## School of Mechanical Sciences

### Courses List

| Course code | Course Title | Credit Structure | | | |
|---|---|---|---|---|---|
| | | L | T | P | C |
| ME601 | Advanced Materials Welding | 3 | 0 | 0 | 6 |
| ME602 | Advanced Convective Heat Transfer | 3 | 0 | 0 | 6 |
| ME603 | Advanced Optimisation Techniques | 3 | 0 | 0 | 6 |
| ME604 | Aerosol Technolgy | 3 | 0 | 0 | 6 |
| ME605 | Computational Heat and Fluid Flow | 3 | 0 | 0 | 6 |
| ME606 | Computer Integrated Manufacturing | 3 | 0 | 0 | 6 |
| ME607 | Fracture, Fatigue and Durability of Materials | 3 | 0 | 0 | 6 |
| ME608 | Fundamentals of Combustion | 3 | 0 | 0 | 6 |
| ME609 | Introduction to Interfacial Sciences and Nano Technology | 3 | 0 | 0 | 6 |
| ME610 | Mathematical Methods | 3 | 0 | 0 | 6 |
| ME611 | Mechanics of Granular Materials | 3 | 0 | 0 | 6 |
| ME612 | Reliability Based Design | 3 | 0 | 0 | 6 |
| ME613 | Continuum Mechanics | 3 | 0 | 0 | 6 |
| ME614 | Thermofluids Engineering | 3 | 0 | 0 | 6 |
| ME615 | Finite Element Method | 3 | 0 | 0 | 6 |
| ME616 | Gas Dynamics | 3 | 0 | 0 | 6 |
| ME617 | Mechanics of Composite Materials | 3 | 0 | 0 | 6 |
| ME618 | Advanced Finite Element Method | 3 | 0 | 0 | 6 |
| ME619 | Microscale transport Phenomena and Microfluids | 3 | 0 | 0 | 6 |
| ME620 | Theory of Elasticity | 3 | 0 | 0 | 6 |
| ME621 | Energy, Environment, and Economics | 3 | 0 | 0 | 6 |
| ME622 | Introduction to Scientific and Parallel Computing | 3 | 0 | 0 | 6 |
| ME623 | Multiscale Modeling of Composite Material Systems | 3 | 0 | 0 | 6 |

**ME 601** **Advanced Materials Welding** **(3-0-0-6)**

Offered to: UG/ PG

Pre-requisites: Nil

Introduction to advanced materials joining processes; microjoining and nanojoining, wire ball bonding; Advanced resistance welding, induction welding, Stud welding; Magnetically impelled arc welding; fundamentals and types of laser welding including hybrid processes; Advanced GMAW and GTAW, activated GTAW; Plasma arc welding, electron beam welding; pressur e welding; ultrasonic welding; explosive welding; diffusion bonding; Friction Welding, friction stir welding; electro-magnetic pulse welding; welding of super alloys, additive manufacturing/ 3D printing, fundamentals of welding automation, welding sensors and data acquisition; welding process modeling and optimization; principles of robotic welding; weld defects; nondestructive inspection and testing of weldments. Mechanical and Microstructural characterization of welds.

**Texts / References**

1. Welding Fundamentals and Processes, ASM Handbook, Vol 6 A, November 2011, AM International
2. Welding Handbook, Welding Processes Part 2, Vol. 3, AWS, 2004.
3. Y N Zhou, Microjoining and Nanojoining , Woodhead publishing, 2008.
4. W Steen, Laser Material Processing, Springer-Verlag, 1991.
5. Liming Liu, Welding and Joining of Magnesium Alloys, Woodhead Publishing, 2010.
6. L-E Lindgren, Computational welding mechanics, Woodhead Publishing Limited 2007.

**ME 602 Advanced Convective Heat Transfer (3-0-0-6)**

Prerequisite: Undergraduate level thermal fluid courses
Course Level: PG/PhD open elective

Course Content:
Introduction to Convective Heat Transfer, governing equations: momentum, energy conservation equation. External forced convection: scaling analysis, similarity solution and integral solution of momentum and energy. Suction and Blowing. Falkner-Skan equation. Internal forced convection: developing flow, hydrodynamically fully developed flow, Mean temperature, flow with uniform heat flux, flow with uniform wall temperature, heat transfer. Laminar slug flow, power law fluids. External natural convection: scaling analysis, similarity and integral solution, with uniform heat flux, with uniform wall temperature. Mixed Convection. Internal Natural Convection: Scaling analysis, heat transfer regimes, partially divided enclosure, inclined enclosures. Introduction to Turbulence: Reynold's averaged Navier-Stokes equation, Turbulent boundary layer, viscous sublayer, fully turbulent sublayer, heat transfer in turbulent boundary layer. Turbulent internal flow. Turbulence modeling: k-epsilon, K-omega, Reynolds stress equation model (RSM) and other models. Convection with change of phase: boiling, condensation. Brief introduction to mass transfer.

**Text and Reference Books:**

"Convection Heat Transfer", Adrian Bejan, Wiley, 4th Edition, 2013. ISBN 78-0-470-90037-6.

1. "Convective Heat Transfer", Louis C Burmeister, Wiley, 2nd Edition, 1993. ISBN 978-0471577096.

