ಬಿ.ಎಂ.ಎಸ್. ತಾಂತ್ರಿಕ ಮಹಾವಿದ್ಯಾಲಯ, ಬೆಂಗಳೂರು

(ಸ್ವಾಯತ್ತ ವಿದ್ಯಾಸಂಸ್ಥೆ)

B.M.S. COLLEGE OF ENGINEERING, BENGALURU.

(Autonomous College under VTU)

DEPARTMENT OF MECHANICAL ENGINEERING

M.TECH. – MACHINE DESIGN

SCHEME & SYLLABUS

A.Y. 2016-17 ONWARDS

ಬಿ.ಎಂ.ಎಸ್. ತಾಂತ್ರಿಕ ಮಹಾವಿದ್ಯಾಲಯ

ಬಸವನ ಗುಡಿ ರಸ್ತೆ, ಬೆಂಗಳೂರು–೫೬೦ ೦೧೯.

B.M.S. COLLEGE OF ENGINEERING

Bull Temple Road, Bengaluru-560 019.

BMS COLLEGE OF ENGINEERING, BENGALURU

Autonomous College under VTU

VISION

Promoting Prosperity of mankind by augmenting human resource capital through Quality Technical Education & Training

MISSION

Accomplish excellence in the field of Technical Education through Education, Research and Service needs of society

DEPARTMENT OF MECHANICAL ENGINEERING

DEPARTMENT VISION

To become a center of excellence in educating students to become successful Mechanical Engineers

DEPARTMENT MISSION

- To empower the students with the fundamentals for a successful career in the field of Mechanical engineering.
- To continue their education through post-graduation, Research & Development.
- To provide service to the society.

Scheme and Syllabus for M.Tech. (Machine Design)

With effect from A. Y. 2016 – 17

M.Tech. (Machine Design) - Programme Educational Objectives

PEO1	Graduates will have knowledge in the discipline of Machine Design with hands on skill in using modern engineering tools to address real world engineering problems and be socially responsible.
PEO2	Graduates shall be successful in their career as analysts and designers of structural components of conventional and advanced materials, participating in a team or individually in an industry, research or academia.
PEO3	Graduates shall be proficient in their communication, presentation and will be prepared to engage in the process of life-long learning through professional development and research.

Programme Outcomes

PO No.	Programme Outcomes (PO)
PO1	Acquire in-depth knowledge of specific discipline or professional area, including wider and global perspective, with an ability to discriminate, evaluate, analyse and synthesise existing and new knowledge, and integration of the same for enhancement of knowledge.
PO2	Analyse complex engineering problems critically, apply independent judgment for synthesising information to make intellectual and/or creative advances for conducting research in a wider theoretical, practical and policy context
PO3	Think laterally and originally, conceptualise and solve engineering problems, evaluate a wide range of potential solutions for those problems and arrive at feasible, optimal solutions after considering public health and safety, cultural, societal and environmental factors in the core areas of expertise.
PO4	Extract information pertinent to unfamiliar problems through literature survey and experiments, apply appropriate research methodologies, techniques and tools, design, conduct experiments, analyse and interpret data, demonstrate higher order skill and view things in a broader perspective, contribute individually/in group(s) to the development of scientific/technological knowledge in one or more domains of engineering.
PO5	Create, select, learn and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modeling, to complex engineering activities with an understanding of the limitations.
PO6	Possess knowledge and understanding of group dynamics, recognise opportunities and contribute positively to collaborative-multidisciplinary scientific research, demonstrate a capacity for self-management and teamwork, decision-making based on open-mindedness, objectivity and rational analysis in order to achieve common goals and further the learning of themselves as well as others.
PO7	Demonstrate knowledge and understanding of engineering and management principles and apply the same to one's own work, as a member and leader in a team, manage projects efficiently in respective disciplines and multidisciplinary environments after consideration of economic and financial factors.
PO8	Communicate with the engineering community, and with society at large, regarding complex engineering activities confidently and effectively, such as, being able to comprehend and write effective reports and design documentation by adhering to appropriate standards, make effective presentations, and give and receive clear instructions.
PO9	Recognise the need for, and have the preparation and ability to engage in life-long learning independently, with a high level of enthusiasm and commitment to improve knowledge and competence continuously.
PO10	Acquire professional and intellectual integrity, professional code of conduct, ethics of research and scholarship, consideration of the impact of research outcomes on professional practices and an understanding of responsibility to contribute to the community for sustainable development of society.
PO11	Observe and examine critically the outcomes of one's actions and make corrective measures subsequently, and learn from mistakes without depending on external feedback.

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M. Tech. in Machine Design

Scheme of Instruction for **First Semester M. Tech. in Machine Design** 2016-2017

Sl. No.	Subject Code	Name of the Subject	Credits				Credits
			L	T	P	S	
1	16MEMDPCAS	Advanced Mechanics of Solids	4	0	0	0	4
2	16MEMDPCDM	Dynamics and Mechanism Design	3	0	1	0	4
3	16MEMDPCAD	Advanced Machine Design	4	0	0	0	4
4	16MEMDPCFE	Finite Element Method	3	0	0	1	4
5	16MEMDPEXX	Elective–I	3	0	0	0	3
6	16MEMDPEXX	Elective–II	3	0	0	0	3
7	16MEMDPCD1	Design Laboratory - I	0	0	1	0	1
8	16APRDICRM	Research Methodology	2	0	0	0	2
	Total		**22**	**0**	**2**	**1**	**25**

Note: Electives to be chosen one from each group.
Elective will be offered for a minimum strength of six candidates (out of 18) / eight candidates (out of 24)

Elective I	
Sub: Code	Subject
16MEMDPECM	Composite Materials Technology
16MEMDPEMD	Mechatronics Systems Design
16MEMDPERD	Robust Design

Elective II	
Sub: Code	Subject
16MEMDPECE	Computational Methods in Engineering Analysis
16MEMDPESE	Statistical Modeling and Experimental Design
16MEMDPEOT	Optimization Techniques

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Scheme of Instruction for **Second Semester M. Tech. in Machine Design** 2016-2017

Sl. No.	Subject Code	Name of the Subject	Credits				Credits
			L	T	P	S	
1	16MEMDPCFM	Fracture Mechanics	4	0	0	0	4
2	16MEMDPCVA	Vibrations & Acoustics	3	0	0	1	4
3	16MEMDPCTR	Tribology	4	0	0	0	4
4	16MEMDPEXX	Elective-III	4	0	0	0	4
5	16MEMDPEXX	Elective-IV	3	0	0	0	3
6	16XXXXIEXX	Elective-V (Institutional)	4	0	0	0	4
7	16MEMDPCD2	Design Laboratory – II	0	0	1	0	1
8	16MEMDPCS1	Seminar – I	0	0	1	0	1
	Total		**22**	**0**	**2**	**1**	**25**

Note: Electives to be chosen one from each group.
Elective will be offered for a minimum strength of six candidates (out of 18) / eight candidates (out of 24)

Elective III	
Sub: Code	Subject
16MEMDPETP	Theory of Plasticity
16MEMDPERT	Rotor Dynamics
16MEMDPETS	Theory of Plates and Shells

Elective IV	
Sub: Code	Subject
16MEMDPEEM	Experimental Mechanics
16MEMDPEDF	Design for manufacture
16MEMDPERB	Robotics

Elective V (Institutional)	
Sub: Code	Subject
16MEMDIECA	Computer Applications in Design
16MEMDIECG	Computer Graphics
16MEMDIESS	Smart Materials and Structures

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Scheme of Instruction for **Third Semester M. Tech. in Machine Design** 2016-2017

Sl. No.	Course Code	Subject	Credits				Credits
			L	T	P	S	
1	16MEMDPCIN	Internship/Industrial training	0	0	21	0	21
2	16MEMDPCP1	Project Phase: I	0	0	04	0	04
		Total	0	0	**25**	0	**25**

NOTE: III Semester:

- **Internship:** The student shall undergo internship for 16 weeks.

  Preliminary Report submission and Evaluation after 8th week of Internship to be carried out by the Internal Guide of the college and a senior faculty for 100 marks

  Final Report submission and Evaluation after 16th week of Internship to be carried out by the Internal Guide of the college and a senior faculty of Dept. Report Evaluation to be completed within two weeks of submission for 100 marks.

  Viva-Voce on Internship - To be conducted by the Internship Guide (from the college) and the External Guide / Examiner within 2 weeks of Submission with a senior faculty / HoD as chairman for 100 marks

- **Project Phase: I**

  Problem formulation and submission of **synopsis** within 8 weeks from the commencement of 3rd semester, which shall be evaluated for 50 marks by the committee constituted for the purpose by the Head of the Department comprising the guide, senior faculty of the department with HoD as Chairman.

  Literature survey and progress done after 16 weeks shall be evaluated by guide and external examiner with senior faculty / HoD as chairman for 50 marks.

