SEMESTER I

21MD01 APPLIED NUMERICAL METHODS

3 1 0 4

NUMERICAL SOLUTION OF SYSTEM OF EQUATIONS: Solving system of linear equations –Thomas algorithm, Gauss Jacobi and Gauss Seidel methods, successive over relaxation method, system of non-linear equations - Newton Raphson method, eigenvalues - power method and inverse power method. Curve fitting - linear regression, multiple linear regression, cubic splines - Bezier curves and B-splines. (12+4)

NUMERICAL SOLUTION TO ORDINARY DIFFERENTIAL EQUATIONS: Boundary value problem **-** Shooting method, finite difference method, derivative boundary conditions. Finite Element Method - Rayleigh-Ritz method, Collocation and Galerkin methods. (11+4)

NUMERICAL SOLUTION TO PARTIAL DIFFERENTIAL EQUATIONS: Finite difference method: Liebmann's method for Laplace and Poisson equations, alternating direct implicit method, irregular and non-rectangular grids, explicit method and Crank-Nicolson method for parabolic equations, higher order parabolic equations, explicit method for hyperbolic equations, higher order elliptic equations. (12+4)

MODELLING AND SIMULATION: Simulating deterministic behaviour, area under a curve, generating random numbers, simulating probabilistic behaviour, inventory model: gasoline and consumer demand. (10+3)

Total L: 45 +T:15 = 60

REFERENCES:

1. Curtis F Gerald and Patrick O Wheatly, "Applied Numerical Analysis", Pearson Education, New Delhi, 2013.
2. Frank R Giordano, William P Fox and Steven B Horton, "A first course in Mathematical Modeling", Cengage Learning, New Delhi, 2014.
3. John H Mathews and Kurtis D Fink, "Numerical Methods using MATLAB", Pearson Education, New Delhi, 2018.
4. Richard L Burden, J. Douglas Faires and Annette M. Burden, "Numerical Methods", Cengage Learning, New Delhi, 2016.
5. Steven C Chapra and Raymond P Canale, "Numerical Methods for Engineers", Tata McGraw-Hill, New Delhi, 2020.

21MD02 APPLIED ELASTICITY AND PLASTICITY

3 0 0 3

ANALYSIS OF STRESS AND STRAIN: Introduction to general theory of elasticity, assumptions and applications of linear elasticity, stress tensor, Cauchy's stress principle, principal stresses, octahedral stresses, equations of equilibrium, strain tensor, principal strains, kinematic equations and compatibility conditions, Generalized Hooke's law, plane stress and plane strain conditions, elasticity theorems, strain energy in elastic body. (12)

ELASTICITY PROBLEMS AND EXPERIMENTAL STRESS ANALYSIS: Transformation of compatibility condition from strain components to stress components, Airy's stress function, two dimensional problems in cartesian and polar coordinate systems, axisymmetric problems, stress concentration, effect of circular holes on stress distribution in plates; Fundamental concepts in measurements, grid method, brittle coating method, strain gages, rubber model method and Fischer's method for stress concentration, photo elasticity and Moiré fringes. (12)

CONTACT STRESSES: Introduction, geometry of contact surfaces, notation and meaning of terms, expressions for principal stresses, method of computing contact stresses – Hertzian, JKR, DMT models. (5)

PLASTICITY I : Plastic flow, microscopic and macroscopic descriptions, role of geometry and thermodynamics in plastic deformation, stress-strain curve of real materials, yield criterion, hardening rules, strain hardening parameters, rate dependent and rate independent plasticity. (7)

PLASTICITY II : Equivalent stresses, Prandtl-Reuss and Levy-Mises equations, plastic instability, effect of strain rate and temperature on flow stress, introduction to slip line field theory and applications. (9)

Total L: 45

REFERENCES:

1. Timoshenko S P and Goodier J N "Theory of Elasticity" Tata McGraw Hill Publications, 2010.
2. Durelli A J, Phillips E A and Tsao C H "Introduction to Theoretical and Experimental analysis of stress and strain" McGraw Hill Publications,1958.
3. George E Dieter. "Mechanical Metallurgy" McGraw Hill Education, Third edition 2017.
4. Chakrabarthy J "Theory of Plasticity" Butterworth Heinemann Publications 2012.
5. James F. Doyle, "Modern experimental stress analysis: Completing the solution of partially specified problems" Wiley publications, 2012.
6. T.G.Sitharam and L.Govindaraju "Elasticity for engineers" I.K. International Publishers, 2017.

21MD03 MACHINERY VIBRATION AND DIAGNOSTICS

3 0 0 3

FUNDAMENTALS OF VIBRATION: Introduction**, s**ources and effects of vibration, types of vibration, harmonic analysis, transient time function, random time function, frequency spectrum; Single Degrees of Freedom System**:** free vibration, free damped vibration, forced vibration: nature of exciting forces, critical speeds, quality of balance, vibration Isolation. (12)

TWO AND MULTIPLE DEGREES OF FREEDOM SYSTEMS: Normal mode vibration, co-ordinate coupling, Lagrange's equation, free harmonic vibration, tuned un-damped vibration absorbers; MDOF: influence coefficients, orthogonality, matrix iteration, Holzer method, branched system, geared system, Rayleigh's principle, Dunkerley's principle. (12)

TRANSIENT AND RANDOM VIBRATION: Impulse and arbitrary excitation, base excitation, Laplace transform formulation, response spectrum; Random vibration: frequency response function, spectral density, probability distribution, correlation, Fourier transform; Case studies. (10)

VIBRATION AND NOISE - MEASUREMENT AND CONTROL: Vibration analysis overview, measuring instruments: selection of sensors, acceleration mountings, vibration exciters; Experimental methods in vibration analysis: free and forced tests, FFT analyzer, Nyquist criteria, methods of vibration control, excitation reduction at source, balancing of rigid, flexible and variable mass rotors; Dynamic properties and selection of structural materials: viscoelastic polymers; Noise sources and control: noise in centrifugal fans and blowers, gears, chain drives and bearings, reduction measures, machine enclosures, silencers and mufflers. (11)

Total: 45

REFERENCES:

1. Thomson W T, "Theory of Vibration with Applications", Prentice Hall of India, 2008.
2. Singiresu S Rao "Mechanical Vibrations", Prentice Hall, 2016.
3. Ashok Kumar Mallik, "Principles of Vibration Control", Affiliated East-West Press, 1990.
4. Lewis H Bell, "Industrial Noise Control Fundamentals and Applications", Marcel Dekkev Inc.,1993.
5. Tse Hinkle and Morse, "Mechanical Vibrations", OBS Publishers and Distributors, 2004.

21MD04 MECHANISMS AND ROBOT KINEMATICS

3 1 0 4

KINEMATIC ANALYSIS AND DYNAMICS OF MECHANISMS: Kinematic analysis: Analysis of complex mechanisms, Goodman analysis, auxiliary point method; Dynamics of mechanisms: inertia force in linkages, kineto-static analysis by complex numbers, superposition and matrix methods, virtual work. (12+4)

KINEMATIC SYNTHESIS: Graphical synthesis, motion, path and function generation: two, three and four prescribed positions, overlay method, cognate linkages; Analytical synthesis techniques: Freudenstein's equation, Complex number modelling, the dyad or standard form, three prescribed positions for motion, path and function generation, ground pivot specification. (12+4)

SPATIAL MECHANISMS: Introduction, kinematic analysis of closed loop spatial mechanisms; Transformations describing planar finite displacements, planar finite transformations, identity transformation, planar matrix operator for finite rotation, homogeneous co-ordinates and finite planar translation - concatenation of finite displacements - rotation about an axis not through the origin, rigid body transformations, spatial transformations (10+3)

ROBOTICS: Topology arrangements of robotic arms, D-H parameters, forward kinematics, treatment of inverse position, velocity and acceleration analysis, actuator force analysis; Parallel kinematic manipulators, configurations and characteristics. (11+4)

Total L: 45 + T:15 = 60

REFERENCES:

1. Uicker G R, Pennock J and Shigley J E, "Theory of Machines and Mechanisms", Oxford University Press, 2016.
2. Dan B Marghitu, "Mechanisms and Robots Analysis with MATLAB", Springer, 2009.
3. Asok Kumar Mallik, Amitabha Ghosh and Günter Dittrich, "Kinematic Analysis and Synthesis of Mechanisms", CRC Press, 1994.
4. Xiao-Ping Susan Su, Computer-aided Kinematic and Dynamic Analysis of Spatial Mechanisms, Davis, 1997
5. Arthur G. Erdman, George N. Sandor, Sridhar Kota, "Mechanism Design: Analysis and Synthesis", Prentice Hall, 2004.