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**ME 603** **Advanced Optimization Techniques** **(3-0-0-6)**

Offered to: UG/ PG

Pre-requisites: IEOR

**Contents:**

- Review of Linear Programming Methods and Models
- **Post optimal Analysis in Linear Programming**: Applications of Modified Simplex Method, Sensitivity Analysis
- **Dynamic Programming**
- **Game Theory**: Two Person Zero Sum Games, Pure and Mixed Strategy Problems, Rule of Dominance
- **Non-Linear Programming**: Classical and Numerical Methods for Single and Multivariable Optimisation, Kuhn-Tucker Conditions, Cutting Plane Method, Lagrange's method
- **Multi Criteria Decision Making**: AHP, TOPSIS, COPRAS, Evidential Reasoning, DEA
- **Genetic Algorithm:** Single and Multiple Objective GA -- Unconstrained & Constrained
- Introduction to Simulated Annealing, Ant Colony Optimization Particle Swarm Optimization, Artificial Neural Network, Tabu Search
- Introduction to System Simulation

**Recommended Readings:**


1. Singiresu S. Rao; Engineering Optimization – Theory and Practices; New Age International Publishers; 3rd Edition; 2013.
2. Hamdy A. Taha; Operations Research; Pearson Prentice Hall; 8th Edition; 2008.
3. Fredrick S. Hillier, G. J. Liberman; Introduction to Operations Research; McGraw Hill Inc.; 1995.
4. Kalymanoy Deb; Optimization for Engineering Design; PHI; 2003.
5. Christos H. Papadimitriou, Kenneth Steiglitz; Combinatorial Optimization; PHI; 2006.
6. David E. Goldberg; Genetic Algorithms in Search, Optimization and Machine Learning; Addison – Wesley; 1989.
7. Kalymanoy Deb; Multi-objective Optimization Using Evolutionary Algorithms; John Wiley & Sons; 2001.
8. Dorigo M., Stutzle T.; Ant Colony Optimization; Cambridge M. A., MIT Press; 2004.
9. Maurice Clerc; Particle Swarm Optimization; ISTE Ltd.; 2006.
10. Glover, Fred W., Laguna, Manuel; Tabu Search; Springer US; 1997.
11. P. J. van Laarhoven, E.H. Aarts; Simulated Annealing: Theory & Applications; Springer US; 1987.

**ME 604** **Aerosol Technology** **3-0-0-6**

Offered to: UG/ PG

Pre-requisites: Nil

**Course content:**Particle Size, shape, concentrations. Size distributions. Moments. Weighted distr ibutions.Particle motion, Stokes' law, settling velocity. Langevin Dynamics, Brownian Dynamics.
Formation, growth and coagulation of nanoparticles, condensation and nucleation, coagulation kernels.
Nonspherical nanoparticles, statistical fractals and fractal structure, aggregation of non-spherical nanoparticles.
Filtration, deposition mechanisms, respiratory deposition.
Common measurement techniques, mobilitybased measurements, equivalent diameters, characterization of non-spherical nanoparticles.
Aerosols and radiative properties, effects on air pollution.

**References:**

1) Hinds, W. C., "Aerosol technology: properties, behavior, and measurement of airb orne particles", John Wiley & Sons, United States. 2nd edition.

2) Friedlander, S.K., "Smoke, Dust and Haze: Fundamentals of aerosol dynamics", Oxford University Press, United Kingdom.

**ME 605** **Computational Heat and fluid flow** **3-0-0-6**

Offered to: UG/ PG

Pre-requisites: Fluid Mechanics (ME219) or any related course

Course content:

1. Preliminaries: Continuum approximation, governing equations for fluid flow and heat transfer, introduction to computational fluid dynamics
2. Discretization methods: Finite difference method: Taylor series, backward, forward and central differences, truncation error, discretization of 1D diffusion equation, TDMA and Gauss-Seidel method

Finite volume method: Control volume approach, basic rules

3. Finite volume method for diffusion problems: Discretization and solution of 1D diffusion equations, boundary conditions, unsteady 1D diffusion equation, explicit, Crank-Nicolson and implicit schemes, 2D and 3D situations
4. Finite volume method for convection-diffusion equations: Failure of central schemes,properties of discretization schemes, upwind, QUICK, hybrid and power law schemes, 2D and 3D discretized equations

5. Finite volume method for Navier-Stokes equations: Navier-Stokes equations, related difficulties, staggered grid, SIMPLE, SIMPLER, SIMPLEC and PISO, fractional step method

**References:**

1. An Introduction to Computational Fluid Dynamics: The Finite Volume Method, H. Versteeg, W. Malalasekera, 2nd edition, Prentice Hall, 2007

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

3. Computational Fluid Dynamics: The Basics with Applications, J. D. Anderson, McGraw Hill Education, 2017

4. Computational Methods for Fluid Dynamics, J.H. Ferziger, M. Peric, 3rd edition, Springer, 2002

**ME 606** **Computer Integrated Manufacturing** **3-0-0-6**

**Offered to:** UG/PG
**Pre-requisites:** Nil

Introduction to Computer Integrated Manufacturing (CIM). Computer-Aided Design (CAD)., Computer Graphics, Computer-Aided Manufacturing (CAM). CAD/CAM Integration. Industrial automation and control technologies, ADC and DAC, CNC programming, Material Handling
technologies. Automatic Data Acquisition technologies. Various Manufacturing Systems: Group Technology & Cellular Manufacturing Systems, Flexible Manufacturing Systems, Robotics, Transfer lines, Automated Material Handling and Assembly Systems, Automated Guided Vehicles, Automated Storage and Retrieval System. Quality Control Systems. Computer-Aided Process Planning.
Concurrent Engineering. Production Planning and Control Systems. Lean and Agile Manufacturing. Concurrent engineering, Web-based manufacturing.

