Department: Mechanical Engineering

Programme: M. Tech. in Mechanical Engineering

Learning Outcomes based Curriculum

Preamble

In a learning outcome-based teaching pedagogy, the demonstrated achievement of outcomes in terms of knowledge, understanding, skills, attitudes, and the academic standard of the graduates is a key concern. Designing the programme outcomes (POs) for a particular post graduate (PG) programme, based on what a postgraduate in Mechanical Engineering is expected to know, understand and able to do at the end of the study programme is undoubtedly an important aspect. The expected POs are also crucial reference points in the sense that these assist in formulating graduate attributes, qualification descriptors, programme learning outcomes and course outcomes etc. Proper formulation of the above also helps in curriculum planning and development, and also in the design, delivery and review of academic programmes. The two years M. Tech. programme in Mechanical Engineering has been designed taking into consideration the above factors so that all the attributes of a learning outcome based curriculum is met. Additionally, inputs from statutory bodies such as AICTE, NAAC and NBA, along with inputs from stake holders are also taken in consideration before formulating the curriculum.

1. Introduction

The M. Tech. programme in Mechanical Engineering is offered with the following Programme Educational Objectives (PEOs).

1. Impart knowledge on advanced topics of Mechanical Engineering.
2. Practice engineering knowledge, critical thinking and real life problem solving.
3. Pursue research and develop creative and innovative ideas in Mechanical Engineering and other interdisciplinary areas.
4. Prepare students for higher learning and successful career in academia, industry and the government sector.
5. Inculcate in students the sense of responsibility, professionalism, ethics and leadership.

2. **Qualification descriptors for the graduates**

(i) **Knowledge & Understanding** (maximum 3)

- Demonstrate a dedicated understanding in field of specialization in mechanical engineering,its different learning areas and applications, and its linkages with related disciplinary areas/subjects;
- Demonstrate procedural knowledge that creates different types of professionals related to the specialized domain of mechanical engineering, including research and development, teaching and academics and also the industrial sector.
- Demonstrate comprehensive knowledge about the domain of specialization, including research, relating to essential learning areas pertaining to mechanical

engineering. Also develop techniques and skills required for identifying problems and issues relating to the specialized field of study.

(ii) **Skills & Techniques** (Maximum 3)

- Demonstrate skills in areas related to specialization in mechanical engineering and be up to date on the current developments in the field of specialization.
- Demonstrate skills related to the specialization in mechanical engineering which are transferable and relevant/requiredforjobs in industrial sectors and employment opportunities.
- Apply one's knowledge on the specialization in mechanical engineering and transferable skills to new/unfamiliar contexts, to identify andanalyseproblems and issues and solve complex problems with well-definedsolutions.

(iii) Competence (Maximum 3)

- Meet one's own learning needs, drawing on a range of current research and development work and professional materials;
- Communicate the results of studies undertaken in an academic field accurately in a range of different contexts using the main concepts, constructs and techniques of the subject(s)
- Demonstrate competence in identifying information needs, collection of relevant quantitative/qualitative data, analysis and interpretation of data using methodologies as appropriate to the subject(s) for formulating evidence-based solutions and arguments.

3. **Graduates Attributes**
   - Scholarship of knowledge
   - Critical thinking
   - Problem solving
   - Research skill
   - Modern tool usage
   - Collaborative and multidisciplinary work
   - Project management
   - Communication
   - Life-long learning
   - Ethical practices and social responsibility
   - Independent and reflective learning

4. **Program Outcomes:** The students from this program will attain:
   1. An ability to independently carry out research /investigation and development work to solve practical problems.
   2. An ability to write and present a substantial technical report/document.
   3. An ability to demonstrate a degree of mastery and in-depth knowledge in the following specialized areas:
      a. Numerical and experimental fluid flow and heat transfer
      b. Design, analysis and optimization of Mechanical systems
      c. Materials engineering for design
      d. Renewable thermal energy

5. PROGRAMME STRUCTURE

Currently, the M. Tech. in Mechanical Engineering is being offered in two specializations viz. Thermal and Fluids Engineering and Machine Design. Detail course structure for the Machine Design spcialization is given below.

Structure of the M. Tech. curriculum (Specialization: Machine Design)

Total Credits: 65

	Course Category	Course Detail								Category-wise credits
		SN	Code	Title	L	T	P	Cr	CH	
I	Core courses	1	ME-501	Advanced Solid Mechanics	3	1	0	4	4	44
		2	ME-623	Mathematical Methods for Engineers	3	1	0	4	4	
		3	ME-509	Advanced Dynamics and Vibration	3	0	0	3	3	
		4	ME-502	Finite Element Methods	3	1	0	4	4	
		5	ME-510	Engineering Design Laboratory	0	0	3	6	3	
		6	ME-592	Term Paper	0	0	0	0	2	
		7	ME-613	MTech Thesis part I					12	
		8	ME-614	MTech Thesis part II					12	
II	Elective courses	1	xx-xxx	Open Elective I					3	21
		2	xx-xxx	Elective I					3*	
		3	xx-xxx	Elective II					3*	
		4	xx-xxx	Open Elective II					3	
		5	xx-xxx	Elective III					3	
		6	xx-xxx	Elective IV					3*	
		7	xx-xxx	Elective V					3*	
									Total credits	**65**

6. SEMESTER-WISE SCHEDULE
Specialization: Machine Design

Semester	Course detail								Total Credits
	SN	Code	Title	L	T	P	CH	Cr	
I	1	ME-501	Advanced Solid Mechanics	3	1	0	4	4	20
	2	ME-623	Mathematical Methods for Engineers	3	1	0	4	4	
	3	ME-509	Advanced Dynamics and Vibration	3	0	0	3	3	
	4	xx-xxx	Open Elective I					3	
	5	xx-xxx	Elective I					3*	
	6	xx-xxx	Elective II					3*	
II	1	ME-502	Finite Element Methods	3	1	0	4	4	21
	2	ME-510	Engineering Design Laboratory	0	0	3	6	3	
	3	ME-592	Term Paper	0	0	0	0	2	
	4	xx-xxx	Open Elective II					3	
	5	xx-xxx	Open Elective III					3	
	6	xx-xxx	Elective III					3*	
	7	xx-xxx	Elective IV					3*	
III	1	ME-613	MTech Thesis part I					12	12
IV	1	ME-614	MTech Thesis part II					12	12
Total	**15**	**Minimum credit to be completed for award of the degree**							**65**

7. Mapping of courses with program outcomes (POs)

The M. Tech. Mechanical Engineering programme has three programme outcomes formulated in line with the graduate attributes of NBA. Similarly each course offered in various semesters also has certain course outcomes (COs). The COs of each and every course is linked with the POs in such a way that the strongest relation has the weight of 3 and the weakest relation is 1. Accordingly, the weight factor of the POs from the respective course is determined. The details regarding the CO PO linkage are attached below.

CO-PO mapping of M.Tech. Programme in Mechanical Engineering (Machine Design):

Course		PO1	PO2	PO3
ME501	CO1	1	×	3
	CO2	2	×	3
	CO3	3	×	3
	CO4	2	×	2
	CO5	3	×	3
ME623	CO1	2	3	×
	CO2	×	2	3
	CO3	3	×	×
	CO4	3	×	×
	CO5	×	3	2
ME509	CO1	2.5	×	2
	CO2	×	2.5	2.5
	CO3	2.5	×	3

	CO4	3	×	2.5
	CO5	×	2.5	3
	CO6	3	×	2.5
ME502	CO1	2	×	3
	CO2	3	×	3
	CO3	2	×	2
	CO4	2	×	3
	CO5	3	×	3
	CO6	3	×	3
ME510	CO1	2.5	×	2.5
	CO2	×	2.5	3
	CO3	3	×	×
	CO4	2.5	×	2.5
	CO5	×	2.5	3
	CO6	2.5	×	2.5
ME613	CO1	2	×	3
	CO2	1	×	2
	CO3	3	×	2
	CO4	2	×	2
	CO5	1	×	2
	CO6	×	3	×
ME614	CO1	3	×	2
	CO2	1	2	3
	CO3	1	×	3
	CO4	1	×	3
	CO5	×	3	1
	CO6	×	3	×
ME592	CO1	1	×	3
	CO2	1	3	2
	CO3	1	1	2
	CO4	1	3	2
ME511	CO1	×	×	2
	CO2	×	×	2
	CO3	3	×	3
	CO4	×	×	3
	CO5	3	×	3
	CO6	3	×	3
	CO7	3	×	3
ME512	CO1	×	×	2
	CO2	×	×	2
	CO3	3	×	3
	CO4	3	×	3
	CO5	3	×	3
	CO6	3	×	3
	CO7	2	×	2
ME513	CO1	3	×	3
	CO2	2	×	2
	CO3	3	×	3