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Scheme of Instruction for **Fourth Semester M. Tech. in Machine Design** 2016-2017

Sl. No.	Course Code	Subject	Credits				Credits
			L	T	P	S	
1	16MEMDPCPR	Project Work	0	0	23	0	23
2	16MEMDPCS2	Technical Seminar	0	0	2	0	2
		Total	**0**	**0**	**25**	**0**	**25**

IV Semester:

- **Project Phase-II** - Internal Evaluation of progress in Project work shall be evaluated after 8 weeks for 100 marks by the committee constituted for the purpose by the Head of the Department comprising the guide and senior faculty of the department with HoD as Chairman
- **Project Phase-III** - Internal Evaluation of Project Demonstration, which shall be evaluated after 15 weeks for 100 marks by the committee constituted for the purpose by the Head of the Department.
- **Final Evaluation of Project Work and Viva-voce**.
  - Final evaluation of project to be carried out after 16 weeks from the date of commencement of 4th semester.
  - The Internal Examiner (the project guide with a teaching experience of at least three years) and External Examiner with HoD as chairman will complete the final evaluation of Project.
- Internal and External Examiners shall carry out the evaluation for 100 Marks each and the average of these marks shall be the final marks of the Project Evaluation.
- **Viva – Voce** : The Viva-Voce shall be conducted jointly by Internal Examiner and External Examiner with HoD as chairman for 100 Marks.

Course		Credits : 04				Marks	
Name	ADVANCED MECHANICS OF SOLIDS	L	T	P	S	CIE	SEE
Code	16MEMDPCAS	4	0	0	0	50	50

Course Content:

UNIT - I

Introduction to Stress: Definition and Notation for forces and stresses. Components of stresses, equations of Equilibrium, Specification of stress at a point. Principal stresses and shear stresses and Mohr's diagram in three dimensions. Boundary conditions. Stress transformation, Stress components on an arbitrary plane, Stress invariants, Octahedral stresses, Decomposition of state of stress.

8 Hours

UNIT - II

Introduction to Strain : Deformation, Strain Displacement relations, Strain components, The state of strain at a point, Principal strain, Strain transformation, Compatibility equations, Cubical dilatation.

Stress -Strain Relations and the General Equations of Elasticity: Generalized Hooke's; law in terms of engineering constants. Formulation of elasticity Problems. Existence and uniqueness of solution, Saint -Venant's principle, Principle of super position and reciprocal theorem. **14 Hours**

UNIT – III

Energy Methods: Work done by forces and elastic strain energy stored, Begg's Deformeter, First theorem of Castigliano, Theorem of virtual work, Kirchhoff's theorem. **6 Hours**

UNIT – IV

Two Dimensional Problems in Cartesian Co-Ordinates: Airy's stress function, investigation for simple beam problems. Bending of a narrow cantilever beam under end load, simply supported beam with uniform load, Use of Fourier series to solve two dimensional problems. **8 Hours**

UNIT - V

Two Dimensional Problems in Polar Co-Ordinates: General equations, stress distribution symmetrical about an axis, Thick cylinder, shrink fit, Strain components in polar co-ordinates, Rotating disk and cylinder, Thermal stresses in thin discs, Stress concentration around a circular hole in an infinite plate. Thermo-elastic stress –strain relations.

Torsion of Prismatic Bars: Torsion of Circular and elliptical cross section bars, Membrane analogy, Torsion of thin walled closed tubes. **16 Hours**

Text Books:

1. Timoshenko and Goodier, **"Theory of Elasticity"** -'McGraw Hill Book Company.
2. L S Srinath **"Advanced Mechanics of Solids"** - Tata Mcgraw Hill Company.
3. Arther P Boresi and Richard J Schmidt, Advanced Mechanics of Materials, 6th Ed 2002

References Books:

1. T. G. Sitharam, Applied Elasticity - Interline publishing.
2. Dym C. L and Shames. I. H, Solid Mechanics: A variation Approach – Mc GraW Hilll New York-1973.
3. Sadhu Singh **,** Theory of Elasticity, Khanna publisher

4. Richard G Budynas, Advanced strength and applied stress analysis, Second Edition, Mc Graw Hill International, Edition 1999.
5. Martin H Sadd, Elasticity: Theory, Applications and Numerics, Academic Press, 2009.

Course Outcomes:

Upon completion of this course, student will be able to:

CO 1	Apply basic concepts in continuum mechanics of solids viz. Stress and strain tensors, equilibrium, compatibility and constitutive equations and methods of solution to elasticity problems
CO 2	Evaluate stresses and displacements in simple solids such as pressurized cylinders, shrink fitted cylinders, rotating disc and shaft, plate with hole and non-circular shafts and thin tubes under torsion.
CO 3	Use MATLAB or equivalent software to evaluate and plot particular solutions.
CO 4	Apply principles of continuum mechanics to design a structure or component to achieve desired performance under realistic constraints.

Scheme of Examination for Semester End Examination:

Answer Five Full questions selecting one from each unit.

To set One question each from unit I, III, IV and Two questions each from units II & V.

Course		Credits : 04				Marks	
Name	DYNAMICS AND MECHANISM DESIGN	L	T	P	S	CIE	SEE
Code	16MEMDPCDM	3	0	1	0	50	50

Course Content:

UNIT - I

Geometry of Motion: Introduction, analysis and synthesis, Mechanism terminology, planar, Spherical and spatial mechanisms, mobility, Grashoffs law, Equivalent mechanisms, Unique mechanisms, Inversions of mechanism. **03 Hours**

UNIT - II

Synthesis of Linkages: Type, number, and dimensional synthesis, Function generation, Path generation and Body guidance, Precision positions, Structural error, Chebychev spacing, Two position synthesis of slider crank mechanisms, Crank-rocker mechanisms with optimum transmission angle Motion Generation: Poles and relative poles, Location of poles and relative poles, polode, Curvature, Inflection circle. **07 Hours**

UNIT - III

Graphical Methods of Dimensional Synthesis: Two position synthesis of crank and rocker mechanisms, Three position synthesis, Four position synthesis (point precision reduction) Overlay method, Coupler curve synthesis, Cognate linkages. **08 Hours**

Ana1ytical Methods of Dimensional Synthesis: Freudenstein's equation for four bar mechanism and slider crank mechanism, Examples, Bloch's method of synthesis, Analytical synthesis using complex algebra. **06 Hours**

UNIT - IV

Generalized Principles of Dynamics: Fundamental laws of motion, Generalized coordinates, Configuration space, Constraints, Virtual work, principle of virtual work, Energy and momentum, Work and kinetic energy, Equilibrium and stability, Kinetic energy of a system, Angular momentum, Generalized momentum. Lagrange's Equation: Lagrange's equation from D'Alembert's principles, Examples, Hamiltons equations, Hamiltons principle, Lagrange's, equation from Hamiltons principle, Derivation of Hamiltons equations, Examples. **10 Hours**

UNIT – V

System Dynamics: Gyroscopic action in machines, Euler's equation of motion, Phase Plane representation, Phase plane Analysis, Response of Linear Systems to transient disturbances.

05 Hours.

List of Practical's:

1. Kinematic analysis of four bar mechanism and slider bar mechanism using ADAMS Software.
2. Kinematic analysis of complex mechanisms using ADAMS Software.
3. Develop a code in MATLAB to for kinematic analysis of four bar mechanism and slider bar mechanism.
4. Write a MATLAB code to synthesize a four bar mechanism using Freudenstein's method for function generation.
5. Write a MATLAB code to generate phase plane plot.

Text Books:

1. Joseph Edward Shigley and John Joseph Uicker, "Theory of Machines and Mechanism" -McGraw-Hill, 1995.
2. Greenwood, "Classical Dynamics", Prentice Hall of India, 1988.

References Books:

1. K. J. Waldron& G. L. Kinzel, "Kinematics, Dynamics and Design of Machinery", Wiley India, 2007.
2. A. G. Ambekar, "Mechanism and Machine Theory", PHI, 2007.
3. Ghosh and Mallick, "Theory of Mechanism and Mechanism", East West press 2007.
4. David H. Myszka, "Machines and Mechanisms", Pearson Education, 2005.
5. G. K. Grover "Mechanical Vibrations" NemChad and Bros. 1996.

Course Outcomes:

Upon completion of this course, the student will be able to

CO1	Carry out mobility analysis of mechanism and perform velocity and acceleration of complex planer mechanism.
CO2	Synthesize mechanisms for function generation and path generation.
CO3	Analyze the Dynamics of Mechanical systems using D'Alemberts, Lagrange's, and Hamiltons Principles.
CO4	Demonstrate the skills to use software to analyze mechanisms

Scheme of Examination for Semester End Examination:

Answer Five Full questions selecting one from each unit.
To set One question each from unit I, II, V and Two questions each from units III & IV.

Course		Credits : 04				Marks	
Name	ADVANCED MACHINE DESIGN	L	T	P	S	CIE	SEE
Code	16MEMDPCAD	4	0	0	0	50	50

Course Content:

UNIT - I

Introduction: Role of failure prevention analysis in mechanical design, Modes of mechanical failure, Review of failure theories for ductile and brittle materials including Mohr's theory and modified Mohr's theory, Numerical examples.

