M.Tech. Programme in 'Mechanical Engineering'
School of Engineering, IIT Patna

1. Introduction to the Programme

The department of Mechanical Engineering proposes to introduce a 'M.Tech programme in Mechanical Engineering'. In line with other established IITs, our M.Tech. programme in Mechanical Engineering will allow the enrolled students to choose one of the three possible streams within Mechanical Engineering: (i) *Thermo-fluids* stream, (ii) *Solid Mechanics & Design* stream and (iii) *Manufacturing* stream. The programme coursework requires four core and six elective courses. Two of these four core courses will be common for all the three streams. However, the other two core courses will be stream-specific.

Eligibility Criteria:

1. B.Tech./B.E. in Aerospace, Aeronautical, Automobile, Production, Manufacturing or Mechanical Engineering
2. A valid GATE score in one of the following GATE papers: (a) Aerospace Engineering (AE), (b) Mechanical Engineering (ME), (c) Production and Industrial Engineering (PI).

2. Course structure and syllabus

2.1 Name of courses

- **Core Courses**
  1. SE503: Advanced Engineering Mathematics (3-0-0-6)
  2. ME519: Advanced Engineering Software Lab (1-0-4-6)
  3. ME521: Advanced Fluid Mechanics (3-0-0-6) for *Thermo-Fluids* stream
     ME523: Advanced Dynamics & Vibration (3-0-0-6) for *Solid Mechanics & Design* stream
     ME525: Metal Cutting & Analysis (3-0-0-6) for *manufacturing* stream
  4. ME522: Advanced Heat Transfer(3-0-0-6) for *Thermo-Fluids* stream
     ME524: Theory of Elasticity (3-0-0-6) for *Solid Mechanics & Design* stream
     ME526: Metal Forming & Analysis (3-0-0-6) for *manufacturing* stream

- **Lab Courses**
  ME527: Thermo-Fluids Lab-I (0-0-6-6) for *Thermo-Fluids* stream
  ME529: Solid Mechanics & Design Lab-I (0-0-6-6) for *Solid Mechanics & Design* stream
  ME531: Manufacturing Lab I (0-0-6-6) for *manufacturing* stream
  ME528: Thermo-Fluids Lab-II (0-0-6-6) for *Thermo-Fluids* stream
  ME530: Solid Mechanics & Design Lab-II (0-0-6-6) for *Solid Mechanics & Design* stream
  ME532: Manufacturing Lab II (0-0-6-6) for *manufacturing* stream

- **Electives I-III**

  Elective requirements for all three streams will be met by the following courses. A student must select three courses from three different groups.

Group A	ME503: Computational Fluid Dynamics MA507: Nonlinear Optimization ME504: Vehicle Dynamics and Multi-body Systems
Group B	ME533: Finite Element Analysis EE501: Control of Mechatronics Systems PH515: MEMS and NEMS ME535: Acoustics
Group C	ME742: Advanced Manufacturing Processes ME501:Robotics: Advanced Concepts & Analysis ME581: Bio Mechanics and Bio Mechatronics EE503: Signal Processing in Mechatronic Systems MA511: Large Scale Scientific Computation ME537: Refrigeration and Air-Conditioning

- **Electives IV-VI**

  Elective requirements for all three streams will be met by the following courses. A student must select three courses from three different groups.

Group A	ME 542: Aerodynamics ME512: Mobile Robotics ME534: Wear & Lubrication of Machine Components ME506: Emerging Smart Materials for Mechatronics Applications ME502: Industrial Automation
Group B	ME546: Multiphase Flow & Heat Transfer ME554: Rotor Dynamics CE505: Application of probabilistic methods in engineering
Group C	MA502: Numerical Optimization MA504: Computational Differential Equations MA512: Mathematical Modeling MA508 Fuzzy Set and Artificial Intelligence MA514: Design of Experiments ME541: Turbulent Shear Flow ME536: Non-linear Systems Dynamics

2.2 Course Curriculum

Semester I

Sr. no	Course Number	Course Title	L	T	P	C
1.	SE503	Advanced Engineering Mathematics	3	0	0	6
2.	ME521 ME523 ME525	Advanced Fluid Dynamics (for *Thermo-Fluids* stream) Advanced Dynamics & Vibration (for *Solid Mechanics and Design* stream) Metal Cutting & Analysis (for *Manufacturing* stream)	3	0	0	6
3	ME527 ME529 ME531	Thermo Fluids Lab I (for *Thermo-Fluids* stream) *Solid Mechanics and Design* Lab I (for *Solid Mechanics and Design* stream) Manufacturing Lab I (for *Manufacturing* stream)	0	0	6	6
4		Elective I	3	0	0	6
5		Elective II	3	0	0	6
6		Elective III	3	0	0	6
7	HS513	Technical Communication	2	0	0	4
8	SE507	Seminar-I	0	0	4	4
		Total	17	0	10	44

Semester II

Sr. no	Course Number	Course Title	L	T	P	C
1	ME519	Advanced Engineering Software Lab	1	0	4	6
2	ME522 ME524 ME526	Advanced Heat Transfer (for *Thermo-Fluids* stream) Theory of Elasticity (for *Solid Mechanics and Design* stream) Metal Forming & Analysis (for *Manufacturing* stream)	3	0	0	6
3	ME528 ME530 ME532	Thermo Fluids Lab II (for *Thermo-Fluids* stream) *Solid Mechanics and Design* Lab II (for *Solid Mechanics and Design* stream) Manufacturing Lab II (for *Manufacturing* stream)	0	0	6	6
4		Elective IV	3	0	0	6
5		Elective V	3	0	0	6
6		Elective VI	3	0	0	6
7	SE508	Seminar	0	0	4	4
		Total	13	0	14	40

Semester III

Sr. no	Course Number	Course Title	L	T	P	C
1	ME600	Comprehensive Viva	0	0	0	10
2	ME601	Project-Phase I				40
		Total				50

Semester IV

Sr. no	Course Number	Course Title	L	T	P	C
1	ME602	Project Phase II				45
		Total				45

Total credits = 44+40+50+45=179

2.3 Detailed Syllabus

(Core courses)

SE503: Advanced Engineering Mathematics **(3-0-0-6)**

Prerequisite NIL

Linear Algebra: Matrix algebra; basis, dimension and fundamental subspaces; solvability of Ax = b by direct Methods; orthogonality and QR transformation; eigenvalues and eigenvectors, similarity transformation, singular value decomposition, Fourier series, Fourier Transformation, FFT. Vector Algebra & Calculus: Basic vector algebra; curves; grad, div, curl; line, surface and volume integral, Green's theorem, Stokes's theorem, Gauss-divergence theorem. Differential Equations: ODE: homogeneous and non-homogeneous equations, Wronskian, Laplace transform, series solutions, Frobenius method, Sturm-Liouville problems, Bessel and Legendre equations, integral transformations; PDE: separation of variables and solution by Fourier Series and Transformations, PDE with variable coefficient.

Numerical Technique: Numerical integration and differentiation; Methods for solution of Initial Value Problems, finite difference methods for ODE and PDE; iterative methods: Jacobi, Gauss-Siedel, and successive over-relaxation.

Complex Number Theory: Analytic function; Cauchy's integral theorem; residue integral method, conformal mapping.

Statistical Methods: Descriptive statistics and data analysis, correlation and regression, probability distribution, analysis of variance, testing of hypothesis.

Text Books:

1. H. Kreyszig, "Advanced Engineering Mathematics", Wiley, (2006).
2. Gilbert Strang, "Linear Algebra and Its Applications", 4th edition, Thomson Brooks/Cole, India (2006).
3. J. W. Brown and R. V. Churchill, "Complex Variables and Applications", McGraw-Hill Companies,
Inc., New York (2004).
4. J. W. Brown and R. V. Churchill, "Fourier Series and Boundary Value Problems", McGraw-Hill
Companies, Inc., New York (2009).
5. G. F. Simmons, "Differential Equations with Applications and Historical Notes", Tata McGraw-Hill Edition, India (2003).
6. S. L. Ross, "Differential Equations" 3rd edition, John Wiley & Sons, Inc., India (2004).
7. K. S. Rao, "Introduction to Partial Differential Equations", PHI Learning Pvt. Ltd (2005).
8. R. Courant and F. John, "Introduction to Calculus and Analysis, Volume I and II", Springer-Verlag, New York, Inc. (1989).

ME 521 Advanced Fluid Mechanics **(3-0-0-6)**

Concepts of fluids: Definitions of fluids, concept of continuum, different types of fluid, tensor analysis, governing laws of fluid mechanics in integral form,Reynold's transport theorem, mass, momentum and energy equations in integral form and their applications, differential fluid flow analysis, continuity equation, Navier-Stokes equation and exact solutions. Potential flow analysis: Two-dimensional flow in rectangular and polar coordinates, continuity equation and the stream function, irrotationality and the velocity potential function, complex potential function, vorticity and circulation, flow over immersed bodies and D' Alembert's paradox, aerofoil theory and its application. Viscous flow analysis: Low Reynold's number flow, approximation of Navier-stokes equation, approximate solutions of Navier-Stokes equation, Stokes and Oseen flows, hydrodynamic theory of lubrication, Prandtl's boundary layer equations, Large Reynold's number flow approximation, flow instabilities and onset of turbulence. Compressible fluid flow: One dimensional isentropic flow, Fanno and Rayleigh flows, choking phenomenon, normal and oblique shocks. Micro and nano flow: Physical aspects of micro and nano flows, governing equations, surface tension driven flows, modeling of micro and nano flows.

Text Books:

1. White, F.M., Viscous Fluid Flow, McGraw-Hill, New York, 3rd edition 2006.
2. Bachelor G. K. An introduction to Fluid Dynamics , Cambridge University Press, 2007.
3. Streeter V.L. and Wylie E. B., Fluid Mechanics , Tata McGraw-Hill, Delhi 2001.
4. Shames I. H., Mechanics of Fluids , Tata McGraw Hill, Delhi, 4th edition 2003.
54. Douglas and Swaffield, Fluid Mechanics , Prentice Hall, 5th edition 2006.
6. Yahya S. M., Fundamentals of Compressible Flow , Tata McGraw Hill, Delhi, 3rd edition 2003.
7. Karniadakis G., Beskok, A., and Narayan A. Microflows and Nanoflows , Springer, 1st edition 2005.
8. Journal of Fluid Mechanics,Cambridge University Press.
9. Physics of Fluids , , American Institute of Physics.