	CO4	3	×	2
	CO5	3	×	3
	CO6	2	×	2
	CO7	2	×	2
ME503	CO1	2	×	2
	CO2	2	×	3
	CO3	2	×	3
	CO4	3	×	3
	CO5	3	×	3
	CO6	3	×	3
ME505	CO1	3	2.5	2
	CO2	2.5	1.5	2.5
	CO3	2.5	2.5	3
	CO4	3	2	2.5
	CO5	2	×	2.5
	CO6	1.5	×	1.5
	CO7			
ME506	CO1	×	×	2
	CO2	×	×	2
	CO3	3	×	3
	CO4	3	×	3
	CO5	3	×	3
ME538	CO1	3	×	3
	CO2	2	×	3
	CO3	3	1	2
	CO4	3	1	3
	CO5	2	×	3
	CO6	3	×	2
ME575	CO1	2	2	3
	CO2	2	2	2
	CO3	3	3	2
	CO4	3	3	1

8. EVALUATION PLAN:

The evaluation plan adopted is a continuous comprehensive evaluation system designed by the university as follows.

1. Sessional Test-I	25
2. Mid-sem examination	40
3. Sessional Test-II	25
4. End-sem Examination	60

The evaluation plan adopted is a continuous comprehensive evaluation system designed by the university. As a part of the evaluation plan, question papers are set with levels based on Bloom's taxonomy, with each question linked to the respective course outcomes. Subsequently, the attainment of course outcomes is assessed based on the students' performance in the test (marks attained by the students against questions linked to a particular course outcome).

9. **DETAILED SYLLABUS:** The detailed syllabus along with their credit structure is given in Annexure II.

Annexure II

M. Tech. Mechanical Engineering Syllabus

(Specialization: Machine Design)

ME-501: Advanced Solid Mechanics L-T-P-CH-CR: 3-1-0-4-4

Analysis of stress: Introduction, Cauchy's formula, principal stresses, stress invariants, three- dimensional Mohr's circle, octahedral stresses, hydrostatic and deviatoric stresses, differential equations of equilibrium in rectangular and polar coordinates, stress boundary conditions, plane stress and plane stress problems;
Analysis of strain: Introduction, definitions of normal and shear strains, principal strains, strain invariants, plane strain in rectangular and polar coordinates, compatibility conditions;
Stress-strain relations for linearly elastic bodies: Generalized Hooke's law, relations between elastic constants;
Axisymmetric problems: Thick and thin-walled cylinders, composite tubes, rotating disks;
Energy methods: Introduction, principle of superposition, elastic strain energy and complementary energy, reciprocal relations, Maxwell-Betti theorem, Castigliano's theorem, principle of virtual work, statically indeterminate structures, Kirchoff's theorem;
Bending of beams: Bending of symmetrical and unsymmetrical straight beams, shear stresses in beams, shear center and shear flow, curved beam;
Torsion: Torsion of circular, elliptical and rectangular bars, thin walled sections; Elastic stability: Euler's buckling load, beam column, eigenvalue problem; Assignment and mini-project.

Course outcomes:

CO1: Understand advanced stress-strain correlations.
CO2: Obtain simple mathematical and physical relationships between mechanics and materials.
CO3: Critical thinking and critical judgment of assumptions adopted.
CO4: Establish links between theoretical and practical applications.
CO5: Identify, formulate, model and analyze the complex engineering structural problem.

Textbooks

1. Srinath L.S. *Advanced Mechanics of Solids* (Tata McGraw-Hill, New Delhi, 2009)
2. Raymond P. Solid Mechanics in Engineering (Willey, 2001)

References

1. Sadd M.H. *Elasticity: Theory, Applications, and Numerics* (Academic Press, 2009)
2. Budynas R.G. *Advanced Strength and Applied Stress Analysis* (McGraw Hill, 1999)
3. Boresi A.P. and Schmidt, R.J. *Advanced Mechanics of Materials* (John Willey & Sons, 2003)

ME-623: Mathematical Methods for Engineers L-T-P-CH-CR: 3-1-0-4-4

Linear Algebra:
Introduction to Matrices & Linear Transformations;
Vector Spaces: Definition, linear independence of vectors, basis, inner product and inner product space, orthogonality, Gram-Schmidt procedure, subspaces;
Operational Fundamentals: Range and null space (rank & nullity), elementary transformations; Systems of Linear Equations: Nature of solutions, existence and uniqueness of solution, Gauss elimination and Gauss Jordon methods, Echelon form, pivoting, LU decomposition and Cholesky method, Gauss-Seidel and

Jacobi iterative methods, condition number, minimum norm and least square error solutions;
Eigenvalues and eigenvectors of matrices: Properties like multiplicity, eigenspace, spectrum and linear independence of eigenvectors, similarity transformation and Jordon canonical form, eigenvalues/eigenvectors of symmetric matrices: orthogonal diagonalization.
Iterative methods to find eigenvalues/eigenvectors of symmetric matrices: Forward iteration and Mises power method, inverse iteration;
Eigenvalue problems of general matrices & Singular value decomposition;

Vector Analysis:

Curves in space: Parametric representation, tangent vector, arc length, curvature, principal normal vector, osculating plane, bi-normal vector;
Surfaces: Parametric representation, tangent vector and tangent plane;
Scalar & Vector fields: Gradient, directional derivative, potential; divergence, curl, solenoidal and irrotational vector fields; Line integral and path independence; Surface and volume integrals; Gauss (divergence), Stokes and Green's theorems;

Topics in Numerical Methods:

Solution of nonlinear equations and systems, Newton-Raphson method for systems of nonlinear equations;
Interpolation and approximation: Polynomial interpolation - Lagrange and Newton single- polynomial interpolation, limitations of single-polynomial interpolation, Hermite interpolation; Piecewise polynomial interpolation - piecewise cubic interpolation, spline interpolation
Numerical integration: Newton-Cotes integration formulae, trapezoidal rule, Simpson's rule;
Richardson Extrapolation and Romberg integration; Gaussian quadrature

Ordinary Differential Equations (ODEs):

Fundamental ideas: Autonomous systems, equilibrium points, linear homogeneous systems with constant coefficients;
Numerical solution of ODEs: Euler's method, improved Euler's method, Runge-Kutta methods; Solving systems of ODEs;
Stability of dynamic systems: Phase plane analysis, limit cycles, Lyapunov stability analysis; Series Solutions and Laplace & Fourier transform methods of solving ODEs;

Partial Differential Equations (PDEs):

Quasi-linear second order PDEs: Hyperbolic, parabolic and elliptic forms, Initial and boundary conditions;
Hyperbolic equations: Method of separation of variables, solution of the wave equation by separation of variables, D'Alembert's solution of the wave equation;
Parabolic equations: Heat conduction in a finite bar, Heat conduction in an infinite wire;
Elliptic equations: Steady-state heat flow in a rectangular plate, steady-state heat flow with internal heat generation;
Numerical solution of partial differential equation.

Course-outcomes:

Students after successful completion of this course on mathematics will be able to:
CO1: Demonstrate an understanding of the mathematical concepts
CO2: Perform computations in higher mathematics
CO3: Develop and maintain problem-solving skills
CO4: Use mathematical ideas to model real-world problems
CO5: Communicate mathematical ideas with others

Textbooks:

1. Dasgupta B. *Applied Mathematical Methods*, Pearson Education (2006)

2. Kreyzig E. *Advanced Engineering Mathematics*, John Wiley & Sons, (2001)

References:

1. Strang G. *Linear Algebra and its Application*, Cengage Learning (2006)
2. O'Neil P.V. *Advanced Engineering Mathematics*, Cengage Learning (2007)
3. Arfken G. B. *et al*, *Mathematical Methods for Physicists*, Elsevier (2005)

ME-509: Advanced Dynamics and Vibration **L-T-P-CH-CR: 3-0-0-3-3**

Principles of dynamics: Generalized co-ordinates, degrees of freedom, constraints; equations of motions, Hamilton's principle, Lagrange's equations,
Single, two and multiple degrees of freedom systems,
Free and forced Vibration, transverse and torsional vibrations of two and three rotor systems, critical speeds,
Vibration isolation and measurements, normal mode vibration, coordinate coupling.
Vibration absorbers. Effect of damping; Continuous systems: vibration of strings, beams, bars; Raleigh-Ritz and Galerkin's methods.
Measurement techniques, vibration measuring instruments- design and working principle.