Fatigue of Materials: Introductory concepts, High cycle and low cycle fatigue, Fatigue design models, Fatigue design methods, Fatigue design criteria, Fatigue testing, Test methods and standard test specimens, Fatigue fracture surfaces and macroscopic features, Fatigue mechanisms and microscopic features. **14 Hours**

UNIT - II

Stess-Life (S-N) Approach: S-N curves, Statistical nature of fatigue test data, General S-N behavior, Mean stress effects, Different factors influencing S-N behaviour, S-N curve representation and approximations, Constant life diagrams, Fatigue life estimation using S-N approach.

Strain-Life(ε-N)approach: Monotonic stress-strain behavior, Strain controlled test methods, Cyclic stress-strain behavior, Strain based approach to life estimation, Determination of strain life fatigue properties, Mean stress effects, Effect of surface finish, Life estimation by ε-N approach.

14 Hours

UNIT - III

LEFM Approach: LEFM concepts, Crack tip plastic zone, Fracture toughness, Fatigue crack growth, Mean stress effects. Notches and their effects: Concentrations and gradients in stress and strain, S-N approach for notched membranes, mean stress effects and Haigh diagrams, Notch strain analysis and the strain – life approach. Neuber's rule. **9 Hours**

UNIT - IV

Fatigue from Variable Amplitude Loading: Spectrum loads and cumulative damage, Damage quantification and the concepts of damage fraction and accumulation, Cumulative damage theories, Load interaction and sequence effects, Cycle counting methods, Life estimation using stress life approach. **7 Hours**

UNIT - V

Surface Failure: Introduction, Surface geometry, Mating surface, Friction, Adhesive wear, Abrasive wear, Corrosion wear, Surface fatigue spherical contact, Cylindrical contact, General contact, Dynamic contact stresses, Surface fatigue strength. **6 Hours**

Text Books:

1. Ralph I. Stephens, Ali Fatemi, Robert, Henry o. Fuchs, "Metal Fatigue in engineering", John Wiley Newyork, Second edition. 2001.
2. Jack. A. Collins, "Failure of Materials in Mechanical Design", John Wiley, Newyork 1992.
3. Robert L. Norton , "Machine Design", Pearson Education India, 2000

Reference Books:

1. S. Suresh, "Fatigue of Materials", Cambridge University Press, -1998.
2. Julie. A. Benantine, "Fundamentals of Metal Fatigue Analysis", Prentice Hall, 1990.
3. Fatigue and Fracture, ASM Hand Book, Vol 19, 2002.

Course Outcomes:

Upon completion of this course, the student will be able to

CO1	Predict failure of engineering components using appropriate failure theories.
CO2	Identify and explain the types of fractures of engineered materials and their characteristic features;
CO3	Estimate life of components using stress life, strain life and LEFM approach.
CO4	Categorize different types of surface failures.

Scheme of Examination for Semester End Examination:

Answer Five Full questions selecting one from each unit.
To set One question each from unit III, IV, V and Two questions each from units I & II.

Course		Credits : 04				Marks	
Name	FINITE ELEMENT METHOD	L	T	P	S	CIE	SEE
Code	16MEMDPCFE	3	0	0	1	50	50

Course Content:

UNIT - I

Introduction to Finite Element Method: Basic Steps in Finite Element Method to solve mechanical engineering Solid Mechanics problems: Functional approach and Galerkin approach, Displacement Approach: Admissible Functions, Convergence Criteria: Conforming and Non-Conforming elements, C_o C_1 and C_n Continuity Elements. Basic Equations, Element Characteristic Equations, Assembly Procedure, Boundary and Constraint Conditions. **8 Hours**

UNIT - II

Solid Mechanics : One-Dimensional Finite Element Formulations and Analysis – Bars-uniform, varying and stepped cross section-Basic(Linear) and Higher Order Elements Formulations for Axial and Temperature Loads with problems. Beams- Basic (Linear) Element Formulation-for uniform and stepped cross section- for different loading and boundary conditions with problems. Trusses: Basic(Linear) Elements Formulations for different boundary and loading condition -Axial and Temperature Loads with problems. **9 Hours**

UNIT - III

Two Dimensional Finite Element Formulations for Solid Mechanics Problems: Triangular Membrane/CST Element, Four-Noded Quadrilateral Membrane QUAD 4 Element Formulations for in-plane loading with sample problems. Shape functions for Higher order Triangular and Quadrilateral membrane elements Triangular Axi-symmetric basic Element formulation for axi-symmetric loading with sample problems. Serendipity and Lagrange family Elements. **8 Hours**

UNIT - IV

Three Dimensional Finite Element Formulations for Solid Mechanics Problems: Finite Element Formulation of 4 noded Tetrahedral Element, 8 noded Hexahedral Element, Shape functions for Higher order elements. **6 Hours**

UNIT - V

Dynamic Analysis: Finite Element Formulation for point/lumped mass and distributed masses system, Finite Element Formulation of one dimensional dynamic analysis: bar, truss and beam element. Finite Element Formulation of Two dimensional dynamic analysis: triangular membrane element. Evaluation of eigen values and eigen vectors applicable to bars and beams.

08 Hours.

Text Books:

1. T. R. Chandrupatla and A. D. Belegundu, "Introduction to Finite Elements in Engineering", Prentice Hall, 3rd Ed, 2002.

2. Lakshminarayana H. V., "Finite Elements Analysis– Procedures in Engineering", Universities Press, 2004.

Reference Books:

1. Rao S. S, "Finite Elements Method in Engineering", 4th Edition, Elsevier, 2006.
2. P. Seshu, "Finite Element Analysis", PHI, 2004.
3. J. N. Reddy, "Introduction to Finite Element Method", McGraw -Hill, 2006.
4. Bathe K. J., "Finite Element Procedures", Prentice-Hall, 2006.
5. Cook R. D., "Finite Element Modeling for Stress Analysis", Wiley, 1995.

Self-Study:

On FEM analysis of machine members by using reputed commercial software for stress distribution, stress concentration and report writing on results of analysis.

Course Outcomes:

Upon completion of this course, the students will be able to

CO1	Develop governing equation for a mechanical system and apply principles of variation and integral formulation to formulate finite element equations.
CO2	Formulate one dimensional, two dimensional and axisymmetric elements.
CO3	Analyse problems related to 1D, 2D and solids of revolution.
CO4	Develop mass matrices and compute eigen values and eigen vectors for a 1D and 2D analysis of mechanical components.
CO5	Demonstrate the use of commercial FEA packages to solve complex problems.

Scheme of Examination for Semester End Examination:

Answer Five Full questions selecting one from each unit.
To set One question each from unit I, IV, V and Two questions each from units II & III.

ELECTIVE - I

Course		Credits : 03				Marks	
Name	COMPOSITE MATERIALS TECHNOLOGY	L	T	P	S	CIE	SEE
Code	16MEMDPECM	3	0	0	0	50	50

Course Content:

UNIT - I

Introduction to Composite Materials: Definition, Classification, Types of matrix material and reinforcements, Characteristics & selection, Fiber composites, Laminated composites, Particulate composites, Prepegs, and sandwich construction. **5 Hours**

UNIT - II

Macro Mechanics of a Lamina: Hooke's law for different types of materials, Number of elastic constants, Derivation of nine independent constants for orthotropic material, Two - dimensional relationship of compliance and stiffness matrix. Hooke's law for two-dimensional angled lamina, Engineering constants - Numerical problems. Invariant properties. Stress-Strain relations for lamina of arbitrary orientation, Numerical problems. **9 Hours**

UNIT – III

Micro Mechanical Analysis of a Lamina: Introduction, Evaluation of the four elastic moduli, Rule of mixtures, Numerical problems. Experimental Characterization of Lamina- Elastic Moduli and Strengths

Failure Criteria: Failure criteria for an elementary composite layer or Ply, Maximum Stress and Strain Criteria, Approximate strength criteria, Inter-laminar Strength, Tsai-Hill theory, Tsai, Wu tensor theory, Numerical problem, practical recommendations. **9 Hours**

UNIT - IV

Macro Mechanical Analysis of Laminate: Introduction, Code, Kirchoff hypothesis, Classical Lamination Theory, Derivation of A, B, and D matrices, Hygroscopic effect, Special cases of laminates, Numerical problems. **8 Hours**

UNIT - V

Manufacturing, Testing and Applications:

Layup and curing - open and closed mold processing, Hand lay-up techniques, Bag molding and filament winding. Pultrusion, Pulforming, Thermoforming, Injection molding, Cutting, Machining, joining and repair.

NDT tests – Purpose, Types of defects, NDT method - Ultrasonic inspection, Radiography, Acoustic emission and Acoustic ultrasonic method.

Applications: Aircrafts, missiles, Space hardware, automobile, Electrical and Electronics, Marine, Recreational and sports equipment-future potential of composites. **8 Hours**

Text Books:

1. Autar K. Kaw, "Mechanics of Composite materials", CRC Press, 2nd Ed, 2005.
2. Madhijit Mukhopadhay, "Mechanics of Composite Materials & Structures", Universities Press, 2004.