21MD05 MECHATRONICS SYSTEM DESIGN

3 0 0 3

MECHATRONIC SYSTEMS: Key elements- Types of actuators and drives-magnetostrictive, fluidic and electrical (PMDC, AC Induction, Stepper, Servo), control valves,Mechatronic design process, optimization of Mechatronic design. (10)

FLUIDIC SYSTEM DESIGN: Design of sequential circuits: Cascade, KV-Map and step counter methods; Integration of fringe condition modules, sizing and selection of components in hydraulic and pneumatic systems, Analysis of hydraulic circuits - synchronizing circuits, regenerative circuits. (13)

SENSORS AND CONTROLLERS: Sensors: proximity, displacement, velocity, acceleration, force, torque, temperature and flow measurements, Selection of sensors for mechatronic systems; Types of Controllers- Embedded, PLC and PC based;Embedded controllers: types and applications; PLCs: construction and working, programming using ladder logic diagram for mechatronic systems; Servo valves and Proportional valves. (12)

REAL TIME INTERFACING AND DESIGN OF MECHATRONIC SYSTEMS: Data acquisition systems, Virtual Instrumentation, interfacing of sensors/actuators with PC, Fault diagnosis - condition monitoring, adaptive control and SCADA systems, Design and development of Mechatronic systems- Automatic Washing Machine, Hard Drive control, Auto-focusing in Digital Cameras, Active suspension in vehicles, Visual Servoing models. (10)

Total L: 45

REFERENCES:

1. Devdas Shetty and Richard A Kolk, “Mechatronics System Design”, Cengage Learning, Second edition, 2010.
2. W.Bolton, “Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering”, Pearson Education, Sixth edition, 2015.
3. Anthony Espisito, “Fluid Power with Application”, Pearson, 2013.
4. David W.Pessen, “Industrial Automation: Circuit Design and Components”, Wiley India, 2011.
5. Sanjay Gupta and Joseph John, “Virtual Instrumentation using Lab VIEW”, Tata McGraw Hill Education, Second edition, 2010.
6. Jovitha Jerome, “Virtual Instrumentation Using LabVIEW”, Prentice Hall, 2010.

21MD06 RESEARCH METHODOLOGY AND IPR

VIDE AUTOMOTIVE ENGINEERING 21AE06

21MD72 AUDIT COURSE I

VIDE AUTOMOTIVE ENGINEERING 21AE72

21MD51 VIBRATION ENGINEERING LABORATORY

0 0 4 2

In this course students will be provided with an orientation programme on the following equipment/software for the duration of 20 hours. After this orientation, each student is expected to formulate and complete an activity of interest which has to be derived from the orientation programme under the guidance of a faculty. The details like background, problem definition, state of technology/knowledge in that area by a good literature review (5 latest papers), objectives, methodology, equipment that can be used (from the orientation programme), results from the experiments and their interpretation with respect to the assumptions/background and a formal conclusion are expected in the report which is to be submitted at the end of the semester. This work is evaluated for the credit assigned. Expected hours needed for this work is 40 hours

Topics for orientation

1. Introduction to Virtual Instrumentation (VI) software and Data Acquisition (DAQ) systems.
2. Vibration response of a given structure using free and forced vibration test- FRF, Damping ratio with and without smart materials.
3. Vibration response of balanced and unbalanced systems.
4. Shock response of a system subjected to impact loading.
5. Determination of mass ratio in tuned dynamic vibration absorber.
6. Sound level measurement using (a) Sound level meter and (b) Microphone and VI software.

CASE STUDY

Analysis of typical structures using any one or a combination of the above.

Total P:60

REFERENCES:

1. Laboratory Manual prepared by Department of Mechanical Engineering, PSG College of Technology.

2. Rao, Singiresu S. "Mechanical Vibrations Laboratory Manual." Edition Addison-Wesley Publishing Company, New York (1995).
3. Balachandran, B., Azarm, S., Magrab, E. B. (2011). An Engineer's Guide to MATLAB: With Applications from Mechanical, Aerospace, Electrical, Civil, and Biological Systems Engineering. United Kingdom: Prentice Hall.

21MD52 SENSOR INTERFACE AND AUTOMATION LABORATORY

0 0 4 2

In this course students will be provided with an orientation programme on the following equipment/software for the duration of 20 hours. After this orientation, each student is expected to formulate and complete an activity of interest which has to be derived from the orientation programme under the guidance of a faculty. The details like background, problem definition, state of technology/knowledge in that area by a good literature review (5 latest papers), objectives, methodology, equipment that can be used (from the orientation programme), results from the experiments and their interpretation with respect to the assumptions/background and a formal conclusion are expected in the report which is to be submitted at the end of the semester. This work is evaluated for the credit assigned. Expected hours needed for this work is 40 hours

Topics for orientation

1. Calibration of sensors using Virtual Instrumentation software
2. Sensor interface using Virtual Instrumentation software
3. Control of actuators using Virtual Instrumentation software
4. System control using PI and PID controllers
5. Co-ordinated motion of multiple pneumatic actuators in a desired sequence using PLC's
6. Co-ordinated motion of multiple pneumatic actuators in a desired sequence using Cascade method

CASE STUDY

Interface and integration of sensors/ actuators for development of mechatronic systems

Total P: 60

REFERENCES:

1. Laboratory Manual prepared by Department of Mechanical Engineering, PSG College of Technology.
2. Frank Lamb, "Industrial Automation Hands On", McGraw Hill Book Company,2013
3. Robert H. Bishop, "LabVIEW Student Edition", Pearson, 2016.

SEMESTER II

21MD07 DESIGN FOR MANUFACTURE AND ASSEMBLY

3 1 0 4

TOLERANCE AND PROCESS CAPABILITY ANALYSIS: Rules and methodologies used to design components for manual, automatic and flexible assembly, DFA index, poka-yoke, six sigma concepts; Cumulative effect of tolerances, dimensional chain analysis -equivalent tolerances method, equivalent standard tolerance grade method, equivalent influence method; Process capability, process capability metrics, Cp, Cpk, cost aspects. (12+4)

GEOMETRIC TOLERANCING AND SELECTIVE ASSEMBLY: Limits and fits, surface finish, review of relationship between attainable tolerance grades and different machining processes; Geometric tolerancing for manufacture as per Indian standards and ASME Y 14.5-2018 standard;Interchangeable part manufacture; Selective assembly – Model-I: group tolerances of mating parts equal; Model-II: total and group tolerances of shaft equal; Control of axial play - introducing secondary machining operations, laminated shims, selective assembly, examples. (10+3)

TRUE POSITION THEORY AND DATUM SYSTEMS: True position theory - comparison between coordinate and conventional method of feature location, true position tolerancing, virtual size concept, floating and fixed fasteners, projected tolerance zone, zero true position tolerance, compound assembly; Functional inspection techniques using CMM and paper layout gauging; Degrees of freedom, grouped datum systems - different types, two and three mutually perpendicular grouped datum planes; Grouped datum system with spigot and recess, pin and hole; Grouped datum system with spigot - recess pair and tongue - slot pair - computation of translational and rotational accuracy, geometric analysis and applications; Datum features - functional and manufacturing, redimensioning to suit manufacturing (12+4)

REDESIGN, TOLERANCE CHARTING AND DFE: Redesign of castings based on parting line considerations, minimising core requirements, redesigning cast members using weldments, design guidelines for welding. Redesign of components to facilitate machining; Tolerance charting: Operation sequence for typical shaft type of components, preparation of process drawings for different operations, tolerance worksheets and centrality analysis, examples; Design for the Environment - environmental objectives, global issues, regional and local issues-basic DFE methods-design guidelines-examples of application. (11+4)

Total L: 45 + T: 15 = 60

REFERENCES:

1. James G. Bralla, “Design for Manufacturability Handbook”, McGraw Hill Professional, 1999.
2. Harry Peck, "Designing for Manufacture", Pitman Publications, 1983.
3. Matousek, "Engineering Design - A Systematic Approach", Blackie and Son Ltd., London, 1974.
4. Spotts M F, "Dimensioning and Tolerance for Quantity Production", Prentice Hall Inc., 1983.
5. Boothroyd G, Dewhurst P and Knight W, “Product Design for Manufacture and Assembly”, Marcell Dekker, 2015.
6. T. E. Graedel, Braden R. Allenby, “Design for environment” Prentice Hall, 1998.