Course outcomes:

CO1: Solve complex engineering problem in the field of Dynamics and Vibration.
CO2: Understanding the role of dynamics and vibration in engineering problem and to know the physical approach to both.
CO3: To derive and obtain mathematical and physical relationships in problems related to vibration analysis.
CO4: Critical thinking and critical judgment of assumptions adopted in practical problem from the field of dynamics and vibration.
CO5: To model a vibration control system and knowledge about design of realistic system.
CO6: Establish links between theoretical and practical applications of dynamics and vibration.

Textbooks:

1. Meirovitch L. *Elements of Vibration Analysis* (McGraw Hill, Second edition, 2006)
2. Meirovitch L. *Principles & Techniques of Vibrations* (Prentice Hall, New Jersey, 1997)
3. Thomson W. T. *Theory of Vibration with Applications* (CBS Publ., 5th edition, 1997)

References:

1. Rao J. S. and Gupta K. *Theory and Practice of Mechanical Vibrations* (New Age Publication, 1999)
2. Inman D. J. *Engineering Vibrations* (Prentice Hall, New Jersy, 4th Edition, 2013)
3. Tse F. S., Morse I. E. and Hinkle R. T. *Mechanical Vibrations* (CBS Publ., 2nd edition, 2004)

ME-613 : MTech Thesis Part I **L-T-P-CH-CR: 0-0-0-0-12**

Course-outcomes:

CO1: Demonstrate scholarly knowledge on the chosen research topic.
CO2: Formulate a complex and novel research problem.
CO3: Demonstrate the ability to acquire new skills and knowledge to analyze and model the chosen

research problem.
CO4: Use modern tools and techniques to solve the problem and analyze the results.
CO5: Create innovative ideas and products to cater to address problems of societal need and industrial relevance.
CO6: Present the research findings in the form of a sound technical report.

ME-614 : M Tech Thesis Part II **L-T-P-CH-CR: 0-0-0-0-12**

Course Outcomes:

CO1: Demonstrate the ability to solve complex and multidisciplinary research problems in a time-bound manner.
CO2: Critically assess, analyze, evaluate and present the research findings.
CO3: Create innovative ideas and products to cater to address problems of societal need and industrial relevance.
CO4: Identify scope for future research based on the thesis work.
CO5: Acquire the ability to independently write sound thesis and research papers.
CO6: Demonstrate good presentation skills

ME-592: Term Paper **L-T-P-CH-CR: 0-0-0-4-2**

Course outcomes:

On successful completion of this seminar, the graduates will be able to
CO1: Understand thoroughly a particular topic at higher level
CO2: Acquire the art of presenting a selected topic of research systematically
CO3: Identify research problem to be carried out as a part of his/her final year thesis work.
CO4: Write a review on a particular research topic of his/her choice

ME-502: Finite Element Methods **L-T-P-CH-CR: 3-1-0-4-4**

Introduction, basic concept, comparison with finite difference method; Variational methods: Calculus of variation, Rayleigh-Ritz and Galerkin methods;
One-dimensional problems: Formulation by different approaches, derivation of elemental equations, assembly, solutions and post-processing, bending of beams, analysis of truss and frame, other problems of solid mechanics, fluid mechanics and heat transfer;
Two-dimensional problems: Modeling of single variable problems, triangular and rectangular elements, applications in solid mechanics, fluid mechanics and heat transfer;
Numerical considerations: Numerical integration, error analysis, mesh refinement;
Plane stress and plane strain problems; Bending of plates; Eigenvalue and time dependent problems; Discussion about preprocessors, postprocessors;
Application of commercial software packages; Assignment and mini-project.

Course outcomes:

CO1: Learn the behaviour and uses of different types of elements.
CO2: Find stress, strain and deformation of engineering problems of any dimensions using FEM.
CO3: Understand the concepts behind variation methods in FEM.
CO4: Solve complicated integration problem by using numerical integration technique.
CO5: Built FE model, analyze, solve and design of complex geometric problems using the commercial

FE software package.

CO6: Pursue research in the field of FEM.

Textbooks

1. Chandrupatla T.R. and Belegundu, A.D. *Introduction to Finite Elements in Engineering*, Vol.1 (Prentice Hall, 2002)
2. Bathe K.J. *Finite Element Procedures in Engineering Analysis* (Prentice Hall, 1996)

References

1. Reddy J.N. *An introduction to the Finite Element Method* (McGraw-Hill, 2006)
2. Cook R.D., Malkus, D.S. and Plesha, M.E. *Concepts and Applications of Finite Element Analysis* (Wiley, 2007)
3. Hughes T.J.T. *The Finite Element Method* (Dover Publications, 2000)
4. Zienkiewicz C. and Taylor, R.L. *The Finite Element Method* (McGraw-Hill, 1989)

ME-510: Engineering Design Laboratory **L-T-P-CH-CR: 0-0-3-6-3**

Introduction to Computer-Aided Design and Analysis: Basic Drafting, Modelling of Parts, Assembly. Introduction to Finite Element Programmimg: Basic engineering analysis of Beams, Trusses, Plates; Stress analysis of structure with individual and combined loading; Sensitivity analysis; Solution to problem with Mechanical, Thermal and Thermo-Mechanical loading.
Introduction to computational modeling: Introduction to MATLAB; MATLAB Basics: Arrays and Matrix Operations; Programming with MATLAB; Calling MATLAB in-built Functions; User- defined Functions; Plotting with MATLAB; Introduction to different tool-boxes & Simulink.
Experiments with Solids: Material properties; Experimental measurement of force, torque, stress, strain, and displacement in solids and structures; Photo-elasticity and strain gauges; Investigation of the micro-structure of materials; Digital image correlation technique.
Analysis of Experimental Data: Error analysis, Uncertainty analysis, Data reduction techniques, Statistical analysis of data, Probability distributions and curve fitting.

Course outcomes:

CO1: Use of Design software for drawing drafting and modeling of engineering parts
CO2: Use of FEM packages like ANSYS for solving any engineering problems from basic to complex type.
CO3: Write program in C language to solve a class of engineering problems.
CO4: Write program in MATLAB to solve a class of engineering problems.
CO5: Understand different experimental process and techniques for different experimental analysis.
CO6: Analyze experimental data to conclude on their significance and basic of statistical tool

Textbooks

1. Wheeler A.J. and Ganji, A.R. *Introduction to Engineering Experimentation* (Pren-tice Hall, 2003)
2. Chapman S. J. *MATLAB Programming for Engineers* (Cengage Learning, 2007)

References

1. Munford P., Normand, P. *Mastering Autodesk Inventor 2016 and Autodesk In-ventor LT 2016* (John

Wiley Sons, 2016)
2. Kent L.L. *ANSYS Workbench Tutorial Release 14* (SDC Publications, 2012)
3. Doeblin E.O., *Engineering Experimentation* (McGraw-Hill, 1995).
4. Chapra S.C., *Applied Numerical Methods with MATLAB for Engineering and Science* (McGraw-Hill Science, 2004).
5. MATLAB Handbook

ME-511: Experimental Stress Analysis for Design **L-T-P-CH-CR: 3-0-1-5-4**

Review of Stress and Strain Analysis: Stress-strain relations and general equations of elasticity; Strain Measuring Devices: Various types of strain gauges, Electrical resistance strain gauges: gauge factor, types, gauge materials, backing materials, adhesives, protective coatings, bonding of strain gauges, lead wires and connections, Semiconductor strain gauges,
Performance of Strain Gauges: Temperature compensation, transverse sensitivity, gauge length, response, excitation level, stability;
Strain gauge circuits, recording instruments for static and dynamic applications, strain gauge rosettes analysis, stress gauge;
Photoelasticity: Theory of photoelasticity, analysis techniques, three dimensional photoelasticity; Brittle coating methods of strain indication;
Introduction to Moiré fringe technique;
Residual Stress Analysis: Analytical and numerical solution of residual stresses in metal working processes (autofrettage, welding etc.), Experimental methods for assessing residual stresses: Sachs boring, X-ray diffraction, neutron diffraction and hole drilling method, inference of residual stresses from microhardness test.