ME523 Advanced Dynamics and Vibration (3-0-0-6)

Review of Newtonian mechanics for rigid bodies and system of rigid bodies; coordinate transformation between two set of axes in relative motion between one another; Euler angles; angular velocity, angular acceleration, angular momentum etc. in terms of Euler angle parameters; Newton-Euler equations of motion; elementary Lagrangian mechanics: generalized coordinates and constraints; principle of virtual work; Hamilton's principle; Lagrange's equation, generalized forces. Lagrange's equation with constraints, Lagrange's multiplier. Nonlinear effects in Dynamics. Review of the single DOF system and simple Multi-DOF lumped parameter systems. Equations of motion for free and forced vibration of distributed parameter systems: axial vibration of a bar, transverse vibration of a string, torsional vibration of a shaft, transverse vibration of beams. Boundary-value problem and boundary conditions. Differential eigenvalue problem, eigenfunction and natural modes. Orthogonality of eigenfunctions and expansion theorem. Rayleigh quotient. Response to initial conditions and external excitations. Discretization of distributed parameter system: Algebraic eigenvalue problem, eigenvalue and eigenvectors. Introduction to Modal analysis.

Text Books:

1. H. Baruh, Analytical Dynamics, McGraw-Hill (1999).
2. L. Meirovitch, Methods of Analytical Dynamics, Dover Publication, 2010.
3. D.T. Greenwood, Principles of Dynamics, Prentice-Hall International, 1988.
4. A.A. Shabana, Dynamics of Multibody Systems, 4th Cambridge University Press, 2013.
5. L. Meirovitch, Fundamentals of Vibration, McGraw Hill, 2000.
6. W.T. Thompson, M.D. Dahleh, C. Padmanabhan, Theory of Vibration with Application, 5th Ed., Pearson, 2008.
7. S.S. Rao, Mechanical Vibration, 4th Ed., Pearson, 2004.
8. W. Weaver, Jr., S.P. Timoshenko, D.H. Young, Vibration Problems in Engineering, 5th Ed., John Wiley and Sons, 1990.

ME525 Metal Cutting and analysis (3-0-0-6)

Single and multipoint tool geometry (ASA, ORS, NRS, MRS), conversion of tool angles; mechanics of chip formation (for ductile and brittle materials): Levy Lodes' theorem, fracture mechanics; Orthogonal and oblique cutting mechanics; dynamometry (strain gauge, piezo etc); Surface roughness in machining; Thermal aspects of machining; tribology in metal cutting; tool coatings and coating techniques; Economics of machining; Machinability; Cutting fluids: properties, types, application techniques, emissions and its adverse effects; Chip breaker; Recent advances in machining: hard turning, high seed machining, diamond turning, machining of advanced materials, machining with minimum quantity cutting fluids and cryogenic fluids; Grinding: mechanics, forces, specific energy, temperature, wheel wear and surface finish; Broaching: mechanics;

Text Books:

[1] M. C. Shaw, Metal Cutting, Tata McGraw Hill, New Delhi, 2004.
[2] M. C. Shaw, Principles of Abrasive Processing, Oxford University Press, 1996.
[3]Bhattacharyya, A., Metal cutting: theory and practice, New Central Book, Kolkata, 1984.
[4] G. K. Lal, Introduction to Machining Science, New Age International Publishers, 2007.
[5] G. Boothroyd and W. A. Knight, Fundamentals of Machining and Machine Tools, CRC-Taylor and Francis, 2006.
[6] A. Ghosh and A. K. Malik, Manufacturing Science, East West Press, 2010.
[7] P. H. Black, Metal Cutting Theory, McGraw Hill, 1961.

ME519 Advanced Engineering Software Laboratory (1-0-4-6)

CAD/CAM: 2D and 3D geometric transformation, Composite Transformation, Projections; Curves: Cubic, Bezier, Splines; Surfaces: Quadric, Coons patch, Super Quadric, Bezier, B-Splines. Process planning, CL data generation, Automatic CNC code generation.

FEM: Solid model creation, different types of elements, chunking of model, meshing, mesh quality, different kinds of analysis : static, dynamic, transient, thermal, electro-magnetic, acoustics, sub-structuring and condensation, Error and convergence.

Non-linear static and dynamic analysis, contact analysis, multi-physics problem, rigid body analysis of flexible element.

CFD: Different types of CFD techniques, various stages of CFD techniques (i) pre processor: governing equations, boundary conditions, grid generation, different discretization techniques (ii) processor: solution schemes, different solvers (iii) post-processing: analysis of results, validation, grid independent studies etc. Developing codes using commercial/open source software for solving few problems of laminar and turbulent flow with heat transfer applications.

Engineering softwares related to CAD/CAM, FEM, CFD, with both GUI and script like languages, are to be used for laboratory assignments.

Text Books:

1. D. F. Rogers and J. A. Adams, “Mathematical Elements for Computer Ggraphics”, McGraw-Hill, 1990
2. M. Groover and E. Zimmers, “CAD/CAM: Computer-Aided Design and Manufacturing”, Pearson Education, 2009.
3. A. Saxena and B. Sahay, “Computer Aided Engineering Design”, Springer, 2007.
4. J. N. Reddy, “An Introduction to Finite Element Methods”, 3rd Ed., Tata McGraw-Hill, 2005.
5. J. Fish, and T. Belytschko, “A First Course in Finite Elements”, 1st Ed., John Wiley and Sons, 2007.
6. J. D. Anderson, “Computational Fluid Dynamics”, McGraw-Hill Inc. (1995).
7. H. K. Versteeg and W. Malalaskera, “An Introduction to Computational Fluid Dynamics”, Dorling Kindersley (India) Pvt. Ltd. (2008).
8. S. Biringen and C Chow, An Introduction to Computational Fluid Mechanics by Example

ME522 Advanced Heat Transfer (3-0-0-6)

Conduction: Equations and boundary conduction in different coordinate systems; Analytical Solutions: separation of variables, Laplace Transform, Duhamel’s theorem: Non-impulse initial conditions; Numerical Methods: Finite difference and flux conservation; Interfacial heat transfer. Convection: Conservation equations and boundary conditions; Heat transfer in laminar developed and developing boundary layers: duct flows and external flows, analytical and approximate solutions, effects of boundary conditions; Heat transfer in turbulent boundary layers and turbulent duct flows;

Laminar and turbulent free convection, jets, plumes and thermal wakes, phase change. Radiation: Intensity, radiosity, irradiance, view factor geometry and algebra; formulations for black and non–black surfaces, spectrally–selective surfaces (solar collectors); Monte Carlo methods for radiation exchange; The radiative transfer equation, extinction and scattering properties of gases and aerosols, overview of solution methods and applications. Interaction between conduction, convection and radiation: Coupled problems; Examples in manufacturing and electronic cooling applications; Micro channels and micro fins.

Text Books:

[1] M N Ozisik, *Heat Conduction*, 2nd ed, John Wiley & Sons, 1993
[2] Kakaç, S., Yener, Y., Heat Conduction, 3rd edition, Taylor & Francis, 1993.
[3] F P Incropera and D P Dewitt, *Introduction to Heat Transfer*, 3rd ed, John Wiley & Sons, 1996
[4] W. M. Kays and E. M. Crawford, *Convective Heat and Mass Transfer*, Mc Graw Hill,1993.
[5] Adrian Bejan, *Convective Heat Transfer*, John Wiley and Sons, 1995.
[6] M F Modest, *Radiative Heat Transfer*, McGraw-Hill, 1993
[7] R Siegel and J R Howell, *Thermal Radiation Heat Transfer*, 3rd ed, Taylor & Francis, 1992

ME524 Theory of Elasticity (3-0-0-6)

Stress and strain tensors, equations of equilibrium and compatibility in rectangular and curvilinear coordinates, Cauchy's formula, stress transformation, principal stresses, Lame's stress ellipsoid, Cauchy stress quadratic, octahedral stress, stress-strain relations, basic equations of elasticity, Boundary value problem, Uniqueness of solutions, Torsion of non-circular sections, St. Venant's theory of torsion, Scalar and Vector potentials, Strain potentials. Plane state of stress and strain, Airy's stress function for problems, Representation of biharmonic function using complex variables, Kolosoff-Mushkelishvili method. Thermal stress, Applications to problems of curved beam, thick cylinder and rotating disc, stress concentration. Introduction to numerical methods in elasticity. Contact problems, energy and variational principles Theory of Elasticity:

Text Books:

1. S.P. Timoshenko and J.N. Goodier, Theory of Elasticity, Tata McGraw-Hill, 2010.
2. L.S. Srinath, Advanced Solid Mechanics, Tata McGraw-Hill, 2002.
3. I.S. Sokolnikoff, Mathematical Theory of Elasticity, 2nd Ed., McGraw-Hill, 1956.
4. Y.C. Fung, Foundations of Solid Mechanics, Prentice-Hall, 1965.

ME526 Metal Forming and Analysis (3-0-0-6)

Stress-strain relations in elastic and plastic deformations, Yield criteria for ductile metals, Work hardening and Anisotropy in yielding, Flow curves, Elements of theory of plasticity, Formulation of plastic deformation problems, Application of theory of plasticity for solving metal forming problems using slab method, Upper and lower bound methods, slip line field theory, Effects of temperature and strain rate in metal working, Friction and lubrication in cold and hot working, Technology and Analysis of important metal forming processes– Forging, Rolling, Extrusion, Wire Drawing, Sheet metal forming processes like Deep drawing, Stretch forming, Bending, Introduction to Finite Element Analysis of metal forming processes.

Texts Books:

[1] R.H Wagoner, Metal Forming Analysis, Cambridge University Press
[2] G. W. Rowe, Principles of Industrial Metal working processes, CBS publishers and Distributors
[3] B. L. Juneja, Fundamentals of Metal forming processes, New age international publishers

[4] A. Ghosh and A. K. Malik, Manufacturing Science, East West Press
[5] J. Chakrabarty, Theory of Plasticity, McGraw Hill, 1998.
[6] Dieter, Mechanical Metallurgy, McGraw Hill. Inc
[7] By William F. Hosford, Robert M. Caddell, Metal Forming: Mechanics and Metallurgy, Cambridge University Press

ME503 Computational Fluid Dynamics **(3-0-0-6)**

Concept of Computational Fluid Dynamics: Different techniques of solving fluid dynamics problems, their merits and demerits, governing equations of fluid dynamics and boundary conditions, classification of partial differential equations and their physical behavior, Navier-Stokes equations for Newtonian fluid flow, computational fluid dynamics (CFD) techniques, different steps in CFD techniques, criteria and essentialities of good CFD techniques.

Finite Difference Method (FDM): Application of FDM to model problems, steady and unsteady problems, implicit and explicit approaches, errors and stability analysis, direct and iterative solvers. Finite Volume Method (FVM): FVM for diffusion, convection-diffusion problem, different discretization schemes, FVM for unsteady problems.

