representation of a robotic joint, performance and stability of feedback control, P, PI, PD and PID control, state-feedback control, joint controllers; Non-linear control; stability and force control.	6	Using linear and nonlinear control techniques when a robot moves slowly
9	Applications: Robots in materials handling, machine loading/unloading and programming for case study.	3	Understanding robotic applications and learning code for real-time controlling of simple robots.

Total: 39

Text Books:

1. Introduction to Robotics by S. K. Saha, McGraw Hill,2ndEdition,2014

Reference Books:

2. Introduction to Robotics: Mechanics and Control by John J. Craig,, Prentice Hall

, Robot Modeling and Control by Mark W. Spong Wiley

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	MED529	Composite Materials	3	0	0	9

Course Objective
• To learn the properties of fiber-reinforced polymer composites • To learn the mechanical performance of laminated composites, including failure behavior.

• To model, simulate and optimize the performance of composite structures.
Learning Outcomes
Upon successful completion of this course, students will able to: • Identify, describe and evaluate the properties of fibre reinforcements, polymer matrix materials and commercial composites. • Develop competency in one or more common composite manufacturing techniques, and be able to select the appropriate technique for manufacture of fibre-reinforced composite products. • Analyse the elastic properties and simulate the mechanical performance of composite laminates; and understand and predict the failure behaviour of fibre-reinforced composites • Apply knowledge of composite mechanical performance and manufacturing methods to a composites design project

Module	Topics	Lecture Hours	Learning Outcome
1	Introduction to composites: Brief History, Constituent Materials, Laminate , FRP, micro-mechanics & macro-mechanics, Applications	2	Understand the Composite, its advantage, classification and the terminology used for studying mechanics of

			composites
2	Fabrication: Liquid resin impregnation routes, Pre-Pregs methods, Consolidation of resin moulding compounds, Injection moulding and hot pressing of thermoplastics. Fabrication of metal matrix composite.	4	Understanding the manufacturing process of composite
3	Micromechanical Analysis: Assumptions, strength-stiffness, Shear , Poisson Ration	6	Develop concepts of volume and weight fraction of fiber and matrix, density and void fraction in composites
4	Elastic Properties of Unidirectional Lamina: , stress – strain relations for general anisotropic, specially orthotropic and transversely isotropic materials, Transformation Matrix	7	Find the engineering constants; Develop stress-strain relationships, elastic moduli, strengths of a unidirectional/bidirectional lamina
5	Analysis of Laminated Composites: Classical Laminate Theory, Displacement Field, Strain Displacements Relations, Constitutive Relations, Classification of Laminates and their properties.	8	Find the elastic stiffnesses of laminate based on the elastic moduli of individual laminas and the stacking sequence
6	Analysis of Laminated Plate & FEM:	6	Ability to analyze problems

	Classical Plate theory, Bending of composite plate, Shear deformation theories: FSDT, HSDT, Layerwise		on bending, buckling, and vibration of laminated plates and beams
7	Hygrothermal Effects of Laminates , Failure Theories and Strength of Unidirectional Lamina Design of Composite structure & Example	6	Develop the relationships of mechanical and hygrothermal loads applied to a laminate to strains and stresses in each lamina

Text:

1. Mechanics of Composite Material & Structures, M Mukhopadhyay, Universities press 2013.

References:

1. An Introduction to Composite Materials, By D. Hull and Clyne, Cambridge University Press 2010
2. Engineering mechanics of composite materials, I. M. Daniel & O. Ishai, 2nd edn., oxford university press, 2006.
3. Principles of composite material mechanics, R. F. Gibson, 2nd edn. CRC Press, 2007.
4. Mechanics of Composite Material, Autar K. Kaw, CRC Press
5. Mechanics of composite materials, Rr. M. Jones, 2nd edn. Taylor & francis, 1999.

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	MED530	Theory of Plates and Shells	3	0	0	9

Course Objective
• To study the behaviour of the plates and shells with different geometry under various types of loads. • To understand theory and design of plate and thin shell structures of different geometries. • To understand the basic governing differential equations involved for analysing the plate and shell structure. • To understand the solution techniques for bending of the plate and shells under various types of loading.
Learning Outcomes
Upon successful completion of this course, students will: • have a broad understanding formulation of engineering structure under loading. • have an understanding about different boundary conditions and there uses for the solution of the problem .

- be able to solve inversely the bending problem of plate and shell.

Module	Topics	Lecture Hours	Learning outcomes
1	Introduction to elasticity (pre-requisite of this course).	4	Understanding the basic concept of classical elasticity theory
2	Introduction to Plates: Classification of Plates, Basic Theory of Plate Bending, Governing Equations of Plates, Boundary Conditions on different Edges, Governing Equations for Deflection of Plate	9	Understand the basic theory, governing equations and design of plate structures.
3	Rectangular plates: Navier’s Solution for Simply Supported Rectangular Plates, Levy’s Solution for Rectangular Plates, Method of Superposition.	9	Student will learn the solution technique for the bending of a rectangular plate with different boundary conditions.
4	Circular Plates: Basic Relation in Polar Coordinates, Symmetrical Bending of Uniformly Loaded	8	Student will learn the bending relationship of a circular plates under various

	Circular Plates, Symmetrical Bending under point loading, Annular plates.		loading condition.
5	Shells structure: Introduction, Parametric representation of a surface, Governing Equations of Shells, Boundary Conditions, Governing Equations for bending of shells, Analysis of Shells	9	Understand the basic theory and design of shell structures of different geometries.