Course-outcomes:

CO1: Understand the basic difference among analytical, numerical and experimental stress analysis techniques and their need.
CO2: Understand the different experimental measurement techniques for in-service stresses and the underlying physical principle of each of the technique.
CO3: Understand the different destructive and non-destructive techniques for experimental measurement of residual stresses and the underlying physical principle of each of the technique.
CO4: Select a suitable method for experimental determination of stresses for a problem on hand.
CO5: Interpret and Analyze the experimental data obtained from different experimental stress measurement methods.
CO6: Understand the different influential parameters affecting the measurement in each experimental stress analysis method and associated errors.

Textbooks

1. Dove R.C. and Adams P. H. *Experimental Stress Analysis* (McGraw Hill, 1992)
2. Dally J.W. and Riley W.F. *Experimental Stress Analysis* (McGraw-Hill Inc., New York, 1998)
3. Srinath, L.S. and Raghavan M.R. *Experimental Stress Analysis* (Tata McGraw-Hill, 1998).

References

1. Freddi A. Olmi G. and Cristofolini L. *Experimental Stress Analysis for Materials and Structures* (Springer,Switzerland, 2015)
2. Timoshenko S.P. and Goodier J.N. *Theory of elasticit*, (McGraw-Hill International Editions, 1970)
3. Sharpe W.N. *Handbook of Experimental Solid Mechanics* (Springer, 2008)

4. Noyan I.C. and Cohen J.B. *Residual Stress* (Springer, 1987)
5. Kandil F.A., Lord J.D., Fry A.T. and Grant P.V. *A review of residual stress measurement methods—A guide to technique selection* (NPL Report MATC(A)04, February 2001, NPL Materials Centre Queens Road, Teddington, Middlesex, UK)
6. Kamal S.M. Borsaikia A. and Dixit U.S. Experimental assessment of residual stresses Induced by the thermal autofrettage of thick-walled cylinders, *Journal of Strain Analysis*, Vol. 51(2), pp.144-160,2016

ME-512: Theory of Plasticity **L-T-P-CH-CR: 3-0-0-3-3**

Stresses and Strain: Stress and strain behavior of materials, plastic and tangent modulus, strain hardening, plastic instability in tensile test, empirical stress-strain equations, effect of pressure, strain-rate and temperature. Analysis of stress tensor, eigenvalues, decomposition of stress tensor into deviatoric and hydrostatic components, octahedral stresses. Analysis of strain and strain-rates. Stress equilibrium and virtual work, objective stress rates.
The criteria of yielding. Isotropic and anisotropic hardening. Rules of plastic flow: Levy-Mises and Prandtl-Reuss equations. Hill's 1948 and 1979 yield criteria for anisotropic yielding. Anisotropic flow rule. Upper bound and lower bound theorems with a few applications.
Axisymmetric elastic-plastic problems: Hydraulic autofrettage, Swage autofrettage and Thermal autofrettage; Expansion of hole in a plate.
Plane stress elastic-plastic problems: Bending of beam. Indentation problem: by upper bound and cavity method
Dynamics Elasto-plastic problems: Longitudinal stress wave propagation in a rod, Taylor rod problem.
Introduction to Updated Lagrangian and Eulerian formulations.

Course-outcomes:

CO1: Understand the basic concepts of fundamental variables such as stress, strain and displacement tensor under the application of load, strain-rate, strain-hardening.
CO2: Understand typical plastic yield criteria established in constitutive modeling.
CO3: Understand the anisotropic yield criterion, e.g., Hill's 1948 and 1979 criterion.
CO4: Apply basic analytical equations and constitutive models in the analysis of structures subjected to plastic deformation.
CO5: Analyze axisymmetric elastic-plastic problems of practical importance and indentation problems using the principles of plasticity theory.
CO6: Understand the principles of new autofrettage techniques such as thermal and rotational autofrettage.

Textbooks

1. Dixit P.M. and Dixit U.S. *Plasticity: Fundamentals and Applications* (CRC Press, 2015)
2. Chakrabarty J. *Theory of Plasticity* (Elsevier Butterworth-Heinemann, 2006)

References

1. Dixit P.M. and Dixit U.S. *Modeling of Metal Forming and Machining Processes by Finite Element and Soft Computing Methods* (Springer, 2008)
2. Rees D.W.A. *Basic Engineering Plasticity* (Elsevier Butterworth-Heinemann, 2006)
3. Lal G.K. and Reddy N.V. *Introduction to Engineering Plasticity* (Narosa, 2009)
4. Kamal S.M. and Dixit U.S. Feasibility study of thermal autofrettage of thick-walled cylinders, *ASME Journal of Pressure Vessel and Technology*, Vol. 137(6), pp. 061207-1−061207-18, 2015.

ME513: Introduction to Fracture Mechanics **L-T-P-CH-CR: 3-0-0-3-3**

Fatigue: Mechanisms of fatigue crack initiation and propagation; Notch sensitivity; Factors influencing fatigue strength, Prevention of fatigue failure.
Introduction to fracture: Failure and fracture, Types of fracture, Modes of fracture failure.
Energy of Fracture: Energy balance during crack growth, Griffith's theory, Crack stability, Fracture criterion, Strain energy release rate.
Linear Elastic Fracture Mechanics: Analysis of crack tip stress, Irwin's fracture criterion, Determination of stress intensity factor, Fracture toughness.
Elastic-Plastic Fracture Mechanics: Crack tip opening displacement, J-Integral and its applications; Computational Fracture Mechanics: Finite element method, Virtual crack extension, Virtual crack closer integral;
Advanced Topics: Fracture in composite, Fracture in nanometer scale. Case studies on fracture failure.

Course Outcomes:

Towards the end of the course the student would be able to:

CO1: Identify the different principles, causes, modes of fatigue crack initiation and propagation.
CO2: Gain detailed knowledge of the theories and mechanics behind fracture of different materials.
CO3: Apply knowledge of fracture and failure in the field of mechanical design through different case studies.
CO4: Present the outcome carried out in the form of group projects on advanced designing of mechanical/structural components considering the in-depth knowledge of material fracture and failure.
CO5: Correlate design considerations with material fracture toughness.

Textbooks

1. Kumar, P. *Elements of Fracture Mechanics* (Tata McGraw-Hill, New Delhi, 2009)
2. Anderson, T.L. *Fracture Mechanics: Fundamentals and applications* (3rd ed., CRC Press, 2005)

References

1. Sanford R.J. *Principles of Fracture Mechanics* (Prentice Hall, 2003)
2. Bolotin V.V. *Mechanics of Fatigue* (CRC Press, 1999)
3. Broek, D. *Elementary Engineering Fracture Mechanics* (Kluwer Academic Publishers, 1986)
4. Rolfe S.T. and Barsom J.M. *Fracture and Fatigue Control in Structures: Applications of Fracture Mechanics* (Butterworth-Heinemann, 2000)
5. Maiti S.K. *Fracture Mechanics: Fundamental and Applications* (Cambridge University Press, 2015)
6. Kundu T, *Fundamental of Fracture Mechanics* (CRC Press, Taylor & Francis, 2008)
7. Kuna M. *Finite Elements in Fracture Mechanics* (Springer, 2013)
8. Gdoutos E. E. *Fracture of Nano and Engineering Materials and Structures* (Springer, 2006)

ME521: Robotics **L-T-P-CH-CR: 3-1-0-4-4**

Introduction: A brief history; Types of robots; Basic principles in robotics; Notation.
Mathematical Representation of Robots: Position & orientation of a rigid body; Transformation between coordinate systems; Homogeneous transformation and its properties; Representation of joints; Representation of links using Denavit-Hartenberg parameters; Link transformation matrices.
Kinematics of Serial Manipulators: Degrees of freedom; Direct kinematics problem; Inverse kinematics

problem; Redundant manipulators.
Velocity Analysis and Statics of Manipulators: Linear and angular velocities of a rigid body; Linear and angular velocities of links in serial manipulators; Jacobian; Singularities of serial manipulators; Statics of serial manipulators; Redundancy resolution.
Elements of Kinematics of Parallel Manipulators: Degrees of freedom; Direct kinematics problem; Inverse kinematic problem; Mobility of parallel manipulators; Jacobian, Statics & Singularity.
Dynamics of Manipulators: Forward and inverse dynamics of manipulators; Newton-Euler and Lagrangian formulations.
Trajectory Planning and Generation: General considerations in path description and generation; Joint space schemes; Cartesian space schemes.
Position and Force Control of Manipulators: Feedback control of a single-link manipulator; PID control of a multi-link manipulator; Non-linear control of manipulators; Partitioning a task for force and position control; Hybrid position/force controller; Stability analysis.
Elements of a Robot: Actuators, Transmission & Sensors.