Prediction of Viscous Flows: Pressure Poisson and pressure correction methods for solving Navier-Stokes equation, SIMPLE family FVM for solving Navier-Stokes equation, modelling turbulence. **CFD for Complex Geometry:**Structured and unstructured, uniform and non-uniform grids, different techniques of grid generations, curvilinear grid and transformed equations.

Lattice Boltzman and Molecular Dynamics: Boltzman equation, Lattice Boltzman equation, Lattice Boltzman methods for turbulence and multiphase flows, Molecular interaction, potential and force calculation, introduction to Molecular Dynamics algorithms.

Text Books:

1. J. D. Anderson, “Computational Fluid Dynamics”, McGraw-Hill Inc. (1995).
2. S. V. Patankar, “Numerical Heat Transfer and Fluid Flow”, Hemisphere Pub. (1980).
3. K. Muralidhar, and T. Sundarajan, “Computational Fluid Flow and Heat Transfer”, Narosa (2003).
4. D. A. Anderson, J. C. Tannehill and R. H. Pletcher, “Computational Fluid Mechanics and Heat Transfer”, Hemisphere Pub. (1984).
5. M. Peric and J. H. Ferziger, “Computational Methods for Fluid Dynamics”, Springer (2001).
6. H. K. Versteeg and W. Malalaskera, “An Introduction to Computational Fluid Dynamics”, Dorling Kindersley (India) Pvt. Ltd. (2008).
7. C. Hirsch, “Numerical Computation of Internal and External Flows”, Butterworth-Heinemann, (2007).
8. J. M. Jaile, “Molecular Dynamics Simulation: Elementary Methods”, Willey Professional, 1997.
9. A. A. Mohamad, “Lattice Boltzman Method: Fundamentals and Engineering Applications withComputer Codes”, Springer (2011).

ME537 Refrigeration and Air conditioning **(3-0-0-6)**

Pre-requisites: Nil

Refrigeration

Refrigeration systems: Vapour compression, vapour absorption and air refrigeration system, Thermo-electric refrigeration, Cryogenics.
Refrigeration Hardware: Refrigerant compressors, refrigerant condensers, refrigerant evaporators, receiver, expansion devices, filter-drier, moisture indicator etc.
Refrigeration Controls: HP/LP cut-out, Solenoid valve, evaporator pressure regulator, Accumulators, Suction pressure regulator.
Capacity control techniques: Hot gas by-pass scheme, Cylinder loading scheme, suction gas throttling scheme
Refrigerants: Classification and nomenclature, desirable properties of refrigerants, common refrigerants, environmental issues-Ozone depletion and global warming
Alternative refrigerants: low GWP and zero ODP newer refrigerants.
Applications of Refrigeration: Industrial refrigeration, Transport refrigeration, food preservation (cold storage)

Air-conditioning
Review of Basic psychrometry: Sensible cooling/heating processes, humidification /dehumidification processes on psychrometric chart etc.
Classification of air-conditioners: unitary systems (Window type/self-contained/single-package unit), split-unit and Central air conditioning system
Cooling/Heating load calculations: Transmission load, Solar heat gain, Occupancy load, Equipment load, Infiltration and ventilation load.
Duct Design: Design considerations and procedures
Air Conditioning controls: basic elements, types of control systems

Texts and References:

1. Dossat R.J., 2008. Principles of Refrigeration, Pearson Education (Singapore) Pte. Ltd.
2. Stoecker W., 1982. Refrigeration and Air Conditioning, Tata McGraw-Hill Publishing Company Limited, New Delhi.
3. Khan, M.K., 2012, Chapter 15: Refrigeration, Air Conditioning and Cold Storage, Handbook of Food Process Design, pp. 381-429., Wiley-Blackwell (UK).
4. Arora C.P., 2005. Refrigeration and Air Conditioning, Tata McGraw-Hill Publishing Company Limited, New Delhi.
5. Ameen A., 2006. Refrigeration and Air Conditioning, Prentice Hall of India Private Limited, New Delhi.
6. American Society of Heating Refrigerating and Air Conditioning Engineers Inc, 2013 ASHRAE Handbook- Refrigeration Fundamentals.
7. American Society of Heating Refrigerating and Air Conditioning Engineers Inc, 2011 ASHRAE Handbook- HVAC Applications.

ME535 Acoustics **(3-0-0-6)**

Acoustics: Mathematical basis for Acoustics- PDE, Vectors, divergence (Greens) theorem, Stokes theorem, Signal processing. Development of Wave equation, Helmholtz equation. Acoustic wave equation- Plane waves, Acoustic -Power, Intensity & measurement. Transmission, Absorption and attenuation of sound waves in fluids, Spherical Waves, monopole, dipole, quadropole and piston radiator. Radiation and Reception of Acoustic waves. Active sound control Pipes, Cavities, Waveguides, Resonators, Filters and Ducts-Plane Waves, energy dissipation, finite amplitudes and transmission phenomena, horn radiator, mufflers, silencers. Noise, signal detection, hearings and Speech-Noise spectrum and band level, combining band levels and Tones, Detecting signal in noise, Detection threshold, Ear-Thresholds, Equal loudness level contours, Critical bandwidth, Masking Loudness level, Pitch and frequency. Environmental Acoustics- weighted Sound levels, Speech interference, Criteria for Community noise Highway noise, Aircraft noise rating, Hearing loss, Legislations for Noise control. Architectural acoustics, Reverberation time, Sound Absorption materials, Direct and Reverberant Live rooms, Acoustic factors in design Transduction-transducers/transmitters- anti reciprocal, reciprocal. Loudspeakers, Microphones. Introduction to Underwater Acoustics.

Text Books:

[1] Fundamental of Physical Acoustics, David T Black Stock, John Wiley & Sons, Inc

[2] Noise and Vibration Control Engineering: Principles and Applications Leo L. Beranek , John Wiley & Sons, Inc

[3] Handbook of Noise and Vibration Control edited by Malcolm J. Crocker, John Wiley & Sons, Inc., New York, 2007

ME536 Nonlinear System Dynamics (3-0-0-6)

Introduction to Nonlinear Dynamical System: Linear vs. nonlinear behavior, Classification of nonlinear Systems, Examples of structural, fluid-mechanical and chemical/biological systems, Existence and uniqueness of solutions.

First-order nonlinear systems: Autonomous systems: Equilibrium points, linear systems, invariant sets, linearization, phase diagrams and velocity fields, behavior dependence on parameters, bifurcations of equilibria (saddle-node, pitchfork and transcritical), implicit function theorem. Nonautonomous systems.

Second-order nonlinear conservative/nonconservative systems: Phase plane analysis, equilibrium points, linearization, stability, periodic orbits and saddle points, potential function and phase portrait, parameter-dependent conservative systems, local bifurcations, examples of global bifurcations, effect of dissipative forces.

First-order system in the plane: General phase plane analysis, linearization, general solution for linear systems, classification of equilibrium points, limit cycles, Bendixon's criterion and Poincare Bendixon theorem. Point mapping techniques, exact transformations, and Poincare mappings.

One-dimensional linear and nonlinear mappings: Fixed points, linearization, stability, parameter-dependent mappings, bifurcations.

Perturbation and other approximate methods: Introduction to regular and singular perturbation expansions through algebraic and transcendental equations; roots of equations and dependence on parameters. Perturbation method for free oscillations, secular terms, frequency dependence on response, Poincare-Lindstedt technique for periodic solutions, Harmonic balance and Fourier series for periodic solutions. Averaging methods, amplitude and frequency estimates, slowly varying amplitude and phase ideas, self-excited oscillations. Multiple time-scale techniques. Forced oscillations, concept of a resonance, oscillations far from resonance, near resonances and strong and weak excitations, response near primary resonance, softening and hardening nonlinearities, Duffing's equation and primary and secondary resonances, forced response of self excited systems near resonance, frequency locking and entrainment.

General linear systems with constant and periodic coefficients: Concepts of stability (Lyapunov, Poincare, etc.), stability by linearization, boundedness of solutions, Mathieu's equation, transition curves and periodic solutions for Mathieu-Duffing system.

Relaxation oscillations: The van der Pol oscillator.

Multi degree of freedom systems: Examples, various types of resonances – external, internal, and combination, etc., response prediction using methods of averaging and multiple scales.

Some more on bifurcations, structural stability and chaos.

Experimental Demonstration: String ballooning motion. Fun with Cantilever beam of large deformation and other developed models. Electronic Circuit building. Numerical computation with Matlab/ Mathematica.

Text Books:

1. Jordan, D. W. and Smith, P.: Nonlinear Ordinary Differential Equations, 3rd Edition, Clarendon Press, Oxford, 1999 ed.
2. Nayfeh, A. H. and Mook, D. T.: Nonlinear Oscillations, Wiley Interscience, New York., 1979 ed.
3. Nayfeh, A. H and Balachandran, B. : Applied Nonlinear Dynamics: Analytical, Computational and Experimental Methods, Wiley, 2008 ed.
4. Strogatz, S. H. : Nonlinear Dynamics And Chaos: With Applications To Physics, Biology, Chemistry, And Engineering, Westview Press, 2001 ed.
5. Ogorzalek Maciej J.:Chaos and Complexity in Nonlinear Electronic Circuits, World Scientific Series on Nonlinear Science Series A, 1997 ed.

ME534 Wear and Lubrication of Machine components (3-0-0-6)

Course objectives: Surface failure due to rubbing is a critical problem that affects the life and reliability of modern machinery. The knowledge of surface interaction is interdisciplinary and essential to design for life and reliability and also enable innovation in electromechanical and material engineering design. The course focuses on theories of friction, wear, contact and lubrication, approaches to model basic tribological elements/systems, and methods to simulate tribological processes. Course content: Definition of Tribology, Significance for Maintenance and Reliability of machines, Terotechnology. Surface- roughness, materials, mechanics of surface/solid contacts Friction Laws of Friction, Mechanisms of Friction, Friction Space, Stiction, Stick Slip, Surface Temperature, surface energy, micro and nano scale viewsWear Adhesive Wear, Delamination Wear, Fretting Wear, Abrasive Wear, Erosive Wear, Corrosive Wear, Mild and Severe Oxidational Wear, Wear-Mechanism Maps, Stribeck Curve, Reciprocatory, Rotary, Rolling/sliding-HeathcoteLubrication- Regimes, Boundary Lubrication, Solid-Film Lubrication, Mixed Lubrication, Hydrodynamic Lubrication, Hydrostatic Lubrication, EHL, Lubrication in vacuum, Bearings- Rolling element, Step, Pad, Journal, Spiral groove, porous, air bearing, Gears, Cams, reciprocatory Lubricant-composition, basefluids, rheology, Additives- boundary layer. Nano additivesDynamic seals-Mechanical face seals, Rotary Lip seal, Elastomeric, Bushing, Labyrinth, applications of sealsNanoscale tribology Interatomic Interactions, Atomic Force Microscope (AFM), Challenges of Tribological Testing at Small Scales Tribological tests Friction, Wear, Life tests, Standards, Reciprocatory, Rotary, rolling/Sliding-spiral orbit, Dry and Lubricated tests, Scaling up subscale tests, component tests. Nano scale testsSurface engineering- coatings, modifications, repairMaterials-metals, polymer, ceramics for Tribological designCase Studies Sliding Contacts, Rolling Contacts, Bearing Design, Coating Selection. Electric Contacts, Microelectromechanical Systems (MEMS)

Text Books:

1. Tribology, Principles and Design Applications, by Arnell et al.
2. Principles and Applications of Tribology, by B. Bhushan
3. Tribology Handbook, by B. Bhushan
   Contact Mechanics KL Johnson, 1985 Cambridge
4. Basic Lubrication Theory, By A. Cameron, 1976

MA507: Nonlinear Optimization (3-0-0-6)

Nonlinear programming: Convex sets and convex functions, their properties, convex programming problem, generalized convexity, Pseudo and Quasi convex functions, Invex functions and their properties, KKT conditions.
Goal Programming: Concept of Goal Programming, Model Formulation, Graphical solution method.
Separable programming. Geometric programming: Problems with positive coefficients up to one degree of difficulty, Generalized method for the positive and negative coefficients.

