Master of Technology

in

ENGINEERING MECHANICS AND DESIGN

Course Structure, Scheme of Evaluation and Syllabi

(*Effective from July 2017*)

Department of Applied Mechanics

Motilal Nehru National Institute of Technology Allahabad
Allahabad, U.P. -211004, INDIA

Course Structure and Evaluation Scheme

(Master of Technology in *Engineering Mechanics and Design*)

I Semester (Total Credits = 20):

Course Code	Subject Name	L	T	P	Credits	Distribution of Marks out of 100		
						TA	Mid Sem. Exam	End Sem. Exam
AM2101	Applied Mathematics and Computation	4	0	0	4	20	20	60
AM2102	Continuum Mechanics	4	0	0	4	20	20	60
AM21XX	**Elective-I**	4	0	0	4	20	20	60
AM21XX	**Elective-II**	4	0	0	4	20	20	60
AM21XX	**Elective-III**	4	0	0	4	20	20	60

List of Electives (Semester I):

Elective-I:		**Elective-III:**	
AM2104	Biomechanics	**AM2114**	Dynamics of Structures
AM2110	Applied Elasticity	**AM2115**	Structural Reliability
AM2140	Advanced Fluid Mechanics	**AM2116**	Design of Thin Walled Structures
		ME2125	Computer Aided Design
Elective-II:			
AM2111	Finite Element Methods		
AM2112	Optimization Techniques		
AM2113	Computational Solid Mechanics		
AM2125	Non-Destructive Testing		

II Semester (Total Credits = 20):

Course Code	Subject Name	L	T	P	Credits	Distribution of Marks out of 100		
						TA	Mid Sem. Exam	End Sem. Exam
AM2201	Analysis and Design of Plates and Shells	4	0	0	4	20	20	60
AM2251	Experiments in Solid Mechanics	0	0	6	4	50	-	50
AM22XX	**Elective-IV**	4	0	0	4	20	20	60
AM22XX	**Elective-V**	4	0	0	4	20	20	60
AM22XX	**Elective-VI**	4	0	0	4	20	20	60

List of Electives (Semester II):

Elective-IV:		Elective-VI:	
AM2210	Wave Propagation in Solids	**AM2216**	Applied Plasticity
AM2212	Theory of Stability	**AM2217**	Fracture Mechanics
AM2224	Electro-acoustic Transducers	**AM2218**	Continuum Damage Mechanics
AM2206	Computational Fluid Dynamics	**AM2219**	Analysis and Design of Composite Structures
Elective-V:			
AM2213	Mechanics of Composite Materials		
AM2214	Multi-Functional Materials and Structures		
AM2215	Multiscale Modeling of Advanced Materials		

III Semester (Total Credits = 20):

S. No.	Subject Name	Credits
AM2391	**Special Study/Term Project/State of the Art/Colloquium/Industrial/Research Training (Proposed)**	4
AM2392	**Thesis/Project**	16

IV Semester (Total Credits = 20):

S. No.	Subject Name	Credits
AM2492	**Thesis/Project**	20

Note: The distribution of thesis evaluation marks will be as follows:

1. Supervisor(s) evaluation component: 60%
2. Oral Board evaluation component: 40%

AM2101 Applied Mathematics and Computation		
Designation	:	Compulsory
Pre-requisites	:	*Engineering Mathematics &Computer Programming*
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme):20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).

Syllabus

Review of Elementary Engineering Mathematics: Solution of homogeneous and non-homogeneous equations; Power series; Laplace transform and its applications; Fourier series and Fourier transform
Linear Algebra: Matrices and Linear Transformations, Operational Fundamentals of Linear Algebra, Systems of Linear Equations, Gauss Elimination Family of Methods, Special Systems and Special Methods, Numerical Aspects in Linear Systems, Eigenvalues and Eigenvectors, Diagonalization and Similarity Transformations, Jacobi and Givens Rotation Methods, Tri-diagonal Matrices, QR Decomposition Method, Eigenvalue Problem of General Matrices, Singular Value Decomposition, Direct and Iterative solvers.
Ordinary Differential Equations: Introduction to ordinary differential equations, homogeneous linear equations of second order, non-homogeneous linear equations of second order, free and forced oscillation problems, problems with variable coefficients, system of equations.
Partial Differential Equations (PDEs): Existence and uniqueness of differential equations, nature of solution, Hyperbolic, Parabolic and Elliptic PDEs, nonlinear PDEs.
Nonlinear Equations: Motivation, Open and braketing method, Bisection, Fixed point, Newton's method, Secant and False position method, Rate of convergence, Merits and demerits of methods.
Numerical Integration: Motivation, Newton-Kotes method, Trapezoidal rule, Simpson's rule, Rhomberg integration, Gauss Quadrature.
Initial Value Problem: Motivation, Euler's method, Modified Euler method, Runge-Kutta methods, Adaptive integrations and multistep methods.
Boundary-value and Eigen-value Problem: Methods and Applications in Mechanics.

Reference Books

1. Numerical Methods in Engineering: M. Salvadori.
2. Applied Numerical Methods: B. Carnahan.
3. Applied Numerical Analysis: C.F. Gerald and P.O. Wheatley.
4. Numerical Mathematics & Computing: W. Cheney and D. Kincaid.
5. Applied Partial Differential Equations: Paul DuChateau and David Zachmann.
6. Partial Differential Equations for Scientists and Engineers: Stanley J. Farlow.
7. Numerical Methods for Partial Differential Equations: William F. Ames.
8. Numerical Methods for Elliptic and Parabolic Partial Differential Equations**:** John R Levison, Peter Knabner, Lutz Angermann.

AM2102 Continuum Mechanics

Designation	:	Compulsory
Pre-requisites	:	*Basic Engineering Mathematics, Linear Algebra*
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme):20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).

Syllabus

Mathematical Preliminaries and Introduction: Index notation, range and summation convention, free and dummy indices, Kronecker delta, Levi-Civita symbol, co-ordinate transformations, Cartesian tensor, properties of tensors, tensors as linear operators, invariants of tensor, eigen values and Eigen vectors, polar decomposition, scalar, vector and tensor functions, comma notation, gradient of a scalar, gradient of a vector, divergence and curl of a tensor, integral theorems of vectors and tensors. Notion of a continuum, configuration, mass and density, descriptions of motion, material and spatial coordinates.

Kinematics of Deformation and Motion: Deformation gradient tensor, stretch and rotation, right and left Cauchy-Green deformation tensors, Eulerian and Lagrangian strain tensors, strain-displacement relations, infinitesimal strain tensor, infinitesimal stretch and rotation, compatibility conditions, principal strains and strain deviator, material and local time derivatives, stretching and vorticity, path lines, stream lines, vortex lines, Reynolds transport theorem, circulation and vorticity.

Forces and Stresses: Body and surface forces, Cauchy Stress Tensor, First and Second Piola-Kirchhoff Stress Tensor, Deviatoric and Pressure Components, Principal Stress.

Fundamental Balance Laws of Continuum Mechanics: Balance of Mass – Continuity Equation; Balance of Linear Momentum – Equations of Motion / Equilibrium Equations; Moments of Momentum (Angular Momentum); Balance of Energy - First Law of Thermodynamics, Energy Equation; Equations of State – Entropy, Second Law of Thermodynamics; Clausius-Duhem Inequality, Dissipation Functions

Constitutive Relations and Material Models: Constitutive Assumptions; Ideal Fluids; Elastic Fluids, Hyperelastic Material; Notion of Isotropy; Isothermal Elasticity - Thermodynamic Restrictions, Material Frame Indifference, Material Symmetry; Hooke's law, Stokes problem and Newtonian fluids.