21MD08 FINITE ELEMENT ANALYSIS IN MECHANICAL DESIGN

3 1 0 4

FINITE ELEMENT FORMULATION: Concepts of finite element method, finite element formulation using variational, weighted residual and weak form techniques. (4+2)

STATIC ANALYSIS USING ONE DIMENSIONAL ELEMENTS: Static analysis using one dimensional elements: Linear and quadratic spar elements, truss and beam elements, beams on elastic foundation - treatment of boundary condition and temperature effects, solution of problems. (8+2)

STATIC ANALYSIS USING TWO DIMENSIONAL ELEMENTS: Triangular element: Formulation of stiffness matrix and load vectors, temperature effects, torsion of circular and non-circular cross-sections; Quadrilateral element: Evaluation of stiffness and stress matrices by Gaussian quadrature based on isoparametric formulation; Solution of plane stress and plane strain problems; Axisymmetric triangular element: Formulation of stiffness matrix and load vectors, problem modelling and boundary conditions, solution of problems; Higher order elements; Overview of three dimensional stress analysis. (11+4)

EIGENVALUE ANALYSIS: Formulation and solution of undamped and damped free vibration problems - lumped and consistent mass matrices, solution of longitudinal, transverse and torsional vibration problems using 1D elements; Formulation and solution of buckling problems using 1D element. (11+4)

HEAT TRANSFER ANALYSIS: Review of differential equations of heat transfer, one dimensional and two-dimensional finite element formulation using variational and Galerkin’s methods, solution of steady state heat transfer problems, analysis of tapered fin. (11+3)

Total L: 45 + T: 15 = 60

REFERENCES:

1. Cook, R.D., Malkus, D. S., Plesha,M.E., and Witt,R.J “ Concepts and Applications of Finite Element Analysis”, Wiley, 2007.
2. Chandrupatla T R and Belegundu A D, “Introduction to Finite Elements in Engineering”, Pearson Education, New Delhi, 2011.
3. Logan D L, “A First Course in the Finite Element Method”, Thomson Learning, 2010.
4. Reddy J.N, “An Introduction to Finite Element Method”, McGraw Hill Education, 2015.
5. Bhavikatti SS, “Finite Element Analysis”, New Age International Publishers, 2015.
6. Dixit U.S, “Finite Element Methods for Engineers”, Cengage Learing India Pvt. Ltd, 2009.

21MD82 AUDIT COURSE II

VIDE AUTOMOTIVE ENGINEERING 21AE82

21MD61 COMPUTER AIDED ENGINEERING LABORATORY

0 0 4 2

Topics for orientation

1. Static analysis of typical industrial components
2. Dynamic analysis of mechanical systems
3. Steady state and transient thermal analysis of parts/processes
4. Thermo-mechanical analysis of components
5. Estimation of fatigue life of mechanical/automotive components
6. Design optimization using FEA
7. Fluid flow analysis
8. Multibody dynamic analysis of mechanism

CASE STUDY

Finite Element analysis of sub-systems/complex components of typical mechanical systems followed by design sensitivity analysis

Total P: 60

REFERENCES:

1. Laboratory Manual prepared by Department of Mechanical Engineering.
2. Nitin S. Gokhale, “Practical finite element analysis”, Finite to Infinite 2008.

21MD62 ADVANCED ANALYSIS AND SIMULATION LABORATORY

0 0 4 2

Topics for orientation
1. Experimental modal analysis of typical structures.
2. Dynamic stress analysis of typical structures under harmonic excitation.
3. Operating deflection shape analysis of typical machineries like pump, machine tool, etc.
4. Crack propagation analysis of typical parts.
5. Structural integrity assessment of components using collapse load analysis.

CASE STUDY
Analysis of typical structures using any one or a combination of the above.

REFERENCES:

1. Finite Element Modeling and Simulation with ANSYS Workbench, Xiaolin Chen, Yijun Liu, CRC Press, 2014.
2. The Finite Element Method and Applications in Engineering Using ANSYS, Erdogan Madenci, Ibrahim Guven, Springer, 2015.
3. Modal Testing: Theory, Practice and Application, D. J. Ewins, Research Studies Press LTD, 2000.
4. Mechanical Behavior of Materials: Engineering Methods for Deformation, Fracture and Fatigue, Norman E. Dowling, Pearson Education, 2013.
5. Fracture Mechanics: Fundamentals and Applications, Anderson Ted L, Taylor & Francis, 2017.
6. Structural Integrity Assessment, P. Stanley, CRC Press, 1992.

Total P: 60

21MD63 INDUSTRIAL VISIT AND TECHNICAL SEMINAR

VIDE AUTOMOTIVE ENGINEERING 21AE63

SEMESTER – III

21MD71 PROJECT WORK – I

VIDE AUTOMOTIVE ENGINEERING 21AE71

SEMESTER – IV

21MD81 PROJECT WORK – II

VIDE AUTOMOTIVE ENGINEERING 21AE81

PROFESSIONAL ELECTIVES THEORY COURSES (FOUR TO BE OPTED)

21MD21 MODELING OF DYNAMIC SYSTEMS

3 0 0 3

MATHEMATICAL MODELS OF PHYSICAL SYSTEMS: Introduction to control systems: differential equations of physical systems, dynamics of robotic mechanisms, transfer functions, block diagram algebra, signal flow graphs; Feedback characteristics of control systems: feedback and non-feedback systems, reduction of parameter variations, control over system dynamics, control of the effects of disturbance signals, linearizing effect, regenerative feedback. (11)

COMPONENTS OF CONTROL SYSTEMS AND FREQUENCY RESPONSE ANALYSIS: Linear approximation of non-linear systems: stepper motors, hydraulic systems, pneumatic systems; Frequency response analysis and stability in frequency domain: correlation between time and frequency response- polar plots- bode plots, all-pass and minimum-phase systems; Experimental determination of transfer functions: log-magnitude versus phase plots, Nyquist stability criterion, assessment of relative stability, closed loop frequency response, sensitivity analysis. (12)

TIME RESPONSE ANALYSIS AND STABILITY IN TIME DOMAIN: Standard test signals: time response of first-order systems, time response of second-order systems, steady-state errors and error constants, effect of adding a zero to a system; Design specifications of second-order systems; Design considerations for higher-order system: performance indices, robotic control systems, approximation of higher-order systems by lower order systems; State variable analysis: concept of stability, necessary conditions, Routh stability criterion, relative stability analysis . (11)

DESIGN AND STATE VARIABLE ANALYSIS: Preliminary considerations, realization of basic compensators: cascade compensation in time domain and frequency domain, feedback compensation, robust control system design; State variable analysis and design: concepts of state, state variables and state model, state models for linear-continuous-time systems, state variables and linear discrete-time systems, solutions of state equations; concepts of controllability and observability, pole placement by state feedback. (11)

Total L: 45

REFERENCES:

1. Nagrath I J and Gopal M, “Control Systems Engineering”, 6th Edition, New Age International Publishers, 2018.
2. Ogata, K., System dynamics (Vol. 13). Upper Saddle River, NJ: Pearson/Prentice Hall. 2004
3. Gopal M, "Control Systems – Principles and Design", 4th Edition, McGraw Hill Education, 2012.
4. Norman S Nise, “Control System Engineering”, Wiley India Edition, Wiley Publications, 2018.
5. Sergey Edward Lyshevski, “Control Systems – Theory with Engineering Applications”, 1st Edition, Jaico Publishing House, 2004.