Text Books:

1. C. Ugural, *Stresses in Plates and Shells*, 2nd ed., McGraw-Hill, 1999

Reference Books:

4. S. P. Timoshenko and S. Woinowsky-Krieger, *Theory of Plates and Shells,* McGraw Hill Pub
5. Analysis of plates by T.K.Varadan and K.Bhaskar , Narosa Publishing House, 1999

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	MED531	Fracture Mechanics	3	0	0	9

Course Objective
• To make the students conversant with the fundamentals of crack propagation in materials and structures. • This includes development of the strain energy release rate (GIC) and the critical stress intensity factor (KIC). • Emphasis will be placed on developing the correlation between microstructure control and the resistance to crack propagation which this variable produces
Learning Outcomes
Upon successful completion of this course, students will: • have a broad understanding on the fracture behavior of materials. • have an understanding about different types of the fracture and the their post effect on the material behavior • be able to solve the fracture mechanics problem.

Module	Topics	Lecture Hours	Learning outcomes
1	Overview of Engineering Fracture Mechanics: Types of fracture,	4	Understanding the basic concept of material

	Microstructural description of fracture, Mechanisms of Fracture, Review of Theory of Elasticity, Stress concentration factor.		behaviour and their mechanics
2	Tensor and Index Notation: Einstein summation convention, Free indices, Kronecker delta, Permutation symbol, Tensors of various ranks, Partial derivatives, Governing Eqs in index notation	8	Understand the basic mathematical preliminary required to deal for the analysis of fracture mechanics problem
3	Linear Elastic Fracture Mechanics (LEFM): Asymptotic field, Airy stress function, Stress intensity factors (SIF), K_{I}, K_{II}, K_{III}, Determination of SIF, Fracture toughness, Irwin's criterion, K-dominance, Small scale yielding, Fracture testing, Structure design by LEFM.	8	Student will learn the concept of linear fracture mechanics and related theories
4	Energy Approach: Energy release rate G, Griffith criterion, Relationship between G and K, J-integral	8	Student will learn the energy concept in fracture mechanics

5	Nonlinear Fracture Mechanics: HRR-singularity field, J-dominance, Small scale yielding, Large scale yielding, Crack initiation and growth.	7	Understand the nonlinear fracture mechanics problem
6	Fracture Resistance of Materials: Fracture criteria, effect of alloying and second phase particles, effect of processing and anisotropy, effect of temperature, closure.	4	Student will get idea of the effect of inclusion of foreign particles and processing anisotropy on the fracture behavior

Text Book:

1. D. Broek: Elementary Engineering Fracture Mechanics, Springer; 4th edition (1982)

Reference Book:

1. Prashant Kumar: Elements of Fracture Mechanics, McGraw-Hill (2009), ISBN: 9780070656963
2. T. L. Anderson: Fracture Mechanics: Fundamentals and Applications,CRC Press,2 edition (1994), ISBN-10: 0849342600
3. Richard W. Hertzberg: Deformation and Fracture Mechanics of Engineering Materials, Wiley (1995),ISBN-10: 0471012149

Course Type	Course Code	Name of Course	L	T	P	Credit

DE	MED532	Theory of Plasticity	3	0	0	9

Course Objective
• To study the elastic plastic behavior of the engineering materials under various types of loads. • To understand theory and design of material flow. • To understand the basic governing equations involved for analysing flow behaviour of the materials. • To understands the role of yield criteria in determining the elastic limit under multiaxial stress and the various theories involved.
Learning Outcomes
Upon successful completion of this course, students will: • have a broad understanding on the mechanism of plastic deformation from fundamentals of material science. • have an understanding about plasticity theory and there uses for the solution of the problem . • be able to solve the problem of generic engineering components under plastic deformation.

Module	Topics	Lecture Hours	Learning outcomes
1	Mathematical preliminaries and Introduction to elasticity (pre-requisite of this course).	4	Understanding the Cartesian tensor algebra and the basic concept of classical elasticity theory
2	Introduction to plasticity theory: Stress and strain; constitutive responses; physics of plasticity; application of plasticity theory for different materials;	9	Understanding the basic materials behaviour beyond elastic limit, governing equations and flow behaviour.
3	Formulation of rate-independent plasticity; maximum dissipation postulate; yield criteria; Flow rules and hardening rules.	9	Student will learn the mathematical description of the non-linear behavior of solid materials.
4	Uniqueness theorems; extremum principles in plasticity; limit analysis; shakedown theorems. plane problems in plasticity; slip line theory and its applications; plastic stability;	8	Student will learn various plasticity theorem and their limitation to estimate deformations and collapsed loads in engineering

			applications.
5	Plastic buckling; global and local criteria of plastic stability; strain localization and shear bands	9	Basic understanding on the application of plasticity theory such as buckling and bending of beams.

