HUM 5151: RESEARCH METHODOLOGY AND TECHNICAL COMMUNICATION [1 0 3 2]
Total contact periods: 12 hours for theory + 36 hours of Laboratory

Course Outcomes:
At the end of the program the students will be able to:

CO1	***Recognize*** the concepts of research and identify the types of research
CO2	***Identify*** the problem and ***develop*** the research design to a problem
CO3	***Demonstrate*** effective mechanics of ***writing*** reports/manuscripts
CO4	***Exhibit*** effective technical presentation skills
CO5	***Develop*** a good research proposal

Theory:
Introduction, Types of research and Significance of research, The research process: The eight-step model.
Reviewing the literature and summarizing the literature.
Formulating a research problem: Identifying variables and hypotheses development.
Research Design, Measurement scales, Data collection-primary and secondary sources of data, Establishing reliability and validity of research instrument.
Sampling- types of sampling techniques, Ethical issues in data collection, processing data and displaying data.
Writing a research proposal, Writing a research report, Presentation of figures and tables.
Referencing-IEEE, APA and Harvard style of referencing.
Making an effective technical presentation.
Laboratory:
Recap of basic concepts of Research Methodology, Use of numerical computation tools for research, Presentation -1 (Beginning level of research), Presentation -2 (Intermediate level of research), Presentation -3 (Analysis/Evaluate level of research), Report writing

References

1. Dr. Ranjit Kumar, Research Methodology: A step by step guide for beginners, SAGE, 4th edition. 2015.
2. Geoffery R. Marczyk, David DaMatteo & David Festinger, Essentials of Research Design and Methodology, John Wiley & Sons, 2004.
3. John W. Creswel, Research Design: Qualitative, Quantitative and Mixed Method Approaches, SAGE 2004.
4. Donald R Cooper & Pamela S Schindler, Business Research Methods, McGraw Hill International, 2007.
5. C. R. Kothari, Research Methodology: Methods and Techniques, New Age International Publisher, 2008.

MAT5155: Applied Numerical Methods [3 1 0 4]

Total contact hours: 48 hours

Course Outcomes:

At the end of the program the students will be able to:

CO1	Understand the interpolation aspects, and finite differences. and study the evaluation of numerical differentiation, integration
CO2	Understand numerical solutions of algebraic and transcendental equations, linear and quadratic factors of polynomials.
CO3	Apply the matrix decomposition methods to solve system of linear equations and eigen value applications.
CO4	Solve of differential equations and system of differential quations through various numerical methods and solution of system of non-linear equations. Solve the boundary value problems by finite difference method, standard five point formula, Leibenann method etc
CO5	Find the Solution of parabolic, hyperbolic PDE's through various finite difference methods, explicit finite difference methods and understand the concept of finite element method

*Add or delete rows as required

Numerical solutions of algebraic and transcendental equations,

Roots of algebraic and transcendental equations, Newton Raphson Method and error formula, Birge Vieta method, Bairstow Method [06]

Interpolation for equal and Unequal Intervals

Finite differences and shift operators, Interpolations: Forwarda and backward interpolation formulae. Finite difference theorem on a polynomial function, Lagrange's interpolation, inverse interpolation, Newton divided difference interpolation formula Numerical differentiation, formulae for first and second order derivative, Newton-Cote's formula, Trapezoidal, Simpson's 1/3 rd and 3/8 th rules , Error formulae of Trapezoidal, Simpson's 1/3 rd and 3/8 th rule [10]

Solution of System of linear equations

LU decomposition method, Cholesky decomposition method, Gauss-Seidal method and Relaxation method, Tridiagonal system, Eigen values and Eigen vectors : Computation of numerically largest eigen value and corresponding eigen vectors. [10]

Numerical solution of System of nonlinear equations

Newton-Raphson method, Initial value problems: Taylor's method and problems,Euler's method and Euler's modified method, Runge-Kutta method - fourth order, Runge Kutta method for simultaneous differential equations and higher order differential equations,Milne's predictor corrector method, Adam Bashforth method, Boundary Value Problems ,Solution of BVPs by Finite Difference method. [10]

Numerical solution of ordinary and Partial differential equations

Classification of P.D.E,Finite difference approximation to derivatives. Solution of Laplace equation, Poisson equation. Derivation of Standard five point formula and Diagonal five point formula, Parabolic P.D.E,Derivation of Explicit finite difference scheme, Derivation of Crank – Nicholson method ,Hyperbolic P.D.E ,Solution of hyperbolic equation . [12]

References:

1. Atkinson K.E An Introduction to Numerical Analysis, edn 3, John Wiley and Sons (1989).
2. Carnahan, Luther and Wikes : Applied Numerical Methods, TMH, New edition (1969).
3. Hilderband F.B: Introduction to Numerical Analysis, Edn 5, Tata McGraw Hill, New Delhi, New edition
4. Conte S.D and Be Doo, Introduction to Numerical analysis, McGraw Hill.
5. Gerald C.F. and Patrick D. Wheatley: Applied Numerical Analysis, 3rdedn. 1984, Addison Wesley.
6. J. W. Thomas, Numerical Partial Differential Equations: Finite Difference Methods, Springer Verlag.
7. G. D. Smith, Numerical Solution of Partial Differential Equations, Oxford Univeristy Press.
8. Jain, Iyengar and Jain: Numerical methods for Scientific and Engineering Computations, New Age Publishers.