Search Techniques: Direct search and gradient methods, Unimodal functions, Fibonacci method, Golden Section method, Method of steepest descent, Newton-Raphson method, Conjugate gradient methods.
Dynamic Programming: Deterministic and Probabilistic Dynamic Programming, Discrete and continuous dynamic programming, simple illustrations.
Multiobjective Programming: Efficient solutions, Domination cones.

Text Books:

1. Mokhtar S. Bazaaraa, Hanif D. Shirali and M.C.Shetty, Nonlinear Programming, Theory and Algorithms, John Wiley & Sons, New York (2004).

Reference Books:

1. D. G. Luenberger, Linear and Nonlinear Programming, Second Edition, Addison Wesley (2003).
2. R. E. Steuer, Multi Criteria Optimization, Theory, Computation and Application, John Wiley and Sons, New York (1986).

EE501: Control of Mechatronic Systems (3-0-0-6)

Time response design: Routh-Hurwitz test, relative stability, Root locus design, construction of root loci, phase lead and phase-lag design, lag-lead design.
Frequency response design: Bode, polar, Nyquist, Nichols plot, lag, lead, lag-lead compensator, time delay, process plant response curve. PID controller design.
Modern control: Concept of states, state space model, different form, controllability, observability; pole placement by state feedback, observer design, Lunenburg observer, reduced order observer, observer based control.
Optimal control design: Solution-time criterion, control-area criterion, performance indices; zero steady state step error systems; modern control performance index: quadratic performance index, Ricatti equation.
Digital control: Sampling process, sample and hold, analog to digital converter, use of z-transform for closed loop transient response, stability analysis using bilinear transform and Jury method, digital control design using state feedback.
Non-Linear Control System: Common physical non-linear system, phase plane method, system analysis by phase plane method, stability of non-linear system, stability analysis by describing function method, Liapunov's stability criterion, Popov's stability criterion.

Text Books:

1. K. Ogata, "Modern Control Engineering", Prentice Hall India (2002).
2. Gene F. Franklin, J. D. Powell, A E Naeini, "Feedback Control of Dynamic Systems", Pearson (2008).
3. John Van De Vegte, "Feedback Control Systems", Prentice Hall (1993).
4. Thomas Kailath, "Linear Systems", Prentice Hall (1980).
5. Alok Sinha, "Linear Systems: Optimal and Robust Control", Taylor & Francis (2007).

6. Brian D. O. Anderson and John B. Moore, “Optimal Control: Linear Quadratic Methods”, Dover Publications (2007).
7. K. Ogata, “Discrete-Time Control Systems”, PHI Learning (2009).
8. H.K. Khalil, “Nonlinear Systems”, Prentice Hall (2001).

PH515: MEMS and NEMS (3-0-0-6)

Micro and nano mechanics – principles, methods and strain analysis, an introduction to microsensors and MEMS, Evolution of Microsensors & MEMS, Microsensors & MEMS applications, Microelectronic technologies for MEMS, Micromachining Technology – Surface and Bulk Micromachining, Micromachined Microsensors, Mechanical, Inertial, Biological, Chemical, Acoustic, Microsystems Technology, Integrated Smart Sensors and MEMS, Interface Electronics for MEMS, MEMS Simulators, MEMS for RF Applications, Bonding & Packaging of MEMS, Conclusions & Future Trends. **Nanoelectromechanical systems (NEMS) –** a journey from MEMS to NEMS, MEMS vs. NEMS, MEMS based nanotechnology – fabrication, film formation and micromachining, NEMS physics – manifestation of charge discreteness, quantum electrodynamical (QED) forces, quantum entanglement and teleportation, quantum interference, quantum resonant tunneling and quantum transport, Wave phenomena in periodic and aperiodic media – electronic and photonic band gap crystals and their applications, NEMS architecture, Surface Plasmon effects and NEMS fabrication for nanophotonics and nanoelectronics, Surface Plasmon detection – NSOM/SNOM.

Text Books:

1. Electromechanical Sensors and Actuators, Ilene J. Busch-Vishniac, Springer, 2008.
2. Introduction to Microelectronics Fabrication, Vol. V, G. W. Neudeck and R. F. Pierret (eds.), Addison – Wesley, 1988.
3. Introduction to Microelectromechanical Microwave Systems, H. J. De Loss Santos, 2nd edition, Norwood, MA: Artech, 2004.
4. Microsystems Design, S. D. Senturia, Kluwer – Academic Publishers, Boston MA, 2001.
5. Principles and Applications of Nano-MEMS Physics, H. J. Delos Santos, Springer, 2008.
6. Materials and Process Integration for MEMS Microsystems, Vol. 9, Francis E. H. Tay, Springer, 2002.

Reference Books:

1. Quantum Mechanical Tunneling and its Applications, D. K. Roy, World Scientific, Singapore, 1986
2. Encyclopedia of Nanoscience and Technology, Vol. 5, H. S. Nalwa (ed.), American scientific Publishers, 2004
3. Carbon Nanotubes and Related Structures, P. J. F. Harris, Cambridge University Press, UK, 1986.
4. Carbon Nanoforms and Applications, M Sharon and M. Sharon, Mc Graw Hill, 2010
5. VLSI Technology, S. M. Sze (eds.), Mc-Graw Hill, NY, 1983
6. Quantum Phenomena, S. Datta, Addison – Wesley, 1989.

ME742 Advanced Manufacturing Processes (3-0-0-6)

Advanced Engineering Materials & the limitations of Conventional manufacturing processes; Classification of advanced manufacturing processes; Water jet & abrasive water jet machining; Ultrasonic machining; Electrical discharge machining; Ion Beam, Electron Beam & Laser beam in manufacturing; PVD & CVD; Micro and Nano Manufacturing.

Text Books:

1. A Ghosh and A K Mallik, Manufacturing Science, Affiliated East-West Press Pvt Ltd, 1995.
2. James Brown, Modern Manufacturing Processes, Industrial Press Inc, 1991.
3. William M. Steen, Laser Material Processing, 3rd edition, Springer, 2003.
4. Mark J. Jackson, Microfabrication and Nanomanufacturing, Taylor & Francis, 2008.
5. Chue San Yoo, Semiconductor Manufacturing Technology, World Scientific, 2008

ME501 Robotics: Advanced Concepts and Analysis (3-0-0-6)

Introduction to robotics: brief history, types, classification and usage and the science and technology of robots.
Kinematics of robot: direct and inverse kinematics problems and workspace, inverse kinematics solution for the general 6R manipulator, redundant and over-constrained manipulators.
Velocity and static analysis of manipulators: Linear and angular velocity, Jacobian of manipulators, singularity, static analysis.
Dynamics of manipulators: formulation of equations of motion, recursive dynamics, and generation of symbolic equations of motion by a computer simulations of robots using software and commercially available packages.
Planning and control: Trajectory planning, position control, force control, hybrid control Industrial and medical robotics: application in manufacturing processes, e.g. casting, welding, painting, machining, heat treatment and nuclear power stations, etc; medical robots: image guided surgical robots, radiotherapy, cancer treatment, etc;
Advanced topics in robotics: Modelling and control of flexible manipulators, wheeled mobile robots, bipeds, etc. Future of robotics.

Reference Books:

1. M. P. Groover, M. Weiss, R. N. Nagel and N. G. Odrey, “Industrial Robotics-Technology, Programming and Applications”, McGraw-Hill Book and Company (1986).
2. S. K. Saha, “Introduction to Robotics”, Tata McGraw-Hill Publishing Company Ltd. (2008).
3. S. B. Niku, “Introduction to Robotics–Analysis Systems, Applications”, Pearson Education (2001).
4. . A. Ghosal, Robotics: “Fundamental Concepts and Analysis”, Oxford University Press (2008).
5. Pires, “Industrial Robot Programming–Building Application for the Factories of the Future”, Springer (2007).

6. Peters, “Image Guided Interventions – Technology and Applications”, Springer (2008).
7. K. S. Fu, R. C. Gonzalez and C.S.G. Lee, “ROBOTICS: Control, Sensing, Vision and Intelligence”, McGraw-Hill (1987).
8. J. J. Craig, “Introduction to Robotics: Mechanics and Control”, 2nd edition, Addison-Wesley (1989).

EE503: Signal Processing in Mechatronic Systems (3-0-0-6)

Discrete- Time Signals: Sequences; representation of signals on orthogonal basis; Sampling and Reconstruction of signals
Discrete systems: Z-Transform, Analysis of LSI systems, Frequency Analysis, Inverse Systems, Discrete Fourier Transform (DFT), Fast Fourier Transform algorithm, Implementation of Discrete Time Systems.
Frequency selective filters: Ideal filter characteristics, lowpass, highpass, bandpass and bandstop filters, Paley-Wiener criterion, digital resonators, notch filters, comb filters, all-pass filters, inverse systems, minimum phase, maximum phase and mixed phase systems.
Design of FIR and IIR filters: Design of FIR filters using windows, frequency sampling, Design of IIR filters using impulse invariance, bilinear transformation and frequency transformations, Butterworth, Chebyshev Filters.
Introduction to multi-rate signal processing: Decimation, interpolation, polyphase decomposition; digital filter banks: Nyquist filters, two channel quadrature mirror filter bank and perfect reconstruction filter banks, subband coding.
Introduction to DSP Processors: Introduction to various Texas processors such as TMS320C6713, TMS320C6416, DM6437 Digital Video Development Platform with Camera, DevKit8000 OMAP3530 Evaluation Kit.
Applications: Application of DSP to Speech and Radar signal processing, A few case studies of DSP applications in multimedia using TI DSP kits.