Reference Books

1. Introduction to the Mechanics of a Continuous Medium: Lawrence E. Malvern.
2. An Introduction to Continuum Mechanics: Morton M. Gurtin.
3. Introduction to Continuum Mechanics for Engineers: Ray M. Bowen.
4. Continuum mechanics for engineers: G. Thomas Mase and George E. Mase.
5. Theory and Problems of Continuum Mechanics: George E. Mase.
6. Nonlinear Continuum Mechanics for Finite Element Analysis: J. Bonet and R. D. Wood.
7. Continuum mechanics and plasticity: Han Chin Wu.

AM2104 Biomechanics		
Designation	:	Elective
Pre-requisites	:	Basics of engineering mechanics, and Anatomy of human body
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme): 20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).

Syllabus

Application of Statics to Biomechanics:
Basics concepts of Force Moments and Torque Equilibrium, analysis of systems in equilibrium. Skeletal joints, Skeletal muscle. Mechanics of the elbow, shoulder, Spinal column, Hip, Knee and ankle. Basic assumptions and limitations.

Deformable body Mechanics:
Applied forces and Deformations, internal forces and moments, Stress and Strain, Basic loading configurations, Uniaxial tension test, Load- elongation diagrams, Hooke's Law, Work and Strain Energy, Properties based on Stress-strain Diagrams, Idealized model for material behavior and Mechanical properties of materials.

Multi axial Deformation and stress analysis:
Poisson's ratio, Biaxial and tri axial stresses, Failure theories, allowable stress and factor of safety, Fatigue and endurance, Torsion, Bending and combined loading.

Mechanical Properties of Bone and Soft Tissues
Mechanics of bone, Composition of bone, Mechanical properties of bone, Bone fractures and Bone Remodeling, Biomechanics of Tendon and Ligaments. Biomechanics of Skeletal Muscles. Biomechanics of Articular cartilage.

Term Paper: On recent advances based on literature survey and/or lab/industry visit

Reference Books

1. Biomechanics: Fung Y.C.
2. Biomechanics and Motor Control of Human Movement: Winter D.A.
3. Basic Biomechanics of the Skeletal System: Frankel V.H. and Nordin Margareta.
4. Fundamentals of Biomechanics: Nihat Ozkaya and Margareta Nordin.

AM2110 Applied Elasticity		
Designation	:	Elective
Pre-requisites	:	Mechanics of Materials
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme):20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).

Syllabus

Analysis of Stress: Concept of Stress, Stress Components, Equilibrium Equations, Stress on a General Plane (Direction Cosines, Axis Transformation, Stress on Oblique Plane through a point, Stress Transformation), Principal Stresses, Stress Invariants, Deviatoric Stresses, Octahedral Stresses, Plane Stress, Stress Boundary Condition Problem.
Analysis of Strain: Deformations (Lagrangian Description, Eulerian Description), Concept of Strain, Strain Components (Geometrical Interpretation), Compatibility Equations, Strain transformation, Principal Strains, Strain Invariants, Deviatoric Strains, Octahedral Strains, Plane Strain, Strain Rates.
Stress-Strain Relations: Introduction, One-Dimensional Stress-Strain Relations (Idealized Time independent and Time–dependent stress-strain laws), Linear Elasticity (Generalized Hooke's Law), Stress-Strain Relationships for Isotropic and Anisotropic Materials (Plane stress and Plane Strain)
Basic Equations of Elasticity for Solids: Introduction, Stresses in Terms of displacements, Equilibrium Equations in terms of displacements, Compatibility equations in Terms of Stresses, Special cases of Elasticity equations (Plane Stress, Plane strain, Polar Co-ordinates), Principle of Superposition, Uniqueness of Solution, Principle of virtual work, Potential and Complementary energy, Variational Principles, St. Venant's Principle, Methods of analysis for Elastic Solutions, Elastic solutions by Displacement and stress Functions, Airy's Stress Function (Plane stress, Plane strain, Polar Co-ordinates).
Torsion: Introduction, Circular shaft, Torsion of non-circular cross-section, St. Venant's theory, Warping function, Prandtl's stress function, Shafts of other cross-sections, Torsion of bars with thin walled sections.
Viscoelasticity: Introduction, Viscoelastic models (Maxwell, Kelvin-Voigt, Generalized Maxwell and Kelvin models), Viscoelastic stress-strain relationships.

Reference Books

1. Mathematical Theory of Elasticity: I. S. Sokolnikoff
2. Advanced Mechanics of Materials: Boresi
3. Theoretical Elasticity: A. E. Green and W. Zerna
4. Theory of Elasticity: Timoshenko and Gere
5. Advanced Strength and Applied Elasticity: A. C. Ugural and S. K. Fenster
6. Applied Elasticity: R.T.Fenner
7. Advanced Strength of Materials: L. S. Srinath

AM2140 Advanced Fluid Mechanics		
Designation	:	Elective
Pre-requisites	:	*Engineering Fluid Mechanics, Thermodynamics*
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme):20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).

Syllabus

Basic Conservation & Governing Laws: Statistical & continuum methods, Eulerian & Lagrangian coordinates, material derivatives, control volumes, Reynolds' transport theorem (RTT), conservation of mass, momentum and energy, constitutive equations, Navier-Stokes equations- differential & integral approach, energy equations, governing equations for Newtonian fluids, boundary conditions.
Potential Flows: Stokes stream functions, solution of potential equation, flow in a sector, flow around a sharp edge, flow near a blunt nose, force and moment on a circular cylinder and sphere, conformal transformations, Joukowski transformations.
Viscous Incompressible Flows: Exact solutions for Couette flow, Poiseuille flow, flow between rotating cylinders, Stokes' first problem, Stokes' second problem, pulsating flow between parallel surfaces, stagnation-point flow, flow in convergent and divergent channels, flow over porous wall. Stokes approximation, rotating sphere in a fluid, uniform flow past a sphere and cylinder, Ossen's approximation, Hele-Shaw flow.
Introduction to Boundary Layer: Derivation of boundary layer equation, How potential flow complements B.L. equation, Integral solution of B.L., Laminar and turbulent boundary layers, transition; B.L. separation and control.
Introduction to Compressible Flow: Velocity of sound and its importance, physical difference between incompressible, subsonic and supersonic flows, Mach number and its significance. Isentropic flow through nozzles, shocks and expansion waves, Rayleigh and Fanno Flow.

Reference Books

1. Fundamental Mechanics of Fluids: I.G. Currie
2. Foundations of Fluid Mechanics: S.W. Yuan
3. Advanced Fluid Mechanics: K. Muralidhar and G. Biswas
4. Boundary Layer Theory: H. Schlichting
5. Modern Compressible Flow with Historical Perspective: John D. Anderson
6. Fundamentals of Aerodynamics: J.D. Anderson
7. Fundamentals of Fluid Mechanics: B.R. Munson, D.F. Young and T.H. Okiishi
8. Introduction to Fluid Mechanics: R.W. Fox and A.T. McDonald
9. Viscous Fluid Flow: F.M. White

AM2111 Finite Element Methods		
Designation	:	Elective
Pre-requisites	:	Linear Algebra with Matrix Operations, Differential Equations, Mechanics of Materials, Theory of Elasticity.
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme): 20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).

Syllabus

Introduction: Course objectives, History of FEM, Application Areas, Concept of Discretization and Interpolation, Different Steps in Finite Element Analysis, Demonstration through FE Analysis of Axially Loaded Bar.

Variational Methods & Energy Principles: Brief Introduction to Variational Calculus, Energy Principles – Principle of Virtual Work and Complementary Virtual Work, Principle of Minimum Potential Energy and Complementary Potential Energy, Mixed Principles.