MME 5181: ADVANCED MECHANICAL VIBRAITON [3 1 0 4]

Total contact periods: 48 hours

Course Outcomes:

At the end of the program the students will be able to:

CO1	**Define** the terminologies and **understand** the theoretical concepts associated with the course on Advanced Mechanical Vibration
CO2	**Apply** the basic principles of mechanical vibration to engineering systems
CO3	**Implement modeling** concepts to **solve** complex engineering problems associated with the course on Advanced Mechanical Vibration
CO4	**Analyze** complex problems associated with the course on Advanced Mechanical Vibration and interpret the results obtained
CO5	**Write and test computer codes** related to the concepts learnt during the course on Advanced Mechanical Vibration
CO6	***Select***, ***understand,*** and ***evaluate*** technical literature related to new developments in Advanced Mechanical Vibration

Vibration fundamentals, Single degree freedom systems, damping, free and forced vibration, force transmissibility, vibration isolation. [12]
Two-degree freedom systems-dynamic vibration absorber, multi-degree freedom system, whirling of shaft with and without damping**.** Continuous systems, [10]
Finite element method, Standard and nonstandard eigenvalue problem, concept of iteration and methods, Rayleigh damping. [08]
Nonlinear vibration solution methods, sub harmonic & super harmonic oscillations, graphical methods, stability of equilibrium states, limit cycles and chaos, Perturbation method, Duffing's system, VanderPol's systems. [06]
Random vibration: Gaussian random process, Fourier analysis, power spectral density, wide band and narrow band processes, response of a single degree of freedom system. [05]
Vibration measurement and applications: Vibration Transducers, electrodynamic and linear variable differential transformer transducers; Vibration pickups, Exciters-mechanical exciters, electrodynamic shaker**,** Signal analysis: modulation, spectrum analyzers, bandpass filter, Dynamic testing of machines and structures, Experimental modal analysis, Machine condition monitoring and diagnosis. [07]

References:

1. Singirisu Rao S , *Mechanical Vibration*, Pearson Education, Delhi, 5th edition 2011.
2. S. Graham Kelly, *Fundamentals of Mechanical Vibrations*, McGraw-Hill, Singapore, 2nd edition, 2000.
3. S. Graham Kelly, *Schaum's Outline of Mechanical Vibrations (Schaum's Outline Series*), McGraw-Hill Publication,1996.
4. Rao J. S. and Gupta K., *Introductory Course on Theory and Practice of Mechanical Vibrations*, New Age Publishers, 2nd edition, 1999.
5. Groover G.K., *Mechanical Vibrations*, Nem Chand and Bros, 8th Edition, 2009.

6. Seto W.W., *Theory and Problems in Mechanical Vibrations,* McGraw-Hill Publication,1989.

DEPARTMENT OF MECHANICAL AND MANUFACTURING ENGINEERING

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MME 5182: FATIGUE OF MATERIALS [3 1 0 4]

Total contact hours: 48 hours
Course Outcomes:
At the end of the program the students will be able to:

CO1	***Discuss*** the fundamental concepts related to the course on Fatigue of Materials
CO2	***Apply*** the fundamental concepts on high cycle, low cycle, variable amplitude and multiaxial fatigue behavior of metals
CO3	***Implement*** appropriate high cycle and low cycle fatigue model to analyze the given engineering problems on metal fatigue
CO4	***Discuss*** the engineering problems on Thermomechanical fatigue and Fatigue of weldments.
CO5	***Analyze*** problems on metal fatigue using computers.
CO6	***Select***, ***understand*** and ***evaluate*** technical literature related to new developments in Fatigue of Materials.
CO7	***Evaluate*** the environmental and societal impact of solution to problems related to Fatigue of Materials

Structure and deformation of materials, strategies in fatigue design, fatigue design philosophies, Modes of mechanical failure, fatigue mechanisms and microscopic features, macro aspects of fatigue of metals. *Stress-life approach:* Stress-life (S-N) curves, fatigue limits, mean stress effects on S-N behavior, factors influencing S-N behavior, S-N curve representation and approximations, stress concentration effects, notch sensitivity factor, Life estimation using S-N approach. Cumulative damage theories and life prediction. *Cyclic deformation and Strain-life approach:* Monotonic stress-strain behavior, cyclic stress-strain behavior, cyclic stress-strain curve determination, stress-plastic strain power law relationship, fatigue crack initiation in ductile solids, cyclic deformation and crack initiation in brittle solids. Strain-life curve, determination of fatigue properties, transition life, mean stress effects and strain life equations, notch stresses and strains, notch strain analysis- Neuber's rule, fatigue testing procedures and statistical analysis of fatigue data. *Variable amplitude loading:* Fatigue from Variable amplitude loading – damage quantification, load interaction and sequence effects, cycle counting methods. *Multi-axial fatigue:* States of stress and strain, proportional versus non-proportional loading, multi-axial theories. *Effect of temperature on fatigue:* Lowtemperature fatigue, high-temperature fatigue, Thermo-mechanical fatigue. *Fatigue of weldments:* Stress-life & strain-life behaviors, improving fatigue resistance, life estimation. Fatigue life extension methods.

References:

1. Stephens Ralph I, Fatemi Ali, Stephens Robert R and Henry, *Metal Fatigue in Engineering*, (2e), John Wiley and Sons Inc, New York, 2001.
2. Norman E Dowling, *Mechanical Behaviour of Materials*, (4e), Prentice Hall, 2012.
3. Suresh S, *Fatigue of Materials*, (2e), Cambridge University Press., UK, 1998.

4. Julie A Bannantine, Jess J Comer and James L Handrock, *Fundamentals of Metal fatigue and Analysis*, Prentice Hall, 1990.
5. Jack A Collins, *Failure of Materials in Mechanical Design*, (2e), John Wiley & Sons., New York, 1993.

MME 5183: GEOMETRIC MODELLING FOR CAD [3 1 0 4]

Total contact periods: 48 hours

Course Outcomes:

At the end of the program the students will be able to:

CO1	***Discuss*** and ***apply*** the fundamental concepts of Geometric modelling for CAD.
CO2	***Analyze*** complex problems related to Geometric modelling for CAD.
CO3	***Implement*** appropriate model or technique to ***analyze*** and ***solve*** the given complex engineering problems concerning Geometric modelling for CAD; ***recognize the limitations*** of the model or technique.
CO4	***Solve*** complex engineering problems and ***interpret*** the analytical results related to Geometric modelling for CAD.
CO5	***Select***, ***understand*** and ***evaluate*** technical literature related to new developments in Geometric modelling for CAD.
CO6	***Implement*** the concepts concerned to this course on geometric modelling for CAD through customized computer programs and/or commercial geometric modelling software.