Text books:

1. S. K. Mitra, Digital Signal Processing: A computer-Based Approach, 3/e, TMcHl, 2006.
2. A. V. Oppenheim and R. W. Shafer, Discrete-Time Signal Processing, Prentice Hall India, 2/e, 2004.
3. J. G. Proakis and D. G. Manolakis, Digital Signal Processing: Principles, Algorithms and Applications, 4/e, Pearson Education, 2007.

Reference Books:

1. V.K. Ingle and J.G. Proakis, “Digital signal processing with MATLAB”, Cengage, 2008.
2. T. Bose, Digital Signal and Image Processing, John Wiley and Sons, Inc., Singapore,04.
3. L. R. Rabiner and B. Gold, Theory and Application of Digital Signal Processing, PH, 2005.
4. A. Antoniou, Digital Filters: Analysis, Design and Applications, Tata McH, 2003.

ME504: Vehicle Dynamics and Multi-body Systems (3-0-0-6)

Introduction to vehicle dynamics: Vehicle coordinate systems; loads on axles of a parked car and an accelerating car. Acceleration performance: Power-limited acceleration, traction-limited acceleration.
Tire models: Tire construction and terminology; mechanics of force generation; rolling resistance; tractive effort and longitudinal slip; cornering properties of tire; slip angle; camber thrust; aligning moments.
Aerodynamic effects on a vehicle: Mechanics of airflow around the vehicle, pressure distribution, aerodynamic forces; pitching, rolling and yawing moments; crosswind sensitivity.
Braking performance: Basic equations for braking for a vehicle with constant deceleration and deceleration with wind-resistance; braking forces: rolling resistance, aerodynamic drag, driveline drag, grade, tire-road friction; brakes, anti-lock braking system, traction control, braking efficiency.
Steering systems and cornering: Geometry of steering linkage, steering geometry error; steering system models, neutral steer, under-steer, over-steer, steering ratio, effect of under-steer; steering system force and moments, low speed and high speed cornering; directional stability of the vehicle; influence of front-wheel drive.
Suspension and ride: Suspension types—solid axle suspensions, independent suspensions; suspension geometry; roll centre analysis; active suspension systems; excitation sources for vehicle rider; vehicle response properties, suspension stiffness and damping, suspension isolation, active control, suspension non-linearity, bounce and pitch motion.
Roll-over: Quasi-static roll-over of rigid vehicle and suspended vehicle; transient roll-over, yaw-roll model, tripping.
Multi-body systems: Review of Newtonian mechanics for rigid bodies and system of rigid bodies; coordinate transformation between two set of axes in relative motion between one another; Euler angles; angular velocity, angular acceleration, angular momentum etc. in terms of Euler angle parameters; Newton-Euler equations of motion; elementary Lagrangian mechanics: generalised coordinates and constraints; principle of virtual work; Hamilton's principle; Lagrange's equation, generalized forces. Lagrange's equation with constraints, Lagrange's multiplier.

Text Books

1. T.D. Gillespie, "Fundamental of Vehicle Dynamics", SAE Press (1995)
2. J.Y. Wong, "Theory of Ground Vehicles", 4th Edition, John Wiley & Sons (2008).
3. Reza N. Jazar, "Vehicle Dynamics: Theory and Application", 1st Edition, 3rd Printing, Springer (2008).
4. R. Rajamani, "Vehicle Dynamics and Control", Springer (2006).
5. A.A. Shabanna, "Dynamics of Multibody Systems", 3rd Edition, Cambridge University Press (2005).

Reference Books:

1. G. Genta, "Motor Vehicle Dynamics", World Scientific Pub. Co. Inc. (1997).
2. H.B. Pacejka, "Tyre and Vehicle Dynamics", SAE International and Elsevier (2005).
3. Dean Karnopp, "Vehicle Stability", Marcel Dekker (2004).
4. U. Kiencke and L. Nielsen, "Automotive Control System", Springer-Verlag, Berlin.

5. M. Abe and W. Manning, “Vehicle Handling Dynamics: Theory and Application”, 1st Edition, Elsevier (2009).
6. L. Meirovitch, “Methods of Analytical Dynamics”, Courier Dover (1970).
7. H. Baruh, “Analytical Dynamics”, WCB/McGraw-Hill (1999).

ME506: Emerging Smart Materials for Mechatronics Applications (3-0-0-6)

Introduction: Smart materials and their application for sensing and actuation, Mechatronics aspects.
Piezoelectric materials: Piezoelectricity and piezoelectric materials, Constitutive equations of piezoelectric materials, Piezoelectric actuator types, Control of piezoelectric actuators, Applications of piezoelectric actuators for precise positioning and scanning.
Shape memory alloys (SMA): Properties of shape memory alloys, Shape memory effects, Pseudo-elasticity in SMA, Design of shape memory actuator, selection of materials, Smart actuation and control, Applications of SMA in precision equipments for automobiles, trains and medical devices.
Electro-active polymers (EAPs): Ionic polymer metal composites (IPMC), Conductive polymers, Carbon nanotubes, Dielectric elastomers, Design & control issues for EAP actuators, Applications of EAP for biomemetic, tactile display and medical devices.
Magnetostrictive materials: Basics of magnetic properties of materials, magnetostriction: constitutive equations, types of magnetostrictive materials, Design & control of magnetostrictive actuators, Applications of magnetostrictive materials for active vibration control.
Summary, conclusion and future outlook: Comparative analysis of different smart materials based actuators, Conclusions, Future research trend and applications trends of smart materials and smart materials based actuator technology.

Texts Books:

1. Jose L. Pons, Emerging Actuator Technologies, a Micromechatronics Approach, John Wiley & Sons Ltd, 2005. .
2. Ralph Smith, Smart Material Systems: Model Development, SIAM, Society for Industrial and Applied Mathematics, 2005. .
3. F. Carpi, D. De Rossi, R. Kornbluh, R. Pelrine, P. Sommer-Larsen, Dielectric Elastomers as Electromechanical Transducers, Elsevier, Hungry, 2008. .
4. Y. B. Cohen, Electroactive Polymer (EAP) Actuators as Artificial Muscles Reality, Potential and Challenges, SPIE press, USA, 2004.

ME502: Industrial Automation (3-0-0-6)

Unit 1: Automation: Introduction, automation principles and strategies, basic elements of advanced functions, levels modeling of manufacturing systems.
Unit 2: Material handling: Introduction, material handling systems, principles and design, material transport system: transfer mechanisms automated feed cut of components, performance analysis, uses of various types of handling systems including AGV and its

various guiding technologies.
Unit 3: Storage system: Performance, location strategies, conventional storage methods and equipments, automated storage systems. **Unit 4:** Automated manufacturing systems: Components, classification, overview, group technology and cellular manufacturing, parts classification and coding, product flow analysis, cellular manufacturing, application considerations in G.T.
Unit 5: FMS: Introduction, components, application, benefits, planning and implementation, transfer lines and fundamentals of automated production lines, application, analysis of transfer line without internal storage (numerical problems).
Unit 6: Inspection Technology: Introduction, contact and non-contact conventional measuring, gauging technique, CMM, surface measurement, machine vision, other optical inspection techniques, non-contact non-optical inspection technologies versus.
Unit 7: Manufacturing support system: Process planning and concurrent engineering- process planning, CAPP, CE and design for manufacturing, advanced manufacturing planning, production planning and control system, master production schedule, MRP.
Unit 8: Capacity planning, shop floor control, inventory control, MRP-II, J.I.T production systems. lean and agile manufacturing.

Text Books:

1. M.P. Groover, Automation, "Production Systems and Computer Integrated manufacturing", 2nd Edition, Pearson Education (2004).

References Books:

1. Vajpayee, "Principles of CIM", PHI, 1992.
2. Viswanathan and Narahari, "Performance Modeling of Automated Manufacturing Systems", PHI, 2000.
3. R.S. Pressman, "Numerical Control and CAM, John Wiley , 1993.

MA 502 Numerical Optimization **(3-0-0-6)**

Introduction to optimization problems, Convex sets and convex funcions, their properties, convex programming problems, Lagranges Multiplier mehtod, Optimality conditions for unconstrained minimization and constrained minimization problems, KKT conditions. Unimodal functions, Fibonnacci search, Linesearch methods, Convergence of generic line search methods, Method of steepest descent, more general descent methods, Conjugate gradient methods, Fletcher Reeves methods for nonlinear functions, Interior point methods for inequality constrained optimization, Merit functions for constrained minimization, logarithmic barrier function for inequality constraints, A basic barrier-function algorithm, perturbed optimality conditions, A practical primal-dual method . Newton's method for first-order optimality, The Sequential Quadratic Programming iteration, Line search SQP methods, Trust-region SQP methods . Mulitobjective programming, Efficient solutions, Dominated cones, Formulation of Goal programming problems and solution methodologies for linear Goal programming problem. Introduction to Evolutionary methods and global optimization.

Texts Books:

1. J. Nocedal and S. Wright, Numerical Optimization, Springer Verlag 1999.

2. P. Gill, W. Murray and M. Wright, Practical Optimization, Academic Press 1981 .
3. R. Fletcher, Practical Methods of Optimization, 2nd edition Wiley 1987, (republished in paperback 2000) .
4. A. Conn, N. Gould and Ph. Toint, Trust-Region Methods, SIAM 2000 .

MA504 Computational Differential Equations (3-0-0-6)

Introduction to Scientific Computing

Problem Classification, Linear Systems of ODEs with Constant Coefficients, Some Stability Concepts for ODEs, Stability for a Solution Trajectory of an ODE System, Stability for Critical Points of ODE Systems, Some ODE Models in Science and Engineering. Basic Principles of Numerical Approximation of ODEs, Numerical Solution of IVPs with Euler's Explicit and Implicit Method , Trapezoidal Method, Higher-Order Methods for the IVP, Runge-Kutta Methods, Linear Multistep Methods, Accuracy, Stability . Difference Methods for BVPs, Accuracy, Spurious Oscillations, Linear Two-Point BVPs, Nonlinear Two-Point BVPs, The Shooting Method, Ansatz Methods for BVPs. Classical PDE Problems, Differential Operators Used for PDEs, Some PDEs in Science and Engineering, Initial and Boundary Conditions for PDEs, The Finite Difference Method, Discretization of a Problem with Different BCs, The Method of Lines for Parabolic PDEs, Generalizations of the Heat Equation, The Convection-Diffusion-Reaction PDE, The General Nonlinear Parabolic PDE, Ansatz Methods for the Model Equation, The Finite Difference Method, Discretization of a Problem with Different BCs, Introduction to Finite Element Method, The Finite Difference Method, Discretization of a Problem with Different BCs, Numerical Stability for Hyperbolic PDEs , Nature Laws, Constitutive Equations, Equations in Heat Transfer Problems, Equations in Mass Diffusion Problems, Equations in Mechanical Moment Diffusion Problems, Equations in Elastic Solid Mechanics Problems, Equations in Chemical Reaction Engineering Problems, Equations in Electrical Engineering Problems, Conservative Equations, Equations in Financial Engineering.