21MD22 MECHANICS OF COMPOSITES AND SMART MATERIALS

3 0 0 3

COMPOSITES AND SMART MATERIALS: Modern materials in design, types, metals, polymers, ceramics, composites, classification of composites, advantages, applications and limitations, matrix and reinforcement-their roles, principal types of fiber and matrix materials; Smart materials: rheological, magnetostrictive materials, characteristics and applications for design of intelligent structures. (11)

MANUFACTURE OF COMPOSITE COMPONENTS: Lay-up and curing, open and closed mould processes, bag moulding, filament winding, pultrusion, pulforming, thermoforming, injection moulding, blow moulding; An overview of metal matrix composite processing and ceramic matrix composite processing; Quality inspection methods. (10)

MICRO AND MACRO MECHANICAL BEHAVIOUR OF A LAMINA: Volume and mass fractions, evaluation of elastic moduli, strength of unidirectional lamina, Hooke's law for different types of materials, engineering constants for orthotropic materials; Stress, strain relations for plane stress in an orthotropic material and in a lamina of arbitrary orientation, strength of an orthotropic lamina, failure theories. (12)

MACRO MECHANICAL BEHAVIOUR OF A LAMINATE: Classical laminate theory, laminate code, stress-strain relationship; Resultant forces and moments in a laminate, types of laminates-stiffness matrices, inter laminar stresses; Analysis of composite structures: Fatigue, fracture mechanics-basic principles, crack initiation, crack growth modes, environmental effects; Composite joints-bonded, bolted joints. (12)

Total L: 45

REFERENCES:

1. Autar K Kaw, "Mechanics of Composite Materials", CRC Press, NY, 2006.
2. Matthews F L and Rawlings R D, “Composite Materials: Engineering and Science”, Woodhead Publishing, 1999.
3. Srinivasan A V and Michael McFarland, “Smart Structures: Analysis and Design”, Cambridge University Press, UK, 2001.
4. Ronald F Gibson, “Principles of Composite Material Mechanics", McGraw Hill Book Co, 2016.
5. Mallick P K, “Fiber reinforced composites: materials, manufacturing and design”, CRC press, 2012.
6. Robert M Jones, "Mechanics of Composite Materials", Taylor and Francis, 1999.

21MD23 INDUSTRIAL TRIBOLOGY

3 0 0 3

REVIEW OF TRIBODESIGN AND LUBRICATION: Specific principles, Tribological problems in machine design, Surface topography, tribological processes: contact process-contact mechanics, Hertzian and Non Hertzian contact,friction process-sliding and rolling friction, wear process-wear mechanisms, Stick-slip effects, Friction and wear test methods, tribological materials and their properties;Lubrication: Basic modes-hydrodynamic lubrication, Elastodynamic lubrication, Mixed lubrication, Boundary lubrication; Hydrostatic lubrication, lubricant, additives. surface treatment to improve tribological properties. (12)

ROLLING CONTACT BEARINGS : Nominal life, static and dynamic capacity, equivalent load, probabilities of survival - cubic mean load, Selection of deep groove, angular contact, cylindrical and taper roller bearings, bearing mounting, preloading of bearings.
HYDRODYNAMIC BEARINGS: Fundamentals of fluid film formation, Mechanism of pressure development in oil film, Reynold’s equation, Hydrodynamic journal bearing- Sommerfeld number, bearing performance, temperature rise; Hydrodynamic thrust bearings - Raimondi and Boyd Method, fixed and tilting pads, single and multiple pad bearings. (11)

HYDROSTATIC BEARINGS: Arrangement, advantages and limitations, Hydrostatic step bearing analysis-energy losses, optimum design, temperature rise; Hydrostatic conical thrust bearing, pad coefficients; Hydrostatic journal bearings - design procedures; Hydrostatic squeeze film bearings-analysis, Aerostatic bearings: principle, requirement, merit, demerit and application, thrust bearings and journal bearings - design procedure;
SEALS: Different types - mechanical seals, lip seals, packed glands, soft piston seals, mechanical piston rod packing, labyrinth seals and throttling bushes, oil flinger rings and drain grooves - selection of mechanical seals. (12)

COMPUTATIONAL HYDRODYNAMICS: Finite difference equivalent of the Reynolds equation, Numerical analysis of hydrodynamic lubrication in idealized journal and partial arc bearings, Vibrational stability in journal bearings-determination of stiffness and damping coefficients; Elasto-Hydrodynamic Lubrication: Pressure-viscosity term in Reynold’s Equation - Hertz theory- Ertel-Grubin Equation, lubrication of spheres, introduction to thermo-hydrodynamic lubrication. (10)

Total L: 45

REFERENCES:

1. GwidonStachowiak, Andrew W Batchelor, “Engineering Tribology”, Butterworth-Heinemann, 2013
2. Phakatkar H G and Ghorpade RR, “Tribology”, NiraliPrakashan, 2015.
3. Prasanta Sahoo “Engineering Tribology” PHI Learning Pvt. Ltd. 2005.
4. Neale M J,“Tribology Handbook”, Elsevier, 2017.
5. Hutchings I M, “Tribology-Friction and Wear of Engineering Material”, Edward Arnold, London, 2017.
6. Connor J J O and Boyd, “Standard Handbook of Lubrication Engineers”, ASLE, McGraw Hill Book Co., 1969.

21MD24 GEOMETRIC MODELING

3 0 0 3

OVERVIEW OF CAD SYSTEMS AND GRAPHICS TRANSFORMATION: Conventional and computer aided design processes, subsystems of CAD-CAD hardware and software, analytical and graphics packages, CAD workstations. networking of CAD systems, generative, cognitive and image processing graphics, static and dynamic data graphics; Transport of graphics data: graphic standards, generation of graphic primitives, display and viewing, transformations, customizing graphics software. (12)

MATHEMATICAL REPRESENTATION OF CURVES AND SURFACES: Introduction, wireframe models, parametric representation of curves-analytic - synthetic, curve manipulation; Surface models: types of surfaces, introduction to parametric representation of surfaces, design examples. (11)

MATHEMATICAL REPRESENTATION OF SOLIDS: Fundamentals of solid modeling, boundary representation, constructive solid geometry, solid manipulations, solid modeling based applications. (10)

VISUAL REALISM AND COMPUTER ANIMATION: Model cleanup, hidden line removal, shading, computer animation, animation systems, design applications. mass property calculations**,** geometrical property formulation, mass property formulation, design and engineering applications. (12)

Total L: 45

REFERENCES:

1. Ibrahim Zeid, "CAD/CAM Theory and Practice", McGraw Hill Inc., New Delhi, 2009.
2. Radhakrishnan P, Subramanyan S and Raju V, “CAD/CAM/CIM”, New Age Internationals, 2012.
3. Radhakrishnan P and Kothandaraman C P, "Computer Graphics and Design", Dhanpat Rai and Sons, 2012.
4. Michael E Mortenson, "Geometric Modeling", John Wiley and Sons Inc., 2006.
5. M. Morris Mano, Michael D. Ciletti, “Digital Design” 5th Edition, Pearson Prentice Hall, 2013
6. Donald D. Hearn, M. Pauline Baker, Warren Carithers, “Computer Graphics with OpenGL”, 4th Edition, Pearson Education, 2015.

21MD25 PROBABILISTIC METHODS IN MECHANICAL DESIGN

3 0 0 3

MODELING OF UNCERTAINTY: Concept of reliability: Measures of reliability, reliability evaluation; Mathematics of probability: Set theory, axioms of probability, Bayes’ theorem; Modeling of uncertainty: Quantifying randomness, analytical models to quantify randomness involving continuous and discrete random variables, multiple random variables and multivariate distribution; Problems on design of structures. (10)

PROBABILITY DISTRIBUTIONS: Continuous random variables: Normal or Gaussian distribution, lognormal random variable, beta distribution; Discrete random variables: Binomial distribution, geometric distribution, return period, Poisson and exponential distributions; Combination of continuous and discrete random variables- hypergeometric and hyperbinomial distributions; Extreme value distributions: Asymptotic distributions, two-parameter Weibull distribution; Practical problemswith seismic load, wind pressure, flood level, etc., as probability distributions. (7)

DETERMINATION OF DISTRIBUTIONS AND PARAMETERS: Determination of probability distribution and estimation of parameters, Interval estimation of mean and variance; Practical problems in design considering material property as probability distribution. (6)

RANDOMNESS IN RESPONSE VARIABLES: Responses as functions of single and multiple random variables; Partial and approximate solutions; Multiple random variables with unknown relationship; Regression analysis – linear and nonlinear models;Practical problems in design considering randomness in seismic load, vehicular live loads, aerodynamic load, etc. (10)

RELIABILITY ANALYSIS: Deterministic and probabilistic approaches, development of the risk-based design format, first-order reliability methods;Case studies on structures with load and resistance as independent random variables; Overview of second-order reliability methods, probabilistic sensitivity indices, system reliability evaluation; Monte Carlo simulation technique. (12)

Total L: 45

REFERENCES:
1. AchintyaHaldar, SankaranMahadevan, “Probability, Reliability, and Statistical Methods in Engineering Design”, John Wiley & Sons, 2000.
2. Patrick D. T. O Connor, Andre Kleyner, “Practical Reliability Engineering”, John Wiley and Sons, 2012.
3. Charles Ebeling, “An Introduction to Reliability and Maintainability Engineering”, Tata McGraw Hill, 2010.
4. Alessandro Birohini, “Reliability Engineering - Theory and Practice”, Sixth Edition, Springer, 2017.
5. Sheldon Ross,” Introduction to Probability Models”, 12th Edition, Academic Press, 2019.
6. L.S. Srinath, “Reliability Engineering”, Fourth Edition, East West Press, 2005.