Reference Books:

1. Mein Schwartz, "Composite Materials", handbook, McGraw Hill, 1984.
2. P. K. Mallik, Marcel Decker, "Fiber Reinforced Composites", CRC Press, 3rd ed, 1993.
3. Robert M. Jones, "Mechanics of Composite Materials", Taylor & Francis, 1998.
4. J. N. Reddy, "Mechanics of Laminated Composite Plates & Shells", CRC Press, 2nd Ed, 2004.
5. Michael W Hyer, "Stress analysis of fiber Reinforced Composite Materials", McGraw Hill International, 2009.
6. Krishan K. Chawla, "Composite Material Science and Engineering", Springer, 3rd ed, 2012.

Course Outcomes:

Upon completion of this course, the student will be able to

CO1	Identify the role of matrices and reinforcements used in practical composite structures.
CO2	Analyze problems on micro and macro mechanical behavior of lamina.
CO3	Assess the strength of laminated composite and predict its failure for given static loading conditions.
CO4	Develop understanding of different methods of manufacturing and testing of composites.
CO5	Make oral presentation on recent advancements in the field of composite materials and structures.

Scheme of Examination for Semester End Examination:

Answer Five Full questions selecting one from each unit.
To set One question each from unit I, IV, V and Two questions each from units II & III.

Course		Credits : 03				Marks	
Name	MECHATRONICS SYSTEM DESIGN	L	T	P	S	CIE	SEE
Code	16MEMDPEMD	3	0	0	0	50	50

Course Content:

UNIT - I

Introduction: Definition and Introduction to Mechatronic Systems. Modeling & Simulation of Physical systems Overview of Mechatronic Products and their functioning, measurement systems. Control Systems, simple Controllers. Study of Sensors and Transducers: Pneumatic and Hydraulic Systems, Mechanical Actuation System, Electrical Actual Systems, Real time interfacing and Hardware components for Mechatronics. **8 Hours**

UNIT - II

Electrical Actuation Systems: Electrical systems, Mechanical switches, Solid state switches, solenoids, DC & AC motors, Stepper motors. System Models: Mathematical models:- mechanical system building blocks, electrical system building blocks, thermal system building blocks, electromechanical systems, hydro-mechanical systems, pneumatic systems. **9 Hours**

UNIT - III

Signal Conditioning: Signal conditioning, the operational amplifier, Protection, Filtering, Wheatstone Bridge, Digital signals, Multiplexers, Data Acquisition, Introduction to digital system processing, pulse-modulation. MEMS and Microsystems: Introduction, Working Principle, Materials for MEMS and Microsystems, Micro System fabrication process, Overview of Micro Manufacturing, Micro system Design, and Micro system Packaging. **10 Hours**

UNIT - IV

Data Presentation Systems: Basic System Models, System Models, Dynamic Responses of System. **6 Hours**

UNIT – V

Advanced Applications in Mechatronics: Fault Finding, Design, Arrangements and Practical Case Studies, Design for manufacturing, User-friendly design. **6 Hours**

Text Books:

1. W. Bolton, "Mechatronics", Addison Wesley Longman Publication, 1999.
2. HSU "MEMS and Microsystems design and manufacture", Tata McGraw-Hill Education, 2002.

Reference Books:

1. Lawrence J. Kamm, "Understanding Electro-Mechanical Engineering an Introduction to Mechatronics", Wiley-IEEE Press, 1st edition, 1996.
2. Devdas Shetty and Richard A. Kolk, "Mechatronics System Design", Cengage Learning, 2nd ed, 2011.
3. Mahalik, Mechatronics, Tata McGraw-Hill Education, 2003.
4. HMT, "Mechatronics"- Tata McGraw-Hill Education, 1998.
5. Michel B. Histand and David. Alciatore, "Introduction to Mechatronics & Measurement Systems", McGraw Hill, 2002.
6. Fine Mechanics and Precision Instruments- Pergamon Press, 1971.

Course Outcomes:

Upon completion of this course, the student will be able to

CO1	Appreciate multi-disciplinary nature of modern engineering systems.
CO2	Model and analyse mechanical and electrical systems and their connection.
CO3	Be able to integrate mechanical, electronics, control and computer engineering in the design of mechatronics systems.
CO4	Address issues of design, fabrication, and packaging issues of Microsystems.

Scheme of Examination for Semester End Examination:

Answer Five Full questions selecting one from each unit.
To set One question each from unit I, IV, V and Two questions each from units II & III.

Course		Credits : 03				Marks	
Name	ROBUST DESIGN	L	T	P	S	CIE	SEE
Code	16MEMDPERD	3	0	0	0	50	50

Course Content:

UNIT - I

Quality by Experimental Design: Quality, western and Taguchi quality philosophy, Elements of cost, Noise factors causes of variation, Quadratic loss function and variation of quadratic loss functions.

Robust Design: Steps in robust design: parameter design and tolerance design, reliability improvement through experiments, illustration through numerical examples.

Experimental Design: Classical experiments: factorial experiments, terminology, factors. Levels, Interactions, Treatment combination, randomization, 2-level experimental design for two factors and three factors. 3-level experiment deigns for two factors and three factors, factor effects, factor interactions, Fractional factorial design, Saturated design, Central composite designs, Illustration through numerical examples. **9 Hours**

UNIT - II

Measures of Variability: Measures of variability, Concept of confidence level, Statistical distributions: normal, log normal and Weibull distributions. Hypothesis testing, Probability plots, choice of sample size illustration through numerical examples. Analysis and interpretation of experimental data: Measures of variability, Ranking method, column effect method and plotting method, Analysis of variance (ANOVA), in factorial experiments: YATE's algorithm for ANOVA, Regression analysis, Mathematical models from experimental data, illustration through numerical examples.

10 Hours

UNIT - III

Taguchi's Orthogonal Arrays: Types orthogonal arrays, Selection of standard orthogonal arrays, Linear graphs and interaction assignment, dummy level technique, Compound factor method, modification of linear graphs, Column merging method, Branching design, Strategies for constructing orthogonal arrays. Signal to Noise ratio (S-N Ratios) : Evaluation of sensitivity to noise, Signal to noise ratios for static problems, Smaller – the – better types, Nominal – the –better – type, larger – the-better – type. Signal to noise ratios for dynamic problems, Illustrations through numerical examples.

10 Hours

UNIT - IV

Parameter Design and Tolerance Design: Parameter and tolerance design concepts, Taguchi's inner and outer arrays, Parameter design strategy, Tolerance deign strategy, Illustrations through numerical examples**.** **5 Hours**

UNIT - V

Reliability Improvement Through Robust Design: Role of S-N ratios in reliability improvement; Case study; illustrating the reliability improvement of routing process of a printed wiring board using robust design concepts. **5 Hours.**

Text Books:

1. Madhav S. Phadake, "Quality Engineering using Robust Design", Prentice Hall,1989.
2. Douglas Montgomery, "Design and analysis of experiment", Willey India Pvt. Ltd., 2007.
3. Phillip J. Ross, Taguchi, "Techniques for Quality Engineering", McGraw Hill Int. Ed., 1996.

Reference Books:

1. Thomas B. Barker, "Quality by Experimental Design" , Marcel Dekker IncASQC Quality Press, 1985.
2. C. F. Jeff Wu, Michael Hamada, "Experiments planning, analysis and parameter design optimization", John Wiley Ed., 2002.
3. W. L. Condra, Marcel Dekker , "Reliability improvement by Experiments", Marcel Dekker Inc ASQC Quality Press, 1985.

Course Outcomes:

Upon completion of this course, the student will be able to

CO1	Apply Design of Experiments (DOE) techniques to various methods of design.
CO2	Analyse and evaluate design parameters using different design strategies.
CO3	Illustrate through numerical examples improvements in design parameters.
CO4	Perform case studies involving identification of parameters, analysis of experimental data in a robust design.

Scheme of Examination for Semester End Examination:

Answer Five Full questions selecting one from each unit.
To set One question each from unit I, IV, V and Two questions each from units II & III.

ELECTIVE – II

Course		Credits : 03				Marks	
Name	COMPUTATIONAL METHODS IN ENGINEERING ANALYSIS	L	T	P	S	CIE	SEE
Code	16MEMDPECE	3	0	0	0	50	50

Course Content:

UNIT - I

Approximations and Round off Errors: Significant figures, accuracy and precision, error definitions, round off errors and truncation errors. Mathematical modeling and Engineering problem solving, simple mathematical model, Conservation Laws of Engineering. **7 Hours**

UNIT - II

Roots of Equations: Bracketing methods-Graphical method, Bisection method, False position method, Newton- Raphson method, Secant Method. Multiple roots, Simple fixed point iteration.

Roots of Polynomial: Polynomials in Engineering and Science, Muller's method, Bairstow's Method Graeffe's Roots Squaring Method. **9 Hours**

UNIT - III

Numerical Differentiation and Numerical Integration: Newton –Cotes and Gauss Quadrature Integration formulae, Integration of Equations, Romberg integration, Numerical Differentiation Applied to Engineering problems, High Accuracy differentiation formulae. **6 Hours**

UNIT - IV

System of Linear Algebraic Equations And Eigen Value Problems: Introduction, Direct methods, Cramer's Rule, Gauss Elimination Method, Gauss-Jordan Elimination Method, Triangulaization method, Cholesky Method, Partition method, Error Analysis for direct methods, Iteration Methods.