**Texts/References:**

[1] S. S. Pande, Computer Graphics and Product Modeling for CAD/CAM, Narosa Publication, ISBN 978-81-8487 128-9, 2012
[2] Groover, M. P., Automation production systems, and computer-integrated manufacturing, second edition, Prentice-Hall of India, New Delhi, 2001.
[3] System approach to Computer-integrated design and manufacturing, Nanua Singh, Wiley India 1995. ISBN: 978-0-471-58517-6

**ME 607** **Fracture, Fatigue and Durability Of Materials** **3-0-0-6**

**Course Level:** UG/PG Level
**Prerequisite:** For UG student Minimum CPI is required

Principles of Elastic and Elastic-plastic fracture principles. Experimental evaluation of Fracture and Fatigue strength of engineering materials, Standards and experimental procedures for measurement of properties based on fracture mechanics approach. Applications to safe life design of components. Mechanisms of damage due to fatigue during service. Methods of evaluation of fatigue strength. Conventional and fracture mechanics based approach for evaluation of materials for fatigue damage and crack growth. Mechanisms of mechanical failures, failure analysis and approaches for failure prevention. Damage characterization using non-destructive testing and evaluation. Application of the concepts of fracture, fatigue and damage evaluation procedures for design and residual life assessment. Environmental damage and control. Principles and methods on Non Destructive testing. Detection and characterization of defects during pre-service and in-service inspection of components and structures. Principle of general and localized corrosion. Methods of evaluation of corrosion resistance of materials. Corrosion control practices. Advantages and limitations of safe-life design concepts based on fracture mechanics and damage tolerance approaches.

**References:**

1. Fracture Mechanics: Fundamentals and Applications, Third Edition, T.L. Anderson (CRC Press, 2005),
2. Electrochemical Methods of Corrosion Testing, Metals Hand Book. Vol 13, Sully J R and Taylor D. W. 1987
3. Fracture and Fatigue Control in Structures: Applications of Fracture Mechanics Third Edition, John M. Barsom and Stanley T. Rolfe, ASTM, 1999
4. Metals Handbook Volume 17 - Nondestructive Evaluation and Quality Control, ASM International, Materials Park, OH.5. Grandt,
5. Fundamentals of Structural Integrity: Damage Tolerant Design and Nondestructive Evaluation, A. F. Jr.,John Wiley & Sons, Inc. Hoboken, NJ, 2004.

**ME 608** **Fundamentals of Combustion** **3-0-0-6**

Offered to: UG/PG

Pre-requisites: Nil

Course Contents

1. Introductory thermodynamics, Laws of Thermodynamics, idea gas mixtures, and introduction to heat and mass transfer
2. Fuels and their properties, Stoichiometry, chemical equilibrium, adiabatic flametemperature, enthalpy of combustion, basic combustion kinetics, derivation of the governing equations for a reacting flow, application to flow reactor models
3. Classification of flames, laminar vs. turbulent, deflagration vs. explosion vs detonation, premixed vs diffusion
4. Theory of premixed flame, flammability limits, quenching and blow-off, Ignition, Flame stabilization,
5. Introduction to diffusion flames and combustion of jets, Turbulent premixed and non-premixed flames,
6. Droplet evaporation and combustion, Combustion of a carbon particle

**Text Books**

1. An Introduction to Combustion Concepts and Applications by S.R. Turns, McGraw Hill
2. Analytic Combustion by Anil W. Date, Cambridge University Press
3. Understanding Combustion by H.S. Mukunda, Macmillan India

**Reference Books**

1. Principles of Combustion by Kenneth Kuo, John Wiley
2. Combustion by Irvin Glassman, Academic Press
3. Combustion Theory by F. A. Williams, ABP
4. Turbulent Combustion by Norbert Peters - Cambridge University Press
5. Combustion Physics by Chung K. Law - Cambridge University Press

**ME 609 Introduction to Interfacial Science and Nanotechnology 3-0-0-6**

**Prerequisite:** Undergraduate level thermal fluid courses and introductory Physics and Chemistry.

**Course Level:** PG/PhD open elective

**Course Content:**

Introduction to interfacial science, colloids and nanotechnology, Classification of colloi dal systems, Size distributions, shape, density, weighted distributions of nanoparticles.

Surface thermodynamics, surface tension, Contact angle, Wetting and Capillary phenomena. SAMS, wetting, Surface engineering. Surfactants and micellar thermodynamics, surfactant ph aseequilibria. Adsorption and adsorption isotherms, LangmuirBlodgett layers and Bila yers. Emulsions.

Molecular forces overview, self-diffusion and Brownian motion, Interactions of polar and dipolarmolecules, dispersion forces, Van der Waals forces between surfaces and particles.

Electrostatics: Basics, Effect of electrolyte and DLVO theory, Colloidal interactions not described by DLVO theory. Interactions between biological molecules. Electrophoresis, Zeta Potential, Dielectrophoresis.