Text Books:

2. Plasticty Theory, J. Lubliner, 2nd ed., McGraw-Hill, 1999

Reference Books:

3. Fundamentals of the theory of plasticity, L. M. Kachanov
4. Nonlinear Solid Mechanics, D. Bigoni
5. Plasticity: Fundamentals and applications, P. M. Dixit and U. S. Dixit
6. Theory of Plasticity, J. Chakrabarty

Course Type	Course Code	Name of Course	L	T	P	Credit

DE	MED 533	Acoustics and Noise control	3	0	0	9

Course Objective
• Noise and Harshness has become a major issue in today’s society, which calls for a quitter technology. • This course will be extremely useful for engineers and researchers to design quitter machines or machine components.

Learning Outcomes
Upon successful completion of this course, students should be able to: • Understand the concept of technical acoustics • Apply the concept in solving industrial problems • Develop software code for a proper mathematical modeling • Identify a suitable research topic to solve realistic industrial problem

Unit No.	Topics	Lecture Hours	Learning Outcome

1	Fundamentals of vibration, Sound and vibration, Acoustics and engineers, basics of acoustics, dB levels, Concept of acoustic impedance etc.	5	Brush up of Vibration fundamentals. Introducing acoustics to aspiring engineers.
2	Type of waves, Characteristic of waves, Mathematical models of sound waves, 3D Wave equation,	6	Acoustic wave phenomena and developing various mathematical models.
3	Acoustics of cavity, Helmholtz resonator, noise control techniques, Noise Control Application, Acoustics of Mufflers etc.	8	Different types of noise control techniques and devices.
4	Experimental Techniques, Source Modeling, Acoustic Structure Interaction, Sound Radiation from Vibrating Infinite Plate.	8	Learning how sound interact with different structures and quantifying sound radiation from the structure.
5	Types of Microphones and specifications, Octave bands.	2	Introducing sensors to pickup acoustic signals and their analysis.
6	Wavenumber space, K-Space Diagram, Concept of Angular Spectrum, Green's function, Rayleigh Integral, Velocity and far field pressure calculations, Directivity and Sound power calculation.	10	Learning various mathematical techniques to predict sound power level at a distance from the source.

Text Book

1. M. L. Munjal. Noise and Vibration Control, World Scientific Press: Singapore (2014).
2. Lawrence E. Kinsler, Austin R. Frey, Alan B. Coppens and James V. Sanders . Fundamentals of Acoustics, Wiley: New York (1999).

Other References

1. Uno Ingard. Notes on Acoustics, Firewal Media: Delhi (2010).
2. E. G. Williams. Fourier Acoustics: Sound Radiation and Near Field Acoustic Holography, Academic Press: New York (1999).
3. Acoustics of Ducts and Mufflers, 2nd Edition,M. L. Munjal, John Wiley and Sons, ISBN: 978-1-118-44312-5.(2014)

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	MED 534	Automation and control	3	0	0	9

Course Objective
• The course is intended to provide knowledge of any industrial operations involving control of position, velocity,

temperature, pressure etc. • It is desirable that most engineers and scientists are familiar with theory and practice of automatic control.
Learning Outcomes
Upon successful completion of this course, students will: • have a broad understanding of open-loop and closed-loop control system used in practice. • be able to compare the performance of different control systems by using both the time response and the frequency response method.

Unit No.	Topics	Lecture Hours	Learning Outcome
1	Introduction: Review of Laplace Transform, Close-loop control versus open-loop control, Linear Time Invariant (LTI) systems.	3	Understanding basics of close-loop and open-loop control systems
2	Representation of physical system: Transfer function and impulse response function, modelling in state space, transformation of mathematical models with MATLAB, signal flow graphs, linearization of nonlinear mathematical models	5	To enable students to model dynamic systems and analyze dynamic characteristics
3	Mathematical modeling of control systems: Mechanical, Electrical and Electronic systems, liquid-level systems, pneumatic and hydraulic systems.	5	The students will be introduced the concepts of resistance and capacitance to

			describe the dynamics of control systems
4	Time response analysis: Transient and Steady-State Response Analyses, 1st order, 2nd order and higher-order systems, Routh’s Stability Criterion, Effects of Integral and Derivative Control Actions on System Performance, Steady-State Errors in Unity-Feedback Control Systems,	5	Understanding the basis for performance analysis of control systems by specifying test input signals
5	Control Systems Analysis and Design by the Root-Locus Method: Plotting Root Loci with MATLAB, Root-Locus Plots of Positive Feedback Systems, Lag, Lead and Lag–Lead Compensation	6	Understanding the movement of the closed-loop poles in the s-plane and modification of the dynamics to satisfy the given specifications
6	Frequency-Response Method: Bode Diagrams, Polar Plots, Log-Magnitude-versus-Phase Plots, Nyquist Stability Criterion	7	The students will be able to use the data obtained from measurements on the physical system for control without deriving its mathematical model.
7	PID Controllers: Ziegler–Nichols Rules for Tuning PID Controllers, Design of PID Controllers with Frequency-Response Approach	4	The students will learn different procedures for tuning gain values of PID controllers used in practice

8	Case study by using MATLAB	4	Application of basic control theory in realistic problems and analyses

Total 39

Text book

1. Modern Control Engineering by K.Ogata, 5th edition, Prentice Hall, 2010.

Reference books:

1. Automatic Control Engineering by F.H.Raven, 5th ed., McGraw Hill International, 1994.
2. Digital Control Systems by B.C.Kuo, Prentice Hall.