Text Books:

1. J.C. Butcher, Numerical methods for ordinary differential equations, John Wiley and Sons, 2008.
2. K. E. Atkinson, W. Han, D. Stewart, Numerical solution of ordinary differential equations, John Wiley and Sons, 2009.
3. D. F. Griffiths, D.J. Higham, Numerical Methods for Ordinary Differential Equations: Initial Value Problems, Springer, 2010.
4. Tveito, R. Winther, Introduction to partial differential equations: a computational approach, Springer, 2005.
5. R.M. M. Mattheij, S. W. Rienstra, J. H. M. ten Thije Boonkkamp, Partial differential equations: modeling, analysis, computation, SIAM, 2005.
6. G. D. Smith, Numerical solution of partial differential equations: finite difference methods, Oxford University Press, 1985.
7. J. A. Trangenstein, Numerical solution of hyperbolic partial differential equations, Cambridge University Press, 2009.

SE504 Modeling and Simulation of Mechatronic Systems (3-0-0-6)

Physical Modelling: Mechanical and electrical systems, physical laws, continuity equations, compatibility equations, system engineering concept, system modelling with structured analysis, modelling paradigms for mechatronic system, block diagrams, mathematical models, systems of differential-algebraic equations, response analysis of electrical systems, thermal systems, fluid systems, mechanical rotational system, electrical-mechanical coupling.
Simulation Techniques: Solution of model equations and their interpretation, zeroth, first and second order system, solution of 2nd order electro-mechanical equation by finite element method, transfer function and frequency response, non-parametric methods, transient, correlation, frequency, Fourier and spectra analysis, design of identification experiments, choice of model structure, scaling, numeric methods, validation, methods of lumped element simulation, modelling of sensors and actuators, hardware in the loop simulation (HIL), rapid controller prototyping, coupling of simulation tools, simulation of systems in software (MATLAB, LabVIEW) environment.

Modelling and Simulation of Practical Problems:

- Pure mechanical models
- Models for electromagnetic actuators including the electrical drivers
- Models for DC-engines with different closed loop controllers using operational amplifiers
- Models for transistor amplifiers
- Models for vehicle system

Text Books:

1. L. Ljung, T. Glad, “Modeling of Dynamical Systems”, Prentice Hall Inc. (1994).
2. D.C. Karnopp, D.L. Margolis and R.C. Rosenberg, “System Dynamics: A Unified Approach”, 2nd Edition, Wiley-Interscience (1990).
3. G. Gordon, “System Simulation”, 2nd Edition, PHI Learning (2009).
4. V. Giurgiutiu and S. E. Lyshevski, “Micromechatronics, Modeling, Analysis, and Design with MATLAB”, 2nd Edition, CRC Press (2009).

ME 512 Mobile Robotics (3-0-0-6)

Objectives: Mobile robots are now enabling human beings to physically reach and explore unchartered territories in the Universe. Be a place as distant as Mars, in abysmal depths of ocean, or shrouded by thick glaciers of Antarctic, mobile robots help exploring everything; yet this is just the beginning. Even in day to day life autonomous cars hold a potential to revolutionize transportation and domestic mobile robots help humans in cleaning, elderly help, etc. National defense is an area replete with the use of mobile robots. This course will present various aspects of design, fabrication, motion planning, and control of intelligent mobile robotic systems. The focus of the course is distributed equally on the computational aspects and practical implementation issues and thereby leads to a well rounded training. The course will give students an opportunity to design and fabricate a mobile robotic platform and program it to apply learned theoretical concepts in practice as a semester long class project.

Syllabus:

Robot locomotion: Types of locomotion, hopping robots, legged robots, wheeled robots, stability, maneuverability, controllability;
Mobile robot kinematics and dynamics: Forward and inverse kinematics, holonomic and nonholonomic constraints, kinematic models of simple car and legged robots, dynamics simulation of mobile robots.
Perception: Proprioceptive/Exteroceptive and passive/active sensors, performance measures of sensors, sensors for mobile robots like global positioning system (GPS), Doppler effect-based sensors, vision based sensors, uncertainty in sensing, filtering;
Localization: Odometric position estimation, belief representation, probabilistic mapping, Markov localization, Bayesian localization, Kalman localization, positioning beacon systems.
Introduction to planning and navigation: path planning algorithms based on A-star, Dijkstra, Voronoi diagrams, probabilistic roadmaps (PRM), rapidly exploring random trees (RRT), Markov Decision Processes (MDP), stochastic dynamic programming (SDP);
Robotics Project: Students will work on a semester long project consisting of design, fabrication, and programming a mobile robotic platform.

Texts Books:

1. Melgar, E. R., Diez, C. C., Arduino and Kinect Projects: Design, Build, Blow Their Minds, 2012.
2. R. Siegwart, I. R. Nourbakhsh, “Introduction to Autonomous Mobile Robots”, The MIT Press, 2011.
3. Peter Corke , Robotics, Vision and Control: Fundamental Algorithms in MATLAB, Springer Tracts in Advanced Robotics, 2011.

ME541 Turbulent Shear Flows **(3-0-0-6)**

Students who may find this course useful: PhD, M. Tech and 3rd/4th–year B. Tech. Students from Mechanical, Civil and Chemical Engineering Departments.

Pre-requisite: ME204 (Fluid Mechanics I) of IIT Patna or an equivalent basic course in Fluid Mechanics

Course Contents:

1. Flow instability and transition to turbulence
2. Nature of turbulence
3. Indicial notation for tensors
4. Fourier transforms and Parseval’s theorem
5. Governing equations of turbulence
6. Eulerian Lagrangian and Fourier descriptions of turbulence
7. Statistical description of turbulence (Reynolds-averaged Navier-Stokes and Reynolds stress evolution equations)
8. Kolmogorov’s hypotheses
9. Filtered description of turbulence (Bridging methods and large eddy simulation)
10. Boundary layer flow and other important turbulent shear flows (wake, jet, channel flow, etc.)

11. Development of turbulence closure models (Boussinesq approximation and Reynolds-stress evolution equation closures)
12. Rapid distortion theory (RDT) of turbulence

Turbulence processes (Cascade, dissipation, material element deformation, mixing, etc.)

Texts Books:

1. Pope, S. B., Turbulent Flows, Cambridge University Press, 2000.
2. Wilcox, D.C., Turbulence Modeling for CFD, D.C.W. Industries, 3rd Edition, 2006.
3. White, F.M., Viscous Fluid Flow, TATA McGraw Hill, 2011
4. Tennekes, H. and Lumley, J.L., A First Course in Turbulence, The MIT Press, 1972.

MA511 Large Scale Scientific Computation (3-0-0-6)

Introduction to sparse matrices, Storage Schemes, Permutations and Reorderings, , Sparse Direct Solution Methods. Iterative methos and Preconditioning Convergence Krylov Subspaces, Arnoldi's Method, GMRES, Symmetric Lanczos Algorithm, Conjugate Gradient Algorithm, Convergence Analysis, Block Krylov Methods, Preconditioned Conjugate Gradient, Preconditioned GMRES, Jacobi, SOR, and SSOR Preconditioners, ILU Factorization Preconditioners, Block Preconditioners, Types of Partitionings, Techniques, Direct Solution and the Schur Complement, Schur Complement Approaches, Full Matrix Methods, Graph Partitioning: Geometric Approach, Spectral Techniques.

Newton's method and some of its variations, Newton method in several dimension, continuation methods, conjugate direction method and Davidon-Fletcher-Powell Algorithms, Introduction to Non-linear Multigrid with applications.

HPC kernels (BLAS, multicore and GPU computing)

Texts Books:

1. O. Axelsson, Iterative Solution Methods Cambridge Univ. Press, 1994.
2. W. Hackbusch, Multigrid Methods and Applications. Springer-Verlag, 1985.
3. J.M. Ortega and W.C. Rheinboldt, Iterative Solution of Nonlinear Equations in Several Variables.Academic Press, NY, 1970.
4. C.W. Ueberrhuber, Numerical Computation : Methods, Software and Analysis. Springer-Verlag,Berlin, 1997.
5. P. Wesseling, An Introduction to Multigrid Methods. John Wiley & Sons, 1992.
6. Yousef Saad, Iterative Methods for Sparse Linear Systems, SIAM 2003.

ME581 Biomechanics and Biomechatronics (3-0-0-6)

Introduction to Biological System, Cell, Tissues and Connective Tissues and their Phenomenological Models: Bone, Tendon, Cartilage, Smooth Muscle cells, Growth, Remodeling and Residual Stresses, Circulation system, Neural system and control, Instrumentation Technique, Therapeutic and Prosthetic Devices and Instrumentation, Introduction to Biosensor**,** Experimental Demonstration, Project evaluation and Guest lecture by Medical Professionals.

Texts Books:

1. Jay D. Humphrey and Sherry DeLange "An Introduction to Biomechanics: Solids and Fluids, Analysis and Design", Springer; 1st EditionCarl-Fredrik Mandenius and Mats Bjorkman "Biomechatronic Design in Biotechnology: A Methodology for Development of Biotechnological Products", Wiley; 1st Edition
2. *Stephen C***.** *Cowin* and *Jay D. Humphrey* Edt. , "Cardiovascular Soft Tissue Mechanics ", Kluwer Academic Publishers
3. L. Gorton Edt. "Biosensors and Modern Biospecific Analytical Techniques" Elsevier Science; 1st. Edition
4. Y.F. **Al-Obaid**, F.N. **Bangash** and T.**Bangash**, "Trauma - An Engineering Analysis" Springer; 1st Edition
5. John G. Webster Edt. "Medical Instrumentation: Application and Design", Wiley; 3rd Edition

ME 554 Rotor Dynamics (3-0-0-6)

Rotor-Bearing Interaction, Flexural Vibration, Critical Speeds of Shafts, Jeffcott Rotor Model, Unbalance Response, Effect of Damping, Campbell Diagram, Effects of Anisotropic Bearings, Unbalanced Response of an Asymmetric Shaft, Parametric Excitation, Gyroscopic Effects, Rotor with Non-central Disc, Rigid-rotor of Flexible Bearings, Stodola Model, Effect of Spin Speed on Natural Frequency, Forward and Backward Whirling Motion, Aerodynamic Effects, Instability: Rub, Tangential forces, Rotor-shaft Continuum, Effect of Rotary Inertia and Shear-Deformation within the Shaft, Equivalent Discrete System, Finite Element model for Flexural Vibration, Torsional Vibration, Geared and Branched Systems, Transfer Matrix Model, Fluid Film Bearings: Steady State Characteristics of Bearings, Reynolds's Equation, Oil-Whirl, Rigid And Flexible Rotor Balancing, Active Vibration Control of Rotor-Bearing System: Active Magnetic Bearing, Condition Monitoring of Rotating Machinery, Measurement Techniques. Rolling element bearings, Fault diagnosis.