Introduction to CAD: Impact of computers on the Shigley's design procedure. Geometric modelling for CAD, Geometry based modeling, Feature based modeling. [02]

Hardware and software for CAD: Hardware for CAD: CPU, Memory, Input devices, Output devices: Graphics display devices (DVST, DBST, Refreshed raster scan terminal), plotters, printers. Hardware integration and networking, data structure and database. Software for CAD: Database structure and database, software modules for CAD, Graphics and data exchange standards. Commercial software for geometric modeling. [04]

Geometric transformations: Translation, scaling, rotation, and reflection of 2D objects. Concatenated transformation matrices for 2D transformation, disadvantage of concatenation with 2D translation, homogeneous coordinate transformations. Translation, scaling, reflection and rotation of 3D geometric entities using homogeneous coordinates. Concatenation matrices for rotation, scaling and reflection of 3D geometric entities about arbitrary axis/arbitrary plane. [04]

Transformation matrices for projections: Parallel, oblique and general parallel projection of 3D geometric entities. Transformation matrices for general perspective projection and isometric projection of 3D geometric entities. [03]

Geometric modelling: Implicit, explicit, parametric representation of geometric entities; advantages and disadvantages of parametric representation. [01]

Parametric representation of curves: ***Analytical curves:*** Parametric representation of straight line, circle, circular arc, parabola, ellipse, elliptical arc, hyperbola. ***Synthetic curves:*** Introduction to synthetic curves, types of continuity C^0, C^1 and C^2. Parametric representation of Hermite cubic spline curve, four-point form of the cubic splines. Bezier curves, difficulties of cubic splines overcome by Bezier curves, parametric representation of Bezier curves, properties of Bezier curves, disadvantages of Bezier curves, Composite cubic Bezier curves. B-Spline curves, advantages of B-Spline over Bezier curves, Parametric representation of B-Spline curves. NURBS (Rational Curves), Manipulation of curves. [12]

Parametric representation of surfaces: ***Analytical surfaces:*** Parametric representation of plane surface, ruled surface, tabulated surface, surface of revolution, Coon's surface, Bilinear surface patch. ***Synthetic surfaces:*** Parametric representation of synthetic surfaces - Algebraic form, geometric form and n-point form, Parametric definition of Bezier surface, B-Spline surface and NURBS surface. Manipulation of surfaces. [08]

Solid modelling: Hyperpatch, Pure primitive instancing, Sweep representation, Constructive Solid geometry, Boundary representation, Half-space method. Decomposition methods: Octree and Voxel based solid modelling. [04]

Raster graphics: Algorithms to display lines - DDA, Bresenham's line algorithms. Bresenham's circle algorithm, Mid-point Ellipse algorithm. Visual Realism: removal of hidden lines, surfaces and solids. [04]

Geometric and mass properties: Computation of geometric properties - curve length, surface area, volume of a solid entity, volumetric center of a solid entity. Computation of mass properties – mass, mass center, first and second moments of inertia, products of inertia.
[03]

Assembly modelling: Assembly tree, spatial relationship between parts, mating conditions, bottom-up approach, top-down approach. [03]

References:

1. Michael E. Mortenson, GEOMETRIC MODELING, Wiley Computer Publishing, John Wiley and Sons, Inc. (Second Edition), 1996.
2. Ibrahim K Zeid, *CAD/CAM Theory and Practice*, Tata McGraw Hill, New Delhi, 1998.
3. David F Rogers and J Alan Adams, *Mathematical Elements for Computer Graphics*, Tata McGraw Hill, New Delhi, 2002.
4. David F Rogers and J Alan Adams, *Procedural Elements for Computer Graphics*, McGraw Hill, New York, 2001.
5. Ram B, *Computer Fundamentals Architecture and Organization*, New Age International Ltd New Delhi, 2000.
6. Donald Hearn and M Pauline Baker, *Computer Graphics*, Prentice Hall of India, New Delhi, 2000.

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MME 5184: SOLID MECHANICS [3 1 0 4]

Total contact hours: 48 hours

Course Outcomes

At the end of the program the students will be able to:

CO1	Understand and remember the terminologies and concepts pertaining to this course on Solid Mechanics
CO2	Apply the knowledge of mathematics and fundamental principles concerned to this course on solid mechanics
CO3	Implement the mathematical models involved in this course on solid mechanics to solve the complex engineering problems
CO4	Formulate and analyse complex problems to reach substantiated conclusions by evaluating available data using engineering principles pertaining to this course on solid
CO5	Write and implement computer programs for solving engineering problems concerned in this course on solid mechanics

Analysis of Stress: Deformable bodies, stress, strain, mechanical properties of solids, State of stress and stress components, Stresses on an arbitrary plane, Principal stresses, Octahedral stresses, Equations of equilibrium. **Analysis of Strain:** Deformation in the neighbourhood of a point, 3D strain components, Volumetric strain, Principal strains, Compatibility conditions. **Stress-strain Relations:** Generalized Hooke's law, Stress strain equations for isotropic materials, Young's modulus, modulus of rigidity, Bulk modulus. **Theories of Failure:** Maximum normal stress theory, maximum shear stress theory, maximum strain theory, maximum elastic energy theory, distortion energy theory, Factor of safety. **Energy Methods:** Hooke's Law and Principle of superposition, Corresponding forces and displacements, work done by forces and elastic strain energy, Reciprocal relations, Castigliano's theorems. **Bending of Beams**: Introduction, straight beams and axi-symmetrical bending, bending stresses. **AxiSymmetric Problems**: Introduction, equilibrium equations, thick and thin cylinders.

References:

1. L.S. Srinath "Advanced Mechanics of Solids", Tata Mcgraw Hill, 1980.
2. S.M.A. Kazmi "Solid Mechanics", Tata Mcgraw Hill, 1980.
3. E.P. Popov "Introduction to Mechanics of solids", Prentice Hall of India, Ltd, 1973.
4. Y.C.Fung "Foundations of solid mechanics", Prentice Hall of India, 1968.
5. S.A.Urry and P.J.Turner "Solving problems in solid mechanics" – vol 1 and 2, Longman Scientific and technical U.K., 1986.
6. S.C.Goyal and M.R.Sethia " Mechanics of solids", Sandhya Prakashan – 1997.
7. N.Krishnaraja and D.R. Gururaja "Advanced Mechanics of solids and structures", Narosa Publishing House, 1997.