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	MED535	Vibration Control	3	0	0	9

Course Objective
• To develop the bridge between the structural dynamics and control communities • To providing an overview of the potential of smart materials for sensing & actuating purpose in active vibration control.

• To understand the passive damping techniques.
Learning Outcomes
Upon successful completion of this course, students will: • Understand the smart material, actuator sensor • Understand the design consideration to suppress the vibration • Understand the active control of space vehicle, satellite submarine etc

Unit No.	Topics	Lecture Hours	Learning Outcome
1	Review of Basics of Mechanical Vibrations. Basics of Vibrations for Simple Mechanical Systems, Introduction to Damping in Free and Force Vibrations, Free and Forced Vibrations of Two Degree of Systems, Multi Degree of Freedom Systems	6	Understand the basics of Vibration and its types
2	Basics of Vibrations Control: Reduction at source , Feedback Control System, Shunt Damping	6	Understand the preliminary Vibration control strategies.

3	Vibration Isolation, Vibration Generation Mechanism,: Source Classification, Self Excitation Vibration, Flow Induction Vibration, Damping: Models and Measures	6	Understanding the source of vibrations and Isolation of the source & use of damper
4	Design Considerations in Material Selection: Design Sensitivity ,Design Specification, Design for Enhanced Material Damping	6	Understanding the design consideration to suppress the vibration
5	Principles of Passive Vibration Control: Basics of Passive Vibration Control. Design of Absorber, Shock Absorber, Isolators with Stiffness and Damping	5	Understanding the passive vibration control strategy
6	Principles of Active Vibration Control: Basics of Active Vibration Control, Piezoelectric Material , Piezoelectric Accelerometers	5	Understanding the Use active material, actuator and sensor for vibration control
7	Electro-rheological (ER) Fluids , Magneto-rheological (MR) Fluids, Magneto and Electrostrictive Materials, Shape Memory Alloy	5	Understanding the advanced active control units and materials

Text:

1. Principles of Vibration Control by A.K. Mallik, East-West Press

Reference:

1. Vibration Control of Active Structures - An Introduction by André Preumont, springer

2. Passive and Active Structural Vibration Control in Civil Engineering, edited by T.T. Soong, M.C. Costantinou, Springer

3. Mechanical Vibrations: Active and Passive Control by Tomasz Krysinski and François Malburet

Course Type	Course Code	Name of Course	L	T	P	Credit
OE	MEO577	Structural Dynamics and Aeroelasticity	3	0	0	9

Course Objective
• To learn the concept of modal analysis, various methods of structural dynamics analysis of simple beam structures and simplified analysis of such aeroelastic phenomena as divergence, control-surface reversal, and flutter. • To learn the importance of incorporating aeroelastic phenomena in aircraft design and some elementary methods for doing so.
Learning Outcomes
Upon successful completion of this course, students will be: • Familiar with modal representation and to be able to solve elementary structural dynamics

problems for beams;

- Able to formulate and solve static aeroelasticity problems such as typical section and wing divergence problems;
- Able to use simplified unsteady aerodynamic theories to formulate and solve typical section flutter problems with one and two degrees of freedom
- Developed a qualitative understanding of the role of aeroelastic phenomena, such as divergence, control-surface reversal, and flutter, in aircraft design and performance.

Unit No.	Topics	Lecture Hours	Learning Outcome
1	Introduction : Structural Dynamics, Uniform Beam Bending , Beam Torsion	7	Understanding the modal representation and solve elementary structural dynamics problems for beams
2	Torsional divergence and static airload distributions, Complete vehicle equilibrium and sweep effects, Control effectiveness and reversal of complete vehicle	8	Understanding the formulation and solution of static aeroelasticity problems
3	Lifting surface flutter, flutter analysis using modal representation, the p, k and p-k methods of solutions, effects of Mach number, altitude	9	Understanding the simplification of unsteady aerodynamic theories to

	and mass ratio		formulate and solve typical section flutter problems
4	panel flutter, linear theory for flat panels and design considerations	7	Understanding the supersonic flutter theories
5	Assumed mode solutions for flat and cylindrical panels, Non-linear theory for flat panels and development of fatigue criteria.	8	Understanding the supersonic flutter theories

Text:

1. D.H. Hodges and G.A. Pierce, "Introduction to Structural Dynamics and Aeroelasticity" Cambridge Aerospace Series, 2012.

Reference:

1. E.H. Dowell et.al., "A Modern Course in Aero elasticity", Sijthoff & Noordhoff, 1980..
2. R.L. Bisplinghoff and H. Ashley, "Principles of Aeroelasticity", Dover, 1962.
3. Y.C. Fung, "An Introduction to the Theory of Aeroelasticity", John Wiley & sons, 1955.