Eigen values and Eigen Vectors: Bounds on Eigen Values, Jacobi method for symmetric matrices, Givens method for symmetric matrices, Rutishauser method for arbitrary matrices, Power method, Inverse power method. **9 Hours**

UNIT - V

Linear Transformation: Introduction to Linear Transformation, The matrix of Linear Transformation, Linear Models in Science and Engineering

Orthogonality and Least Squares: Inner product, length and orthogonality, orthogonal sets, Orthogonal projections, The Gram-schmidt process, Least Square problems, Inner product spaces.

8 Hours

Text Books:

1. Steven C. Chapra, Raymond P. Canale "Numerical Methods for Engineers"- 5th Edition, Tata McGraw Hill, 2007.
2. S. S. Sastry "Introductory Method of Numerical Analysis", PHI, 2009.
3. M K. Jain, S.R.K Iyengar, R K. Jain "Numerical Methods for Scientific and Engg. Computation". New Age International, 2003.

Reference Books:

1. Perviz Moin "Fundamentals of Engineering Numerical Analysis", Cambridge, 2010.
2. David. C. Lay, "Linear Algebra and its applications" -3rd edition, Pearson Education, 2005.
3. Laurence V Fausett, "Applied Numerical Analysis using Matlab", Pearson, 2008.

Course Outcomes:

Upon completion of this course, the student will be able to

CO1	Construct and analyse mathematical models of physical applications.
CO2	Find the roots of polynomials, algebraic, transcendental or simultaneous system of equations in science and engineering problems.
CO3	Integrate and differentiate a function for given set of tabulated data with greater accuracy for engineering problems.
CO4	Solve system of linear algebraic equations and compute eigen values and eigen vectors of matrices.
CO5	Demonstrate use of computational tools like MAT Lab to obtain solution to complex mathematical models.

Scheme of Examination for Semester End Examination:

Answer Five Full questions selecting one from each unit.
To set One question each from unit I, III, V and Two questions each from units II & IV.

Course		Credits : 03				Marks	
Name	STATISTICAL MODELING AND EXPERIMENTAL DESIGN	L	T	P	S	CIE	SEE
Code	16MEMDPESE	3	0	0	0	50	50

Course Content:

UNIT - I

Statistical Modeling and Data Analysis: Introduction, Review of basic statistical concepts: Concepts of random variable, Sample and population, Measure of Central tendency; Mean, median and mode. Illustration through Numerical examples, Normal, Log Normal & Weibull distributions. Illustration through Numerical examples. **9 Hours**

UNIT - II

Introduction to Designed Experiments: Strategy of experimentation, Some typical applications of experimental design, Basic principles, Guidelines for designing experiments, A brief history of statistical design, Summary: Using statistical techniques in experimentation. **10 Hours**

UNIT - III

Factorial Experiments Basic definitions, The advantages of factorials, The two factorial design. Introduction, Factorial Experiments Terminology: factors, levels, interactions, Two-level experimental designs for two factors and three factors. Illustration through Numerical examples. **10 Hours**

UNIT - IV

Regression Analysis: linear and multiple Regression analysis, Mathematical models from experimental data. Illustration through Numerical examples. **4 Hours**

UNIT - V

Signal to Noise Ratio: Evaluation of sensitivity to noise. Signal to Noise ratios for static problems: Smaller-the-batter type, Nominal the-better-type, Larger-the better type. Signal to Noise for Dynamic problems. Illustration through Numerical examples. **6 Hours**

Text Books:

1. Design and Analysis of Experiments, Douglas C. Montgomery, 5th Edition Wiley India Pvt. Ltd. 2007.
2. Quality engineering using robust design, Madhav s. Phadke, Prentice Hall PTR, Enflewood Cliffs, NewJersy 07632, 1989.

Reference Book:

1. Thomas B. Barker, "Quality if experimental design", Marcel Dekker Inc ASQC Quality Press.1985.
2. C.F. Jeff Wu Michael Hamada, "Experiments Planning Analysis and Parameter Design Optimization", Wiley Editions. 2002.
3. L. W. Condra, "Reliability Improvement with design of Experiments", 2nd ed, CRC Press, 2001
4. Phillip j. Ross, "Taguchi Techniques for Quality Engineering", 2nd ed. McGraw Hill International Editions, 1996.

Course Outcomes:

Upon completion of this course, the student will be able to

CO1	Statistically model a population and fit in a suitable distribution for the population for further analysis.
CO2	Analyse and apply statistical concept in the design of experiments.
CO3	Develop experimental models for 2 factors or 3 factors.
CO4	Establish a regression pattern for given mathematical model established for experiment and evaluate signal to noise ratio for sensitivity.

Scheme of Examination for Semester End Examination:

Answer Five Full questions selecting one from each unit.
To set One question each from unit I, IV, V and Two questions each from units II & III.

Course		Credits : 03				Marks	
Name	OPTIMIZATION TECHNIQUES	L	T	P	S	CIE	SEE
Code	16MEMDPEOT	3	0	0	0	50	50

Course Content:

UNIT - I

Introduction: Terminology, Design Variables, Constraints, Objective Function, Variable Bounds, Problem Formulation, Engineering Optimization Problems. Calculus method. Linear Programming. Simplex method, Concept of Duality **9 Hours**

UNIT - II

Single Variable Optimization Problems: Optimality Criterion, Bracketing Methods, Region Elimination Methods, Interval Halving Method, Fibonacci Search Method, Golden Section Method, Successive Quadratic Estimation Method. Gradient Based Methods: Newton-Raphson Method, Bisection Method, Secant Method. Application to Root finding. **10 Hours**

UNIT - III

Multivariable Optimization Algorithms: Optimality Criteria, Unidirectional Search, Direct Search Methods: Hooke-Jeeves pattern search method, Powell's Conjugate Direction Method. Gradient Based Methods: Cauchy's Steepest Descent Method, Newton's method, Marquardt's Method. **6 Hours**

UNIT - IV

Constrained Optimization Algorithms: Kuhn Tucker conditions, Transformation Methods: Penalty Function Method, Method of Multipliers, Sensitivity analysis. **4 Hours**

UNIT - V

Further Topics in Optimization Techniques: Quadratics Programming, sequential quadratic programming; Integer Programming, Penalty Function Method, Branch and Bound Method, Geometric Programming, Applications Design of experiments and Taguchi method – Application and problem solving; Dynamic programming, principle of optimality, recursive equation approach and applications; Genetic algorithm. **10 Hours**

Text Books

1. S. S. Rao, "Engineering Optimization: Theory and Practice", John Wiley & Sons, 1996.
2. Kalyanmoy Deb, "Optimization for Engineering Design: Algorithms and Examples", 2nd ed, Prentice Hall of India, 2004.

Reference Books

1. E. J. Haug and J. S. Arora, "Applied Optimal Design", Wiley, New York.
2. G.V. Reklaites, A. Ravindran and K.M. Rogsdeth, "Optimization", Wiley, New York.

Course Outcomes:

Upon completion of this course, the student will be able to

CO1	Formulate engineering optimization problem and solve LPP by simplex method.
CO2	Solve single and multivariable optimization problem by various relevant method.
CO3	Develop algorithm for constrained optimization.
CO4	Examine various optimization techniques and demonstrate their applicability.

Scheme of Examination for Semester End Examination:

Answer Five Full questions selecting one from each unit.
To set One question each from unit I, III, IV and Two questions each from units II & V.

Course		Credits : 01				Marks	
Name	DESIGN LABORATORY - 1	L	T	P	S	CIE	SEE
Code	16MEMDPCD1	0	0	1	0	50	50

Course Content:

Experiment #1
Numerical Calculation and MATLAB Simulation
Part A: Invariants, Principal stresses and strains with directions
Part A: Maximum shear stresses and strains and planes, von-Mises stress
Part C: Calculate and Plot Stresses in Thick-Walled Cylinder

Experiment #2
Stress analysis in Curved beam in 2D
Part A : Experimental studies using Strain Gauge Instrumentation.
Part B : 2D Photo elastic Investigation.
Part C : Modelling and Numerical Analysis using FEM.

Experiment #3
Stress analysis of rectangular plate with circular hole under i. Uniform Tension and ii. shear
Part A: Matlab simulation for Calculation and Plot of normalized hoop Stress at hole boundary in Infinite Plate
Part B: Modelling of plate geometry under chosen load conditions and study the effect of plate geometry.
Part C: Numerical Analysis using FEA package.

Experiment #4
Single edge notched beam in four point bending.
Part A: Modelling of single edge notched beam in four point bending.
Part B: Numerical Studies using FEA.
Part C: Correlation Studies.

Experimental #5
Torsion of Prismatic bar with Rectangular cross-section.
Part A: Elastic solutions, MATLAB Simulation
Part B: Finite Element Analysis of any chosen geometry.
Part C: Correlation studies.

Experiment #6
Contact Stress Analysis of Circular Disc under diametrical compression
Part A: 3-D Modelling of Circular Discs with valid literature background, supported with experimental results on contact stress.
Part B: Numerical Analysis using any FEA package.
Part C: 2D Photo Elastic Investigation.