Course outcomes:

CO1: Understand the concept of robotics.
CO2: Represent robots in mathematical form.
CO3: Understand forward and inverse kinematics of manipulators.
CO4: Understand concepts like Jacobian, workspace, singularity etc.
CO5: Understand forward and inverse dynamics of manipulators.
CO6: Plan robot trajectory in various schemes.
CO7: Control robot using feedback control, PID control and do stability analysis.
CO8: Develop robotic system using its components, which are Actuators, Transmission & sensors.

Textbooks

1. Ghosal A. *Robotics - Fundamental concepts & Analysis* (Oxford university press, 2006)
2. Craig J. J. *Introduction to Robotics - Mechanics & Control* (Addison - Wesley Publishing Company, New York, 1986)

References

1. Asada H. and Slotine J. E. *Robot Analysis & Control* (John Wiley & Sons, New York, 1986)
2. Nakamura Y. *Advanced robotics - Redundancy & Optimization* (Addison - Wesley Publishing Company, New york, 1991)
3. Merlet J.P. *Parallel Robots* (Kluwer Academic Publishers, Netherlands, 2000)

ME606: Stability Problems in Applied Mechanics L-T-P-CH-CR: 3-1-0-4-4

Basic Dynamic Considerations: Introduction; One-Dimensional Flows: Flows on the Line; Parameter Dependent Flows & Bifurcations; Flows on the Circle;
Two Dimensional Dynamic Systems: Phase-plane Description; Linearized Stability Analysis; Limit cycle and its Stability; Parametric Instability: Floquet Theory.
Stability of Static Equilibrium: Introduction; Euler's Method: Buckling of Columns; Energy Method: Approximate Solution; Non- adjacent Equilibrium Configuration: Snap Buckling; Asymmetric Deformation, Imperfection Sensitivity; Buckling due to Follower Load: Insufficiency of Static Analysis; Euler Buckling Load Revisited: Dynamic Analysis; Second Revisit of Buckling of Column (Euler Load); Other Examples of Instability.

Stability Problems in Dynamics: Introduction; Different Notions of Stability; Stability of Equilibrium Configuration; Stability of a Rotating Rigid Body; Parametric Instability of a Linear Continuous System; Periodic Solution of Non-Linear Oscillators and its Stability.
Emergence of Length Scale and Pattern Formation: Introduction; Stripes of Zebra Skin; Turning Pattern; Rayleigh-Taylor Instability; Staffman-Taylor Instability; Rayleigh-Plateau Instability; Rayleigh Benard Convection; On the Nature of Bifurcation; Faraday Instability; Rotating Couette Flow; Hydraulic Jump.

Textbooks:

1. Mallik, A. K. and Bhattacharjee, J. K. *Stability Problems in Applied Mechanics*, Narosa Publication (2005)

References:

1. Dym, C.L., *Stability Theory & its application to Structural Mechanics*, Noordhoff International Publications, Holland (1974)
2. Baznat, Z.P. and Cedolin, L., *Stability of Structures*, Oxford University Press, NY (1991)
3. Timoshenko, S.P. and Gere, J.M., *Theory of Elastic Stability*, Mc-Graw Hill, New York (1961)
4. Strogatz, S. H., *Nonlinear Dynamics & Chaos*, Addison-Wesley Pub. Co. Reading (1994)
5. Jordan D.W.and Smith, P., *Nonlinear Ordinary Differential Equations*, Clarendon Press, Oxford (1999)

ME-607: Soft Computing Techniques in Engineering **L-T-P-CH-CR: 3-0-0-3-3**

Introduction to soft computing, hard computing, Need for soft computing;
Neurons and neural networks; Basic models of artificial neural networks – single-layer perceptron, multilayer perceptron; Radial basis function networks; SOM; Recurrent neural networks; Training of neural network; Applications of neural networks in mechanical engineering;
Introduction to fuzzy sets, Fuzzy reasoning and clustering;
Optimization tools: Traditional and non-traditional, genetic algorithms, simulated annealing etc.; Combined techniques: Genetic Algorithms–Fuzzy Logic, Genetic Algorithms–Neural Networks, Neural Networks–Fuzzy Logic.
Support Vector Machine (SVM) - introduction, principle and application.

Course outcomes:

CO1: Understand advanced techniques of soft computing in design and manufacturing process.
CO2: Critical thinking and critical judgment on practical implementation of soft computing tools.
CO3: Interpretation on design and analysis of engineering problems and use the artificial module in different application.
CO4: Establish links between theoretical and practical applications.
CO5: In hand practice to software packages, programming and problem solving.
CO6: Student would be able to know the different technologies involved in advanced automated system, robotics and expert system
CO7: Students will learn how to design and work with system by imparting human cognitive intelligence

Textbooks:

1. Pratihar D. K. *Soft Computing* (Narosa Publishing House, 2015)
2. Haykin S. *Neural Networks: A Comprehensive Foundation* (Pearson Education, 2nd ed., 2009)
3. Chen G. and Pham T.T. *Introduction to Fuzzy Sets, Fuzzy Logic, and Fuzzy Control Systems* (CRC

Press, 2001)

References:

1. Dixit, P. M. and Dixit, U. S., *Modeling of metal forming and machining processes: by finite element and soft computing methods*, (Springer, 1st ed., 2008)
2. Deb K. *Optimization for Engineering Design: Algorithms and Examples* (Prentice Hall, 2006)
3. Aliev R.A. and Aliev R.R. *Soft Computing and its Applications* (World Scientific Publishing, 2001)

ME-608: Mechatronics and Industrial Automation **L-T-P-CH-CR: 3-0-0-3-3**

Introduction to Mechatronics: Introduction, Elements of Mechatronics system, Applications. Sensors and Actuators: Sensing principle, Electrical actuators, Hydraulic and Pneumatic actuators.
Signal Processing: Signal conditioning devices, Protection, Conversion and pulse width modulation, Data conversion devices.
Microprocessors: Introduction to microprocessors, Introduction to microprocessor programming, Internal architecture of 8085 microprocessor.
Principles of Automation Technology: Automation system components, Discrete manufacturing automation, Continuous process automation.
Programmable Logic Controllers (PLC): Industrial Control, Structure of PLC, Programming languages for PLC, Boolean logic for process control, Timers, Counters and other functions.
Feedback Control: Continuous and Time- Discrete control, On/Off control, PID control, Distributed Control System (DCS)
Man-machine communication: Supervisory control and data acquisition (SCADA) Assignment and mini-project.

Course Outcomes:

CO1: Identify key elements of mechatronics system and its components.
CO2: Understand the concept of signal processing
CO3: Interface sensors, actuators using appropriate micro-controller.
CO4: Understand microprocessor and its architecture.
CO5: Understand the importance and application of PLC in automation in industries
CO6: Control mechatronic systems.
CO7: Understand automation technology in industries.
CO8: Interface using HMI.

Textbooks

1. Bolton W. *Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering* (Pearson education, 2007)
2. Lamb F. *Industrial Automation: Hands-On* (McGraw-Hill Education, 2013)

References

1. Appukuttan (2007) K.K. *Introduction to mechatronics* (Oxford University Press)
2. Stenerson Hall, 2003) J.*Industrial automation and process control* (Prentice)

ME-609: Design of Internal Combustion Engine **L-T-P-CH-CR: 3-0-0-3-3**

Prerequisite for engineering design and design conditions of internal combustion engine components, Design of parts working under alternating loads, piston, piston ring and pin, Design of connecting rod small end, big end, shank and bolts, pressure on crank pin and journals, Design of crank web, inline and V engine crankshafts, Design of cylinder block, upper crankcase, liner, cylinder head and studs, Design of cam profile, harmonics of cam, valve gear, valve spring and camshaft, electronic control system for IC engine.