Course Type	Course Code	Name of Course	L	T	P	Credit
OE	MEO578	Bond Graphs in Modelling and Simulation	3	0	0	9

Course Objective
• The requirements of a unified approach to modelling, simulation and synthesis of physical system is quite prominent among industries and R&D sectors, in particular. • This course will impart a lesson to create a unified and mathematical model, which may be subjected to predictive or deductive processes
Learning Outcomes
Upon successful completion of this course, students will: • Get a lesson on how to make mathematical models of different physical systems using bond graph approach • Understand a systematic procedure for systems' equations generation through the direct exploitation of cause and effect relationship. • Learn to bring out the power of bond graph modelling in developing control strategies from physical paradigms.

Unit No.	Topics	Lecture Hours	Learning Outcome
1	Elements of analytical mechanics: An invariant nature of power exchange, power variables, reference power directions,	2	Understanding the basic bond graphic elements and their correlations with the

	bond graphic elements and physical system coordinates.		analytical mechanics.
2	The notion of causality: Information exchange and its laws, causality of active and passive elements, junction elements, two-port elements, differential causality, algorithm for assigning causality, causal loop.	3	This unit discusses the notion of causation to incorporate all aspects such as interaction with exterior, storage and constraints of a general system.
3	Creation of system equations: Selection of system states, deriving equations of motion of mechanical and electrical system through bond graph model, systems with differential causality, activated bonds, system equations of motion with field elements, algebraic loops.	3	Student will learn the method of generation of system equations from an augmented bond graph using a step by step procedure.
4	Bond graph modelling methods: Method of flow and effort map, method of gradual uncover, point potential method, gyrator and transformer equivalents.	3	Students will be accustomed with different styles of mapping used in modelling.
5	Modeling in noninertial coordinates: Dynamics of rigid bodies, principle of material objectivity, generalized momenta, compliant fields	4	This unit demonstrates the art of modelling of complex systems having nonlinearity in dynamics
6	Structural members: Euler-Bernoulli beam model, Raleigh beam model, beam-column, consistent inertia field, transverse vibration of uniform beam under transverse loads and moments	4	This unit discusses modeling of beams through various levels of refinements followed by modal bond graph or finite mode analysis.
7	Modelling of multibody systems: Slider-crank and four bar mechanism, mechanical handling systems, modelling of robot,	3	This unit deals with bond graph modeling of mechanisms, simple load

	determination of transfer moduli for 5 DOF robot.		hoisting systems and robotic manipulators.
8	Modelling of power hydraulic systems: Power variables for hydraulic circuits, hydraulic compliances, viscous resistance, hydraulic gyrator and transformer, bond graph model of a hydraulic servomotor.	7	Students will be able to understand the concepts relevant to system dynamics of hydraulic circuits
9	Application of bond graphs to control systems: Signal flow graph from bond graph, position control of a mass on a spring-damper combination, PID control, velocity control of moving cars connected by a spring	3	The students will learn to formulate transfer functions for linear time invariant systems from their bond graph models via signal flow graphs and once transfer functions are obtained, further analysis may be routinely carried on by the techniques well developed in classical control theory of these systems.
10	Introduction to software SYMBOLS-6.0 modelling and simulation practice of some real-life problems.	7	Students will learn handling a new software for simulation of system dynamics

Text Books:

1. Bond Graph in Modeling, Simulation and Fault Identification, by Mukherjee, A., Karmakar, R. and Samantaray, A.K., 2006, I. K. International: New Delhi, India, ISBN 81-88237-96-5.

Reference Books:

1. System dynamics: A unified approach, by Karnopp, D.C., Margolis, D.C. and Rosenberg, R., 1990, John Wiley, New York.
2. Bond graphs - A methodology for modelling multidisciplinary dynamic systems, Borutzky W., 2004, SCS Publishing House, Erlangen, San Diego.

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	MEC536	Computational Lab 2	0	0	3	3

Practical 3

1. Solving the ordinary differential equation through FEM in MATLAB
2. Solving 2D steady state problem using Triangular element
3. Transient analysis with Rectangular element and forward differentiation method
4. Solving 2D steady state problem using Tetrahedral element
5. Numerical integration using Gaussian Quardrature method
6. Static analysis of truss structure
7. Natural Frequency of Truss Structure
8. Beam deflection Calculation for static Load
9. Modal analysis of undamped structure
10. Modal analysis of damped structure

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	MEC537	Computer Aided Engineering and Design Lab.	0	0	3	3

Practical 4
1. Transformation in 2D homogeneous coordinates system 2. Transformation in 3D homogeneous coordinates system 3. Reflection through an arbitrary plane in 3D transformations. 4. Rotation about an arbitrary axis in 3D homogeneous coordinates system. 5. Axonometric projections. 6. Generation of Hermite curve. 7. Generation of Bezier curve. 8. Modeling and interpolation of B-Spline curves. 9. Modeling of NURBS Curves. 10. Modeling and interpolation of different parametric surfaces. 11. Modeling of solids.