Experiment #7
Vibration Characteristics of a Spring Mass Damper System.
Part A: Analytical Solutions.
Part B: MATLAB Simulation., Part C: Correlation Studies.

Experiment #8
Modelling and Simulation of Control Systems using MATLAB

Part A: Analytical Solutions.
Part B: MATLAB Simulation.
Part C: Correlation Studies.

Course Outcomes:

Upon completion of this course, the student will be able to

CO1	Acquire knowledge of stresses, strains and failure theories and analyse them in terms of mathematical models.
CO2	Design and conduct experiments involving photo elasticity and strain gauges.
CO3	Apply Experimental techniques for different engineering problems.
CO4	Use MATLAB and Finite element analysis software and make comparison with other techniques.

Course		Credits : 02				Marks	
Name	Research Methodology	L	T	P	S	CIE	SEE
Code	16APRDICRM	2	0	0	0	50	50

Course Content:

Module 1:

Meaning, Objectives and Characteristics of research - Research methods Vs Methodology - Types of research - Descriptive Vs. Analytical, Applied Vs. Fundamental, Quantitative Vs. Qualitative, Conceptual Vs. Empirical - Research process - Criteria of good research - Developing a research plan.

Module 2:

Defining the research problem - Selecting the problem - Necessity of defining the problem - Techniques involved in defining the problem **-** Importance of literature review in defining a problem **- S**urvey of literature - Primary and secondary sources - Reviews, treatise, monographs, patents - web as a source - searching the web - Identifying gap areas from literature review - Development of working hypothesis.

Module 3:

IPRs- Invention and Creativity- Intellectual Property-Importance and Protection of Intellectual Property Rights (IPRs)- A brief summary of: Patents, Copyrights, Trademarks, Industrial Designs-Integrated Circuits-Geographical Indications-Establishment of WIPO-Application and Procedures.

Module 4:

Aim of this part of the course: is to strengthen students minds towards high quality research through publications, patents and also to learn research ethics. Publications (8-9 hours)

Research concepts (2 hour) Research importance on economy, Research in India and abroad, Importance of publications, Why, where, when to publish? Publication ethics (2 hour), Plagiarism (how to use turn it in effectively), International ethics on research, What and what not to publish, Ethical guidelines, Case studies

Quality vs quantity (2 hour) Searching literature with high quality, Impact factor, Citations (google scholar vs web of science), H-index, Case studies

How to write paper (2 hour), In High quality journals, Conference Articles, Poster preparation, PhD thesis, Inclusion of References

Journal reviewing process (1 hour), Selection of the good journal, Knowledge bout journal template, Refereeing process, Research topic selection, Research today and tomorrow, Lab scale to Industry, Traditional research to Technology based research

Module 5: Self study

Interpretation and report writing - Techniques of interpretation - Structure and components of scientific reports - Different steps in the preparation - Layout, structure and language of the report - Illustrations and tables - Types of report - Technical reports and thesis.

REFERENCES:

1. Garg, B.L., Karadia, R., Agarwal, F. and Agarwal, U.K., 2002. An introduction to Research Methodology, RBSA Publishers.
2. Kothari, C.R., 1990. Research Methodology: Methods and Techniques. New Age International. 418p.
3. Anderson, T. W., An Introduction to Multivariate Statistical Analysis, Wiley Eastern Pvt., Ltd., New Delhi

4. Sinha, S. C. and Dhiman, A.K., 2002. Research Methodology, Ess Ess Publications. 2 volumes.
5. Trochim, W.M.K., 2005. Research Methods: the concise knowledge base, Atomic Dog Publishing. 270p.
6. Day, R.A., 1992.How to Write and Publish a Scientific Paper, Cambridge University Press.
7. Fink, A., 2009. Conducting Research Literature Reviews: From the Internet to Paper. Sage Publications.
8. Coley, S.M. and Scheinberg, C. A., 1990, "Proposal Writing", Sage Publications.
9. Intellectual Property Rights in the Global Economy: Keith Eugene Maskus, Institute for International Economics, Washington, DC, 2000.
10. Subbarau NR-Handbook on Intellectual Property Law and Practice-S Viswanathan Printers and Publishing Private Limited.1998.

Course		Credits : 04				Marks	
Name	FRACTURE MECHANICS	L	T	P	S	CIE	SEE
Code	16MEMDPCFM	4	0	0	0	50	50

Course Content:

UNIT - I

Fracture mechanics principles: Introduction and historical review, Sources of micro and macro cracks. Stress concentration due to elliptical hole, Strength ideal materials, Griffith's energy balance approach. Fracture mechanics approach to design. NDT and Various NDT methods used in fracture mechanics, Numerical problems. The Airy stress function. Complex stress function. Solution to crack problems. Effect of finite size. Special cases, Elliptical cracks, Numerical problems.

12 Hours.

UNIT - II

Plasticity effects: Irwin plastic zone correction. Dugdale approach. The shape of the plastic zone for plane stress and plane strain cases, Plastic constraint factor. The Thickness effect, numerical problems. Determination of Stress intensity factors and plane strain fracture toughness: Introduction, analysis and numerical methods, experimental methods, estimation of stress intensity factors. Plane strain fracture toughness test, The Standard test. Size requirements, Non-linearity. Applicability.

12 Hours

UNIT - III

The energy release rate, Criteria for crack growth. The crack resistance(R curve). Compliance, J integral. Tearing modulus. Stability. Elastic plastic fracture mechanics: Fracture beyond general yield. The Crack-tip opening displacement. The Use of CTOD criteria. Experimental determination of CTOD. Parameters affecting the critical CTOD. Use of J integral. Limitation of J integral.

12 Hours

UNIT - IV

Dynamics and crack arrest: Crack speed and kinetic energy. Dynamic stress intensity and elastic energy release rate. Crack branching. Principles of crack arrest. Crack arrest in practice. Dynamic fracture toughness**.** **6 Hours**

UNIT - V

Fatigue crack propagation and applications of fracture mechanics: Crack growth and the stress intensity factor. Factors affecting crack propagation. Variable amplitude service loading, Means to provide fail-safety, required information for fracture mechanics approach, Mixed mode (combined) loading and design criteria. **8 Hours**

Text Books:

1. David Broek, "Elementary Engineering Fracture Mechanics", Springer Netherlands, 2011.
2. Anderson, "Fracture Mechanics-Fundamental and Application", T.L CRC press1998.
3. Ramesh K, "Engineering Fracture Mechanics", online Solutions Publishing.

Reference Books:

1. Karen Hellan , "Introduction to fracture mechanics", McGraw Hill, 2nd Edition.
2. S. A. Meguid, "Engineering fracture mechanics", Elsevier Applied Science, 1989.
3. Jayatilaka, "Fracture of Engineering Brittle Materials", Applied Science Publishers, 1979
4. Rolfe and Barsom, "Fracture and Fatigue Control in Structures" , Prentice Hall, 1977.
5. Knott, "Fundamentals of fracture mechanisms", Butterworths, 1973.

Course Outcomes:

Upon completion of this course, the student will be able to

CO1	Develop a strong foundation in theory, concepts and principles of fracture mechanics
CO2	Use these principles to evaluate fracture mechanics parameters and characterize status of crack in a structure under different loads
CO3	Predict crack propagation, perform failure analysis of engineering structures and provide alternate solutions
CO4	Acquire judgment and skills in solving theoretical and practical problems
CO5	Use a commercial analysis tool to perform fracture mechanics analysis.

Scheme of Examination for Semester End Examination:

Answer Five Full questions selecting one from each unit.
To set One question each from unit I, IV, V and Two questions each from units II & III.

Course		Credits : 04				Marks	
Name	VIBRATIONS AND ACOUSTICS	L	T	P	S	CIE	SEE
Code	16MEMDPCVA	3	0	0	1	50	50

Course Content:

UNIT - I

Review of Mechanical Vibrations: Basic concepts; free vibration of single degree of freedom systems with and without damping, forced vibration of single DOF-systems, Natural frequency. Transient Vibration of single Degree-of freedom systems: Impulse excitation, Arbitrary excitation, Laplace transform formulation, Pulse excitation and rise time, Shock response spectrum.

12 hours

UNIT - II

Vibration Control: Introduction, Vibration isolation theory, Vibration isolation and motion isolation for harmonic excitation, practical aspects of vibration analysis, Dynamic vibration absorbers, Vibration dampers. Vibration Measurement and applications: Introduction, Transducers, Vibration pickups, Frequency measuring instruments, Vibration exciters. **08 hours**

UNIT - III

Modal analysis, Dynamic Testing of machines and Structures, Experimental Modal analysis, Non Linear Vibrations: Introduction, Sources of nonlinearity, Qualitative analysis of nonlinear systems. Phase plane, Conservative systems, Stability of equilibrium, Method of isoclines, Perturbation method, Method of iteration, Self-excited oscillations. **10 hours**

UNIT - IV

Continuous Systems: Vibrating string, longitudinal vibration of rods, Torsional vibration of rods, Euler equation for beams. **05 hours**

UNIT - V

Fundamentals of Acoustics: Human perception of sound, Sound wave propagation in 1-D, 3-D space. 3-D wave equation, Some important acoustic quantities and relations. **04 hours**

Text Books

1. William T. Thomson, Marie Dillon Dahleh and Chandramouli Padmanabhan, "Theory of Vibration with Application", 5th ed, Pearson Education.
2. S. Graham Kelly, "Fundamentals of Mechanical Vibration" - McGraw-Hill, 2000.
3. S. S. Rao, "Mechanical Vibrations", Pearson Education, 4th edition.