Detailed FE Formulation for Solid Mechanics: Finite element discretization – Piecewise Interpolation & Shape Functions, C^0 and C^1 Interpolation, Conventional 1D, 2D & 3D Elements, Special Elements, Sub Parametric, Super Parametric & Isoparametric elements. FE Formulation Using Variational Methods & Energy Principles. Coordinate transformation & Jacobian, Numerical Integration & Calculation of Element Matrices.

Classical Finite Element Methods: Ritz Method, Method of Weighted Residuals, Galerkin method, Strong & Weak formulation. One & Two dimensional structural & non-structural boundary value problems involving scalar and vector valued dependent variables.

Dynamic Problems and Other Topics (in brief): Dynamic Equations from Hamilton’s Principle, Mass (Consistent & Diagonal) and Damping Matrices, Free Vibration Analysis – Eigen value problem, Time-History analysis in Forced Vibration – Direct (Explicit & Implicit) Integration Methods.

Nonlinear & Stability problems, Error & Error estimation, Conforming & Non conforming Elements, Patch test.

Application through Computer Programming & Commercial Software:

- Input for Geometric & Material Configuration, Loading and Boundary Conditions.
- Automatic Mesh Generation, Nodal Coordinate and Nodal Connectivity.
- Calculation of Element Matrices (Stiffness & Mass Matrices, Load Vector).
- Assembly of Element Matrices to Global Matrices, Imposing Boundary Conditions.
- Solution (Gauss Elimination & other methods), Post Processing.

Reference Books

1. Energy and Finite Element Methods in Structural Mechanics: I. H. Shames and C. L. Dym.
2. Concepts and Applications of Finite Element Analysis: R. D. Cook, D. S. Malkus and M. E. Plesha.
3. The Finite Element Method Vol. I-II: O.C. Zienkiwicz and R.L. Taylor.
4. Finite Element Procedures: K. J. Bathe.
5. An Introduction to Finite Element Methods: J.N. Reddy.
6. Finite Element Methods in Engineering: S.S. Rao.

AM2112 Optimization Techniques		
Designation	:	Elective
Pre-requisites	:	*Differential Calculus & Computer Programming*
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme):20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).

Syllabus

Introduction to Optimization: Design variables, Design constraints, Objective function Design space, feasible region, Problem statement, Local and Global optima, Classification of optimization problems, Solution by calculus and numerical methods.
Linear Programming: Simplex method, Geometric Programming: Application to simple problems.
Non-Linear Programming: Method of approximation programming, Kelly's Cutting Plane method.
Gradient Methods: Steepest descent and Side step method. Conjugate Gradient method, Rosin's Gradient Projection Method, Zotendik's method of feasible directions, Unconstrained minimization, and penalty function technique search procedures.
Genetic Algorithm: Artificial Neural Network, Dynamic programming
Application to Process Equipments, Structural Mechanics, Development of computer programmes.

Reference Books

1. Engineering Optimzation, Theory and Practice: S. S. Rao
2. Optimization of Structural and Mechanical Systems: J. S. Arora
3. Elements of Structural Optimization: R. T. Haftka and Z. Gürdal
4. Cost Optimization of Structures: Fuzzy Logic, Genetic Algorithm and Parallel Computing: H. Adeli and K. C. Sarma
5. An Introduction to Optimization: Edwin K. P. Chong and Stanislaw H. Żak
6. Nonlinear Optimization- Theory and Algorithms: L.C.W. Dixon
7. Linear Programming Vol.I: G. Hadley
8. Nonlinear and Dynamic Programming, Vol.II: G. Hadley

AM2113 Computational Solid Mechanics		
Designation	:	Elective
Pre-requisites	:	*Engineering and Numerical Mathematics, Computer Programming, Advanced Solid Mechanics / Continuum Solid Mechanics, Finite Element Method (basic).*
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme): 20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).

Syllabus

Introduction and Review of Mathematical Preliminaries: Vector and Tensor Analysis, Elements of Linear Algebra, Multivariable Calculus, Linearization of Nonlinear PDE's, Different numerical methods for Computational Solid Mechanics, Programming Languages and Softwares for Computational Solid Mechanics.

Review of Continuum Solid Mechanics and FEM: Kinematics and Deformation Gradient, Material and Spatial Description, Stress and Strain Tensor, Compatibility Equations, Constitutive relations, Elasticity Tensor and Generalized Hooke's law, Different Material Models, Balance Laws and Equilibrium equations, Transformation of Coordinates, Energy Principles based Variational Formulation of Finite Element Equations for General Solid Mechanics Problem.

Elements of Computer Programming (Through programming in FORTRAN/C++): Brief history and evolution of Computers and Programming Languages, Constants and variables, Character variables, Numerical variables – integers and floating point, Variable type declaration, Intrinsic functions, Input-Output formats and statements, Assignment statements, Arithmetic expressions, logical calculations and repetitive calculations through looping, Arrays - of Rank *1*, *2* and *n* - dimension, Dynamic allocation and de-allocation, Procedures and structured programming – Subroutines and Module procedures etc, Pointers and dynamic data structures, Control structures and program design.

Programming for Solution of Linear Problems in One Dimension: Energy Principles and FE formulation for boundary value problems in structural mechanics – Bars, Beams, Shafts etc., Final discretized system of equations and solution techniques for linear problems, Basic structure of a standard FE analysis program, Implementation to the structural mechanics and heat conduction problems, Comparison with results obtained from Softwares like ANSYS, MATLAB etc (depending upon availability).

Programming for Solution of Nonlinear Problems in One Dimension: Mathematical problem formulation, linearization and basic numerical solution procedure, geometric nonlinear elastic problem, elasto-plastic and inelastic problems, Structure of computer program for the solution of nonlinear problems, Comparison with results obtained from Softwares.

Programming for Solution of Linear Problems in Two and Three Dimension: Mathematical problem formulation for – Plates and/or Shells, 3D problems, Final discretized system of equations, Implementation through computer programming, Comparison with results obtained from Softwares.

Project / Term Paper: On a real-life computational solid mechanics problem, as would be assigned to students.

Reference Books

1. Fortran 95/2003 for Scientists and Engineers: Stephen J. Chapman
2. Modern Fortran Explained: Michael Metcalf, John Reid and Malcolm Cohen
3. Computer Programming in Fortran 90 and 95: V. Rajaraman
4. Finite Elements in Plasticity: D. R. J. Owen and E. Hinton
5. Computational Inelasticity: J.C. Simo and T. J. R. Hughes
6. Computational Continuum Mechanics: Ahmed A. Shabana
7. An Introduction to Computational Micromechanics: Tarek I. Zohdi and Peter Wriggers
8. Classical and Computational Solid Mechanics: Y.C. Fung and Pin Ton
9. Computational Solid Mechanics: Variational Formulation and High Order Approximation: Marco L. Bittencourt
10. Handbook of Computational Solid Mechanics: Survey and Comparison of Contemporary Methods : Michal Kleiber

AM2125 Non-Destructive Testing

Designation	:	Elective
Pre-requisites	:	*Basic Material Science and Engineering*
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme):20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials, Term paper).