Course outcomes:

After completing the course, the student will be able to

CO1: The students will have the fundamental knowledge on automotive engines design aspects.

CO2: At the end of the course the students will able to design piston, piston ring, connecting rod small end, big end, shank and bolts, pressure on crank pin etc.

CO3: The students will have command over design of crank web, crankshafts, cylinder block, upper crankcase, liner, cylinder head, and studs.

CO4: Students will understand the mechanical design of the cam profile, harmonics of cam, valve gear,valve spring, and camshaft .

CO5: Students will know the working principles of electronic control system for engine.

Textbooks

1. Hoag, K. and Dondlinger, K. *Vehicular Engine Design* (Springer, New York, 2016)
2. Smith, J. H. *An Introduction to Modern Vehicle Design* (Butterworth-Heinemann, Oxford, 2002)

References

1. Kolchin, A. and Demidov, V. *Design of Automotive Engine* (Mir Publisher, Moscow, 1984)
2. Fenton, J. *Hand Book of Vehicle Design Analysis* (Mechanical Engineering Publication Limited, London, 2013).

ME-610: Kinematics and Dynamics of Internal Combustion Engine L-T-P-CH-CR: 3-0-0-3-3

Fundamentals of kinematics and dynamics, Different components of internal combustion engine, Types of IC Engine (Petrol, Diesel, 4 stroke , 2 strok4), Speed characteristics, Kinematics of crank mechanism comprising of piston stroke, speed and acceleration, Dynamics of crank mechanism comprising of gas pressure forces, masses of crank mechanism, inertial forces, total forces acting in crank mechanism, forces acting on crank pins, forces acting on main journals, crankshaft journals and pin wear, Balancing of diverse types of engines, uniformity of engine torque.

Course outcomes:

After completing the course, the student will be able to

CO1: The students will have the basic knowledge of kinematics and dynamics of internal combustion engine.

CO2: At the end of the course, the students will have knowledge speed characteristics, kinematics of crank mechanism comprising of piston stroke.

CO3: The students will have command over dynamics of crank mechanism comprising of gas Pressure forces, masses of crank mechanism, inertial forces, total forces acting in crank mechanism, forces acting on crank pins, forces acting on main journals, crankshaft journals.

CO4: The students will understand the balancing of diverse types of engines, uniformity of engine torque etc.

Textbooks

1. Hoag, K. and Dondlinger, K. *Vehicular Engine Design* (Springer, New York, 2016)
2. Smith, J. H. *An Introduction to Modern Vehicle Design* (Butterworth-Heinemann, Oxford, 2002)

References

1. Kolchin, A. and Demidov, V. *Design of Automotive Engine* (Mir Publisher, Moscow, 1984)
2. Fenton, J. *Hand Book of Vehicle Design Analysis* (Mechanical Engineering Publication Limited, London, 2013).

ME-503: Mechanics of Composite Materials **L-T-P-CH-CR: 3-1-0-4-4**

Introduction - classifications, terminologies, manufacturing processes and applications of composite materials;
Macro-mechanical behavior of lamina - stress-strain relations, engineering constants for orthotropic materials, transformation of stress and strain, strength and stiffness of lamina, biaxial strength theories;
Micro-mechanical behavior of lamina – volume and mass fractions;
Macro-mechanical behavior of laminates – single-layered configurations, symmetric laminates, anti-symmetric laminates, strength of laminates;
Hygro-thermal analysis of lamina and laminates;
Design of laminates – symmetric, cross-ply, angle-ply and anti-symmetric laminates;
Failure analysis – failure criteria and failure modes, buckling and vibration of laminated beams, plates and shells; Assignment and mini-project.

Course outcomes:

CO1: Acquire knowledge on the types, advantages, applications, and manufacturing processes of composite materials.
CO2: Analyze macro-mechanical and micro-mechanical behavior of lamina.
CO3: Analyze macro-mechanical behavior of laminate.
CO4: Design and analyze of laminated composites materials.
CO5: Design and analyze of laminated composite structure using software packages.
CO6: Acquire knowledge on recent advancement of composite materials and do research on such advanced material in future.

Textbooks

1. Daniel, I.M. and Ishai, O. Engineering Mechanics of Composite materials (Oxford University Press, 2005)
2. Jones, R.M. Mechanics of Composite Materials (Taylor & Francis, 1999)

References

1. Agarwal, B.D., Broutman, L.J. and Chandrashekhara, K. Analysis and Performance of Fiber Composites (John Willey &Sons, 2006)
2. Kaw, A.K. Mechanics of Composite Materials (Taylor & Francis, 2006)
3. Reddy, J.N. Mechanics of Laminated Composite Plates (CRC Press, 1997)

ME-504: Failure Analysis of Materials **L-T-P-CH-CR: 3-0-0-3-3**

Introduction, common causes of failure, failure investigation, principle of failure analysis; Fracture

mechanics – energy approach and stress intensity factor approach to linear elastic fracture mechanics, concept of crack tip opening displacement and J-integral fracture criteria, mechanisms of fracture, evaluation of fracture toughness, fracture in composite materials, computational fracture mechanics analysis, fracture mechanics in nano materials and structures;
Creep - stress-time-temperature relations, creep curve;
Fatigue - stresses in cyclic loading, fatigue testing, S-N curves and endurance limit, mechanisms of fatigue crack initiation and propagation, influence of stress concentration on fatigue strength, notch sensitivity, factors influencing fatigue behavior, prevention of fatigue failure;
Assignment and mini-project.

Course outcomes:

CO1: Identify the different principles, causes and modes of fracture and failure.
CO2: Apply knowledge of fracture and failure in the field of mechanical design.
CO3: Present the outcome in the form of group projects on advanced design of mechanical/structural components considering the in-depth knowledge of material failure.
CO4: Correlate design considerations with material strength and properties of failure.

Textbooks

1. Kumar, P. *Elements of Fracture Mechanics* (McGraw-Hill, 2009)
2. Anderson, T.L. Fracture Mechanics: Fundamentals and Applications (CRC Press, 2004)

References

1. Bruck, D. Elementary Engineering Fracture Mechanics (Springer, 1986)
2. Barson, J.M. and Rolfe, S.T. *Fracture and Fatigue Control in Structures* (Butterworth-Heinemann, 1999)
3. Dieter, G. *Mechanical Metallurgy* (McGraw-Hill, 1986)
4. Calister, W.D. *Material Science and Engineering: An Introduction* (John Wiley & sons, 2009)
5. Gdoutos, E.E. *Fracture of Nano and Engineering Materials and Structures* (Springer, 2006)

ME-505: Advanced Dynamics **L-T-P-CH-CR: 3-1-0-4-4**

Newton and Euler equations of motion for constrained systems; D'Alembert's principle, Lagrange's equations, Hamilton's equations; Rigid body kinematics and dynamics;
Differential approaches for equations of motion;
Integral approach for equations of motion - Hamilton's principle, Boltzmann-Hamel equation; Stability analysis of dynamic systems;
Numerical solutions of nonlinear algebraic and differential equations governing the behaviour of multiple degree of freedom systems;
Computer simulation of multi-body dynamic systems; Assignment and mini-project.

Course-outcomes:

Towards the end of the course the student would be able to
CO1: Application focus on developing and using equations of motion for dynamic systems to address engineering problems.
CO2: Methods for developing governing equations of motion for discrete systems are developed.Newton-Euler and Lagrangian formulations are emphasized with only brief introduction given to other

methods.

CO3: Knowledge on extraction of dynamic equilibrium configurations, linear stability analysis,frequency response analysis, and generation of transient time-domain responses using both direct numerical integration and modal superposition techniques.

CO4: Classical methods for deriving equations of motion for continuous systems motivates a more thorough treatment of the finite element method demonstrated using beam elements.

CO5: Numerical methods associated with advanced dynamics and application.

CO6: Get experimental exposure on advanced dynamics and stability analysis problems.