MME 5168: CAD Lab [0 0 3 1]

Total contact hours: 36 hours

Course Outcomes:
At the end of the program the students will be able to:

CO1	Construct geometrically constrained sketches
CO2	Create 3D models of mechanical parts using appropriate tools and features available in CAD software.
CO3	Assemble the 3D models of mechanical parts using CAD software.
CO4	Construct 3D surface models for mechanical / FMCG consumer products using CAD software.
CO5	Develop the product drawings of mechanical components

Expt. #	**Topic**	**Contact hours**
Expt. 1	Sketcher Exercises-1	03
Expt. 2	Sketcher Exercises-2	03
Expt. 3	Solid Modeling Exercises-1	03
Expt. 4	Solid Modeling Exercises-2	03
Expt. 5	Solid Modeling Exercises-3	03
Expt. 6	Solid Modeling Exercises-4	03
Expt. 7	Solid Modeling Exercises-5	03
Expt. 8	Surface Modeling Exercises-1	03
Expt. 9	Surface Modeling Exercises-2	03
Expt. 10	Surface Modeling Exercises-3	03
Expt. 11	Surface Modeling Exercises-4	03
Expt. 12	Assembly Exercises	03

References:

Sham Tickoo, CATIA – for Engineers and Designers, Dreamtech Press, New Delhi, 2008.

3DEXPERIENCE 2022x: Introduction to CATIA Modeling - Part 1, Ascent - Center for Technical Knowledge

3DEXPERIENCE 2022x: Introduction to CATIA Modeling - Part 2, Ascent - Center for Technical Knowledge

MME 5165: Design Engineering Lab [0 0 3 1]

Total contact hours: 36 hours

Course Learning Outcomes:

At the end of the program the students will be able to:

CO1	***Determine*** the friction and wear characteristics of relatively moving surfaces; lubricating properties of the fluids and performance characteristics of journal bearings.
CO2	***Analyze*** the mechanical systems for undamped, damped, free and forced vibrations, with vibration isolation, absorbers, rotational unbalance, beat phenomenon.
CO3	***Analyze*** the vibrating systems under the time domain and/or frequency domain through experiments and/or by executing programs.
CO4	***Measure*** the natural frequency and mode shapes of mechanical components
CO5	***Design*** experiments to ***acquire*** and ***analyze*** the vibration signals of mechanical components or systems.

Expt. #	**Topic**	**Contact hours**
Expt. 1	Journal bearing, Air bearing	03
Expt. 2	Rheometer, scratch test, wear test (2-body, 2-body)	03
Expt. 3	Measurement of natural frequency and mode shape of mechanical components by (i) impact hammer method (ii) Method of sine wave sweep	03
Expt. 4	Determination of damping, Vibration with oil damper	03
Expt. 5	Balancing of rotating masses, Field balancing	03
Expt. 6	Measurement of amplitude and frequency of mechanical components	03
Expt. 7	Active and passive vibration isolation	03
Expt. 8	Vibration with single and double absorber	03
Expt. 9	Natural Frequency and modal shape of two, three and multi-degree of freedom string; Beat vibration	03
Expt. 10	Open ended experiment – Design and conduct an experiment to acquire vibration signals form a rotating mechanical system	03
Expt. 11	Programming for (i) analyzing undamped, damped, forced vibration systems; (ii) time domain, frequency domain, time-frequency domain	03
Expt. 12	Programming for (i) simulating a bearing/gear vibration signal; (ii) pre-processing and analyzing the raw signals acquired from rotating machinery	03

References:

1. Kenneth C Ludema, Friction, Wear, Lubrication: A Textbook in Tribology, CRC press, 1996.

2. Gwidon Stachowiak, Andrew Batchelor, Engineering Tribology, Elsevier, 4th ed., 2013.
3. Singirisu Rao S., “Mechanical Vibration” Pearson Education, Delhi, 2004
4. S. Graham Kelly, “Fundamentals of Mechanical Vibrations”, McGraw-Hill, Singapore, 1993.
5. Rudra Pratap, “Getting Started with MATLAB”, Oxford University Press, USA

MME 5282: LUBRICATION OF BEARINGS [3 1 0 4]

Total contact periods: 48 hours

Course Outcomes:

At the end of the program the students will be able to:

CO1	**Define** the terms and **understand** the theoretical concepts concerned to the course on Lubrication of Bearings
CO2	**Apply** the fundamental concepts and theories in the Lubrication of Bearings
CO3	**Implement** appropriate **modeling** concepts to solve complex problems associated with the Lubrication of Bearings
CO4	**Analyze** complex problems associated with Lubrication of Bearings and interpret the results obtained
CO5	**Write and test computer codes** related to the concepts learnt during this course on Lubrication of Bearings
CO6	***Select***, ***understand*** and ***evaluate*** technical literature related to new developments in Lubrication of Bearings.
CO7	***Evaluate*** the environmental and societal impact of solution to problems related to Lubrication of bearings

Lubricants: physical properties, lubricants standards, lubrication regimes,
Hydrodynamic Lubrication Theory: Reynolds equation, Design of fluid film bearings, lubricant flow and delivery, Hydrodynamic instability.
Elasto hydrodynamic lubrication: Hertzian stress equation, load capacity, stresses and deflection, bearing life calculation, rolling bearing failures.
Computational hydrodynamics: Finite difference equivalent of the Reynolds equation, Numerical analysis of hydrodynamic lubrication in a real bearing.
Hydrostatic lubrication: generalized approach to hydrostatic bearing analysis, Optimization of hydrostatic bearing design, Aerostatic bearings, Hybrid bearings, Stability of hydrostatic and aerostatic bearings.
Solid lubrication: Lubrication by lamellar solids, Friction and wear characteristics of lamellar solids, Deposition methods of solid lubricants, Solid lubricants as additives to oils and polymers.