Syllabus

Overview of NDT: NDT Versus Mechanical testing, Overview of the Non Destructive Testing Methods for the detection of manufacturing defects as well as material characterization. Relative merits and limitations, Various physical characteristics of materials and their applications in NDT, Visual inspection Unaided and aided.
Surface NDE methods: Liquid Penetrant Testing – Principles, types and properties of liquid penetrants, developers, advantages and limitations of various methods, Testing Procedure, Interpretation of results. Magnetic Particle Testing- Theory of magnetism, inspection materials Magnetisation methods, Interpretation and evaluation of test indications, Principles and methods of demagnetization, Residual magnetism.
Thermography and eddy current testing (ET): Thermography- Principles, Contact and non contact inspection methods, Techniques for applying liquid crystals, Advantages and limitation – infrared radiation and infrared detectors, Instrumentations and methods, applications.Eddy Current Testing-Generation of eddy currents, Properties of eddy currents, Eddy current sensing elements, Probes, Instrumentation, Types of arrangement, Applications, advantages, Limitations, Interpretation/Evaluation.
Ultrasonic testing (UT) and acoustic emission (AE): Ultrasonic Testing-Principle, Transducers, transmission and pulse-echo method, straight beam and angle beam, instrumentation, data representation, A/Scan, B-scan, C-scan. Phased Array Ultrasound, Time of Flight Diffraction. Acoustic Emission Technique, AE parameters, Applications.
Radiography (RT): Principle, interaction of X-Ray with matter, imaging, film and film less techniques, types and use of filters and screens, geometric factors, Inverse square, law, characteristics of films – graininess, density, speed, contrast, characteristic curves, Penetrameters, Exposure charts, Radiographic equivalence. Fluoroscopy- Xero-Radiography, Computed Radiography, Computed Tomography.
Term Paper: On recent advances based on literature survey and/or lab/industry visit.

Reference Books

1. Practical Non-Destructive Testing: Baldev Raj, T.Jayakumar, M.Thavasimuthu
2. Non-Destructive Testing Techniques: Ravi Prakash
3. ASM Metals Handbook, Non-Destructive Evaluation and Quality Control, American Society of Metals, Metals Park, Ohio, USA, 200, Volume-17.
4. Introduction to Non-destructive testing: a training guide: Paul E Mix
5. Handbook of Nondestructive evaluation: Charles J. Hellier
6. ASNT, American Society for Non Destructive Testing, Columbus, Ohio, NDT Handbook,Vol. 1, Leak Testing, Vol. 2, Liquid Penetrant Testing, Vol. 3, Infrared and Thermal Testing Vol. 4, Radiographic Testing, Vol. 5, Electromagnetic Testing, Vol. 6, Acoustic Emission Testing, Vol. 7, Ultrasonic Testing

AM2114 Dynamics of Structures		
Designation	:	Elective
Pre-requisites	:	Engineering Mechanics, Mechanics of Materials, Engineering Mathematics including Differential Equations, Linear Algebra
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme): 20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Tests, Class Tutorials etc).

Syllabus

Introduction: Objectives, Types of Loadings, Essential Characteristics of Dynamic Problems, Discrete & Continuous systems, Rigid body dynamics vs. Vibration.

Fundamental Concepts: Formulation of the Equation of Motion, Newton's laws & D'Alembert's Principle, Lagrange's Equation, Functionals and Energy Principles, Variational Formulations, Hamilton's Principle, Formulation of Vibration Problems: Taught String, Axial Vibration of Bar, Torsional Vibration of Shaft, Flexural Vibration of Beam, Membrane, Thin & Thick plates, 3D Solid etc.

Discrete Single-Degree-of–Freedom Systems: Analysis of Free and Forced Vibrations, Response to Harmonic, Periodic & Impulsive Loadings, Duhamel's Convolution Integral, Vibration Isolation, Complex-Stiffness Damping, Response to General Dynamic Loading, Fourier Analysis.

Discrete Multi-Degree-of-Freedom Systems: Formulation of MDOF Equation of Motion, Evaluation of Structural Property Matrices, Reduction of dynamic matrices, Analysis of Dynamic Response- Superposition method, Iteration method, Direct time integration of linear systems – Explicit & Implicit methods.

Continuous Systems: Eigen Value Problems and Orthogonality of Natural Modes, Rayleigh's Method, Rayleigh-Ritz Method, Coupled natural modes, Numerical methods of Discretization, Dynamics matrix for flexural, axial & torsional effects, Solution methods - Newmark's, Wilson's, Houbolt's Method, Introduction to Nonlinear Vibration and Random Vibration.

Reference Books

1. Structural Dynamics: Theory and Computation: Mario Paz.
2. Elements of Vibration Analysis: Leonhard Meirovitch.
3. Mechanical Vibrations: Geradin and Rixen.
4. Dynamics of Structures: Clough and Penzien.
5. Theory of Vibration with Applications: William T. Thomson.
6. Dynamics of Structures: J L Humar
7. Dynamics of Structures: W C Hurty and M F Rubinstein
8. Structural Dynamics: M. Mukhopadhyay
9. Dynamic loading and design of structures: A. J. Kappos

AM2115 Structural Reliability		
Designation	:	Elective
Pre-requisites	:	Probability Theory, Mechanics of Solids and Structures, Finite Element Methods (basic).
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme): 20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).

<u>Syllabus</u>

Introduction: Course Overview, Basic Statistics, Theory of Probability, Probability Distributions (Continuous & Discrete), Random Variables

Analytical Methods Reliability Analysis: Failure Surface & Definition of Reliability in Normal Space (Cornell's Reliability Index), First Order Reliability Method (FORM), Hasofer-Lind's Definition of Reliability, Rackwitz-Fiessler Algorithm, Asymptotic Integral, Second Order Reliability Method (SORM)

Simulation Methods: Monte-Carlo Methods Latin Hypercube Sampling, Variance Reduction Technique, Importance Sampling and Adaptive Sampling, Subset Simulation

Stochastic Analysis: Implicit Performance Function, Polynomial Response Surface Method (RSM), Stochastic Response Surface Method (SRSM), Stochastic Models of Loads, Code Calibration, Partial Safety Factors, LRFD Format, System Reliability, Time Varying Reliability Analysis

Applications: Reliability Based Optimization, Introduction to Stochastic FEM, Case Studies, Term Project.

<u>Reference Books</u>

1. Probability, Statistics and Reliability for Engineers and Scientists: Ayyub B. M, McCuen R. H.
2. Probability, Random Variables and Stochastic Processes: Papoulis A.
3. Structural Reliability Analysis and Design: Ranganathan R.
4. Structural Reliability: Analysis and Prediction: Melchers R E.
5. Methods of Structural Safety: Madsen H O, Krenk S. and Lind N. C.
6. Reliability Based Structural Design: Choi S. K, Grandhi R. V. and Canfield R A.
7. Reliability and Optimization of Structural Systems: Rackwitz R., Augusti G. and Borri A.
8. Structural Reliability Using Finite Element Methods: Waarts P. H.,
9. Reliability Assessment Using Stochastic Finite Element Analysis: Haldar A. and Mahadevan S.
10. Computational Analysis of Randomness in Structural Mechanics: Bucher C.

<table>
<tr><th colspan="3">AM2116 Design of Thin Walled Structures</th></tr>
<tr><td>Designation</td><td>:</td><td>Elective</td></tr>
<tr><td>Pre-requisites</td><td>:</td><td>Mechanics of Materials, Differential Equations, Linear Algebra</td></tr>
<tr><td>Credit and Contact hours</td><td>:</td><td>4(L) - 0(T) – 0(P) – 4(Cr)</td></tr>
<tr><td rowspan="2">Assessment Methods</td><td rowspan="2">:</td><td>Theory Examination: (Scheme) End Semester Exam: 60 marks
Mid Semester Exam: 20 marks</td></tr>
<tr><td>Internal Assessment (Scheme):20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).</td></tr>
</table>

Syllabus

Introduction: Line and surface structures; Internal/induced forces- Axial/Membrane, Bending/Flexure, Shear and Torsion; Thin and thick structures, Sandwich constructions.