21MD26 DESIGN AND FAILURE ANALYSIS

3 0 0 3

MATERIALS AND DESIGN: Factors affecting the behavior of materials in components, effect of component geometry and shape factors, designing with high strength and low toughness materials, designing for hostile environments, the design process, materials selection in design, processes and their influence on design, systematic process selection; Material selection for sustainability: material life cycle assessment and energy, selecting materials for eco design. (11)

FRACTURE MECHANICS: Ductile fracture, brittle fracture, cleavage-fractography, ductile-brittle transition, fracture mechanics approach to design-energy criterion, stress intensity approach; Time dependent crack growth and damage; Linear elastic fracture mechanics: Griffith theory, energy release rate, instability and R-curve, stress analysis of cracks-stress intensity factor, K-threshold, crack growth instability analysis, crack tip stress analysis; Elastic plastic fracture mechanics: crack tip opening displacement (CTOD), J-integral, relationship between J and CTOD. (12)

DYNAMIC AND TIME-DEPENDENT FRACTURE: Dynamic fracture, rapid loading of a stationary crack, rapid crack propagation, dynamic contour integral, creep crack growth-C Integral, viscoelastic fracture mechanics, viscoelastic J integral; Determination of fracture toughness values: experimental determination of plane strain fracture toughness, K- R curve testing, J measurement, CTOD testing, effect of temperature, strain rate on fracture toughness. (11)

WEAR FAILURES: Types of wear, different methods of wear measurement, analysis of wear failures, wear at elevated temperatures, wear on different materials, role of friction on wear, stick slip friction, creep, stress rupture, elevated temperature fatigue, environmental induced failure. (5)

FAILURE ANALYSIS TOOLS: Reliability concept and hazard function, life prediction, life extension, application of Poisson, exponential and Weibull distribution for reliability, bath tub curve, parallel and series system, MTBF, MTTR, FMEA -design FMEA- process FMEA- analysis causes of failure- modes- ranks of failure modes; fault tree analysis, industrial case studies / projects on FMEA. (6)

Total L: 45

REFERENCES:
1. Anderson T L, “Fracture Mechanics: Fundamentals and Applications”, Taylor and Francis, Fourth Edition 2017.
2. ASM Metals Handbook, "Failure Analysis and Prevention", ASM Metals Park, Ohio, USA, Vol. 11, 2002.
3. Michael F Ashby, “Materials Selection in Mechanical Design”, Butterworth – Heinemann, 2016.
4. Michael F Ashby, Hugh Shercliff and David Cebon, “Materials – Engineering, Science, Processing and Design”, Butterworth – Heinemann, 2013.
5. Shigley and Mische, "Mechanical Engineering Design", McGraw Hill, 2011.
6. Balbir S. Dhillon “Applied Reliability and Quality: Fundamentals, Methods and Procedures” (Springer Series in Reliability Engineering), 2010.

21MD27 STRATEGIES FOR PRODUCT DEVELOPMENT

3 0 0 3

PRODUCT DESIGN APPROACHES AND REVERSE ENGINEERING: Product design: characteristics of successful product development, challenges of product development, phases of design process, product development versus design, types of design and redesign, concept of CPC, PDM/PLM; Product design approaches: quality function deployment, axiomatic design, failure mode and effect analysis, concurrent engineering; Reverse engineering: scanning methods for reverse engineering, reengineering, tear down approach, bench marking, case studies. (12)

NEW PRODUCT DEVELOPMENT: Design creativity, innovations in design alternatives, S-curve, gathering customer needs, organizing and prioritizing customer needs, establishing product function, FAST method, establishing system functionality; Concept generation**:** Five step method, brainstorming, C-sketch method, 6-3-5 method, morphological analysis, TRIZ method; Concept selection: concept screening, concept scoring, technical feasibility, case studies; Role of rapid prototyping in product development. (12)

MATERIAL SELECTION FOR PRODUCT DEVELOPMENT: Performance characteristics of materials, the material selection process, economics of materials, methods of material selection, materials performance indices, material selection by expert systems, value analysis, cradle to cradle reuse practices, composites and advanced materials, case studies. (11)

INTELLECTUAL PROPERTY AND PRODUCT DEVELOPMENT ECONOMICS: Intellectual property, steps in patenting,

preparation of patent application, case studies; Product development economics: elements of economic analysis, economic analysis process, case studies. (10)

Total L: 45

REFERENCES:

1. Kevin Otto and Kristin Wood, “Product Design”, Pearson, 2013.
2. Karl T Ulrich and Steven D Eppinger, “Product Design and Development”, McGraw Hill, 2020.
3. Chitale A K and Gupta R C, “Product Design and Manufacturing”, Prentice Hall of India, 2013.
4. Michael Grieves, “Product Life Cycle Management”, Tata McGraw Hill, 2006.
5. Nigel Cross, “Engineering Design Methods: Strategies for Product Design”, John Wiley and Sons, 2008.
6. Michael F Ashby, “Materials Selection in Mechanical Design”, Butterworth – Heinemann, 2016

21MD28 DESIGN OF AUTOMOTIVE SYSTEMS

3 0 0 3

DESIGN OF PROPULSION SYSTEMS: Review of design considerations for components under static and dynamic loading; Design of I.C engine components - cylinder, piston, connecting rod, crankshaft, flywheel, valves and valve springs; Design principles of electric vehicle. (10)

DESIGN OF TRANSMISSION ELEMENTS AND BRAKES: Clutches: power transmission requirements of clutches, design of single and multi-plate clutches, diaphragm clutch, cone clutch and centrifugal clutch; Design of gear box and drive lines; Concepts of variable transmission systems; Design of power train for vibration; Brakes: brake power requirements, design of drum and disc brakes, principles of regenerative and anti-lock braking systems. (12)

DESIGN OF STREERING AND SUSPENSION SYSTEMS: Design of steering systems, power assisted steering; Suspension systems: classification of suspension, design of springs – coil springs, leaf springs, air springs; Design of steering and suspension systems for vibration. (11)

AUTOMOTIVE BODY DESIGN: Automotive body structural elements: design of automotive beam sections, torsion of thin-wall members, thin-wall beam section design in automobiles, buckling of thin-walled members, design for body bending and body torsion- strength and stiffness requirements; Principles of body panel design; Structural requirements for crashworthiness; Design of body structure for vibration. (12)

Total L: 45

REFERENCES:

1. Bhandari V.B., Design of Machine Elements, Fourth Edition, Tata McGraw Hill, 2017
2. Donald E. Malen, Fundamentals of Automobile Body Structure Design, SAE International, 2011.
3. Heinz Heisler, Vehicle and Engine Technology, Second Edition. SAE International, (1998)
4. Wang J.Y., Theory of Ground Vehicles, Fourth Edition. John Wiley, 2008.
5. Smith J.H., An Introduction to Modern Vehicle Design, Butterworth-Heinmann, (2001)
6. Matchinsky W., Road Vehicle suspensions, PEP, 2000.