Texts Books:

1. J. S. Rao, Rotor Dynamics, Third ed., New Age, New Delhi, 1996 (2009 reprint).
2. M. J. Goodwin, Dynamics of Rotor-Bearing Systems, Unwin Hyman, Sydney, 1989.

Reference Books:

1. E. Krämmer, Dynamics of Rotors and Foundation, Springer-Verlag, New York, 1993.
2. G. Genta, Dynamics of Rotating Systems, Springer, New York, 2005.
3. J.M. Vance, Rotordynamics of Turbomachinery, Wiley, New York, 1988.
4. M.L. Adams, Rotating machinery vibration: from analysis to troubleshooting, Second ed., CRC Press, Boca Raton, 2010.
5. J. Kicinski, Rotor dynamics, Tech. Book, New Delhi, 2010.
6. D. Childs, Turbomachinery Rotordynamics: Phenomena, Modeling and Analysis, Wiley, New York, 1993.

7. Y. Ishida, T. Yamamoto, Linear and Nonlinear Rotordynamics: A Modern Treatment with Applications, 2nd Edition, Wiley, 2012.
8. J.P. Den Hartog, Mechanical Vibration, Courier Dover Publication, 2013.

ME542 Aerodynamics (3 0 0 6)

Pre-requisites: ME 204, ME 206, ME 305 or equivalent

Review of Fluid Mechanics: Navier-Stokes equations, Potential flows, Concepts of lift and drag, Boundary layer theory, Application of potential flow and boundary layer theory in design of airfoils, Turbulence, Compressible flows, Shock and expansion waves,
Incompressible Flow Applications: Incompressible flow over airfoils: Kutta condition, Kelvin's circulation theorem, Classical thin airfoil theory, Incompressible flow over finite wings: Prandtl's classical lifting line theory, Three-dimensional incompressible flows, Panel methods and numerical techniques, Wind tunnel experimentation, Dynamic stall, Delta wings.
Compressible Flow Applications: Introduction to subsonic compressible flow over airfoils, Supercritical Airfoil, Supersonic flows.
Advanced Applications: Aerodynamics of wing-fuselage system and control surfaces, Helicopters, Aerodynamics of birds/insects, Micro-air vehicle.

Texts and References

1. J. D. Anderson, Fundamentals of Aerodynamics, McGraw-Hill Inc. (Indian Edition), 2005.
2. Josep Katz and Allen Plotkin, Low-speed aerodynamics, Cambridge University Press, 2001.
3. Wei Shyy, Yongsheng Lian, Jian Thang, Dragos Viieru and Hao Liu, Aerodynamics of Low Reynolds Number Flyers, Cambridge University Press, 2009.
4. Holt Ashley and Landhall. M. Aerodynamics of Wings and Bodies. Addison-Wesley 1965.
5. Jones.R.T. Wing Theory. Princeton University Press 1990.

ME546 Multiphase Flow and Heat Transfer (3-0-0-6)

Prerequisites: ME 204 and ME 305, or equivalent
Fundamentals: Introduction to liquid-vapor phase change fundamentals, kinetic theory, interfacial tension, wettability, boiling, nucleate boiling, critical heat flux and dryout mechanisms, transition boiling, Leidenfrost, film boiling, nucleation theory, convective flow boiling fundamentals, flow patterns and regime map, condensation, film-wise condensation vs. dropwise condensation theory. Devices and applications areas: introduction to devices and application areas, boilers and condensers, nuclear reactor, thermosyphons, heat pipes, and vapor chambers. Practical considerations: effect of non-condensable gas and surface aging. Current trends: Heat transfer coefficient enhancement techniques, heat and mass transfer at microscopic length scales and gravity levels, microchannels, modeling techniques

Texts Books:

1. Van Carey. *Liquid-Vapor Phase-Change Phenomena*, Taylor and Francis: 2nd Edition, 2007, ISBN: 0-89116-836-2, and 1-56032-074-5

Reference Books:

1. Incropera and Dewitt. *Fundamentals of Heat and Mass Transfer*, Wiley, 6th Edition, ISBN: 9780471457282
2. Leinhard and Leinhard, *A Heat Transfer Textbook*, Phlogiston Press, 3rd Edition, ISBN: 0-9713835-2-9

CE 505 Application of Probabilistic Methods in Engineering (3-0-0-6)

Concept of risk, and uncertainty in engineering analysis and design; Fundamental of probability models. Analytical models of random phenomena: Baysian Analysis, Analysis of variance (ANOVA); Application of central limit theorem, confidence interval, expected value, and return period. Application of Monte Carlo simulation (MCS): Determination of function of random variables using MCS methods; Application of MCS in various engineering problems. Probabilistic analysis and determination: i) Forces induced by earthquakes, ii) Forces induced by wind, iii) Forces induced by sea waves, iv) Load on vehicles induced through surface roughness of roads. Methods of risk Analysis: Composite risk analysis; Direct integration method; Method using safety margin, reliability index and safety factor. Introduction to reliability analysis: Application of Bayes theorem in real life problem; Reliability analysis of simple systems: serial, parallel and combined systems; First order uncertainty and reliability analysis (FORM), First order second moment (FOSM) and Advanced FOSM methods; Applications of risk and reliability analysis in engineering systems. Application of probabilistic methods:i) Fluid-structure interaction, ii) Soil-structure interaction iii) Railways iv) Automobile industry, v) Offshore structure, vi) Hydraulic structure

Texts Books:

1. Scheaffer, R. L., Mulekar, M. S. and McClave, J. T., (2011): Probability and statistics for Engineers, Fifth Edition, Brooks / Cole, Cengage Learning.
2. Ang, A. H-S., and Tang, W. H., (2006): Probability Concepts in Engineering, Volumes 1. John Wiley and Sons.
3. Halder, A and Mahadevan, S., (2000): Probability, Reliability and Statistical Methods in Engineering Design, John Wiley and Sons.
4. Rao, S.S., (1992): Reliability-Based Design, McGraw Hill, Inc.
5. Harr, M.E., (1987): Reliability-Based Design in Civil Engineering. McGraw Hill, Inc.
6. Ang, A. H-S, and Tang, W. H., (1975): Probability Concepts in Engineering Planning and Design, Volumes 2. John Wiley and Sons
7. Benjamin, J., and Cornell. A., (1963): Probability, Statistics, and Decision for Civil Engineers. McGraw Hill.

HS513 (in even semester, in M.Tech.) **Technical Communication**

L-T-P-C : 2-0-0-4

HS514 (in odd semester, in M.Tech.)
HS713(in even semester, in Ph.D.)
HS713(in odd semester, in Ph.D.)

Objective: The course intends to train the learners in using both verbal and non-verbal communication effectively. It also exposes them to different nuances of writing effectively for various professional purposes.

Syllabus:

1. **Technical Communication Skills**: Understanding the process and scope of Communication, Relevance, & Importance of Communication in a Globalized world, Forms of Communication, Role of Unity, Brevity and Clarity in various forms of communication.
2. **Types of Communication**: Verbal & Non-verbal Communication, Classification of NVC, Barriers to Communication, Communicating Globally, Culture and Communication
3. **Soft Skills**: Interpersonal Communication, Listening, Persuasion, Negotiation, Communicating bad news/messages, communicating in a global world.

4. **Writing Skills**: Traits of Technical Writing, Principles of Business Writing, Style of Writing, Writing Memos, Letters, Reports, and Writing Research Papers
5. **Speaking Skills:** Audience-awareness, Voice, Vocabulary and Paralanguage, Group Discussion, Combating Nervousness, Speaking to one and to one thousand, Mock Presentations
6. **Job Interviews**: Preparing for interviews, assessing yourself, Drafting Effective Resume, Dress, decorum and Delivery techniques, Techniques of handling interviews, Use of Non-verbals during Interviews, Handling turbulence during interviews
7. **Group Discussion & Professional Presentations**: Individual Presentations (Audience Awareness, Body Language, Delivery and Content of Presentation).

Texts Books:

1. Sharon Gerson and Steven Gerson. Technical Writing: Process and Product (8th Edition), London: Longman, 2013
2. Rentz, Kathryn, Marie E. Flatley & Paula Lentz. *Lesikar's Business Communication Connecting in a Digital world*, McGraw-Hill, Irwin.2012
3. Allan & Barbara Pease. *The Definitive Book of Body Language,* New York, Bantam,2004
4. Jones, Daniel. *The Pronunciation of English*, New Delhi, Universal Book Stall.2010
5. Sharma, Sangeeta & Mishra, Binod. *Communication Skills for Engineers and Scientists*, New Delhi: PHI Learning, 2009, rpt 2012

MA508 Fuzzy sets and Artificial Intelligence (3-0-0-6)

Basic Concepts of Fuzzy Sets, Fuzzy Logic, Zadeh's Extension Principle, Operations on Fuzzy Sets, Fuzzy Measures, Probability and Possibility Measures, Fuzzy Inference Methodologies, Fuzzy Relations, Applications of Fuzzy Sets in Management, Decision Making, Medicine and Computer Science.
Introduction to Artificial Intelligence, Production System and Artificial Intelligence, Problem Solving by Search, Predicate Calculus, Knowledge Representation, Semantics Nets, Frames, Conceptual Dependencies, Knowledge Bases and Expert Systems, Fuzzy Rule, Neuro Fuzzy Approaches, Case Studies in Various Domain.

Texts Books:

1. S. Russell and P. Norvig, Artificial Intelligence: A Modern Approach, 2nd Ed, Prentice Hall, 2003.
2. H.J.Zimmermann, Fuzzy Set Theory and Its Applications, 2nd Ed., Kluwer Academic Publishers, 1996.
3. D.Dubois and H. Prade, Fuzzy Sets and Systems: Theory and Applications, Academic Press, 1980. References:
4. E. Charniak and D. McDermott, Introduction to Artificial Intelligence, Addison-Wesley, 1985.
5. E. Rich, Artificial Intelligence, McGraw-Hill, 1983.
6. P. H. Winston, Artificial Intelligence, Addison Wesley, 1993.
7. J.Yen and R.Langari, Fuzzy Logic Intelligence, Control, and Information, Pearson Education, 2005.
8. T.J.Ross, Fuzzy Logic with Engineering Applications, McGraw-Hill, 1997.