Thin walled Beams: Introduction to Beam Theories, Bending, Torsion, Lateral Buckling, Flexural Torsional Buckling of Columns.

Design of Pressure Vessels and Piping: Design of pressure vessels- Introduction, Design of different kind of vessels, Openings and nozzles; Design of pipings- Introduction, Design of different piping systems, Branch connections, Pipe flanges

Reference Books

1. Introduction to the Theory of Thin Walled Structures: N W Murray
2. Stability Analysis and Design of Structures: M L Gambhir
3. Fundamental of heat exchanger and pressure vessel technology: J P Gupta
4. Pressure Vessel Design: Concepts and principles: J Spence and A S Tooth
5. Pressure vessels design and practice: S Chattopadhyay
6. Handbook of piping Design: G K Sahu

ME2125 Computer Aided Design

Designation	:	Elective
Pre-requisites	:	Engineering Mathematics
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment: (Scheme) 20 marks (5 marks for attendance + 15 marks for assignments based on software and programming, Surprise Tests, Quizzes, and Tutorials etc)

Syllabus

Introduction: Historical Development, Explicit and Implicit Equations, Intrinsic Equations, Parametric Equations, Coordinate Systems.
Curves: Fundamental of Curve Design, Parametric Space of a Curve, Reparametrization, Space Curves: Spline Curves, Bezier Curves, B-Spline Curve, Rational Polynomials, Rational curves, NURBS.
Surfaces: Fundamental of Surface Design, Parametric Space of a Surface, Reparametrization of a Surface patch, Sixteen point form, Four Curve Form, Plane, Cylindrical and Ruled Surfaces, Surfaces of Revolutions, Bezier Surface, B-Spline Surface.
Solids: Fundamental of Solid Design, Parametric Space of a Solids; Continuity and composite Solids, Surface and Curves in a Solid.
Solid Modeling: Topology and Geometry, Set theory, Euler Operators, Regularized Boolean Operators, Construction Criteria, Graph Based Models, Instances and Parameterized Shapes, Cell-decomposition and Spatial Occupancy Enumeration, Sweep representation, CGS, BRep, Wireframe Analytical properties, Relational properties and Intersection. Applications in Biomedical Engineering Design.

Reference Books

1. CAD/CAM-Principles and Applications: Posinasetti Nageswara Rao.
2. CAD/CAM-Computer-Aided Design and Manufacturing: M P Groover.

AM2201 Analysis and Design of Plates and Shells		
Designation	:	Compulsory
Pre-requisites	:	Mechanics of Materials
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme):20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).

Syllabus

Introduction: Line and surface structures, Membrane, Thin and thick plates.

Pure Bending of Plates: Slope and curvature of slightly bent plates. Relations between moments and curvatures.
Small Deflection theory of Laterally Loaded Plates: Governing differential equation and boundary conditions. Bending of Rectangular Plates. Simply supported rectangular plates. Naviers' solution, Rectangular plates with various loading and edge conditions, levy's solution.
Bending of Circular plates: Governing equation, Axisymmetric loading, Various types of circular plates, Design of Circular Plates, Plate on elastic
Shells: Classification of shells, Engineering use of shell structures.
Membrane Theory: Cylindrical shells and shell of revolution, Axisymmetric and unsymmetrical loading. Solution for stress resultants and displacements. Cylindrical, spherical and conical shells supported at isolated points. Analysis for wind and periodic loads.
Bending Theory of Cylindrical Shell: Governing equations for stresses and displacements for symmetric and general conditions. Flugge and Donnel theories. Cylindrical shells with uniform and Non-uniform thickness.
Design of Plates & Shells: Design Considerations, Design load and other criterions, Design of Rectangular Plates, Design of Shells of Revolution, Design of Cylindrical Shells, Indian Codes of Practice, Other Design Codes, Design of Thin-Walled Industrial Structures.

Reference Books

1. Theory of Plates and Shells: S.Timoshenko and W.Krieger
2. Analysis of Plates: Szilard
3. Plates and Shells: Turner
4. Analysis of Plates: T.K.Vardan and K.Bhaskar.
5. Design of Plate and Shell Structures: Maan H. Jawad

AM2251 Experiments in Solid Mechanics

Designation	:	Compulsory
Pre-requisites	:	*Engineering Mathematics, Theoretical Solid Mechanics*
Credit and Contact hours	:	0(L) - 0(T) – 6(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 50 marks
		Internal Assessment: (Scheme) 50 marks (10 marks for attendance + 40 marks for sessional assessment based on regular performance on Practical and Virtual Experimentation, Demonstration of knowledge and skill development through Surprise / Quiz Tests, Viva etc. and Assignments & Report Writing.

Syllabus

Part-A: Formal Concepts on Experimentation

Introduction to Experimentation: Basic Concepts, Definition of Terms, Calibration, Standards, Dimensions and Units, Measurement Systems - Sensors, Load cells and Electrical Resistance Strain Gages, System Response, Distortion, Experiment Planning, Analysis of Experimental Data.

Experimental Methods in Solid Mechanics: Displacement and Dimensional Measurements, Pressure Measurement, Force, Torque and Strain Measurements, Motion and Vibration Measurement, Data Acquisition and Processing, Report Writing and Presentations, Introduction to Design of Experiments.

Mid Term Project Submission: Design of an Experiment / Fabrication of an Experimental Specimen or Setup (as assigned).

Part-B: Practical Performance of Experimentation

Mechanical Experiments: Review of Undergraduate Experiments in Mechanics of Solids, Shear Centre of Thin-Walled Sections, Combined Bending and Torsion, Tensile / Buckling Tests on Composite Plates / Laminates, Torsion of Composite Tube, Dynamic / Viscoelastic Beam Experiment.

Strain Measurements using Electrical Strain Gage / Strain Rosette, in: Beams, Truss, Composite Laminate, and Pressure Vessel

Part-C: Virtual Experimentation / Simulation and Computer Programming for Analysis of Experimental Data:

Analysis of Obtained Experimental Data Using Computer Programming: Statistical Analysis of Experimental Data, Regression Analysis, Graphical Analysis and Curve Fitting.

Simulation Using Commercial Software: Computational Modeling / Simulation and Validation of Problems Performed through Experiments, subjected to different loading and boundary conditions.

End Semester Project Submission: Practical Experimentation, Computational Modeling and Validation, as well as Statistical / Regression Analysis of Designed / Fabricated Experiment or of Other Problem (as assigned).

Reference Books

1. Experimental Methods for Engineers: Jack P. Holman.
2. Experimental Stress Analysis: James W. Dally and William F. Riley
3. Design & Analysis of Experiments: D. C. Montgomery
4. Design of experiments for Engineers & Scientists: J. Antony
5. Measurement Systems- Applications and Design: E.O. Doebelin
6. Mechanical Measurement: T.G. Beckwith
7. Mechanical Measurements: D.S. Kumar
8. Fortran 95/2003 for Scientists & Engineers: Stephen J. Chapman

AM2210 Wave Propagation in Solids

Designation	:	Elective
Pre-requisites	:	Engineering Mathematics including Differential and Integral Calculus, Advanced Solid Mechanics / Continuum Mechanics.
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme): 20 marks (5 marks for attendance + 15 marks for Take-home assignments and Class Tutorials).

Syllabus

Introduction, Elements of Continuum Mechanics and Linear Elastodynamics: Purpose and overview of the course, **Examples** of wave propagation in forced and free vibration of Solids / structures, **Review of Continuum Mechanics**, Problem statement in **Linear Elastodynamics**, The dynamic reciprocal identity, Reduction to wave equation using Helmholtz decomposition of Displacement field into Scalar and vector potentials.