21MD29 PRODUCTION TOOL DESIGN

3 0 0 3

DESIGN OF CUTTING TOOLS: Cutting tool materials, properties, classification, selection, tool wear, tool life; Single point tool: nomenclature, design of tools for turning, shaping, planning and slotting operations, form tools, tool holders for CNC applications; Multipoint cutters: nomenclature, classification and selection of drills, reamers and milling cutters; design of broaches and hobs. (11)

DESIGN OF JIGS AND FIXTURES: Principles of locating and clamping, design of drill jigs for conventional, SPM and CNC machining centres, different type of jigs, jig bushes, calculation of drilling forces; Fixtures - estimation of machining forces; Design of turning, milling and grinding fixtures; Fixtures for inspection and assembly; Modular fixtures. (11)

DESIGN OF PRESS TOOLS: Study of CNC shearing, press brake, mechanical and hydraulic power presses, , fundamentals of blanking and piercing, tool clearances, estimation of tonnage, standard die sets, design of progressive tools with manual and auto feed, die materials, bending tool. (11)

DESIGN OF DIES: Plastic injection moulding dies: plastic materials, shrinkage, two plate mold design, standard mold plates, parting line, runner and gate design, mold cooling, ejection methods, tool materials, runner less molds. Introduction to Thermo Setting dies, blow molding dies, extrusion dies, forging dies and pressure die casting dies. (12)

Total L: 45

REFERENCES:

1. Arshinov.V and Alekseev.G, "Metal cutting Theory and Cutting Tool Design", MIR Publishers, Moscow, 1976.

2. Donaldson.C and LeCain.C.H, "Tool Design", Tata McGraw Hill Publishing Company Limited, New Delhi, 2012.
3. Joshi P H, “Jigs and Fixtures”, Tata McGraw Hill, 2013.
4. Ostergaurd D E, “Basic Die Making”, McGraw Hill, 2013.
5. Grant H E, "Non-Standard Clamping Devices", Tata McGraw Hill, 2001.
6. Paquin, “Press Tool Design Fundamentals”, Indian Institute of Science, 2012.

21MD30 HUMAN FACTORS ENGINEERING

3 0 0 3

INTRODUCTION: Definition, human technological system, multidisciplinary engineering approach, human–machine system, manual, mechanical, automated system, human system reliability, conceptual design, advanced development, detailed design and development, human system modeling; Information Input: input and processing, text, graphics, symbols, codes, visual display of dynamic information, auditory, tactual, olfactory displays, speech communications; Human output and control: physical work, manual material handling, motor skill, human control of systems, controls and data entry devices, hand tools and devices. (12)

WORKPLACE DESIGN: Applied anthropometry, workspace design and seating, arrangement of components within a physical space, interpersonal aspects of work place design, design of repetitive task, design of manual handling task, work capacity, stress, fatigue. (11)

ENVIRONMENTAL CONDITIONS: Illumination, climate, temperature, noise, motion, sound, vibration; Human factors applications: Human error, accidents, case study on human factors and the automobile, organizational and social aspects, steps according to ISO/DIS6385, OSHA’s approach, virtual environments. (10)

BIOMECHANICS AND BIO-THERMODYNAMICS: Biostatic mechanics, statics of rigid bodies, upper extremity of hand, lower extremity and foot, bending, lifting and carrying, biodynamic mechanics, human body kinematics, kinetics, impact and collision; Biothermodynamics and Bioenergitics: Bio-thermal fundamentals, human operator heat transfer, human system bioenergetics, thermoregulatory physiology, human operator thermos-regularity, passive operator, active operator, heat stress. (12)

Total L: 45

REFERENCES:

1. Chandler Allen Phillips, “Human Factors Engineering”, John Wiley and Sons, New York, 2000.
2. Mark S Sanders, “Human Factors in Engineering and Design”, McGraw Hill, New York, 1993.
3. Bridger R S, “Introduction to Ergonomics”, Taylor and Francis, London, 2017.
4. Neville Anthony Stanton, Alan Hedge, KarelBrookhuis, Eduardo Salas, Hal W. Hendrick “Handbook of Human Factors and Ergonomics Methods” CRC Press, 2004

21MD31 ROTOR DYNAMICS

3 0 0 3

ROTOR DYNAMICS AND MODELS: Co-ordinate systems: steady state rotor motion, elliptical motion, single degree of freedom systems, free and forced vibrations, total motion; The Laval-Jeffcott rotor model: the two degrees of freedom rotor system, translational motion, natural frequencies and natural modes; steady state response to unbalance, the effect of flexible support. (12)

TORSIONAL VIBRATION IN ROTATING MACHINERY: Modeling of rotating machinery shafts of multi degree of freedom systems, determination of natural frequencies and mode shapes of branched systems. (10)

RIGID ROTOR DYNAMICS AND CRITICAL SPEEDS: Rigid disk equation: rigid rotor dynamics, rigid rotor on flexible shaft; Whirling of an unbalanced simple elastic rotor: simple shafts with several disks, effect of axial stiffness, and determination of bending critical speeds,Preparation of Campbell diagram. (12)

BALANCING AND CONDITION MONITORING OF ROTORS: Balancing: single plane balancing, multi-plane balancing, balancing of rigid rotors, balancing of flexible rotors; Condition monitoring **-** noise spectrum, real time analysis, knowledge based expert systems. (11)

Total L: 45

REFERENCES:

1. Rao J S, “Rotor Dynamics”, 3rd Edition, New Age International Publishers, New Delhi, 2018.
2. Timoshenko S, Young D H and Weaver W, “Vibration Problems in Engineering”, John Wiley, 2017.
3. Weng Jeng Chen and Edger J Gunter, “Introduction to Dynamics of Rotor – Bearing Systems”, Trafford Publishing Ltd., London, 2007
4. Yamamoto T and Ishida Y, “Linear and Nonlinear Rotor Dynamics: A Modern Treatment with Applications”, John Wiley and Sons Inc., New York, 2013.
5. Amiya Ranjan Mohanty, “Machinery Condition Monitoring: Principles and Practices”, CRC Press, 2015.

21MD32 OPTIMUM DESIGN OF MECHANICAL SYSTEMS

3 0 0 3

NONLINEAR OPTIMIZATION: Unconstrained optimization: one-dimensional optimization- elimination methods- Dichotomous Search Method- Fibonacci method-golden section methods- quadratic interpolation method-direct root methods; Multivariable optimization: direct search methods, univariate method, pattern search methods, Hookes and Jeeves method, steepest descent; Solving design optimisation and process optimisation problems. (11)

CONSTRAINED MULTIVARIABLE OPTIMIZATION: Multivariable optimization: direct methods, cutting plane method, indirect methods, transformation techniques, and basic approach of penalty function method, Khun-Tucker conditions, Lagrangian method; Solving design optimisation and process optimisation problems. (12)

DYNAMIC PROGRAMMING: Principle of optimality, computational procedure, calculus method of solution; Solving design optimisation and process optimisation problems. (6)

MULTI-OBJECTIVE OPTIMIZATION: Difference between single objective and multi-objective optimization; Multi-criteria decision making techniques – weighted sum method, ε-constraint method, weighted metric method and Pareto optimality. (5)

NON-TRADITIONAL OPTIMIZATION: Genetic algorithms, simulated annealing, neural networks, particle swarm optimization, Teaching–learning-based optimization (TLBO); Solving design optimisation and process optimisation problems. (11)

Total L: 45

REFERENCES:

1. Singiresu S Rao, “Engineering Optimization: Theory and Practice”, 5th Edition, Wiley-Interscience, 2019.
2. Kalyanmoy Deb, “Optimization for Engineering Design”, Prentice-Hall India Pvt. Ltd., New Delhi, 2012.
3. David E Goldberg, “Genetic Algorithms in Search, Optimization and Machine Learning”, 1st Edition, Pearson Education India, 2008.
4. Dimitri P Bertsekas, “Dynamic Programming: Deterministic and Stochastic Models”, Prentice Hall, 1987.
5. Jared L. Cohon, “Multiobjective Programming and Plan”, Dover Publications Inc., 2004.
6. Kaisa Miettinen, “Nonlinear Multiobjective Optimization”, Springer, 2012.

21MD33 COMPUTATIONAL FLUID DYNAMICS

3 0 0 3

CFD AND THERMO-FLUIDS: Review to the physics of thermo-fluids, governing equations -continuity, momentum, and energy conservation - modelling, grid generation, simulation, and high-performance computing. (10)

COMPUTATIONAL APPROACH: Finite difference method, forward, backward and central difference schemes, explicit and implicit methods, properties of numerical solution methods, stability analysis, and error estimation, difference between FDM and FVM, approximation of surface integrals, approximation of volume integrals, interpolation practices, implementation of boundary conditions, specification for a CFD simulation, requirements for accurate analysis and validation for multi scale problems (12)

CFD TECHNIQUES: Mathematical classification of flow, hyperbolic, parabolic, elliptic and mixed flow types, Lax - Wendroff technique, MacCormack’s technique, relaxation technique, artificial viscosity, ADI technique, pressure correction technique, SIMPLE algorithm, upwind schemes, flux vector splitting. (12)

TURBULENCE MODELING AND CFD APPLICATIONS: Turbulence energy equation, one-equation model, two-equation models (k-ω and k- ε models), review on advanced turbulence models, applications to fluid flow and heat transfer problems. (11)

Total L: 45

REFERENCES:

1. Muralidhar K and Sundararajan T, “Computational Fluid Flow and Heat Transfer”, Narosa Publications, 2009.
2. Chung T J, “Computational Fluid Dynamics”, Cambridge University Press, 2010.
3. Joel H Ferziger and Milovan Peric, “Computational Methods for Fluid Dynamics”, Springer Publications, 2002.
4. John D Anderson, “Computational Fluid Dynamics – The Basics with Applications”, McGraw Hill, 1995.
5. Versteeg H K and Malalasekara W, “An Introduction to Computational Fluid Dynamics - The Finite Volume Method', Longman, 2007.