Optical phenomena and Different types of microscopes. Scattering methods: Light, X-ray and neutron scattering.

Nanoparticles: Fractal aggregates. Synthesis, Applications, Characterization of spherical and non-spherical nanoparticles.

Micro-nano Fabrication: Lithographic and Non Lithographic Process. Photolithography, E- Beam Lithography, Soft Lithography, AFM based nanolithography, Dip pen Lithography etc.Microfluidics: Fundamentals, Applications: bioassays and bioarrays, Lab-on-a-chip. Self- assembly of photonic and electronic materials.

Nanomaterials and nanotechnologies implications for manufacturing, environment and society. Filtration of nanoparticles, nanotoxicology. Perspectives and entrepreneurial case studi es. General review.

**Text & Reference Books:**


1. "Intermolecular and Surface Forces", J. N. Israelachvili, Academic Press, 3rd edition, 2011. I SBN978-0-12-375182-9 (Text).
2. "The Colloidal Domain: Where Physics, Chemistry, Biology and Technology Meet", D. F. E vans and H. Wennerstrom, Wiley-VCH, 1999. ISBN 978-0-471-24247-5.
3. “Springer Handbook of Nanotechnology”, Editor: Bharat Bhushan, SpringerVerlag, 3rd edition n,2010, ISBN: 978-3-642-02524-2.
4. Selected representative papers and study materials will be given to student to cover different topics.

**ME 610** **Mathematical Methods** **3-0-0-6**

Pre-requisite: None

Course level: PG/ PhD course,

Openelective

Course content

Linear Algebra: Linear vector space, Matrices and determinants, Inner product and Gram-Schmidt orthonormalization, Eigenvalues and eigenvectors, Hermitian and symmetric matrices, Methods to solve system of simultaneous equations.

Ordinary Differential Equation: Linear homogeneous and inhomogeneous equations for linear differential equations, Bernouilli and Riccati equations, adjoint operators, Strum- Liouville equations, Series solutions, special functions – Bessel, Legendre and Hermite equations.
Complex variables: Complex numbers and their properties, limits, analytic function, Cauchy

Riemann equations, Singularity – Poles, Branch points and branch cuts, Taylor and Laurent series, Cauchy residue theorem and contour integration, conformal mapping.

Vectors and Tensors: Vector analysis, introduction to Tensor analysis, Coordinate transformation and Jacobian, Gauss divergence, Stokes theorem, Irrotational and solenoidal vector fields, Helmholtz decomposition, Metric tensor, covariant and contravariant derivatives.
Partial Differential Equation: Characterization of PDEs, Separation of variables- wave equation and Laplace equation in multi-dimensions, Poisson equation, eigenfunction expansion method, Green's function, Fourier and Laplace transform and their application to differential equation.

**References**

1) Bender, C.M and Orsag S.A. (1978) Advanced Mathematical methods for Scientists and Engineers, McGraw-Hill
2) Horn R.A. and Johnson C.R., Matrix analysis, Cambridge University Press

3) Ablowitz M.J, and Fokas A.S. (1998) Complex variable: Introduction and Applications, Cambridge University Press,

4) Aris R. (1962) Vectors, Tensors and the basic equations of fluid mechanics, Dover Publications

5) Arfken, Weber, Harris (2012), Mathematical methods for physicists, Seventh edition, Academic Press.

**ME 611 Mechanics of Granular Materials 3-0-0-6**

**Pre-requisites:** None
**Course Level:** Open elective for UG (4th year)/PG/PhD

**Course Content:** (a) Introduction: Definition of granular media. Dry and wet granular materials.Ex amples of natural and industrial processes. Classification of flow regimes. Inter-particle forces. Modelling approaches.
(b) Granular solid: Stress, Strain, Principal Stresses, Mohr's circle; Ideal Coulomb material, Mohr Coulomb model, Angle of repose; Janssen's analysis for the static stress field in a siloPacking characteristics. Force chains.
(c) Granular liquid: Balance laws for continuum models. Rheology of dense granular flows. Depthaveraged approach. Mixing and segregation. Granular flow in a silo.
(d) Granular gases: Analogies and differences with a molecular gas. Hydrodynamic description of rapid granular flows. Heuristic hydrodynamic theory. Kinetic theory.

**References:**
(a) An Introduction to Granular Flow by Rao and Nott, Cambridge University Press.
(b) Statics and Kinematics of Granular Materials by R. M. Nedderman, Cambridge Universit y Press.
(c) Granular Media: Between fluid and solid by Andreotti, Forterre and Pouliquen, Cambridge University Press.

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**ME 612 Reliability Based Design 3-0-0-6**

Offered to: UG/PG

Pre-requisites: Nil
**Contents:** Review of Probability, Probability Plotting, Reliability and its Measures, Reliability Analysis for Various Distributions, Reliability of Systems, Fault Tree Analysis, Markov Analysis, Reliability Allocation, Reliability Optimization, Reliability Based Design, InterferenceTheory,Reliability BasedDesignofMechanicalComponents, Maintainability, Availability, FMECA

**Recommended Readings:**

1. C. E. Ebeling; An Introduction to Reliability and Maintainability Engineering; Tata McGraw Hill; 2000.
2. K. C. Kapur, L. R. Lamberson; Reliability in Engineering Design; Wiley India; 1997.
3. S. S. Rao; Reliability Engineering; Pearson Education; 2016.
4. Elsayed A. Elsayed; Reliability Engineering; John Wiley & Sons; 2012.
5. E. E. Lewis; Introduction to Reliability Engineering; John Wiley & Sons; 1996.