References:

1. M. S. Mihir Kumar Ghosh, Bankim Chandra Majumdar, *Fundamentals of Fluid Film Lubrication*. McGraw-Hill Education, 2014. ISBN: 9780071834988.
2. B. J. Hamrock, S Schmid, B. Jacobson *Fundamentals of Fluid Film Lubrication*, McGraw-Hill Mechanical Engineering), January 1994
3. Williams J.A., *Engineering Tribology*, Cambridge University Press, UK, 2005.
4. Neale, M.J., *Tribology Hand Book*, Butterworth Heinemann, London, 1995.
5. Gwidon W. Stachowiak, Andrew W. Batchelor, *Engineering Tribology*, Butterworth Heinemann, London, 2005.

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MTECH in COMPUTER AIDED ANALYSIS AND DESIGN (CAAD)

MME 5283: FINITE ELEMENT METHODS [3 1 0 4]

Total contact hours: 48 hours
Course Outcomes:
At the end of the program the students will be able to:

CO1	Discuss the terminologies and concepts pertaining to this course on Finite Element methods
CO2	Apply the knowledge of mathematics and fundamental principles concerned to this course on Finite Element Methods
CO3	Implement the mathematical models involved in this course on Finite Element Methods to solve the complex engineering problems
CO4	Formulate and analyse complex problems to reach substantiated conclusions by evaluating available data using engineering principles pertaining to this course on Finite Element Methods
CO5	Write and implement computer programs for solving engineering problems concerned in this course on Finite Element Methods

Introduction: General procedure of FEM. **Formulation Methods - Direct Method:** Spring and truss elements, arbitrarily oriented elements, transformation matrix, plane truss. **Energy Method:** Principle of total minimum potential energy, Formulation of plane stress/strain elements. **Galerkin's Weighted Residual Method:** Beam theory, formulation of beam element, arbitrarily oriented beam elements, plane frame. **Isoparametric Elements:** Formulation of truss, plane and solid elements. **Introduction to Analysis Types**: Modal or frequency analysis, thermal analysis, thermos-structural analysis, axi-symmetric analysis, fluid flow analysis.

References:

1. Daryl L Logan, A First Course in Finite Element Method, Thomson Asia Pvt. Ltd, Bangalore, 2002.
2. Akin J.E., Finite Element Analysis for Undergraduates, Academic Press, London, 1989.
3. Martin H.C. and Carey G.F., Introduction to Finite Element Analysis, Tata McGraw Hill, New Delhi, 1975.
4. Segerlind L J., Applied Finite Element Analysis, John Wiley, New York, 1984.
5. Bathe K J, Finite Element Procedures, Prentice Hall of India New Delhi, 2003.
6. Cook Robert D, Concepts and Applications of Finite Element Analysis, John Wiley and Sons New York, 2000.

MME 5267: FEA Lab [0 0 6 2]

Total contact hours: 72 hours

Course Outcomes:
At the end of the program the students will be able to:

CO1	***Model*** and ***analyze*** plane/space trusses, plane/space frames, static structural problems, shells, contact, modal, harmonic, thermal, and coupled field problems using standard FEA software.
CO2	***Evaluate*** the quality of the meshed FEA model and ***perform*** mesh dependency test
CO3	***Write*** macro code for generating mapped mesh models for static structural boundary value problems; ***analyze*** and ***solve*** the same.
CO4	***Design*** FEA based simulation experiments to ***model***, ***analyze*** and ***solve*** boundary value problems
CO5	***Write*** and ***execute*** scripts/programs to ***analyze*** and ***solve*** simplified plane/space trusses, plane/space frames and structural problems

Syllabus:
Modelling and analysis of plane/space trusses, plane/space frames, 2D components, 3D components, shells and contact problems using the GUI of a standard FEA software; Writing macros/codes for developing the mapped mesh for 2D and 3D boundary value problems and analyze the same; Plotting the mesh convergence plot to determine the quality of meshed model; Modelling and analysis of the modal, harmonic and contact structural problems; Modelling and analysis of 2D/3D thermal and thermo-structural problems; Writing and executing scripts/programs for analyzing 1D problems, plane/space trusses, plane/space frames and 2D structural problems.

Experiments/exercises:

Expt. #	**Topic**	**Contact hours**
Expt. 1	Static structural analysis of plane truss, space truss using GUI	3
Expt. 2	Static structural analysis of beam, plane frame, space frame using GUI	3
Expt. 3	Static structural analysis of plane stress, plane strain problems using GUI and free mesh	3
Expt. 4	Static structural analysis of plane stress, plane strain problems using GUI and mapped mesh	3
Expt. 5	Static structural analysis of plane truss, space truss, beam, plane frame and space frame using MACRO	3
Expt. 6	Evaluating the quality of mesh and conducting the mesh convergence test.	3
Expt. 7	Static structural analysis of plane stress, plane strain and axisymmetric problems using MACRO, with free and mapped mesh	3

Expt. 8	Static structural analysis of 3D components using MACRO	3
Expt. 9	Modal and harmonic analysis of mechanical components using MACRO	3
Expt. 10	Thermal analysis of mechanical components using MACRO	3
Expt. 11	Static structural analysis of plane stress, plane strain and axisymmetric problems using MACRO, with free and mapped mesh	3
Expt. 12	Static structural analysis of trusses and beams using ANSYS Workbench.	3
Expt. 13	Static structural analysis of plane stress, plane strain and axisymmetric problems using ANSYS Workbench.	3
Expt. 14	Static structural analysis of 3D components using ANSYS Workbench.	3
Expt. 15	Modal and harmonic analysis of components using ANSYS Workbench.	3
Expt. 16	Thermal analysis of components using ANSYS Workbench.	3
Expt. 17	Fluid flow analysis using ANSYS Workbench.	3
Expt. 18	Contact problem analysis using ANSYS Workbench.	3
Expt. 19	Thermo-structural analysis using ANSYS Workbench.	3
Expt. 20	Fluid structure interaction analysis using ANSYS Workbench.	3
Expt. 21	Write and execute a MATLAB program to solve a truss and a beam problem	3
Expt. 22	Write and execute a MATLAB program to solve a plane stress, plane strain, axisymmetric problem	3
Expt. 23	Open ended question1: Students are asked to design a solution procedure for solving a mechanical engineering boundary value problem	3
Expt. 24	Open ended question2: Students are asked to design a solution procedure for solving a mechanical engineering boundary value problem	3

References:

1. Eliahu Zahavi (1992) “The Finite Element Method in Machine Design” Prentice Hall Inc USA.
2. Ramamurthy V (1997) “Computer Aided Mechanical Design and Analysis” Tata Mcgraw Hill Delhi.
3. Daryl L Logan (2002) “A First Course in the Finite Element Method” Thomson Asia Pvt. Ltd. Bangalore.
4. Tirupathi R. Chandrupatla and Ashok D. Belegundu (2012), “Introduction to Finite Element Engineering” 4th Edition, Pearson.
5. Rudra Pratap, “Getting Started with MATLAB”, Oxford University Press, USA

MME 5004: COMPUTATIONAL FLUID DYNAMICS [3 1 0 4]

Total contact periods: 48 hours

Course Outcomes:

At the end of the program the students will be able to:

CO1	Apply the conservation principles and concepts to derive the governing equations of mass, momentum, energy.
CO2	Apply the finite difference approach to discretize and solve for steady, unsteady flow in one dimension and two dimensions
CO3	Apply the finite volume approach to discretize and solve for steady, unsteady flow in one dimension and two dimensions
CO4	Apply the finite volume approach to discretize and solve for steady convection-diffusion heat transfer and analyse the suitability of various schemes, Apply the various physical conditions by implementing the various boundary conditions
CO5	Apply the concepts of pressure velocity coupling to derive the pressure correction and SIMPLE Algorithm. Implement the concepts of CFD for practical applications using Computer

Governing equations of fluid mechanics: Models of Flow, The substantial derivative and divergence of velocity field- its physical meaning. [03]

Continuity equation: Derivation for finite volume model, fixed and moving with the fluid. Continuity equation: Derivation for infinitesimal element model, fixed and moving with the fluid, The Conservative and Non-conservative forms of the above equations. [03]

Derivation of the general 3-D Cartesian momentum and e**nergy equations:** Non conservative format and transformation of these into conservative formats. [03]

General characteristic of the governing equations: The initial and types of boundary conditions, Dirichlet, Neumann, Cauchy and Robbins boundary conditions, Mathematical behavior of different classes of partial differential equations (Elliptic, Parabolic and Hyperbolic), Equilibrium and Marching behavior. [03]

Format of the differential equation for the conservation of a general dependent property,Φ. Nature of co-ordinates, the independent variables- proper choice of co-ordinates, One-way and two-way co-ordinates, Discretization Process- concept and structure, Methods of deriving the discretized equations, Explicit Taylor series expansion, Consistency and Stability criteria, Simple examples. [04]

Basic solution techniques: Steady state conduction heat transfer, Application of explicit finite difference technique, Application of the explicit finite difference technique to one dimensional steady state heat transfer in a rectangular fin, Implementation of boundary conditions and solution techniques for the above, Extension of the method to 2-D Conduction through a rectangular slab. [04]

Unsteady conduction heat transfer: Explicit, Implicit and Crank Nicholson Method of solving space and time marching in 1D domain- simple examples. [04]

Discretization using control volume technique: For 1D Diffusion Problems, The Basic Four rules criteria in control volume formulation, Discretization of source terms and linearization of the same. Simple problems on steady state diffusion flow problems. Application of control volume technique to two- and three-dimensional steady diffusion flow problems, Application of control volume technique to 1D unsteady heat transfer problem. [04]

Convective flow with diffusion: Numerical methods for steady one-dimensional convective flow with diffusion: control volume approach, The CDS, the Upwind, and Exact schemes, Properties of discretization schemes: Conservativeness, Boundedness and Transportiveness, illustrative numerical examples on the above, Artificial or false diffusion with UDS. [05]

SIMPLE algorithms to solve flow problems: Difficulties and Strategies to overcome in convection dominated diffusion problems, The need for staggered grid, The derivation of the pressure correction equation from continuity equation, Flow chart for SIMPLE algorithm. [04]

Implementation of boundary conditions in CFD: The inlet, exit, outflow and the wall boundary conditions, The constant pressure, symmetry as well as cyclic boundary conditions imposition. [03]

Turbulence modeling and Closure problem: Transition to turbulence in shear flows, nature of turbulence, Wall bounded flows and free shear flows**,** Governing equations. Reynolds averaging. [03]

Closure problem on turbulence: Algebraic models. One equation model. Two equation models, Reynolds stress models (RSM), Unsteady RANS simulations. [05]

References:

1. John D. Anderson Jr., *Computational Fluid Dynamics- The Basics with Applications,* International Edition, McGraw Hill. New York, 1995
2. Suhas V. Patankar, *Numerical Heat Transfer and Fluid Flow*, Hemisphere / McGraw Hill. New York, 1980.
3. Versteeg H.K. and Malalasekera W, *An Introduction to Computational Fluid Dynamics.- The Finite Volume Method,* Longman Scientific & Technical. England, 1995.
4. Ghoshdastidhar, *Computer Simulation of Flow and Heat Transfer,* Tata- McGraw-Hill Book Company. New Delhi, 1998.
5. Muralidhar K and Sundararajan T, *Computational Fluid Flow and Heat Transfer*, Narosa Publishing House, New Delhi, 2003
6. Anderson D.A, Tannehill J.C, and Pletcher, R.H, *Computational Fluid Mechanics and Heat Transfer,* Taylor and Francis Group, New York, 1997.
7. Chung T. J, *Computational Fluid Dynamics,* Cambridge University Press, South Asia Edition, 2003
8. Fletcher C.A.J., *Computational Techniques for Fluid Dynamics*. Vol I and Vol II., Springer, Verlag, Berlin, 1988.