9. J.Kacprzyk, Multistage Fuzzy Control, Wiley, 1997.

MA512 Mathematical Modeling 3-0-0-6

Introduction to modeling; Elementary mathematical models and General modeling ideas; General utility of Mathematical models

Stability theory of system of differential equations; Linear and nonlinear stability; Lyapanov's second method; Basic idea of bifurcation; Illustrations with help of computer programming Role of mathematics in problem solving; Concepts of mathematical modeling; System approach; formulation, Analyses of models; Pitfalls in modeling;

Illustrations models such as Population dynamics, Traffic Flow, Social interactions, Viral infections, Epidemics, Finance, Economics, etc. (The choice and nature of models selected may be changed with mutual interest of lecturer and students.)

Introduction to probabilistic models; Simulation approach. Orthogonal projections, Singular Value Decomposition, Principal Component Analysis, Fourier and Wavelet Transformation and Applications, Kernel Methods

Texts Books:

1. D. N. P. Murthy, N. W. Page, Ervin Y. Rodin, Mathematical modelling: a tool for problem solving in
2. engineering, physical, biological, and social sciences, Pergamon Press, 1990.
3. W.E. Boyce and R.C. DiPrima, Elementary Differential Equations and Boundary Value Problems, 7th
4. Edition, Wiley, 2001.
5. J. D. Murray, Mathematical Biology Volume I,3rd Ed, 2003.
6. J.P. Pinasco and L. Romanelli, Coexistence of Languages is possible, Physica A 361, 355-360 (2006).

MA514 Design of Experiments (3-0-0-6)

Basic design concepts, Selection of factors and levels, Different types of design, Simple comparative experiments, single factor experiments, Random effect model, Completely randomized design, Randomized block design, Incomplete block design, recovery of interblock information, Balanced incomplete block design and their (nonparmetric) analysis, symmetric BIBD, resolvable design, Partially balanced incomplete block designs, Latin square designs and their efficiency, Graeco-Latin square design, missing plot technique, Factorial designs - 2k designs, confounding in factorial design, blocking in 2k designs, fractional replications in 2k designs, 3-level and mixed-level factorials and fractional factorials. Response surface designs and their analysis, central composite designs, hybrid and uniform cell design, Nested designs, staggered nested designs with factorial structure, split plot designs, blocking and efficiency

Texts Books:

1. Montgomery, D. C. (2006), Design and Analysis of Experiments, Wiley
2. Dean, A., and Voss, D. (1998), Design and Analysis of Experiments, Springer
3. Cochran, W. G. and Cox, G. M. (1992), Experimental Designs, Wiley
4. G. Casella (2008), Statistical Design, Springer

Lab Courses

ME529 Solid Mechanics & Design Lab-I (0-0-6-6)

1) Measurement of Mode I fracture toughness of an Aluminum alloy and PMMA using a compact tension (CT) specimen.
2) Measurement of fatigue crack growth and determination of Paris law parameters for an Aluminum alloy using a CT specimen.
3) Measurement of strains using strain gauges.
4) Determination of ductile to brittle transition temperature of Mild Steel and Aluminum using Charpy Impact Testing Machine.
5) Torsion of bars of non-circular cross-section.
6) Measurement of stress concentration factor in a specimen with holes using photo elasticity method.
7) Observation of mode shapes and measurement of natural frequencies of vibration of a circular plate.
8) Detection of location and size of crack in a cracked beam using deflection measurement method.
9) Scanning Electron Microscopy examination of fracture surfaces of specimens fractured in experiment nos. 1), 2) and 4) above.

Texts Books:

1 Holman J.P., Experimental Methods for Engineers, McGraw Hill Series in Mechanical Engineering, ISBN-10: 0073529303, 8th Editions, 2011.
2 Doebelin E.O., Measurement systems- Applications and Design, 4e, Tata McGraw-Hill, 1990
3 Dally, Riley, and McConnell, Instrumentation for engineering measurements, 2e, John Wiley & Sons., 1993
4 Figiola, R.S. and Beasley, D.E., Theory and design for mechanical measurements, 2(e), John Wiley, 1995

ME530 Solid Mechanics & Design Lab-II (0-0-6-6)

1) DAQ and its components, feedback motion control of DC motor, low pass and high pass filters, spectrum analysis.
2) Fault Detection in Rotating Machinery.
3) Electrical motor current signature analysis on Machine Fault Simulator
4) Experimental investigation of Oil whirl-Oil whip in Machine Fault Simulator
5) Study of Air Bearing apparatus and its onset whirl
6) Experimental investigation of Rider's comfort through Active mass suspension
7) To determine the frequency response function of a Cantilever Beam
8) To measure the sound pressure level of shop floor/machine with different weighting scale and validation of inverse proportionality law
9) Dynamic Balancing (on MFS) and Field balancing of Rotating machinery
10) Experimental setup built by students themselves / a precursor to M-Tech. project.

Texts Books:

1. Beckwith T. G., Marangoni, R. D., and Lienhard, J. H., Mechanical Measurements, 5e, Addison Wesley, 1993.
2. Dally, Riley, and McConnell, Instrumentation for engineering measurements, 2e, John Wiley & Sons., 1993
3. Figiola, R.S. and Beasley, D.E., Theory and design for mechanical measurements, 2(e),

John Wiley, 1995

ME531 Manufacturing Laboratory I (0-0-6-6)

Determination of chip reduction coefficient, fabrication single point cutting tool, re-sharpening of twist drill, cutting force measurement using DAQ and Labview, measurement of cutting temperature using DAQ and Labview, estimation of tool life, optimal design of chip breaker, study on Machinability

Texts Books:

1. Bhattacharyya, A., Metal cutting: theory and practice, New Central Book, Kolkata, New Edition

ME532 Manufacturing Laboratory (0-0-6-6)

Direct extrusion and indirect extrusion, effect of lubrication on die pressure and load, rolling, drawing, forging load estimation, sheet bending Estimation, deep drawing analysis, and Forming limit diagram, spinning, blanking and piercing operation.

Text/reference Books
1. G. W. Rowe, Principles of Industrial Metal working processes, CBS publishers and Distributors, New Edition

ME529 Thermal Fluid Laboratory (0-0-6-6)

Fluid Mechanics: measurement of flow through Venturi, orifice, and hot wire anemometer, fluid machinery, and wind tunnel, Conduction: estimation of thermal conductivity and heat capacity, Convection: free and forced convective heat transfer coefficients on different geometries including fins, Heat Exchangers: single phase parallel and cross flow heat exchangers, heat transfer, Radiation heat transfer: Stefan-Boltzmann law, Kirchhoff's law, Lamberts Cosine law, Lamberts law of absorption, inverse square law, view factors, DAQ and Signal Processing: DAQ and its components, feedback temperature control, low pass and high pass filters, spectrum analysis.

Texts Books:

1. Holman J.P., Experimental Methods for Engineers, Mcgraw Hill Series in Mechanical Engineering, ISBN-10: 0073529303, 8^{th} Editions, 2011.
2. Doebelin E.O., Measurement systems- Applications and Design, 4e, Tata McGraw-Hill, 1990
3. Dally, Riley, and McConnell, Instrumentation for engineering measurements, 2e, John Wiley & Sons., 1993
4. Figiola, R.S. and Beasley, D.E., Theory and design for mechanical measurements, 2(e), John Wiley, 1995

ME530 Thermal Fluid Laboratory II (0-0-6-6)

Phase Change Heat Transfer: pool boiling, Leidenfrost, flow boiling, dropwise condensation, film wise Condensation, Surface Tension and Capillarity: wettability and contact angles on hydrophilic, hydrophobic and super-hydrophobic surfaces using a micro-goniometer, Wilhelmy plate method, capillarity, droplet impingement on hydrophilic, hydrophobic and super-hydrophobic surfaces, Turbulence: jet and plumes, Solar Thermal: solar intensity measurement using a Pyranometer, estimation of emissivity using heat source, metal plates and IR camera, evaluation of a solar flat-plate collector system in thermosyphonic and forced flow modes at different radiation levels, inlet water temperature, wind speeds, flow rate, Flow Visualization and Analysis: smoke and dye based flow visualization, e-PIV, µ-PIV.

Texts Books:

1. Beckwith T. G., Marangoni, R. D., and Lienhard, J. H., Mechanical Measurements, 5e, Addison Wesley, 1993
2. Dally, Riley, and McConnell, Instrumentation for engineering measurements, 2e, John Wiley & Sons., 1993
3. Figiola, R.S. and Beasley, D.E., Theory and design for mechanical measurements, 2(e), John Wiley, 1995

ME533 Finite Element Analysis (3-0-0-6)

Matrix methods review, Rayleigh-Ritz and Galerkin's method, weak formulations, FEM formulation in one dimension, interpolation, Multipoint constraints, applications to solid mechanics, heat transfer and fluid mechanics problems, Solution to truss and frame elements, temperature effect, Euler Bernoulli and Timoshenko beam element, C^0 and C^1 elements, Hermite cubic spline functions, shear locking. Eigen value problem and applications, semidiscrete FEM models, Time approximation schemes, Problems in 2-D, plane stress, plane strain, torsion problems, isoparametric formulations, axisymmetric elements, higher order elements, Serendipity elements, quaterpoint element, hybrid element, numerical intergration, reduced integration, convergence and accuracy, norms, modeling consideration, computer implementation: example problems in different fields: solid mechanics, heat transfer, fluid flow etc. Review of equations of elasticity, velocity pressure formulation, LMM and PM model, Limitations of FEM.

Text Book:

1. Reddy, J.N., "An Introduction to Finite Element Methods", 3rd Ed., Tata McGraw-Hill. 2005.

Reference Books:

1. Zienkiewicz, O. C. "The Finite Element Method, 3rd Edition, Tata McGraw-Hill. 2002.
2. Cook, K.D., Malkus, D.S. and Plesha, M.E., "Concept and Applications of Finite Element Analysis", 3th Ed., John Wiley and Sons. 1989.
3. Rao, S.S., "The Finite Element Method in Engineering", 4th Ed., Elsevier Science. 2005.
4. Reddy, J.N. and Gartling, D.K "The Finite Element Method in Heat Transfer and Fluid Dynamics", 2rd Ed., CRC Press. 2001.
5. Fish, J. and Belytschko, T., "A First Course in Finite Elements", 1st Ed., John Wiley and Sons. 2007.
6. Chaskalovic, J., "Finite Element Methods for Engineering Sciences", 1st Ed., Springer. 2008.
7. Bathe, K. J., "Finite Element Procedures", 1st Ed., Cambridge Press.