Waves Propagation in One Dimension: Wave Propagation in general one dimensional elastic continuum, Wave equation for transverse displacement of freely vibrating **Taut String**, Solution by separation of variables, Travelling and Standing wave interpretation and mode shapes; **Axial wave in Bars**, D'Alembert solution for the wave equation, Strain waves and stress waves, Particle velocity vs. wave velocity, Acoustic Impedance, Reflection and transmission at Interface of two materials, Power and energy transport in axial wave, **Flexural waves in Beams**, Solution, Dispersion of Flexural waves, Phase velocity and Group velocity, Power and energy in flexural wave.

Waves Propagation in Two and Three Dimension: General time-harmonic elastic waves in plane, Polar and axial symmetry, Propagation of wavefront, Expansions behind wavefront, General solution approach, Reflection and transmission at interface, Free waves in infinite space, Reflection from a plane boundary, P and SV waves, SH wave, Scattering by a circular cavity, Diffraction of by a long crack, **Axial and flexural wave equations in Plate**, Solution methods, Generalization to **waves in three dimension**, Eigenvalues and Eigen vectors of Wave euqations.

Waveguides and Guided Waves: Overview on waveguides, **Rayleigh waves** – Governing equations and solution, Wave speed & Particle motion, **SH Plate waves** - Symmetric and Antisymmetric modes, Dispersion, Cut-off frequencies, **Lamb Waves** –Group velocity dispersion curves, Guided waves in Isotropic and **Composite Plates**, Dispersion curves for guided waves in composite plates, Guided waves in cylindrical shells, Conclusion.

Application of Wave Propagation for NDE and SHM (Partial self study, as assigned): Overview, *Nondestructive Evaluation* (NDE) techniques for *Structural Health Monitoring* (SHM), Electroactive and Magnetoactive Materials for SHM, Ultrasonic systems for industrial NDE, Guided waves for Inspection of Plates, Application of Waveguides, Laser-Ultrasonic techniques, Electromagnetic Acoustic Transducers, Acoustic Microscopy, *Piezoelectric Wafer Active Sensors* (PWAS), Coupled-field analysis of PWAS Resonators, PWAS Ultrasonic Transducers, Wave propagation and In-situ SHM using PWAS, Signal Processing and pattern recognition for PWAS based SHM, Practical issues with PWAS, Scopes and conclusion.

Reference Books

1. Wave Propagation in Elastic Solids: J. D. Achenbach.
2. Structural Health Monitoring with Piezoelectric Wafer Active Sensors: Victor Giurgiutiu.
3. Ultrasonic Nondestructive Evaluation - Engineering and Biological Material Characterization: Tribikram Kundu.
4. Wave Propagation: Chiang Mei, Rodolfo R. Rosales and Triantaphyllos Akylas.
5. Wave Motion in Elastic Solids: Karl F. Graff.
6. Fundamentals of Shock Wave Propagation in Solids: Lee Davison.
7. Structural Health Monitoring: F. K. Chang.

AM2212 Theory of Stability		
Designation	:	Elective
Pre-requisites	:	Differential Equations, Engineering Mechanics, Mechanics of Solids, Theory of Elasticity.
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme): 20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).

Syllabus

Introduction and Buckling of Columns: Concepts of Stability, Equilibrium path, Stability criteria, Method of Neutral Equilibrium; Recapitulation of Critical Load for Euler Column, Columns with Different Boundary Conditions, Effective-length concept and design curve, Effects of Imperfections / Initial curvature, Eccentricity of loading etc.; Inelastic buckling of columns, Double and Tangent Modulus theory, Shanley's theory.

Beam-columns and Frames: Governing equation for Beam-columns, Displacement solution and stability for single concentrated transverse load, Beam-Columns with other transverse loading and boundary conditions, Semi-analytic / Series solution based on Energy Principles, Post-buckling behavior;

Introduction to buckling of **Frames**, Modes of Buckling, Critical Load of a Frame by Slope-Deflection Equations and Matrix Analysis, Effect of Initial Bending, Framed Columns.

Torsional and Lateral Stability: Stability of Thin-walled open sections, buckling by torsion and torsion-flexure; Lateral stability of beams with various loadings and end conditions.

Stability of Plates and Shells: Differential Equations of plate Buckling linear theory, stability of Rectangular plates under axial compression and shear, Effect of imperfections, Post-buckling behavior of plates;

Stability of cylindrical **Shells** under uniform axial pressure and torsion, Effect of imperfections.

Approximate Methods of Analysis: Energy Principles and Variational Calculus, Rayleigh-Ritz and Galerkin method, Finite Difference and Finite Element Method.

Reference Books

1. Theory of elastic Stability: S. P. Timoshenko and J. M. Gere
2. Principle of Structural Stability Theory: A.Chazes
3. Stability of Theory of Structures: Ashwani Kumar
4. Background to Buckling: H.G. Allen and P.S. Bulson
5. Structural Stability of Columns and Plates: N.G.R. Iyengar

AM2224 Electroacoustic Transducers

Designation	:	Elective
Pre-requisites	:	*Basic Electrical/Electronics Engineering, Wave Propagation*
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme):20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).

Syllabus

Introduction to Acoustics: Acoustic variables & basic relations, plane & spherical waves, reflection & transmission, radiation & reception of acoustic waves, absorption and attenuation of sound.
Electro-Mechano-Acoustical Analogy: Introduction, basic equations and impedances, transformer and gyrator, simple harmonic oscillator, Helmholtz resonator, loop analysis, circuit elements, Lagrange equation.
Acoustical Elements: Basic acoustic elements, specific acoustic impedance, mechanical impedance, electrical impedance, acoustic radiation impedance, duct impedance, equivalent circuit model, various acoustical examples, frequency and wavelength, dB scale, sound pressure level.
Basic Theory and Modeling of Microphone: Introduction, types, response, sensitivity, specifications, directivity pattern, microphone array, microphone equation, electret condenser microphone (ECM), ECM model for various types of microphone.
Basic Theory and Modeling of Moving Coil Transducer: Introduction, types, reciprocal and anti-reciprocal system, TS parameters, speaker non-linearities, equivalent circuit representation, loudspeaker enclosure, types of loudspeaker enclosure and corresponding circuits, total harmonic distortion, intermodulation distortion, miniature loudspeaker.
Theory and Analysis of Piezoelectric Transducer: Brief introduction to piezoelectricity, piezoelectric materials, piezoelectric devices, polarization, equivalent circuit, piezoelectric accelerometer, piezoelectric speaker, piezoelectric microphone.
Term Paper: On recent advances based on literature survey and/or lab/industry visit.

Reference Books

1. Acoustics: L. L. Beranek.
2. Introduction to Electro acoustics and Amplifier Design: W. M. Leach.
3. Acoustics-An Introduction: H. Kuttruff.
4. Fundamentals of Acoustics: Kinsler, Frey, Coppens, and Sanders.
5. Audio Engineer’s Reference Book: Michael Talbot-Smith(Editor).

AM2206 Computational Fluid Dynamics		
Designation	:	Elective
Pre-requisites	:	*Engineering Fluid Mechanics, Heat Transfer, Engineering Mathematics, CAD, Computer programming.*
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme): 20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials etc).