**ME 613 Continuum Mechanics 3-0-0-6**

1. Introduction and essential mathematics: Concept of continuum, Vectors and Tensors, Indicial notation, Coordinate transformations, Principal values and directions, Invariants of a second-order tensor, Dyadic product, Vector and tensor calculus.

2. Kinematics of deformation: Configurations of a body, displacement, velocity, acceleration, Lagrangian and Eulerian descriptions of ow field. Deformation gradient tensor, Finite strain tensor, Infinitesimal strain, Principal strains, Dilatation, Compatibility equations. Velocity gradient tensor, Rate of deformation tensor, Spin tensor. Example of some simple flows.

3. Stress and conservation laws: Surface traction, Cauchy's stress principle, Symmetry of stress tensor, Principal stresses, Stress invariants, Stress deviator tensor. Some simple states of stress: uniform extension, pure bending, pure torsion, etc. Conservation laws: mass, linear momentum, angular momentum, and energy.

4. Constitutive law and boundary value problems: Frame indifference, Material symmetry. Constitutive equations for general linear elastic solid: isotropic, orthotropic and transversely isotropic solid.

Constitutive equation for Newtonian fluid. Incompressibility. Solution of some boundary value problems of solids and fluids.

**Reference/Text books:**

1. Continuum Mechanics, A. J. M. Spencer. Dover Publications, New York.

2. Continuum Mechanics, P. Chadwick. Dover Publications.

3. Continuum Mechanics for Engineers, G. Thomas Mase and George E. Mase. CRC Press.

4. Continuum Mechanics: Foundations and Applications of Mechanics (Vol. 1), C. S. Jog.

Cambridge University Press.

5. Elasticity: Theory, Applications and Numerics, Martin H. Sadd. Elsevier.

6. Theory of Elasticity, S. Timoshenko and J. N. Goodier. McGraw Hill Education.

**ME 614** **Thermofluids engineering** **3-0-0-6**

Aim of this course is to provide an understanding of fundamental aspects of the physics of therm o-fluid
processes, and to equip the students to analyse practical thermo-
fluids systems. The course covers
important areas of thermodynamics, fluid mechanics, and heat transfer. The course will include le ctures,
open discussions, directed study, and industrial/ laboratory visits.

**Contents:**

**Thermodynamics:**

A revision of basic thermodynamics, ideal and real thermodynamic cycles (power and refrigera tion),analysis of turbines, pumps, compressors, and other energy conversion systems, availability and exergy in various practical systems

**Fluid Mechanics:**

Continuum hypothesis, Newtonian and nonNewtonian fluids, compressible and incompressible fl ows,laminar and turbulent flows. Introduction to Lagrangian and Eulerian description, material d erivative,steady and uniform flows, streamline, path line and streak line, Topics on kinematics, Co nstitutive lawsGoverning equations in differential form, and some exact solutions, Bernouli 's equation and itsapplications Dimensional analysis**,** Flow through pipes, laminar and turbulen t flows, Moody's diagramBoundary layer theory: The concept and theory of Boundary Layer ,boundary layer Separation,
laminar, transition and Turbulent boundary layer Characteristics of Turbulent Flow and ideas rela ted to modelling turbulence

**Heat Transfer:**

Conduction of heat, governing equations and their applications, steady and unsteady con duction,thermal resistances and electrical analogy, Convective heat transfer, conservation equations andsolutions, thermal boundary layer, correlations for forced convection, natural conv ection, laminar, andturbulent flow heat transfer, Design principles of heat exchangers. Analysi s of fins, Introduction toradiative heat transfer

**Text Books:**

1. Advance Engineering Thermodynamic, Adrian Bejan, Wiley, 2006.
2. M.J.Moran and H.N.Shapiro, Fundamentals Of Engineering Thermodynamics, John Wile yand Sons,
3. V. Babu, Fundamentals of Incompressible Fluid Flow.
4. Som, Gautam Biswas, S Chakraborty Introduction to Fluid Mechanics & Fluid Machines.
5. P. K. Kundu, I. M. Cohen, D. R. Dowling, Fluid Mechanics.
6. A. Bejan, Heat Transfer John Wiley, 1993
7. J.P.Holman, Heat Transfer, Eighth Edition, McGraw Hill, 1997.
8. F.P.Incropera, and D.P. Dewitt, Fundamentals of Heat and Mass Transfer, John Wiley, F ourthEdition, 1998.
9. Yunus A Cengel, Heat Transfer: A Practical Approach, McGraw Hill, 2002

**ME 615** **Finite Element Method** **3-0-0-6**

Syllabus:

Fundamentals of Finite Element Formulation:

Method of weighted residual; Weak formulation; Piecewise continuous trial function;

Variational method (Principle of stationary functional); Rayleigh-Ritz method; Rayleigh-Ritz

finiteelement method. One-Dimensional Finite Element Analysis:

Finite element formulation for 1-D problems; Linear bar element; Quadratic bar element; Structural analysis of trusses using bar elements; Beam element; Structural analysis of frames; Temperature effects.