3RD Semester

Course No.	Course Name	L	T	P	CH
MEC 569	Thesis Unit 1	0	0	0	9
MEC 570	Thesis Unit 2	0	0	0	9
MEC571	Thesis Unit 3	0	0	0	9
MEC 572	Thesis Unit 4	0	0	0	9
	Total	**0**	**0**	**0**	**36**

4th Semester

Course No.	Course Name	L	T	P	CH
DEPARTMENTAL/OPEN ELECTIVES (ANY TWO)					
MED573	Advanced Optimization Techniques	3	0	0	9
MED574	Research Methodology	3	0	0	9
MEO579	Computational Fluid Dynamics	3	0	0	9
MEO580	Measurements in Thermal Engineering	3	0	0	9
		3	0	0	9
MEC 575	Thesis Unit 5	0	0	0	9
MEC 576	Thesis Unit 6	0	0	0	9
	Total	**0**	**0**	**0**	**36**

Course Type	Course Code	Name of Course	L	T	P	Credit
OE	MED573	Advanced Optimization Techniques	3	0	0	9

Course Objective
• To understand theory of different optimization methods to solve various types of engineering problems. • To understand physical engineering problem and to construct mathematical formulation towards solving it by selecting proper optimization techniques. • To understand both computer programming and heuristic approaches to solve optimization problems.

Learning Outcomes
Upon successful completion of this course, students will: • have a broad understanding formulation of engineering optimization problem. • have an understanding about single and multivariable engineering problems. • be able to write MATLAB code for single and multivariable engineering problems. • be able to understand and write MATLAB code for Nontraditional optimization technique like GA to solve different engineering problems.

Unit No.	Topics	Lecture Hours	Learning Outcome

1	Basic Concepts: optimization problem formulation.	4	Understanding the types and basic concept of engineering optimization problem formulation.
2	Single variable optimization algorithms: Exhaustive search method, bounding phase method, Interval halving method, golden search method, Newton Rapshon method, bisection method, secant method. Computer programming to solve the single variable problem	9	This unit discuss about different types of classical single variable optimization algorithms. Student will learn to write MATLAB code for these algorithms also.
3	Multivariable optimization algorithms: Unidirectional search, direct search methods, simplex search and gradient based methods. Computer programming to solve Multivariable optimization algorithm	9	This unit discuss about different types of classical multivariable unconstrained optimization algorithms. Student will learn to write MATLAB code for these algorithms also.
4	Constrained optimization algorithms: Linear programming, nonlinear programming penalty function method, method of multipliers, sensitivity analysis, direct search for constrained minimization. Related computer Programming.	8	Student will learn constrained optimization algorithms and their computer programming.
5	Nontraditional optimization: Introduction to Genetic algorithm: Binary coded GA, Limitation – advantage & disadvantage Real coded GA, Micro GA, Scheduling of GA, computer programming, other evolutionary algorithms.	9	This unit demonstrates basics of Nontraditional optimization techniques. Use of Nontraditional optimization like GA to solve different engineering problem, especially mechanical engineering problems.

Text Books:

1. Deb, K. Optimization for engineering design: algorithms and examples. Prentice Hall of India, New Delhi. 2nd Edition 2012

Reference Books:

6. Rao, S.S. Engineering Optimization: Theory and Practice. Wiley. 3rd Edition, 2014
7. Ravindran, A., Ragsdell, K. M., Reklaitis, G. V. Engineering Optimization: Methods and Applications, Willey, 2nd Edition, 2013
8. Rardin, Ronald L. Optimization in operations research. Prentice Hall.

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	MED 574	Research Methodology and Statistics	3	0	0	9

Course Objective
To illustrate to the students a) the basic concepts of research, b) how a scientific research problem has to be formulated and tackled and c) important statistical tools necessary to analyze the collected data for a meaningful research outcome.
Learning Outcomes
On successful completion of the course, the students will

- Learn various types of research process, methodologies to identify, design and execute a research problem based on scientific and statistical tools;
- Learn various types of sample design techniques and its classification, characteristics of a good sample design and how to select a sampling procedure for data collection;
- Learn various types of measurement scales, sources of error in measurement and technique of developing measurement tools to evaluate the collected data;
- Learn various methods of data collection and the reliability and validity of the collected data;
- Learn various ways to prepare and present report for dissemination of research outcome;
- Learn various statistical tools necessary for designing a sample, analyzing the data and making scientific conclusion(s) out of the collected data to arrive at a research outcome.