Syllabus

Basic ideas of CFD: Introduction to CFD, role of CFD and its applications, future of CFD.
Governing equations (GE's) of Fluid dynamics: Modeling of flow, control volume concept, substantial derivative, physical meaning of the divergence of velocity. Continuity equation, momentum equation, energy equation and its conservation form. Equations for viscous flow (Navier-Stokes equations), equations for inviscid flow (Euler equation). Different forms of GE's, initial and boundary conditions.
FVM for Diffusion Problems: FVM for 1D steady state diffusion, 2D steady state diffusion, 3d steady state diffusion. Solution of discretised equations- TDMA scheme for 2D and 3D flows.
FVM for Convection-Diffusion Problems: FVM for 1D steady state convection-diffusion, Central differencing scheme, Conservativeness, Boundedness, Transportiveness, Upward differencing scheme, Hybrid differencing scheme for 2D and 3D convection-diffusion, Power-law scheme, QUICK scheme.
Solution Algorithm for Pressure-velocity Coupling in Steady Flows: Concept of staggered grid, SIMPLE, SIMPLER, SIMPLEC, PISO algorithm.
FVM for Unsteady Flows: 1D unsteady heat conduction (Explicit, Crank-Nicolson, fully implicit schemes), Implicit mecthods for 2D and 3D problems, Discretization of transient convection-diffusion problems, solution procedure for transient unsteady flow calculations (transient SIMPLE, transient PISO algorithms).
Grid Generation: General transformation of the equations. Metices and Jacobians. Types of grids-structured and unstructured grids, grid generation methods- algebraic, differential and hybrid methods. Coordinate stretching, boundary-fitted coordinate systems. Elliptic and hyperbolic grid generation methods, orthogonal grid generation for Navier-Stokes equations, Multi-block grid generation.
Latest development in CFD techniques and newer applications.

Reference Books

1. "An Introduction to Computational Fluid Dynamics: the Finite Volume Method", H.K. Versteeg and W. Malalasekara, 2nd edition, Pearson Education, England, 2007.
2. "Computational Fluid Dynamics for Engineers" B. Andersson & others, 1st edition, Cambridge University Press, U.K., 2012.
3. "Computational Fluid Flow and Heat Transfer" (2nd edition), K. Muralidhar and T. Sundararajan, Narosa Publishing, 2004.
4. "Numerical Heat Transfer and Fluid Flow", S.V. Patankar, McGraw-Hill, New York, 1980.
5. "Principles of Computational Fluid Dynamics", P. Wesseling, Springer-Verlag.
6. "Computational Techniques for Fluid Dynamics Volume I & II" (2nd edition), C.A.J. Fletcher, Springer-Verlag, 1991.
7. "Computational Fluid Mechanics and Heat Transfer" (2nd edition), J.C. Tannehill, D.A. Anderson and R.H. Pletcher, Taylor and Francis, 1997.
8. "Numerical Computation of Internal and External Flows" (Vols. I & II), C. Hirsch, Wiley International, 1988.
9. "Computational Fluid Dynamics for Engineers" (Vols. I & II), K. Hoffmann and S. T. Chiang, Engineering Education System, 1993.

AM2213 Mechanics of Composite Materials		
Designation	:	Elective
Pre-requisites	:	*Continuum Mechanics / Solid Mechanics, Basic Engineering Mathematics, Linear Algebra, Differential Equations*
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme): 20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).

<u>Syllabus</u>

Introduction: Classification and characteristics of composites, Conventional vs. Composite materials, Advantages and limitations, Salient applications in various fields, Fabrication technologies, Properties of matrix and reinforcement materials

Micromechanics: Fiber volume fraction, micro-mechanical relations, determination of strength and stiffness, Environmental effects-Hygro-thermal behavior.

Macromechanics: Basic stress-strain relationships for anisotropic materials, engineering constants for orthotropic materials, stress-strain relations for a lamina of arbitrary orientation, effective moduli, invariant properties of anorthotropic lamina, special cases of laminate stiffness, laminate strength analysis, concept of inter-laminar stresses and delamination

Failure theories and Damage mechanics: Failure mechanisms, maximum stress theory, maximum strain theory, Tsai-Hill theory, Tensor polynomial failure criterion, first ply failure theory, Introduction to damage theory based on continuum damage mechanics.

<u>Reference Books</u>

1. Mechanics of fibrous composites: Carl T. Herakovich
2. Principles of Composite Material Mechanics: R. F. Gibson
3. Mechanics of Composite Materials: R. M. Jones
4. Introduction to Composite Material: Stephen W.Tsai and H. Thomas Hahn
5. Composite Materials and their use in Structures: J. R. Vinson and T.W. Chou

AM2214 Multi-Functional Materials and Structures		
Designation	:	Elective
Pre-requisites	:	Engineering Mathematics, Basic Materials Science, Advanced Solid Mechanics.
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme): 20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).

Syllabus

Introduction and Mathematical Preliminaries: History of advanced material developments, Basic ideas, Demand and applications of multifunctional materials in industry, Tensor analysis, PDEs.

Elementary Anisotropic Elasticity: Deformation, Stress and Strain Tensor, Strain-Displacement and Compatibility Equations, Constitutive relations, Elasticity Tensor and Generalized Hooke's law, Balance Laws and Equilibrium equations, Constitutive relations for Orthotropic, transversely isotropic and isotropic materials.

FRP Reinforced Laminated Composites: Effective lamina properties from fiber-matrix micro mechanics, material and reference axis system, Transformed stiffness of lamina, Stiffness of a laminate, Multidirectional FRP Reinforced Laminated Composites, Hygro-thermal effects.

CNT Reinforced Composites: Basics and categories of CNTs, Effective mechanical properties of CNTs – MD simulation and other methods, Effective properties of CNT reinforced composites.

Functionally Graded Materials (FGMs): Basic idea based on Lessons from Nature, Graded microstructure - Characteristic dimensions and spatial variations, Volume Fraction, rules of mixture and effective field parameters; Characterization of properties of FGM, Macrostructuralthermomechanical properties, Effective material properties for ceramic-metal FGMs, Basic mathematical modeling.

Smart Materials and Composites: Piezoelectric materials, Shape Memory Alloys and Super-elastic Materials, Numerical Modeling of Smart Materials, Aerospace and Biomedical Applications of Smart Materials.

Analysis of Structures (beams and plates) of Functional Materials: Basic beam and plate theory, Analysis of FRP / CNT reinforced laminated composite structures, Analysis of Functionally graded structures, Smart structures with electromechanical loading, Failure criterion and design philosophies.

Reference Books

1. Structural Analysis of Polymeric Composite Materials: Tuttle, Mark E.
2. Shape Memory Alloys: Modeling and Engineering Applications: Lagoudas, Dimitris C. (Ed.)
3. Smart Materials and Structures: M.V. Gandhi and B.S. Thompson
4. Functionally Graded Materials - Nonlinear Analysis of Plates and Shells: Hui-Shen Shen

AM2215 Multiscale Modeling of Advanced Materials		
Designation	:	Elective
Pre-requisites	:	Engineering Mathematics, Basic Materials Science, Advanced Solid Mechanics.
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme): 20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).

Syllabus

Introduction: Examples and motivation for exploring multiscale behaviour of materials, Relevant material properties at different scales.
Review of Preliminaries: Prerequisite mathematics, Fundamentals of Thermodynamics and statistical mechanics.
Molecular Dynamics and Related Issues: Particle-based methods, EAM/MEAM potentials: bridging from QM, Atomistic Plasticity, Damage & Fatigue, Molecular Dynamic Simulation Methods
Meso-scale methods: Overview and need, Quasi-continuum methods, Density Functional method.
Homogenization and Bridging: Multi-scale homogenization and stochastic homogenization, Inter-scale exchange and Scale bridging.
Computational Application: Variational multiscale methods, Numerical resolution and asymptotic behaviour of stochastic PDEs, Enriched continuum models and design.