Two-Dimensional Finite Element Analysis:

2-D elementsfor heat transfer problems: (1) 3-noded triangular element, (2) 4-noded rectangular element and (3) 6-noded triangular element; 2-D stress analysis formulation; Natural coordinates and Coordinate transformations; 2-D elements for structural mechanics: (1) 3-noded triangular element or constant strain element (CST), (2) 4-noded quadrilateral element, (3) 6-noded triangular element and (4) 8-noded quadrilateral element; Numerical integration; Axisymmetric element.

Dynamic Analysis using Finite Element Method:

Equation of motion based on weak form; Equation of motion using Lagrange's approach; Consistent and lumped mass matrices; Finite element formulation for vibration problem.

**Reference/Text Books**:

1. Introduction to Finite Elementsin Engineering BY T. R. CHANDRUPATLA AND A. D. BELEGUNDU; PEARSON EDUCATION INDIA; 2015.

2. A First Course in Finite Elements BY J. Fish AND T. BELYTSCHKo; JOHN WILEY & SONS; 2007.

3. Textbook of Finite Element Analysis BY P. SESHU; PRENTICE-HALL of INDIA PVT. LTD; 2004.

4. An Introduction to the Finite Element Method BY J. N. REDDy; MCGRAW HILL EDUCATION; 2017.

5. Concepts and Applications of Finite Element Analysis BY RoBERT D. COOK; JOHN WILEY & SONS; 2007.

6. The Finite Element Method: Its Basis and Fundamentals(Volume: 1) BY O. C. ZIENKIEWICZ, R. L. TAYLOR AND J. Z. Zhu; BUTTERworTH-HEINEMANN; 2013

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**ME 616 Gas Dynamics 3-0-0-6**

Pre-requisite: Introductory course in Fluid dynamics and thermodynamics

Course level: PG/ PhD course

Course contents
Conservation laws: Introduction to basic concepts in fluid mechanics, Conservation of mass, momentum, Euler equation, Mach number, Speed of sound
Review of thermodynamics: Ideal gases, steady isentropic flow, stagnation properties, Energy, Entropy equation
One dimensional flow: Variable area flow, Choked flow, Subsonic and supersonic nozzles, Flow with friction, Fanno line, Flow with Heat Addition, Rayleigh Line

Shock waves: Normal shock waves, Conservation relations, Hugoniot relation, Moving shocks, strong and weak shocks, Oblique shocks

Two-dimensional flow: Steady 2D Supersonic Flows: Mach Waves, Prandtl-Meyer Function, Expansion Fans, Method of characteristics

One dimensional unsteady flow: Finite Amplitude Waves, Characteristics, Riemann Invariants, Piston problems, boundary interactions, shock tubes, Viscous effects

**References**


1. Liepmann, H.W and Roshko. .A. (2002) Elements of Gas dynamics, Dover Publications

2. Shapiro A.H. The dynamics and thermodynamics of Compressible flow, Dover Publications

3. Anderson J. (1977) Modern Compressible flow: with historical perspective, McGraw Hill Education


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**ME 617 Mechanics of Composite Materials 3-0-0-6**

**Pre-requisite: ME201 Mechanics of Materials or any course on solid mechanics**

Content:

Introduction: Definition, Classification of composites, Constituent materials – fibers, matrices, applications of composites.

Fabrication techniques: Manufacturing of thermoset and thermoplastic composites, Other manufacturing methods, Properties of constituents and composites.

Micromechanics of composites: Volume fraction and weight fraction, prediction of properties from micromechanics, Rule of mixtures.

Analysis of Lamina: Anisotropic elasticity, Properties of lamina, Stress-strain relations of lamina, Transformations of elastic constants.

Analysis of laminates: Laminate configurations and definitions, Assumptions, Classical laminate theory (CLT), Higher order shear deformation theory, Hygrothermoelastic laminate theory.

Failure of composites: Introduction to failure concepts, Micromechanics of failure in unidirectional laminates, Different failure theories

**References:**

Analysis and Performance of Fibre Composites, BD Agarwal and LJ Broutman

Mechanics of Composite Materials and Structures, Madhujit Mukhopadhyay

Mechanics of Fibrous Composites, CT Herakovich

Mechanics of Composite Materials, Jones, R. M., Mc-Graw Hill

Mechanics of Composite Materials, RM Christensen

Materials provided by Instructor

**ME 618 Advanced Finite Element Method 3-0-0-6**

Prerequisites: Finite Element Method (ME 615)

**Nonlinear Finite Element Analysis:**

Introduction to nonlinear systems in solid mechanics; Geometric nonlinearilty; Material nonlinearity; Kinematic nonlinearity; Force nonlinearlity; Solution procedures for nonlinear algebraic equations; Newton-Raphson method; Increment Secant method; Solution steps: State determination; Residual calculation; Convergence check; Patch test.

**Finite Element Analysis for Nonlinear Elastic Systems:**

Stress and strain measures in large deformation; Nonlinear elastic analysis: Total Lagrangian formulation, Updated Lagrangian formulation and critical load analysis; Hyper elastic materials: Variational equation and linearization.

**Finite Element Analysis for Elastoplastic Problems:**

One-Dimensional elasto-plasticity; Multi dimensional elasto-plasticity; Finite rotation with objective integration; Finite deformation elasto-plasticity with hyper elasticity; Return-mapping algorithm.