Module	Topics	Lecture Hours	Learning Outcome
1	Research Process, Types of Research, Problem identification and Hypothesis formulation	5	Basic ideas on research processes, Definition of various types of research, Knowledge on what constitute

			a research and how to identify a research problem, Knowledge on the formulation of hypothesis for research
2	Research Design: General Designs of Research, Randomized and Correlated Groups Design.	5	Meaning of research design, Ideas on the need for research design, Knowledge on the features of a good research problem design, Important concepts relating to research design, Ideas on different research design methodologies, Ideas on the basic principles of experimental designs
3	Sampling Design, Measurement and Scaling, Methods of Data Collection, Reliability and Validity	5	Ideas on the Implications of a Sample Design and its classification, Knowledge on the criteria of selecting a sampling procedure and characteristics of a good sample design, Ideas on measurement scales and sources of error in measurement, Knowledge on

			technique of developing measurement tools, Ideas on the meaning of scaling and important scaling techniques, Ideas on the methods of data collection and the reliability and validity of the collected data.
4	Data Presentation and Report Preparation, Introduction to Qualitative and Quantitative Research Methods.	3	Ideas on Data presentation and report preparation techniques, Sensitizing the students on the very important issues of plagiarism, Preliminary ideas on the qualitative and quantitative research methodologies and their mutual difference.
5	Frequency Distribution, Presentation of Data, Measures of Central Tendency, Measures of Dispersion, Skewness	3	Ideas and knowledge on frequency distribution, cumulative frequency distribution, constructing histograms, Knowledge on the measures of central tendency (Mean, Median and Mode), Various measures of

			dispersion of the data.
6	Probability Distributions, Discrete and continuous random variable, Binomial, Poisson, Normal and Standard Normal distributions.	6	Learn about Experiment, Outcomes, and Sample Space, Calculation of Probability, Ideas on Marginal and Conditional Probabilities, Learn about Mutually Exclusive, Independent and Complementary Events, Learn about Bay’s Theorem, Learn about discrete and continuous random variables and how to calculate their mean and standard deviation, Learn about Binomial, Poisson, Normal and Standard Normal distributions.
7	Sampling and Estimation, Sampling Distribution, Estimation of the mean and proportion, Hypothesis tests about the mean and proportion of a population, t-test and z-test, Estimation and hypothesis testing about two different populations.	6	Learn about sampling and estimation methods, hypothesis testing regarding the properties of the population from the sample statistics (sample mean and variance), Learn about Student’s t-distribution and z-distribution

			and t-test and z-tests, Knowledge on estimation and hypothesis testing about two different populations
8	Hypotheses testing: χ^2- test, Analysis of Variance, Correlation and Regression analysis.	6	Learn about the Chi-Square distribution, Goodness-of-Fit test, Learn about making contingency tables, Learn about testing independence or homogeneity of populations, Learn to infer about the population variance, F-Distribution and one-way ANOVA, Learn about simple linear regression models and analysis.

Textbook:

1. 'Research Methodology - Methods and Techniques' C R Kothari and Gaurav Garg New Age International (P) Limited Publishers 4rth Edition, 2019 New Delhi

2. 'Applied Statistics and Probability for Engineers' D C. Montgomery and George C. Runger 6 th Edition, 2016

References:

1. Research Methodology: A Step-by-Step Guide for Beginners, Ranjit Kumar, SAGE Publications Ltd; Fifth edition 2018.

2. Introductory Statistics, Prem S. Mann, 7th Edition, John Wiley and Sons Inc., 2010, Danvers, MA.

Course Type	Course Code	Name of Course	L	T	P	Credit
OE	**MEO579**	**Computational Fluid Dynamics**	3	0	0	9

Course Objectives
1. The prime objective of this course is to provide the students with in depth understanding of the computational approach for modeling

and solving fluid dynamics as well as heat transfer problems. 2. To enable the students to mathematically represent a physical phenomenon, so that they can generate a mathematical model and finally, a numerical statement of a given problem and solve the problem via implementation of the theoretical knowledge gained. 3. To make the students initially believe and then understand that many of the results in heat transfer/fluid flow that they have studied in undergraduate/post-graduate courses can be generated accurately by themselves using CFD.
Learning Outcomes
1. The students will be familiar to a powerful tool for solving flow and heat transfer problems. This experience will enable them to numerically model a thermo-fluids problem using FDM and FVM. 2. The students will have the feel of the essential role the matrix algebra plays in approximate computations of ODEs and PDEs. 3. The students will be more inclined towards computer programming which will turn out to be very helpful in their Masters research and thereafter.

Modules	**Topics**	**Lecture hours**	**Learning outcomes**

1	Review of governing equations for conservation of mass, momentum and energy in primitive variable form	3	After this revision module, the students will be able to derive the conservation equations using Reynolds transport theorem and will also be able to interpret each equation
2	Mathematical behaviour of the conservation equations, equilibrium and marching problems	3	This important module will enable the students to distinguish given equations based on their characteristics (mathematical nature) and also to choose later, the appropriate differencing schemes as applicable
3	The finite difference method (FDM) and the variational methods, discretization, comparison of finite difference method, finite volume method (FVM) and finite element method (FEM)	2	The students will be acquainted with the brief history of development of the three basic discretization techniques as well as foundation of discretization
4	Review of Taylor's series, implicit, explicit and semi-implicit schemes, alternate direction implicit method	6	This module deals with the foundation of FDM; the students will be able to logically approximate a derivative and a differential equation
5	Convergence, stability analysis of a numerical scheme	4	This module will provide the concept of numerical error and guidelines for using or not using a differencing scheme while solving a CFD problem
6	Solution of linear matrix equation system and programming	2	This module will familiarize the students with the role of linear algebra in solving fluid dynamics problems