21MD34 ADVANCED STRENGTH OF MATERIALS

3 0 0 3

CURVED BEAMS AND BEAMS ON ELASTIC SUPPORTS: Circumferential stress at a point in a curved beam, correction of circumferential stresses in curved beams, deflection of curved Beams, Wrinklerbach formula-limitations, curved beam with restrained ends; Closed ring subjected to a concentrated load and uniform load: beam with a concentrated load; Use of

principle of superposition. beam supported on equally spaced separate elastic supports; UDL over part of the beam, semi-infinite beam subjected to loads at its end with concentrated load near its end. (12)

FLAT PLATES IN BENDING: Plates in which bending action is dominant, small deflections. stress in a circular plate with UDL, simply supported and fixed edges-concentrated load; Stresses in square and rectangular plates with UDL, concentrated load at center, strain energy of a plate. (11)

ROTATING DISKS ANDTORSION OF NON-CIRCULAR SECTIONS: Solid disk, disk with a central hole with external and internal pressures, disks of uniform strength, plastic collapse of rotating disks; Rotating cylinders (circular); Disk of varying thickness: torsion of bar having rectangular sections, elastic membrane (soap film) analogy hollow thin walled tubes, thin wall torsion members with restrained ends, elastic torsion of a circular cross section. (11)

THICK WALLED CYLINDERS: Lame solution for principal stresses, maximum stresses, radial deflection, failure theories, applications, methods of increasing the elastic strength by pre-stressing, analysis of effects of stresses of shrinking a hollow cylinder made of thin walled laminations, auto frettage, stress components and radial displacements for constant temperature. (11)

Total L: 45

REFERENCES:

1. Boresi A P and Sidebottom O M, “Advanced Mechanics of Materials”, John Wiley and Sons, New Delhi, 2002.
2. Srinath L S, “Advanced Mechanical of Solids”, Tata McGraw-Hill, New Delhi 2011.
3. Ghosh D, Advanced Strength of Materials”, New Age International Publishers, New Delhi, 2015.
4. Pachauri and Simant, “Advanced Strength of Materials”, Pragati Prakashan , 250001(India), 2008.
5. Cook R D and Young, “Advanced Mechanics of Materials”, John Wiley Co., New Delhi, 1998.
6. Den Hartog, “Advanced Strength of Materials”, McGraw Hill Inc., New Delhi, 1987.

21MD35 DESIGN OF PRESSURE VESSELS

3 0 0 3

CATEGORIZATION OF STRESSES IN PRESSURE VESSELS: Overview of pressure vessels, development of pressure vessel construction codes (ASME codes), factor of safety, design by rule, design by analysis, modes of failure, design for cyclic loading, stress intensity, stress limits, practical aspects of stress categorization, shape factor considerations . (11)

DESIGN OF CYLINDRICAL SHELLS: Introduction, thin-shell equations, thick-shell equations, buckling of cylindrical shells, discontinuity stresses in pressure vessels, design of heads and covers, hemispherical heads under internal pressure; Stress concentration about a circular hole: cylindrical and spherical shell with a circular hole under internal pressure; Reinforcement of openings; Case Studies: Sizing of a pressure vessel, nozzle reinforcement assessment. (12)

FATIGUE ASSESSMENT OF PRESSURE VESSELS: Introduction, exemption from fatigue analysis, S–N curves, local strain approach to fatigue, design fatigue curves, cumulative damage, cycle counting, fatigue evaluation procedure, example of fatigue evaluation, bolted flange connections, gasket joint behaviour, design of bolts, closure: Case Studies: fatigue evaluation using elastic analysis, fatigue evaluation using the simplified inelastic analysis method. (12)

DESIGN OF VESSEL SUPPORTS: Lug support, support skirts, saddle supports, simplified inelastic methods in pressure vessel design- Elastic analysis incorporating modified Poisson’s ratio, Elastic analysis to address plastic strain intensification; Case Studies: Structural evaluation of a reactor vessel support. (10)

Total L: 45

REFERENCES

1. Somnath Chattopadhyay, “Pressure Vessels Design and Practice”, CRC Press 2004.
2. John F. Harvey, Theory and Design of Pressure Vessels, CBS Publishers and Distributors, 2001.
3. Henry H. Bedner, “Pressure Vessels, Design Hand Book, CBS publishers and Distributors, 1991.
4. Stanley, M. Wales, “Chemical process equipment, selection and Design. Butterworth’s series in Chemical Engineering, (2010)
5. William. J., Bees, “Approximate Methods in the Design and Analysis of Pressure Vessels and Piping”, Pre ASME-Pressure Vessels and Piping Conference, 1997.
6. ASME Boiler and Pressure Vessel Code: An International Code. Rules for construction of pressure vessels. Division 1. United States: American Society of Mechanical Engineers. 2019.

21MD36 FRACTURE MECHANICS

3 0 0 3

FRACTURE MECHANISMS IN METALS AND NONMETALS: Linear elastic fracture mechanics, elastic plastic fracture mechanics, fracture toughness testing; Fracture mechanisms in metals: Ductile fracture, cleavage, the ductile-brittle transition, intergranular fracture; Fracture mechanisms in non-metals: Structure and properties of polymers, yielding and fracture in polymers, fiber-reinforced plastics, ceramics and ceramic composites, concrete and rock. (10)

CREEP: Mechanics of creep, inter-granular, trans-granular creep, creep test, creep strain rate-time curves, deformation mechanism map, high temperature properties of materials long time creep-stress-time relations creep contribution to the fracture mechanism; DVM, DVL German-standard, Hatifield time yield test. (12)

APPLICATION TO STRUCTURES: Linear elastic fracture mechanics, CTOD design curve, failure assessment diagrams-original concept, J-based FAD, application to welded structures, probabilistic fracture mechanics. (11)

FATIGUE CRACK PROPAGATION: Similitude in fatigue, empirical fatigue crack growth equations, crack closure, growth of short cracks, micro-mechanisms of fatigue, fatigue crack growth experiments, damage tolerance methodology. (6)

COMPUTATIONAL FRACTURE MECHANICS: Overview of numerical methods, traditional methods in computational fracture mechanics, the energy domain integral, mesh design, linear elastic convergence study, analysis of growing cracks.(6)

Total L: 45

REFERENCES:

1. Anderson T L, “Fracture Mechanics: Fundamentals and Applications”, Taylor and Francis, (2017).
2. ASM Handbook- Vol.11, "Failure Analysis and Prevention", Metals Park, Ohio, USA, (2002).
3. Prashant Kumar, “Elements of Fracture Mechanics”, McGraw Higher Ed, 2009.
4. Surjya Kumar Maiti, “Fracture Mechanics: Fundamentals and Applications, Cambridge University Press, 2015.
5. Tribikram Kundu, “Fundamentals of Fracture Mechanics”, Taylor and Francis, 2008.