MME 5013: DESIGN FOR MANUFACTURING [3 1 0 4]

Total contact periods: 48

Course Outcomes:

At the end of the program the students will be able to:

CO 1	***Discuss*** the significance of the course DFM
CO 2	***Discuss*** and ***apply*** DFM guidelines related to several manufacturing processes
CO 3	***Discuss*** on sequence of manufacturing process with few examples
CO 4	***Develop*** manufacturing drawing of metal parts using computers
CO5	***Select***, ***understand*** and ***evaluate*** technical literature related to new developments in DFM.
CO6	***Evaluate*** the environmental and societal impact of solution to problems related to DFM

Introduction: Phases of design, essential factors of design, design and manufacturing, producibility requirements in design, DFMA-History, advantages of DFMA in product design, DFMA software, selection of materials and processes. **[06]**

Design for Casting and forging: Sand casting-design rules for sand castings, Investment casting-design guidelines. Characteristics of forging process and design guidelines. **[04]**

Design for die-casting and injection molding: Characteristics of die-casting and injection molding process, Design guidelines for manufacture of parts with examples. **[04]**

Design for sheet metal working and powder metal processing: Characteristics and design guidelines for manufacture of parts with examples. **[04]**

Design for machining: Characteristics and design guidelines for turning, drilling, reaming, shaping, slotting, milling, grinding, honing, lapping, superfinishing and advanced machining processes. **[08]**

Design of Nonmetallic parts: Characteristics of manufacturing process and design guidelines for **p**lastics, rubbers, ceramics and glass. **[03]**

Process engineering: Designing for heat treatment, sequence of operations for manufacturing of round and flat type components, manufacturing of components - shaft, gear, flange, housing having different surface features. **[07]**

Production drawings: Dimensioning for manufacturing, Fits, tolerance and surface finish consideration in design, Preparation of production drawings of components of various products. **[12]**

References:

1. Geoffrey Boothroyd, Peter Dewhurst and Winston A. Knight, *Product Design for Manufacture and Assembly,* (3e), CRC Press, 2011.
2. James G. Brala, *Design for Manufacturability Handbook,* (2e), McGraw Hill, New York, 1999.
3. Kevin Otto and Kristin Wood, *Product Design,* Pearson Education, Delhi, 2001.
4. Chitale A. K. and Gupta R. C., *Product Design and Manufacturing,*PHI Pvt. Ltd., New Delhi, 2005.

5. CorradoPoli, *Design for Manufacturing- A Structured Approach*, Butterworth-Heinemann Ltd., 2001.

MME 5014: FRACTURE MECHANICS [3 1 0 4]

Total contact periods: 48 hours

Course Outcomes:

At the end of the program the students will be able to:

CO1	***Examine*** the basic principles of Linear Elastic Fracture Mechanics and nonlinear fracture mechanics.
CO2	***Assess*** the fracture behavior of mechanical components under static & fatigue loading.
CO3	***Outline*** how fracture toughness is determined using experiments.
CO4	***Identify*** and ***define*** the fundamental concepts behind mixed mode fracture.
CO5	***Examine*** problems involving cracks using computers.

Energy Release Rate and Stress Intensity Factor: Introduction to Fracture Mechanics, Fracture Mechanics approach to design, brittle and ductile fracture, effect of material properties on fracture, Linear Elastic Fracture Mechanics- fracture modes, fracture criteria, mechanisms of fracture & crack growth, Griffith's analysis, energy release rate (G), elastic crack tip fields, Stress Intensity Factor, Crack tip plasticity –Irwin's approach, strip yield model, plastic zone shape and size, plane strain fracture toughness. [10]

Elastic-Plastic Fracture Mechanics: J-integral, path independence, engineer approach, applications to engineering problems. [5]

Fatigue Fracture Mechanics: Fatigue crack growth, crack closure and fatigue threshold, crack growth behavior under variable amplitude loading, effect of overload, prediction of fatigue crack growth and & life of a structural component. [10]

Fracture toughness testing of metals: K_{Ic} test, J_{Ic} measurement. [5]

Mixed mode fracture: Maximum Tangential Stress Criterion, Strain Energy Density Criterion. [10]

Use of computers: FEA of cracks in solids, use of software packages to solve problems involving cracks. [8]

References:

1. Anderson T. L., *Fracture Mechanics-Fundamentals and applications*, (3e), CRC Press, London, 2005.
2. Richard W Hertzberg, Richard P Vinci and Jason L Hertzberg, *Deformation and Fracture Mechanics of Engineering Materials*, (5e), John Wiley & Sons, 2012.
3. Broek D., *The Practical Use of Fracture Mechanics*, Springer Netherlands, 1989.
4. Prashant Kumar, *Elements of Fracture Mechanics*, McGraw Hill Education Private Limited, 2013.
5. Norman E Dowling, *Mechanical Behaviour of Materials*, (4e), Prentice Hall, 2012.

MME 5015: MECHANICS OF COMPOSITE MATERIALS [3 1 0 4]

Total contact hours: 48 hours

Course Outcomes:
At the end of the program the students will be able to:

CO1	***Discuss*** the theoretical concepts and manufacturing techniques concerned to this course on mechanics of Composite materials
CO2	***Select*** and ***apply*** appropriate technique to model complex problems in mechanics of composite materials
CO3	***Implement*** appropriate quantitative model to ***analyze*** the given complex engineering problems concerned to this course on mechanics of composite materials
CO4	***Solve*** the complex engineering problems and ***interpret*** the analytical results concerned to this course on mechanics of composite materials
CO5	***Write*** customised computer programs to ***implement*** the concepts concerned to this course on mechanics of Composite materials

Introduction: Definition, need, general characteristics, applications. Fibers, glass carbon ceramic and aramide fibers. Matrices, polymer, graphite, ceramic and metal matrices, characteristics of fibers and matrices. [03]

Mechanics and Performance: Characteristics of fiber reinforced lamina, laminates, inter laminar stresses, static mechanical properties, fatigue and impact properties, environmental effects, fracture behavior and damage tolerance. [14]

Manufacturing: Bag moulding, compression moulding, pultrusion, filament winding, other manufacturing processes quality inspection methods. [03]

Analysis: Stress analysis of laminated composite beams, plates, and shells, vibration and stability analysis, reliability of composites, FEM of analysis, analysis of sandwich structures. Introduction to micro-mechanics-unidirectional lamina, laminates, interlaminar stresses, static mechanical properties, fatigue properties, impact properties, environmental effects, fracture mechanics and toughening mechanisms, damage prediction, failure modes. [18]

Design: Failure prediction, Maximum stress theory, Maximum strain theory, Azzi–Tsai–Hill theory, Tsai–Wu failure theory, laminate design consideration, bolted and bonded joints. Design examples. [10]

References:

1. Mallick. P.K., *Fiber Reinforced Composites: Materials, Manufacturing and Design (2e)*, CRC Press, 1993
2. Halpin, J.C., *Primer on Composite Materials, Analysis (2e)*, Technomic Publishing Company, 1992

3. Mallick, P.K. and Newman. S., *Composite materials Technology: Processes and properties*, Oxford University Press, USA, 1991.
4. Michael W, Hyer, *Stress analysis of fiber Reinforced Composite Materials*, McGraw Hill Publication, 1998.
5. Rober M. Joness, *Mechanics of Composite Materials*, McGraw Hill Kogakusha Ltd, 2008.