**Finite Element Analysis for Contact Problems:**

Examples of simple one-point contact; General formulation for contact problems; Finite element formulation of contact problems; Three-dimensional contact analysis; Contact analysis procedure and modeling issues.

**Reference/Text Books:**


1. Advanced Topics in Finite Element Analysis of Structures: with Mathematica and MATLAB Computations by M. Asghar Bhatti; John Wiley & Sons; 2006.

2. Nonlinear Finite Element Analysis of Solids and Structures-I by M.A. Crisfield; John Wiley & Sons; 1991.

3. An Introduction to Nonlinear Finite Element Analysis by J.N. Reddy; OUP Oxford; 2014.

4. Finite Element Procedures by K. J. Bathe; Prentice Hall, Pearson Education, Inc.; 2016.

5. Introduction to Nonlinear Finite Element Analysis by N.H. Kim; Springer US; 2015.

6. The Finite Element Method: Structural Mechanics (Volume: 2) by O. C. Zienkiewicz and R. L. Taylor; Butterworth-Heinemann; 2013.

**ME 619 Microscale Transport Phenomena and Microfluidics 3-0-0-6**

For UG, PG electives

**Prerequisite: Fluid Mechanics, Basic Physics and Chemistry. Reference**

Course Content

Introduction and Applications of micro scale fluid flow. Basic concepts in microfluidics: Scaling laws, Fluids and fields. Basic governing equations and basic flow solutions.

Continuum assumption and limits of linear transport properties.

Microscale transport equations, Pressure-driven Microflows, unsteady flows, Stokes Drag, Lubircation Theory, Continuum flow (with slip), Surface Tension Driven Flows, Thin Film Dynamics, free molecular flow.

Electrokinetics: electric double layer, Electro-osmotic flow, Capillary filling, passive valves, electro-wetting, electrophoresis, isoelectric focusing, dielectrophoresis etc.

Biomicrofluidics , Flow of Non-newtonian Fluids.

Micro-fabrication - photolithography, wet and dry etching, molding, casting, assembly etc. Pumps, valves, mixers, sensors. Concepts and examples of micro heat pipes, droplet based microfluidics, Lab on a CD. Lab Demo.

**Books:**

1. Theoretical Microfluidics. Henrik Bruus, Oxford University Press. 2008. ISBN 978–0–19– 923508–7.
2. Microfluidics and Microfabrication. Editor Suman Chakraborty. Springer 2010. ISBN: 978- 1-44-191542-9
3. Intermolecular and Surface Forces. Jacob N. Israelachvili, 3rd edition. Academic Press 2011.ISBN 978-0-12-391933-5.
4. Microfluidics and Microscale Transport Processes. Suman Chakraborty, 1st Edition, CRC Press 2012. ISBN 978-1-43-989924-3

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**ME 620 Theory of Elasticity 3-0-0-6**

Introduction and preliminary mathematics. General deformation, small deformation theory, strain transformation, stress transformation, equilibrium equations, compatibility and constitutive equations, principal stresses and principal strains, boundary conditions. Relations in Cartesian, Cylindrical and Spherical Coordinates.

Stress and displacement formulations, Principle of superposition, Saint-Venant’s Principle, Plane stress, plain strain, generalized plane stress, Antiplane strain, Airy stress function. Solution of two-dimensional problems using Fourier Methods and polynomials. Extension, torsion and bending of cylinders. Thermoelasticity.

**Reference/Text books:**

1. Elasticity: Theory, Applications and Numerics, Martin H. Sadd. Elsevier.
2. Theory of Elasticity, S. Timoshenko and J. N. Goodier. McGraw Hill Education.
3. A Treatise on the Mathematical Theory of Elasticity, A. E. H. Love, Dover Publications.
4. The Linearized Theory of Elasticity, William S. Slaughter, Birkhäuser.

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**ME 621** **Energy, Environment, and Economics** **3-0-0-6**

Type of course: Open elective/ Institute elective

Prerequisites: None

Description:

Energy systems are designed for production, conversion, delivery, and use of energy to satisfy human needs. There is significant economic activity and societal involvement which governs these systems. Currently, a large fraction of the global energy systems utilizes non- renewable non-nuclear fossil fuel based energy sources. The environmental impact vis-à-vis climate change caused by such systems is one of the major challenges we currently face. The interrelatedness of energy systems, economics, and environment is a vital topic with which an engineering professional must be acquainted. The understanding of the historical scenario, current status, and future requirements in these interrelated areas will be developed in this course. This course would addresses strategies adopted by our society (particularly developing countries/ India) and discuss basic economic analysis geared towards decision making in the context of energy systems.

**Syllabus**:

Historical background; current global and local scenarios in the context of energy and environment; quantitative future projections (global and local).
Comparison between developed and developing countries in terms of energy consumptions patterns, environmental regulations, and economics; challenges faced by developing countries and mitigation strategies; energy supply and use in India.
Energy environment interactions; quantifying environmental impacts of fossil fuel based power generation including global climate change; impacts of climate change on developing countries and island nations; international environmental agreements.
Energy systems: definitions, classification, comparison, and working principles; availability/ scarcity of fossil fuels; simplified analysis of exergy and emissions through case studies/ design studies.