21MD37 EXPERIMENTAL STRESS ANALYSIS

3 0 0 3

OVERVIEW OF EXPERIMENTAL STRESS ANALYSIS: Optical methods work as optical computers, multi-scale analysis in experimental mechanics; Stress, strain and displacement fields; Physical principle of strain gauges, photoelasticity and Moiré; Moiré, brittle coatings and holography; Hologram interferometry and speckle methods; Introduction to shearography, TSA, DIC and caustics, fringe patterns – richness of qualitative information, multi-scale analysis in experimental mechanics; selection of an experimental technique. (11)

TRANSMISSION PHOTOELASTICITY: Ordinary and extraordinary rays, light ellipse, passage of light through a crystal plate, retardation plates, stress-optic law, plane polariscope, Jones calculus, circular polariscope, determination of photoelastic parameters at an arbitrary point; Tardy’s method of compensation, calibration of photoelastic materials, fringe thinning methodologies, fringe ordering in photoelasticity; Miscellaneous topics in transmission photoelasticity: Resolving the ambiguity on the principal stress direction, determination of the sign of the boundary stress, compatibility conditions, role of elastic constants on stress field, model to prototype relations, properties of photoelastic model materials. (11)

THREEDIMENSIONAL PHOTOELASTICITY AND DIGITAL PHOTOELASTICITY: overview of digital photoelasticity; Photoelastic coatings: Introduction, correction factors for photoelastic coatings, coating materials, selection of coating thickness, industrial application of photoelastic coatings, calibration of photoelastic coatings; Brittle coatings: Introduction to brittle coatings, analysis of brittle coatings. (11)

STRAIN GAUGES: Introduction to strain gauges, strain sensitivity of a strain gauge, bridge sensitivity, rosettes, strain gauge alloys, carriers and adhesives, performance of strain gauge system, temperature compensation, two-wire and three-wire circuits; Strain gauge selection, bonding of a strain gauge; Applications: soldering, accounting for transverse sensitivity effects, correction factors for special applications; Special gauges- environmental effects, torque gauge, stress gauge, single element strain gauge as stress gauge; Evaluation of SIF by strain gauges, strip gauge, single element strain gauge to evaluate SIF. (12)

Total L: 45

REFERENCES:

1. K. Ramesh, “E-Book on Experimental Stress Analysis”, IIT Madras, 2009.
2. K. Ramesh, “Digital Photoelasticity Advanced Techniques and Applications”, Springer, 2000.
3. W.N. Sharpe (Ed.), “Springer Handbook of Experimental Solid Mechanics”, Springer, 2008.
4. J.W. Dally and W.F. Riley,” Experimental Stress Analysis”, McGraw-Hill, 1991.
5. U. C. Jindal, “Experimental Stress Analysis”, Pearson Education, 2014.
6. Sadhu Singh, “Experimental Stress Analysis”, Khanna Publishers, 2009.

21MD38 DESIGN OF PRESS TOOLS

3 0 0 3

SHEET METAL BEHAVIOUR AND FUNDAMENTALS OF DIES: Sheet metal and its behaviour in metal stamping process, plasticity theories, external influences on the part and their impact on plastic deformation, shear of metal in cutting operation**,** Bending and forming of sheet metal material - movement of metal; Metal stamping die: Description, dies according to their construction, dies according to their effect on the structure of material, new methods in metalworking, fine blanking. (11)

METALWORKING MACHINERY AND CONSTRUCTION OF DIES: Parts of the press, press operating parameters, classification of presses, press mounting, performance and productivity; Metal stamping dies: Tolerancing systems, fabrication and assembly of die components, mounting of blocks, machining of blocks, heat treatment. (11)

BLANKING AND PIERCING OPERATIONS : Sheet metal cutting process, forces involved in the sheet metal cutting process, alignment of cutting tools, design of sheet metal cutting tools, cutting clearances, punching and blanking pressure, cutting force with inclined cutting surfaces, stripping pressure, progressive die design. (12)

BENDING AND FORMING OPERATIONS: Stress, strain, elongation and compression during bending, bend radius, radius of forming tools, edge formability, types of bending operations, spring back, surface flatness after bending, forming, bending and forming pressure calculations. (11)

Total: 45

REFERENCES:

1. Cyril Donaldson, George H.Lecain, V.C. Goold, Joyjeet Ghose, “Tool Design”, Tata McGraw Hill Publishers, 2012.
2. Ivana Suchy, “Handbook of Die Design”, McGraw Hill, 2006.
3. David A Smith, “Die Design Handbook”, Society of Manufacturing Engineers, 1990.
4. Venkataraman, K. “Design of jigs, fixtures and press tools”. John Wiley and Sons, 2015.

21MD39 HUMAN BODY VIBRATION DIAGNOSTICS

3 0 0 3

WHOLE BODY VIBRATION: Vibration and human response, Categorization of vibration (deterministic, random), effects of vibration-criteria, limits, vibration analysis procedure, human vibration-definition, types; standardization bodies-ISO, CEN, National, BSI; Sources-Road, off-road, marine, rail transports; Exposure to whole body vibration-Vibration discomfort Measurement parameters and quantification of the vibration level, frequency response of human whole body vibration , vibration measurement-setup and stimuli, transducers used , vehicle human interface mathematical model-half car, quarter car, equation of motion (multi degree of freedom)-Lagrange’s approach, matrix approach. (12)

BIODYNAMICS, SEATING DYNAMICS AND HAND ARM VIBRATION: Body transmissibility- apparent mass, models, Transmissibility, SEAT value, Seat Testing, Biomechanical models; Sources, exposure to hand arm vibration-White finger syndrome**,** frequency response of hand arm vibration, vibration measurement - setup and stimuli, transducers used, machine human interface model, equation of motion (Multi degree of freedom)-Lagrange’s approach, matrix approach. (12)

MEASUREMENT EVALUATION AND ASSESSMENT OF HUMAN VIBRATION: Frequency analysis, digital frequency weighting, amplitude analysis, ISO evaluation of human exposure to whole body vibration - fatigue decreased proficiency boundary, exposure limit, reduced comfort boundary-BS 6841, ISO 2631, standards for assessment of hand arm vibration-BS 6842 (1987) and ISO 5349 (1986),ISO 5349 (2001) standards for determining the vibration emission value of tools and hand-guided machines - ISO 8662(1, 2, 3…14), standards for testing the dynamic performance of antivibration gloves - ISO 13753, ISO 10819, 1/3 octave frequency analysis. (11)

HEALTH EFFECTS OF VIBRATION, THEIR DIAGNOSIS, AND PREVENTION: Vascular disorders-primary Raynaud's disease, secondary Raynaud's phenomenon, trauma, Occlusive vascular disease, neurogenic, Stockholm workshop scale, preventative measures- managerial, technical, medical, and individual, treatments for injury and disease. (10)

Total L: 45

REFERENCES:

1. M J Griffin,"Handbook of Human Vibration", Academic Press, 2019.
2. Redha Taiar, Christiano Bittencourt Machado, Xavier Chiementin and Mario Bernardo-Filho, “Whole Body Vibrations Physical and biological effects on the Human body” CRC Press, 2017.
3. Neil.J. Mansfield, "Human response to vibration", CRC Press, 2020**.**
4. Thomson W T, "Theory of Vibration with Applications", Prentice Hall of India, 2017.
5. K D Kryter, "The Effects of Noise on Man, Academic Press",2013.
6. P M Nelson,"Transportation Noise Reference Book", Butterworths, 2017.

21MD40 ADVANCED FINITE ELEMENT ANALYSIS

3 0 0 3

BENDING OF PLATES AND SHELLS: Review of elasticity equations, bending of plates and shells – finite element formulation of plate and shell elements, conforming and non-conforming elements, C0 and C1 continuity elements, degenerated shell elements, application and examples. (11)

NON-LINEAR ANALYSIS: Introduction, non-linear differential equation, solution procedures for non-linear problems, linearization and directional derivative; Material non-linearity: Analysis of axially loaded bars, significance of sampling rate, material models for isotropic, orthotropic, anisotropic, hyper-elastic, hardening rules; Geometric non-linearity: Basic continuum mechanics concepts, governing differential equations and weak forms; Introduction to contact problems. (12)

TIME-DEPENDENT ANALYSIS: Numerical integration in time, natural frequencies of one-dimensional bar, time dependent one-dimensional bar analysis; Time dependent heat transfer -transient thermal analysis; Solution of one-dimensional problems. (12)

ERROR, ERROR ESTIMATION AND CONVERGENCE: Sources of error, ill-conditioning, the condition number, diagonal decay test, residuals, discretization error, convergence rate, multi-mesh extrapolation, mesh revision methods, gradient recovery and smoothing, A-Posteriori error estimate, adaptive meshing. (10)

Total L: 45

REFERENCES:

1. Cook, R.D., Malkus, D. S., Plesha,M.E., and Witt,R.J " Concepts and Applications of Finite Element Analysis", Wiley, 2001.
2. Logan D L, "A First Course in the Finite Element Method", Thomson Learning, 2010.
3. Rao S S, "The Finite Element Method in Engineering", Elsevier, 2017.
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OPEN ELECTIVE THEORY COURSES (One to be opted)

21MD91 // Vide 21MC91 BUSINESS ANALYTICS IN PRACTICE

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