Reference Books

1. S. Graham Kelly, "Mechanical Vibrations", Schaum's Outlines, Tata McGraw Hill, 2007.
2. C Sujatha, "Vibrations and Acoustics", Measurements and signal analysis", Tata McGraw Hill, 2010.

Course Outcomes:

Upon completion of this course, the student will be able to

CO1	Model and analyse a free damped, undamped and forced response of a mechanical system.
CO2	Develop equation and analyse the transient response of a single degree freedom system.
CO3	Assess the response characteristics of a continuous mechanical system.
CO4	Analyse and discuss the behaviour of single degree freedom system for linear and non-linear behaviour.
CO5	Undertake literature review on unfamiliar problems related to vibration, comprehend it and make presentation to the engineering community.

Scheme of Examination for Semester End Examination:

Answer Five Full questions selecting one from each unit.
To set One question each from unit II, IV, V and Two questions each from units I & III.

Course		Credits : 04				Marks	
Name	TRIBOLOGY	L	T	P	S	CIE	SEE
Code	16MEMDPCTR	4	0	0	0	50	50

Course Content:

UNIT - I

Introduction to Tribology: Introduction, Friction, Wear, Wear Characterization, Regimes of lubrication, Classification of contacts, lubrication theories, Effect of pressure and temperature on viscosity. Newton's Law of viscous forces, Flow through stationary parallel plates. Hagen's poiseuille's theory, viscometers. Numerical problems, Concept of lightly loaded bearings, Petroff's equation, Numerical problems. **7 Hours**

UNIT - II

Hydrodynamic Lubrication: Pressure development mechanism. Converging and diverging films and pressure induced flow. Reynolds's 2D equation with assumptions. Introduction to idealized slide bearing with fixed shoe and Pivoted shoes. Expression for load carrying capacity. Location of center of pressure, effect of end leakage on performance, Numerical problems.

Journal Bearings: Introduction to idealized full journal bearings. Load carrying capacity of idealized full journal bearings, Sommerfeld number and its significance, short and partial bearings, Comparison between lightly loaded and heavily loaded bearings, effects of end leakage on performance, Numerical problems. **12 Hours**

UNIT - III

Hydrostatic Bearings: Hydrostatic thrust bearings, hydrostatic circular pad, annular pad, rectangular pad bearings, types of flow restrictors, expression for discharge, load carrying capacity and condition for minimum power loss, numerical problems, and hydrostatic journal bearings. EHL Contacts: Introduction to Elasto-hydrodynamic lubricated bearings. Introduction to 'EHL' constant. Grubin type solution. **13 Hours**

UNIT - IV

Antifriction bearings: Advantages, selection, nominal life, static and dynamic load bearing capacity, probability of survival, equivalent load, cubic mean load, bearing mountings. Porous Bearings: Introduction to porous and gas lubricated bearings. Governing differential equation for gas lubricated bearings, Equations for porous bearings and working principal, Fretting phenomenon and its stages. **12 Hours**

UNIT - V

Magnetic Bearings: Introduction to magnetic bearings, Active magnetic bearings. Different equations used in magnetic bearings and working principal. Advantages and disadvantages of magnetic bearings, Electrical analogy, Magneto-hydrodynamic bearings. **6 Hours**

Text Books

1. Mujamdar B. C "Introduction to Tribology of Bearing", Wheeler Publishing, New Delhi 2001.
2. Radzimovsky, "Lubrication of Bearings - Theoretical principles and design" Oxford Press Company, 2000.

Reference Books

1. Dudley D. Fuller " Theory and practice of Lubrication for Engineers", New YorkCompany.1998
2. Moore "Principles and applications of Tribology", Pergamon press, 1975.

3. Oscar Pinkus, Beno Sternlicht, "Theory of hydrodynamic lubrication", McGraw-Hill, 1961.
4. G W Stachowiak, A W Batchelor, "Engineering Tribology", Elsevier publication 1993.
5. William Brian Rowe, "Hydrostatic and hybrid bearings, Butterworth 1983.
6. F. M. Stansfield, Hydrostatic bearings for machine tools and similar applications, Machinery Publishing, 1970.

Course Outcomes:

Upon completion of this course, the student will be able to

CO1	Comprehend basics of tribology and related sciences, theoretical background about processes in tribological system, mechanisms and forms of interaction of friction surfaces.
CO2	Analyze hydrodynamic, hydrostatic, Elasto-hydrodynamic bearing condition.
CO3	Select bearings based on various tribological factors to be considered in moving and rotating parts.
CO4	Understand the application and limitations Magnetic and porous bearings.
CO5	Undertake literature survey on unfamiliar problems related to Tribology, comprehend it and make presentation to the engineering community.

Scheme of Examination for Semester End Examination:

Answer Five Full questions selecting one from each unit.
To set One question each from unit I, IV, V and Two questions each from units II & III.

ELECTIVE – III

Course		Credits : 04				Marks	
Name	THEORY OF PLASTICITY	L	T	P	S	CIE	SEE
Code	16MEMDPETP	4	0	0	0	50	50

Course Content:

UNIT - I

Definition and scope of the subject, Brief review of elasticity, Octahedral normal and shear stresses, Spherical and deviatoric stress, Invariance in terms of the deviatoric stresses, Engineering and natural strains, Mathematical relationships between true stress and true strains, Cubical dilation, finite strains co- efficient Octahedral strain, Strain rate and the strain rate tensor. **12 Hours**

UNIT- II

Material Models, Stress-strain relations, Yield criteria for ductile metal, Von Mises, Tresca, Yield surface for an Isotropic Plastic materials, Stress space, Experimental verification of Yield criteria, Yield criteria for an anisotropic material, flow rule normality of Yield locus, Symmetry and convexity, Deformation of isotropic and kinematic hardening, bilinear stress-strain relationship. **12 Hours**

UNIT - III

Plastic stress-strain relations, Prandtl-Reuss Saint Venant, Levy-Mises, Experimental verification of the Prandtl-Reuss equation, Upper and lower bound theorems. Application to problems: Uniaxial tension and compression. **08 Hours**

UNIT - IV

Bending of beams, Torsion of rods and tubes, Nonlinear bending and torsion equations, Simple forms of indentation problems using upper bounds, Application of Metal forming: Extrusion, Drawing, Rolling and Forging. **10 Hours**

UNIT - V

Slip line theory, Introduction, Basic equations for incompressible two dimensional flow, continuity equations, Stresses in conditions of plain strain convention for slip-lines, Geometry of slip lines, Properties of slip lines, **08 Hours**

Text Books

1. R. A. C. Slater, "Engineering Plasticity - Theory and Application to Metal Forming Process", McMillan Press Ltd., 1977.
2. Sadhu Singh, "Theory of Plasticity and Metal forming Process", Khanna Publishers, Delhi, 1999.

Reference Books

1. Hoffman and Sachs, "Introduction to the Theory of Plasticity for Engineers", LLC, 2012.
2. J Chakrabarty, "Theory of plasticity", Butterworth, 2006.
3. Johnson and Mellor, "Plasticity for Mechanical Engineers", Van Nostrand, 1966.

Course Outcomes:

Upon completion of this course, the student will be able to

CO1	Analyse and determine the elastic and elastoplastic stress- strain behaviour of solid deformable bodies subjected to various types of loads.
CO2	Analyse and asses the yielding behaviour in metallic material using suitable yield criteria.
CO3	Develop plastic stress-strain relation for large plastic deformation and apply same along with knowledge of yield criteria to various metal forming process.
CO4	Develop fundamental equations of slipline field theory.

Scheme of Examination for Semester End Examination:

Answer Five Full questions selecting one from each unit.

To set One question each from unit I, III, V and Two questions each from units II & IV.

Course		Credits : 04				Marks	
Name	ROTOR DYNAMICS	L	T	P	S	CIE	SEE
Code	16MEMDPERT	4	0	0	0	50	50

Course Content:

UNIT - I

Fluid Film Lubrication: Basic theory of fluid film lubrication, Derivation of generalized Reynolds equations, Boundary conditions, Fluid film stiffness and Damping coefficients, Stability and dynamic response for hydrodynamic journal bearing, Two lobe journal bearings.