Various pollutants associated with power generation; generation mechanisms; case study of various pollution control methods in power plants; effects of various pollutants on human health; regulations and norms

New and renewable energy sources as an alternative to fossil fuels (overview of solar energy, wind energy, geothermal etc.); alternative fuels for transportation; comparison of exergy and emissions of alternative energy sources;
Economic analysis for energy systems; assessing cost impacts of energy systems;

financial feasibility evaluation of renewable energy technologies and other economic aspects of energy industry; energy related policies and sustainability as a practical goal.

**Books and references:**

1. Analytic Combustion: With Thermodynamics, Chemical Kinetics and Mass Transfer - Anil W. Date, Cambridge University Press, 2011.

2. Introduction to Environmental Engineering and Science - Gilbert M Masters and Wendell P Ela. Prentice Hall of India, 3rd edition, 2008.

3. GEA, 2012: Global Energy Assessment - Toward a Sustainable Future, Cambridge University Press, Cambridge, UK and New York, NY, USA and the International Institute for Applied Systems Analysis, Laxenburg, Austria. ( mainly Chapter 1 - Energy Primer pp. 99-150, Chapter 3- Energy and Environment-pp 191-254.Chapter 4

– Energy and Health pp. 255-324)

4. Tester J.W., Drake E.M., Driscoll M. J., Golay, M.W, Peters, W.A.,Sustainable Energy Choosing Among Options, PHI Learning Private Limited,New Delhi, 2009.

5. Bejan, Advanced Engineering Thermodynamics , John Wiley, New York, 1988.

6. J. M. Fowler, Energy and the Environment, McGraw Hill, 2nd Edn, New York,1984

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**ME622 Introduction to Scientific and Parallel Computing 3-0-0-6**

Elective for Undergraduate (4th year), Masters and Doctoral students
Pre-requisite: Basic knowledge of computer programming, besides what is set by the instructor.

**Contents**

1. Basics: Brief overview of scientific computing. Essential linear algebra including inverse and transpose of a matrix, eigenvalues and eigenvectors, system of linear equations; Ordinary differential equations (ODEs); Different types of partial differential equations (PDEs). Errors – round-off error, truncation error, numerical error, order of accuracy, etc. Basics of data structures – arrays, linked list, etc.
2. Numerical schemes: Integration – Mid-point rule, Trapezoidal rule, Simpson's rule. Differential equations – Finite difference methods, Euler's method, Runge-Kutta method. Discretization and numerical techniques of PDEs.
3. Data handling and analysis: Statistics – mean, standard deviation, standard error, etc. Data plotting.
4. Parallel computing: Introduction to high-performance computing with an overview of major applications. Parallel architectures, Flynn's taxonomy, shared memory and distributed memory systems. Programming with Message Passing Interface (MPI) and OpenMP.

**Text books/References:**

1. Bhaskar Dasgupta. Applied Mathematical Methods. Pearson (2006).
2. Gilbert Strang. Linear Algebra and its Applications. Cengage Learning (2006).
3. Erwin Kreyszig. Advanced Engineering Mathematics. Wiley (2006).
4. Michael J. Quinn. Parallel Programming in C with MPI and OpenMP. Tata McGraw-Hill Edition (2003).
5. Peter S. Pacheco. An Introduction to Parallel Programming. Elsevier (2011).
6. Michael T. Heath. Scientific Computing. Tata McGraw-Hill Co. Ltd. (2011).

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**ME623** **Multiscale Modeling of Composite Material Systems** **3-0-0-6**

Elective for UG (4th year), M.Tech, Ph.D. students

Pre-requisite: Continuum Mechanics (ME613)

**Course Objective:**

The objective of this course is to introduce the principles, theory and techniques (analytical and computational) for multiscale analysis of composite material systems

**Course Content:**

1. Micromechanics Fundamentals: Introduction to multiscale modeling; Boundary value problems for small-strain linear elasticity; Integral representation of elasticity solutions; Eigenstrains; Inclusions and inhomogenities.
2. Analytical Multiscaling Methods: Mean Field Approaches: Heterogeneities and length scale; Representative Volume Element (RVE); Hill's lemma; Bounds for effective moduli; Determination of effective moduli: Eshelby method, Mori Tanaka method, Self-consistent method; Effective properties of fiber-reinforced composite laminates.
3. Semi-analytical Multiscaling Methods: Transformation Field Analysis (TFA): Mechanical influence functions and concentration factors, Overall stiffness and compliance of multiphase systems, Phase transformations, Transformation influence functions and concentration factors, Capabilities of bounds and estimates of overall and local fields;
4. Computational Multiscaling Methods: Asymptotic Expansion Homogenization (AEH): Two scale formulation, Implementation of AEH using finite element modeling, Periodic boundary conditions, Localization procedures. Reduced order AEH based multiscaling. Non-Uniform Transformation Field Analysis (NTFA);

**Text book(s):**

1. Fundamentals of Micromechanics of Solids by Jianmin Qu and F. Cherkaoui Mohammed; Vol. 92. Hoboken: Wiley, 2006

**Reference(s):**

1. Micromechanics of Composite Materials by George Dvorak. Vol. 186. Springer Science & Business Media, 2012.
2. Practical Multiscaling by Jacob Fish; Prentice Hall, John Wiley & Sons, 2013.
3. Multi-scale Modelling for Structures and Composites by Grigorii Petrovich Panasenko; Springer, 2005.