Textbooks

1. Meirovitch, L.M. Methods of Analytical Dynamics (McGraw-Hill, 1988)
2. Baruh, H. Analytical Dynamics (McGraw-Hill, 1999)

References

1. Greenwood, D.T. Principles of Dynamics (Prentice Hall, 1988)
2. Shabana, A.A. Computational Dynamics (John Wiley & Sons, 2010)

ME-506: Theory of Elasticity and Plasticity **L-T-P-CH-CR: 3-0-0-3-3**

Basic elasticity - cartesian tensor, three-dimensional stress and strain systems, Navier's equations, Airy’s stress function, Mohr’s circle for three-dimensional stress and strain systems, viscoelasticity; Torsion - torsion of noncircular bars, elastic analysis, membrane analogy;
Introduction to plasticity - mechanical behaviour in the plastic range, fundamentals of plasticity theory, solution of elastoplastic problem, Bausschinger effect-yield locus, yield surface;
Yield criteria and flow rules - Tresca theory and von Mises yield criterion, their geometrical representation, experimental evidence for the criteria;
Slip line field theory – two-dimensional plasticity, slip lines, basic equations, Hencky’s first theorem, Geiringer’s velocity equation, application of slip line field theory to plane strain problems;
Application to metal forming, plastic analysis of structures;
Assignment and mini-project.

Course outcomes:

On successful completion of the course, the graduates will be able to

CO1: Understand the basic concepts of fundamental variables such as stress, strain, and displacement under the application of load, equations of equilibrium and compatibility.

CO2: Solve the 2-D elasticity problems using stress function.

CO3: Understand the plastic yield criterions and elastic-plastic constitutive relations.

CO4: Apply the plasticity models in the analysis of components/systems subjected to plastic deformation.

CO5: Use the principles of plasticity to analyze axisymmetric elastic-plastic problems of practical importance such as autofrettage and indentation problem.

Textbooks

1. Timoshenko, S.P. and Goodier, J.N. *Theory of Elasticity* (McGraw-Hill, 1970)
2. Chakroborty, J. Theory of Plasticity (McGraw Hill, 1987)

References

1. Sokolnikoff, I.S. *Mathematical Theory of Elasticity* (McGraw-Hill, 1957)
2. Khan, A. and Huang, S. *Continuum Theory of Plasticity* (Wiley, 1995)

ME-507: Theory of Plates and Shells **L-T-P-CH-CR: 3-0-0-3-3**

Definition of plate and shells;
Small deflections of transversely loaded isotropic thin plates;
Equations and boundary conditions for thin rectangular and circular plates; Different types of supports associated with plate and shells;
Shell behaviour, shell surfaces and characteristics, classifications of shells, equilibrium equations in curvilinear coordinates, force displacement relations;
Moment theory;
Rotationally symmetric shells; Shallow shell theory; Assignment and mini-project.

Course outcomes:

CO1: Acquire knowledge on the behavior and uses of plates and shells.
CO2: Know the different theories used for design and analysis of plate and shell structures.
CO3: Develop a computer program for analysis plates and shells.
CO4: Modelling and analysis of plates and shells under different loading and boundary conditions using commercial software packages.

Textbooks

1. Timoshenko, S. and Woinowsky-Krieger, S. *Theory of plates and shells* (McGraw-Hill, 1959)
2. Ugural, A.C. *Stress in Plates and Shells* (McGraw-Hill, 1998)

ME-508: Continuum Mechanics **L-T-P-CH-CR: 3-0-0-3-3**

Concept of continuum mechanics, mathematical preliminaries related to continuum mechanics; Kinematics – motion of a continuum, displacement vector, deformation and deformable bodies, deformation gradient, strain tensor, equation of continuity, polar decomposition, volumetric and deviatoric strains, transformation of tensor, plane strain deformation;
Kinetics – traction boundary conditions, stress tensor, transformation of stress tensor, deviatoric stress, von Mises stress, balance of energy, entropy inequality;
Constitutive relations for various elastic materials such as thermoelastic material, isotropic thermoelastic material, transversely isotropic thermoelastic material, orthotropic thermoelastic material, incompressible elastic material, thermoviscoelastic material;
Applications to engineering problems such as torsion of a circular cylinder, bending of beams, expansion in pressure vessels, fluid flow between over plates and in circular pipes; Assignment and mini-project.

Course outcomes:

On completion of this course the students should
CO1: Be familiar with linear vector spaces relevant to continuum mechanics,
CO2: Be able to perform vector and tensor manipulations in cartesian and curvilinear coordinate systems,
CO3: Be able to treat general stresses and deformations in a continuum,
CO4: Be able to derive equations of motion and conservation laws for a continuum,
CO5: Be able to numerically model and analyse the stresses and deformations of simple geometries under an arbitrary load in both solids and liquids.

Textbooks

1. Lai, W.M., Krempl, E. and Rubin, D. *Introduction to Continuum Mechanics* (Elsevier, 1996)
2. Gurtin, M.E. *An Introduction to Continuum Mechanics* (Academic Press, 1981)

References

1. Batra, R.C. *Elements of Continuum Mechanics* (AIAA, 2005)
2. Dill, E.H. *Continuum Mechanics: Elasticity, Plasticity, Viscoelasticity* (CRC Press, 2006)
3. Fung, Y.-C. *A First Course in Continuum Mechanics* (Prentice-Hall, 1977)
4. Mase, G.T. *Continuum Mechanics for Engineers* (CRC Press, 1999)

ME-527: CAD-CAM **L-T-P-CH-CR: 3-0-0-3-3**

Introduction and Overview: Components of Computer aided design (CAD), Components of Computer aided manufacturing (CAM)/Computer aided engineering (CAE) systems.
Basic concepts and Application: Basic concept of graphics programming; Transformation matrix-Rendering Graphical user interface; Computer aided drafting systems.
Geometric modeling systems: Wire-frame surface and solid modeling systems Non-manifold systems; Assembly and web-based modeling systems.
Numerical control: Concepts for manual and computer assisted part programming; NC, CNC and DNC Virtual engineering – components and applications.
Introductory laboratory work: laboratory work on CAD (Solid modeling software), laboratory work on CAE (Finite element analysis) software

Course outcomes:

CO1: Have the knowledge of computer aided design and manufacturing for solving related application-oriented problems.
CO2: Understand the advanced design and manufacturing process to cope with latest technology.
CO3: Critical thinking and critical judgment on practical implementation so as to face real life problem solving.
CO4: Interpretation on design and analysis of engineering problems and clear concept and observation.
CO5: Establish links between theoretical and practical applications in real life cases.
CO6: Undertake problem identification, formulation and solution for industrial application.

Textbooks

1. Kunwoo Lee, *Principles of CAD/CAM/CAE systems*, Addison Wesley, 1999.
2. Mikell P. Groover and Emory W. Zimmers *,CAD/CAM: Computer aided design manufacturing*, Prentice Hall, 1996.

Reference Books:

1. Mark E. Coticchia, George W. Crawford, and Edward J. Preston, *CAD/CAM/CAE systems: justification, implementation and productivity measurement* , 2nd edition, New York, Marcel Dekker, 1993.
2. Chris Macmahon and Jimmie Browne *CADCAM: principles, practice and manufacturing management*, 2nd edition, Addison Wesley, 1998.
3. P. Radhakrishnan, S. Subramanyan, and V. Raju *,CAD/CAM/CIM* , 2nd edition, New Age,

ME-538: Computer-Aided-Design in Engineering **L-T-P-CH-CR: 3-1-0-4-4**

Overview of computer aided engineering design;
Transformation - representation and transformation of points, homogeneous coordinates, rotation, reflection, translation, scaling and sharing of lines, combined transformation, solid body transformation;
Projections - orthographic, axonometric, oblique and perspective projections;
Plane curves - parametric and nonparametric curves like circle, ellipse, parabola and hyperbola; Conic sections;
Space curves - cubic splines, parabolic blending, Bézier curves and B-spline curves;
Surface Generation - surface of revolution, sweep surface, quadric surface, bilinear surface, ruled and developable surfaces, Coons linear surface, Coons bicubic surface, Bézier surface, B-spline surface and composite surface;
Solid body modeling - designing three-dimensional models like machine parts, hidden line and surface removal;
Application of commercial solid modelers; Assignment and mini-project.

Course outcomes:

After completion of the course, the students will be able to:
CO1: Create different solid primitives using the different representation schemes.
CO2: Apply geometric transformations on the created wireframe, surface and solid models.
CO3: Understand the fundamentals of various projection techniques required for display.
CO4: Create and control different parametric and non-parametric plane curves and space curves and understand its importance in industrial applications.
CO5: Create and manipulate surface and solid primitives using parametric modeling.
CO6: Use commercial solid modelers.