7	Application of FDM in one- and two dimensional steady and unsteady heat conduction and computer programming, artificial viscosity, upwinding	5	Practical implementation of all the topics covered up to module VI, introduction to numerical diffusion and CFD in fluid flow, students will be able to differentiate between CFD in heat conduction and CFD in fluid dynamics
8	Stream function-vorticity formulation	3	The students will learn the alternate flow equations as well as their solution methods used in early days of numerical treatment of flow problems
9	The finite volume method in orthogonal and non-orthogonal meshes, Green-Gauss theorem, application of FVM for heat conduction and convection-diffusion problem	7	The students will be able to discretize a given equation via direct integration on orthogonal and non-orthogonal meshes. This module will make the limitations of FDM more obvious to the students
10	Implementation of SIMPLE algorithm in two dimensions, Introduction to commercial package ANSYS-FLUENT	4	The students will have the flavour of a segregated fluid flow solver. In this context, they will learn the difficulties posed by the nonlinear convective terms and coupling between pressure and velocity. Thus, they can appreciate the depth and involvement in numerical treatment of a flow problem compared to a heat conduction problem

Text Books:

1. John D. Anderson, Computational Fluid Dynamics The basics with applications, McGraw-Hill Education, 1st Edition, 2017.

References:

2. Richard H. Pletcher, John C. Tannehill and Dale A. Anderson, Computational Fluid Mechanics and Heat Transfer, CRC Press, 3rd Edition, 2012.

3. Joel H. Ferziger and M. Peric, Computational Methods for Fluid Dynamics, Springer, 3rd Edition, 2002.

4. Clive A. J. Fletcher, Computational Techniques for Fluid Dynamics, Springer, 1st Edition, 1988.

5. T. J. Chung, Computational Fluid Dynamics, Cambridge University Press, 2nd Edition, 2010.

5. K. Muralidhar and T. R. Sundararajan, Computational Fluid Flow and Heat Transfer, Narosa Publishing House, 2nd Revised Edition, 2003.

6. S. V. Patankar, Numerical Heat Transfer and Fluid Flow, CRC Press, 1st Edition, 1980.

Course Type	**Course Code**	**Name of Course**	**L**	**T**	**P**	**Credit**
OE	**MEO580**	**Measurements in Thermal Engineering**	3	0	0	9

Course Objectives
Aims to provide the fundamental knowledge of experimental methods in the field of fluid mechanics and heat transfer which will help the students while performing real time experiments and also to understand their applications in real life problems.
Learning Outcomes
Upon successful completion of this course, students will be able: 1. to understand the various measurement techniques and errors associated with measurement analysis. 2. to determine uncertainty in the measurement analysis. 3. to understand about the different measuring devices like Hot wire anemometer, Laser Doppler velocity meter, Capillary method, Saybolt viscometer, Manometer, Pirani gauge, Ionization gauge, Dynamic response of a U-tube manometer, Resistance Thermometer, Pyrometry, etc. 4. to apply the knowledge of fixing permissible error in a measuring device and the importance of considering error while calculating different physical parameters.

Modules	Topics	Lecture hours	Learning outcomes
1	Basic concepts of measurements, Different types of errors in measurements, Statistics in Measurements, Uncertainty in measurements, Linear regression, Parity plot	8	To understand the different types of errors associated with measurement analysis and the determination of uncertainty in measurements
2	Temperature measurements: Thermometer, thermocouples, Temperature measurement in the solid, Measurement of Transient temperature, Resistance Thermometer, Pyrometry	8	To understand the theory and working principles of different instruments used for temperature measurements
3	Measurements of Heat Flux, Interferometry, Differential Interferometer	3	To understand the theory and working principles of different instruments used for heat flux measurements
4	Thermal conductivity measurement: Guarded hot plate apparatus, heat flux meter .	3	To understand the theory and working principles of different instruments used for the thermal conductivity measurements
5	Pressure measurements: Manometer, Vacuum measurements, Pirani / Ionization gauges, Dynamic response of a U-tube manometer	7	To understand the theory and working principles of different apparatus used for the pressure measurements

6	Flow and velocity measurements: Different methods of incompressible and compressible flow measurements, Pitot static tube, Hot wire anemometer, Ultrasonic method, Doppler effect, Vortex Shedding Flow meter, Laser Doppler velocity meter	7	To understand the theory and working principles of different instruments used for the measurements of flow velocity
7	Viscosity Measurement: Capillary method, Torque method, Saybolt viscometer	3	To understand the theory and working principles of different instruments used for viscosity measurements

Text Books:

1. J. P. Holman, Experimental Methods for Engineers, McGraw-Hill Science Engineering; 8th Edition, 2011.

2. S. P. Venkateshan, Mechanical Measurements, John Wiley & Sons and Ane Books Pvt. Ltd., 2nd Edition, 2015.

References:

3. S. M. Yahaya, Compressible Flow, New Age International (p) Ltd., 5th Edition, 2016.

4. E. O. Doebelin, Measurement systems, Application and Design, Tata McGraw-Hill, 5th Edition, 2007.