Reference Books

1. Nano Mechanics and Materials: Theory, Multiscale Methods and Applications: Liu, Wing Kam, Karpov, Eduard G., and Park. Harold S.

2. An Introduction to Thermal Physics: Schroeder, Daniel V.

3. A First Course in Finite Elements: Fish, Jacob and Belytschko, Ted.

4. Nonlinear Finite Elements for Continua and Structures: Belytschko, Ted, Liu, Wing Kam, and Moran, Brian.

AM2216 Applied Plasticity		
Designation	:	Elective
Pre-requisites	:	*Continuum Mechanics/Applied Elasticity*
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme):20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).

Syllabus

Crystal plasticity: Resolved shear stress & strain, Lattice slip systems, Hardening, Yield surface, Flow rule, Micro to Macro plasticity.

Stresses and Strains: The Stress–Strain Behaviour, Analysis of Stress, Mohr's Representation of Stress, Velocity gradient and rate of deformation, Kinematics of large deformation, The Criterion of Yielding, Yielding of materials under complex stress state, Choice of yield function.

Non-Hardening & Elastic-Perfect Plasticity: Classical theories and its application to uniform & non uniform stress states, Hencky vs. Prandtl-Reuss, Elastic–Plastic Torsion and Bending of Beams, Thick walled cylinders.

Theory of the Slipline Field: Formulation of the Plane Strain Problem, Properties of Slipline Fields and Hodographs, Stress Discontinuities in Plane Strain, Construction of Slipline Fields and Hodographs, Analytical and Matrix Methods of Solution, Explicit Solutions for Direct Problems, Some Mixed Boundary-Value Problems, Superposition of Slipline Fields.

Limit Analysis: Collapse of Beams & Structures, Transverse loading of circular plates.

The Flow Curve: Uniaxial tests, Torsion tests, Compression tests, Bulge test, Equations to flow curve, Strain & work hardening hypothesis.

Plasticity with Hardening: Isotropic hardening, Non associated flow rules, Prandtl-Reuss flow theory, Kinematic hardening.

Plastic Instability: Inelastic buckling of struts, Buckling of plates, Tensile instability, Circular bulge instability, Plate stretching.

Reference Books

1. Theory of Plasticity: J. Chakrabarty.
2. Plasticity Theory: Jacob Lubliner.
3. Basic Engineering Plasticity: DWA Rees.
4. The Mathematical theory of plasticity: R.Hill.
5. Finite Elements in Plasticity- Theory & Practice: D. R. J. Owen and E. Hinton.
6. Continuum Theory of Plasticity: S. Huang.
7. Fundamentals of the Theory of Plasticity: L.M. Kachanov.
8. Plasticity for Engineers: Theory and Applications: C. R. Calladine.

AM2217 Fracture Mechanics		
Designation	:	Elective
Pre-requisites	:	*Continuum Mechanics/Applied Elasticity*
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme): 20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).

Syllabus

Introduction: Modes of loading, Crack growth and fracture mechanisms, Need for fracture mechanics, Linear elastic fracture mechanics and elastic plastic fracture mechanics.

Energy Release Rate: Surface Energy, Resistance, Griffith Theory of fracture, Extension of Griffith Theory by Irwin and Orowan, R-Curve, Pop-in phenomena, Crack branching. Necessary and sufficient conditions for fracture.

Crack-Tip Stress and Displacement Fields: Airy's stress function, Westergaard's approach, Generalized Westergaard's approach, William's Eigen function approach, Multi-parameter stress field equations, Influence of the *T*-stress and higher order terms, Role of photoelasticity on the development of stress field equations in fracture mechanics.

Stress Intensity Factor: Equivalence between SIF and *G*, Various methods for evaluating Stress Intensity Factors.

Crack Tip Plastic Zone: Modeling plastic zone at the crack-tip, Irwin and Dugdale models.

Fracture Toughness Testing: Qualitative toughness testing, K_{IC} testing, K-R curve testing, J_{IC} measurements, J-R curve testing, CTOD testing.

Micromechanics of Fracture: Cohesive strength of solids, Cleavage fracture, Intergranular fracture, Ductile fracture, Crack detection methods.

Reference Books

1. Elementary Engineering Fracture Mechanics: D. Broek.
2. Elements of Fracture Mechanics: Prashant Kumar.
3. Fracture Mechanics - Fundamentals and Applications: T. L. Anderson.
4. Introduction to Fracture Mechanics: Kare Hellan.
5. Fracture Mechanics- With an Introduction to Micromechanics: Dietmar Gross and Thomas Seelig.
6. Fracture Mechanics- An Introduction: E.E. Gdoutos.

AM2218 Continuum Damage Mechanics		
Designation	:	Elective
Pre-requisites	:	*Continuum Mechanics, Linear Algebra, Differential Equations*
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme):20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).

Syllabus

Essentials of Continuum mechanics: Tensorial notation, stress, strain, invariants, equilibrium equations, Domain and validity of continuum damage mechanics, concept of representative volume element.

Phenomenological aspects of damage: Damage, measurement of damage, modeling of damage through effective area reduction, void volume fraction and stiffness reduction, representation of damage through different orders of tensors, concept of effective stress, hypothesis of strain equivalence, strain energy equivalence, and complementary strain energy equivalence.

Thermodynamics of damage: State variables, damage as state variables, first and second law of thermodynamics, thermodynamics potentials, dissipation potentials, constitutive equations, evolution equations.

Kinetic Laws of Damage Evolution: Unified formulation of damage laws, damage laws for brittle, quasi-brittle, ductile, creep, low cycle and high cycle fatigue.

Damage Analysis of Structures: Implementation of isotropic damage theory, case studies from literature.

Reference Books

1. A Course on damage mechanics: Jean Lemaitre.
2. Continuum damage mechanics: S. Murakami.
3. Mechanics of solid materials: Jean Lemaitre and J. L. Chaboche.
4. An Introduction to damage mechanics: L. M. Kachanov.
5. Damage mechanics with finite elements: P. I. Kattan and G. Z. Voyiadjis.
6. Damage mechanics: Dusan Krajcinovic.
7. Damage mechanics: George Z. Voyiadjis and Peter I. Kattan.

AM2219 Analysis and Design of Composite Structures		
Designation	:	Elective
Pre-requisites	:	*Continuum Mechanics / Solid Mechanics, Basic Engineering Mathematics, Linear Algebra, Differential Equations*
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme): 20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).

Syllabus

Introduction: Anisotropic elasticity, Virtual Work Principles, Variational Methods, Transformation of Stresses & Strains,

Analysis of Composite Structures: Classical lamination theory, shear deformation theories, Bending, Buckling and Vibration of Beams, Plates and Shells, Damage Mechanisms and Failure Theories.

Characterization and Testing: Characterization of fiber & matrix, Mechanical Testing: Tension, Compression, Shear, Flexure, Fracture Toughness, Impact and Compression After Impact (CAI).

Introduction to Composite Design: Framework for Composite Design, Ply Orientation and arrangement, Use of Failure Criterion, Sizing of the Laminates.

Reference Books

1. Mechanics of fibrous composites: Carl T. Herakovich.
2. Introduction to Composite Material: Stephen W. Tsai and H. Thomas Hahn.
3. Composite Materials and their use in Structures: J. R. Vinson and T.W. Chou.
4. Composite Structures-Testing, Analysis and Design: J. N. Reddy and A.V. Krishna Moorty.
5. Composite Materials - Design and Applications: D. Gay, S. V. Hoa, S. W. Tsai.
6. Introduction to Composite Materials Design: E J. Barbero.