Textbooks

1. Rogers, D.F. and Adams, J.A. *Mathematical Elements for Computer Graphics* (Tata McGraw-Hill, 2002)
2. Mortenson, M.E. *Mathematics for Computer Graphics Applications* (Industrial Press,1999)

References

1. Plastock, R.A. and Kalley, G. *Computer Graphics* (McGraw-Hill, 1986)
2. Mortenson, M.E. *Geometric Modeling* (John Wiley & Sons, 1985)
3. Ryan, D.L. *Computer-Aided Graphics and Design* (Marcel Dekker, 1994)

ME-539: Optimization Techniques in Engineering L-T-P-CH-CR: 3-0-0-3-3

Introduction – definition and importance of optimization, basic terminologies, general problem formulation;
Single variable unconstrained optimization – first and second order optimality criteria, bracketing and refining optimum point, direct search methods, gradient-based search methods;
Multi-variable unconstrained optimization - first and second order optimality criteria, unidirectional search, direct search methods, gradient-based search methods;
Constrained linear programming problems – simplex method, duality in linear programming; Constrained nonlinear programming problems - Kuhn-Tucker conditions, sensitivity analysis, penalty function methods, method of multipliers, direct search methods, sequentially linearized methods, feasible direction method, gradient-based search methods, quadratic programming; Specialized algorithms for integer and geometric programming problems;

Application of different optimization methods to mechanical design problems; Assignment and mini-project.

Course-outcomes:

On completion of the course, students would be able to:
CO1: Formulate different types of single-objective optimization problems
CO2: Select and apply appropriate optimization techniques to problems at hand
CO3: Solve nonlinear problems using both exact and numerical methods
CO4: Solve linear problems using exact methods
CO5: Solve discrete problems using specialized methods

Textbooks

1. Deb, K. *Optimization for Engineering Design – Algorithms and Examples* (Prentice-Hall of India, 1995)
2. Arora, J.S. *Introduction to Optimum Design* (Academic Press, 2004)

References

1. Belegundu, A.D. and Chandrupatla, T.R. *Optimization Concepts and Applications in Engineering* (Pearson Education, 1999)
2. Rao, S.S. *Optimization: Theory and Applications* (Wiley Eastern, 1984)

ME-540: Evolutionary Algorithms for Optimum Design **L-T-P-CH-CR: 3-0-0-3-3**

Introduction - brief review of classical optimization methods, definition and importance of nontraditional techniques; Evolutionary algorithms (EAs) – solution representations for different types of variables, population initialization and evolution;
Genetic algorithm - selection, crossover and mutation operators; Differential evolution – mutation, crossover and selection operators; Particle swarm optimization – personal and global best particles, velocity and position of a particle;
Constraints handling and elite preservation in EAs; Influence of algorithmic parameter values in EAs and hybridized EAs;
Multi-objective optimization – concept of dominance, non-dominated sorting, diversity of solutions, Pareto front;
EAs to different types of problems, in particular to mechanical design problems including structural shape design;
Performance measurements of multi-objective optimizers - concept of dominance relation among Pareto fronts, performance metrics and their properties, statistical methods for comparing performances of multi-objective optimizers;
Assignment and mini-project.

Course-outcomes:

CO1: Understand the need of evolutionary algorithms (EAs) over classical optimization methods
CO2: Learn the general working procedure of EAs
CO3: Learn some well-established EAs in detail
CO4: Learn how multi-objective EAs work
CO5: Evaluate performances of multi-objective EAs

Textbooks

1. Sivanandom, S.N. and Deepa, S.N. *Introduction to Genetic Algorithms* (Springer, 2010)
2. Price, K.V., Storn, R.M. and Lampinen, J.A. *Differential Evolution: A Practical Approach to Global Optimization* (Springer, 2005)
3. Olsson, A.E. *Particle Swarm Optimization: Theory, Techniques and Applications* (Nova Science Pub, 2011)
4. Deb, K. *Multi-Objective Optimization using Evolutionary Algorithms* (John Wiley & Sons, 2001)

References

1. Coello Coello, C.A., Lamont G.B. and van Veldhuizen, D.A. *Evolutionary Algorithms for Solving Multi-Objective Problems* (Springer, 2007)
2. Tan, K.C., Khor, E.F. and Lee, T.H. *Multiobjective Evolutionary Algorithms and Applications* (Springer, 2005)
3. Chakraborty, U.K. *Advances in Differential Evolution* (Springer, 2008)
4. Clerc, M. *Particle Swarm Optimization* (John Wiley & Sons, 2010)
5. Mann, P.S. *Introductory Statistics* (John Wiley & Sons, 2004)

ME-572: Advanced Engineering Materials **L-T-P-CH-CR: 3-0-0-3-3**

Advanced materials for engineering applications, engineering materials - metals, polymers, composites and ceramics;
Structure-property correlation - role of crystal structure, substructure and microstructure on material properties;
High performance structural metallic alloys and their applications, surface engineering of materials and their applications;
Piezoelectric materials, shape memory alloys, smart materials and composite materials and their applications;
Micro-electro-mechanical systems (MEMS) - characteristics of materials for MEMS applications and manufacturing techniques for MEMS components;
Materials for high temperature applications - various alloys and composites, diffusion bond coating; Powder metallurgy; Selection of materials - materials aspects, cost and manufacturing considerations; Applications of materials to automobile and transport vehicles, aerospace, power generation, armament, marine environment and ocean structures, materials for other specialized applications; Assignment and mini-project.

Course outcomes:

On successful completion of this course, students will be able to:
CO1: Gain detailed knowledge on advanced materials, their structure, properties and applications.
CO2: Understand the need of advanced and non-conventional materials for contemporary and specialized engineering applications.
CO3: Correlate material properties with design considerations and materials selection.
CO4: Prepare for advanced design and manufacturing technology.
CO5: Present the outcome in the form of group projects on material characterization and advanced design and manufacturing.

Text Books:

1. Calister, W.D. Material Science and Engineering - An Introduction (John Wiley & sons, 1997)

Reference Books:

1. Gandhi, M.V. and Thompson, B.S. Smart Materials and Structures (Chapman and Hall, 1992)
2. Otsuka, K. and Wayman, C.M. Shape Memory Materials (Cambridge University Press, 1999)
3. Taylor, W. Pizoelectricity (Taylor & Francis, 1985)
4. Mallick, P.K. Fiber Reinforced Composites Materials, Manufacturing and Design (Marcel Dekker, 1993)

ME-575: Advanced Material for Design **L-T-P-CH-CR: 3-0-0-3-3**

Advanced materials for modern Engineering Design: Metals, Polymers, Composites and Ceramics; Proper material selection for design considerations **(5 lectures)**
Structure-property correlation for design purposes: Role of crystal structure, substructure and microstructure on material properties and machine design
Metallic alloys for high performance structural design and their applications, Surface engineering of materials and their applications
Applications of Piezoelectric materials, Shape memory alloys, Smart materials and Composite materials in design of modern engineering components
Micro-electro-mechanical systems (MEMS) for design: Characteristics of materials for MEMS applications and MEMS components
Designing components for high temperature applications: Various alloys and composites, Diffusion bond coating
Application of Powder metallurgy technique in design: Selection of materials, Cost, Design and Manufacturing considerations involved
Advanced materials for design of Automobile and Transport vehicles, Aerospace, Power generation, Armament, Marine environment and Ocean structures, Materials for other specialized applications Advanced material testing for machine design considerations
Assignment and mini-project.

Course outcomes:

On successful completion of this course, students will be able to:
CO1: Gain detailed knowledge on advanced materials, their structure, properties and applications.
CO2: Understand the need of advanced and non-conventional materials for contemporary and specialized engineering applications.
CO3: Correlate material properties with design considerations and materials selection.
CO4: Prepare for advanced design and manufacturing technology.
CO5: Present the outcome in the form of group projects on material characterization and advanced design and manufacturing.

Textbooks:

1. Callister, W. D. Material Science and Engineering - An Introduction. John Wiley & Sons, 7th edition, 2007.
2. Mallick, P.K. Fiber Reinforced Composites Materials, Manufacturing and Design. Marcel Dekker, 2007.

References:

1. Otsuka, K. and Wayman, C.M. Shape Memory Materials. Cambridge University Press, 1999.

2. Gandhi, M.V. and Thompson, B.S. Smart Materials and Structures. Chapman and Hall, 1992.