MME 5017: BIOMECHANICS [3 1 0 4]

Total contact periods: 36 hours

Course Outcomes:

At the end of the program the students will be able to:

CO1	**Explain** the mechanics of muscloskeletal system
CO2	**Apply** the concepts of mechanics to study characteristics of hard tissues
CO3	**Interpret** the viscoelastic behavior of soft tissues and discuss continum mechanics with large strain
CO4	**Describe** the physiological functions of cardiovascular system
CO5	**Evaluate** the dynamic characteristics of cells and tissues

Introduction to Biomechanics: Brief history, Contributions of Biomechanics to health science, Contributions of Biomechanics to the field of Mechanics,

Hemodynamics: Rheology of blood, Large artery hemodynamics, Small artery hemodynamic,

Sports biomechanics : Movement patterns – the essence of sports biomechanics, Qualitative and quantitative analysis of sports movements, forces and torques, The anatomy of human movement,

Skeletal biomechanics: Introduction to bone, Biomechanics of cortical and trabecular bone, Fracture and failure mechanics

Mechanobiology, Structure of ligament, tendon and cartilage and its biomechanics,

Terrestrial locomotion : Jumping, Description of walking and running, Gait analysis

Biomechanics of Cardiovascular system: Biomechanical hierarchy in cardiovascular physiology, Structure-function relationship in cardiovascular tissues, Biomechanical feedback in the cardiovascular system, Experimental and computational methods

References:

Fung YC. Biomechanics: motion, flow, stress, and growth. Springer Science & Business Media; 2013 Mar 20.

Ethier CR, Simmons CA. Introductory biomechanics: from cells to organisms. Cambridge University Press; 2007 Mar 12.

Bartlett R. Introduction to sports biomechanics: Analysing human movement patterns. Routledge; 2014 Jan 15.

MME 5028 Machine Learning and its application to Mechanical Engineering

[L T P C: 3 1 0 4]

Course duration: 48 hours

At the end of this course, the student should be able to:	
CO1	***Model*** the supervised and unsupervised Machine Learning algorithms applicable to mechanical engineering problems.
CO2	***Illustrate*** the performance improving and evaluation techniques applied to ML models
CO3	***Model***, ***train*** and ***test*** the Artificial Neural Networks applicable to mechanical engineering problems.
CO4	***Discuss*** the concepts of Deep learning applicable to mechanical engineering problems.
CO5	***Write*** and ***execute*** programs to ***implement*** the concepts of Machine Learning
CO6	***Select***, ***analyse*** and ***evaluate*** technical literature related to new developments in Machine Learning applied to mechanical engineering.
CO7	***Apply*** the concepts of Machine Learning to ***model*** and ***solve*** a practical problem related to mechanical engineering
CO8	***Discuss*** and ***elaborate*** on the theoretical and mathematical concepts of Machine Learning

Module 1: Machine Learning

Introduction to Machine Learning: Resurgence of Machine Learning, Relation with Artificial Intelligence, Machine Learning Models (classification models, clustering models, prediction models), applications, modes of machine learning. (4 hours)

Supervised learning: Introduction, Regression, logistic regression, Support vector machine, nearest neighbour, K-Nearest Neighbour, probabilistic learning, Naive Bayes, Decision tree and Random Forest. (6 hours)

Model performance improving and evaluation: Dimensionality Reduction Technique, Feature Selection, Feature Scaling, gradient descent rule, regularization, Training, Testing, Cross validation, Confusion matrix, Under-fitting, Overfitting, Correct-fitting, Training accuracy, Testing accuracy, Loss determination-comparison. (6 hours)

Artificial neural network: Neural Network as Oversimplified Brain, Visualizing Neural Network Equations, Neural Network Representation, Single-Layer Perceptron, Multi-Layer Perceptron, Training the Network, Gradient Computation through Backpropagation, Chain Rule, Updating Weights, Use of Neural Networks in Deep Learning. (8 hours)

Deep learning approaches: Introduction, Convolutional neural network, Re-current neural network, long, long short-term memory, Transfer learning, Case studies dealing with vision/numeric inputs. (8 hours)

Module 2: Application of ML to Mechanical Engineering

Case studies and mini-project: Computer implementation (using MATLAB and/or PYTHON) of Machine Learning, applied to problems in design engineering, thermal engineering, manufacturing engineering, materials engineering, and tribology. (16 hours)

References:

1. Jo, T. (2021). Machine Learning Foundations Supervised, Unsupervised, and Advanced Learning. In *Machine Learning Foundations*. Springer International Publishing. https://doi.org/doi.org/10.1007/978-3-030-65900-4

2. Kramer, O. (2016). *Machine learning for evolution strategies*. Springer International Publishing. https://doi.org/10.1007/978-3-319-33383-0 ISSN
3. Rebala, G., Ravi, A., & Churuwala, S. (2021). Introduction to Machine Learning. In *Studies in Computational Intelligence* (Vol. 975). https://doi.org/10.1007/978-3-030-74640-7_4
4. Manohar Swamynathan. (2019). Mastering Machine Learning with Python in Six Steps, A Practical Implementation Guide to Predictive Data Analytics Using Python, Second Edition, APress
5. Rodrigo Fernandes de Mello and Moacir Antonelli Ponti (2018). Machine Learning, A Practical Approach on the Statistical Learning Theory, Springer International Publishing AG
6. Oliver Theobald. (2021). Machine Learning For Absolute Beginners: A Plain English Introduction, Third Edition