Stability of Flexible Shafts: Introduction, equation of motion of a flexible shaft with rigid support, Radial elastic friction forces, Rotary friction, friction Independent of velocity, friction dependent on frequency, Different shaft stiffness Constant, gyroscopic effects, Nonlinear problems of large deformation applied forces, instability of rotors in magnetic field. **12 Hours**

UNIT - II

Critical Speed: Dunkerley's method, Rayleigh's method, Stodola's method. Rotor Bearing System: Instability of rotors due to the effect of hydrodynamic oil layer in the bearings, support flexibility, Simple model with one concentrated mass at the center. **6 Hours**

UNIT - III

Turborotor System Stability by Transfer Matrix Formulation: General turborotor system, development of element transfer matrices, the matrix differential equation, effect of shear and rotary inertia, the elastic rotors supported in bearings, numerical solutions. **10 Hours**

UNIT - IV

Turborotor System Stability by Finite Element Formulation: General turborotor system, generalized forces and co-ordinates system assembly element matrices, Consistent mass matrix formulation, Lumped mass model, linearised model for journal bearings, System dynamic equations Fix stability analysis non dimensional stability analysis, unbalance response and Transient analysis. **14 Hours**

UNIT - V

Blade Vibration: Centrifugal effect, Transfer matrix and Finite element, approaches. **8 Hours**

Text Books:

1. Cameron, "Principles of Lubrication", Longman Publishing Group, 1986.
2. J S Rao, "RotorDynamics", New Age International, 1996.

Reference Books:

1. Donald E Bently and Charles T. Hatch, "Fundamentals of Rotating Machinery Diagnostics", Bently Pressurized Bearing Co; 1 edition 2003.
2. Agnieszka Muszynska, "Rotordynamics", CRC Press, 2005.
3. Bolotin, "Nonconservative problems of the Theory of elastic stability", Macmillan, 1963.
4. Peztel, Lockie, "Matrix Methods in Elasto Mechanics", McGraw-Hill, 1963.
5. Timoshenko, "Vibration Problems in Engineering", Ox ford City Press, 2011.
6. Zienkiewicz, "The finite element method in engineering science", McGraw-Hill, 1971.

Course Outcomes:

Upon completion of this course, the student will be able to

CO1	Model a rotating machine element theoretically for rotor dynamic analysis.
CO2	Analyse Free and Forced lateral response of simple rotor models and of more complex systems including shafts, bearings, seals and stators.
CO3	Formulate Finite element and carry out analysis for Turborotor System Stability.
CO4	Apply Finite element approach to blade vibration.

Scheme of Examination for Semester End Examination:

Answer Five Full questions selecting one from each unit.

To set One question each from unit II, III, V and Two questions each from units I & IV.

Course		Credits : 04				Marks	
Name	THEORY OF PLATES AND SHELLS	L	T	P	S	CIE	SEE
Code	16MEMDPETS	4	0	0	0	50	50

Course Content:

UNIT - I

Bending of long rectangular plate into a cylindrical surface: Differential equation - Bending of plates with different boundary conditions - Long plate on elastic foundation.

Pure Bending: Moment and curvature relations problems of simply supported plates-Strain energy impure bending. **10 Hours**

UNIT - II

Symmetrical Bending of Circular Plates: Differential equation uniformly loaded plates, Plates concentricity loaded plates- loaded at the center. **08 Hours**

UNIT - III

Rectangular Plates: Differential equations - Solution of simply supported plate Various loading conditions, viz, uniformly distributed load, hydrostatic pressure and concentrated load, central as well as non-central, Navier and Levy type solutions with various edge boundary conditions, viz., all edges simply supported, Two opposite edge fixed and two adjacent fixed. **10 Hours**

Bending of plate under combined action of lateral and transverse loads derivation of differential equation, simply supported rectangular plate. **06 Hours**

UNIT - IV

Introduction to Shell Structures - General description of various types. Membrane Theory of thin shells (Stress Analysis): Cylindrical shells - Spherical Shells- Shells of double curvature, Viz, cooling tower Hyperbolic, Parabolic and elliptic paraboloid. **08 Hours**

UNIT - V

Membrane Deformation of Shells: Symmetrical 'loaded shell, symmetrically loaded spherical shell. General Theory of cylindrical shells: Circular; Cylindrical shell loaded symmetrically.

General equation of circular cylindrical shells. Approximate investigation of: bending of circular cylindrical shell. **08 Hours**

Text Books:

1. Timoshenko, Woinowsky and Krieger," Theory of Plates and Shells", McGraw Hill, Newyork.
2. Ansel C Ugural, "Stresses in Plates and Shells", McGraw Hill, 3rd ed, 1985.

Reference Books

1. Wilhelm Flugge, "Stresses in Shells", Springer Verlag, Berlin, 1990.
2. Goldnvizer, "Theory of Elastic Thin Shells", Pergamon Press, New York.
3. R. Szilard, "Theory and Analysis of Plates", Prentice hall, 2004.

Course Outcomes:

Upon completion of this course, the student will be able to

CO1	Understand and develop basic equations for thin plates.
CO2	Develop pure bending equations for circular and rectangular plates.
CO3	Analyze the rectangular plates using Navier and Levy approach.
CO4	Develop equations for combined loading on plates.

Scheme of Examination for Semester End Examination:

Answer Five Full questions selecting one from each unit.

To set One question each from unit I, II, IV and Two questions each from units III & V.

ELECTIVE – IV

Course		Credits : 03				Marks	
Name	EXPERIMENTAL MECHANICS	L	T	P	S	CIE	SEE
Code	16MEMDPEEM	3	0	0	0	50	50

Course Content:

UNIT - I

Introduction: Definition of terms, calibration, standards, dimensions and units, generalized measurement system, Basic concepts in dynamic measurements, system response, distortion, impedance matching, experiment planning. General data acquisition system, Basic components, data transmission

Analysis of Experimental Data: Statistical analysis of experimental data- Probability distribution, Gaussian, normal distribution. Chi-square test, Method of least square, correlation coefficient, multivariable regression, standard deviation of mean, graphical analysis and curve fitting **8 Hours**

UNIT - II

Force, Torque and Strain Measurement: Mass balance measurement, Elastic Element for force measurement, torque measurement. Strain Gages -Strain sensitivity of gage metals, Gage construction, Gage sensitivity and gage factor, Performance characteristics, Environmental effects Strain, gage circuits, Potentiometer, Wheat Stone's bridges, Strain Analysis Methods-Two element and three element, rectangular and delta rosettes, Correction for transverse strains effects **8 Hours**

UNIT - III

Stress Analysis: Two Dimensional Photo elasticity **-** Nature of light, - wave theory of light,- optical interference - Polariscopes stress optic law - effect of stressed model in plane and circular Polariscopes, Isoclinics, Iso-chromatics fringe order determination - Fringe multiplication techniques - Calibration Photoelastic model materials.

Three Dimensional Photo elasticity: Shear difference method, Oblique incidence method, Secondary principals stresses, Scattered light photo elasticity. **9 Hours**

UNIT - IV

Coating Methods: a) Photoelastic Coating Method-Birefringence coating techniques Sensitivity Reinforcing and thickness effects - data reduction - Stress separation techniques b) Brittle Coatings Method: Brittle coating technique Principles data analysis - coating materials, Coating techniques. c) Moire Technique - Geometrical approach, Displacement approach **7 Hours**

UNIT - V

Holography: Introduction, Equation for plane waves and spherical waves, Intensity, Coherence, Spherical radiator as an object (record process), Hurter, Driffeld curves, Reconstruction process, Holograpic interferometry, Realtime. and double exposure methods, Displacement measurement, Isopachics. **7 Hours**

Text Books:

1. Holman, "Experimental Methods for Engineers" 7th Edition, Tata McGraw-Hill Companies, Inc, New York, 2007.
2. R. S. Sirohi, H. C. Radha Krishna, "Mechanical measurements" New Age International Pvt . Ltd., New Delhi, 2004.

3. Ramesh K, "Experimental Stress Analysis", e book, online solutions, 2012.
4. Srinath, Lingaiah, Raghavan, Gargesa, Ramachandra and Pant, "Experimental Stress Analysis", Tata McGraw Hill, 1984.
5. Nakra&Chaudhry, B C Nakra K K Chaudhry, "Instrumentation, Measurement And Analysis", Tata McGraw-Hill Companies, Inc, New York, Seventh Edition, 2006.

Reference Books:

1. Doeblin E. A., "Measurement Systems Application and Design", 4th (S.I.) Edition, McGraw Hill, New York. 1989.
2. Montgomery D.C., "Design and Analysis of Experiments", John Wiley & Sons, 1997.
3. Dally and Riley, "Experimental Stress Analysis", McGraw Hill, 1991.
4. Sadhu Singh, "Experimental Stress Analysis", Khanna publisher, 1990.
5. M. M. Frocht, "Photoelasticity Vol I and Vol II", John Wiley and sons, 1969.
6. Perry and Lissner, "Strain Gauge Primer", McGraw Hill, 1962.

Course Outcomes:

Upon completion of this course, the student will be able to

CO1	Understand functional requirements of a generalized measurement system and identify suitable components for an application.
CO2	Use concepts of Data Acquisition, Processing and apply the same for interpretation and analysis of experimental data.
CO3	Determine stresses and strains in a structure using different methods such as strain gages, photo-elasticity, brittle coating and holography.
CO4	Identify and apply suitable experimental stress analysis to practical problems.

Scheme of Examination for Semester End Examination:

Answer Five Full questions selecting one from each unit.
To set One question each from unit I, IV, V and Two questions each from units II & III.

Course		Credits : 03				Marks	
Name	DESIGN FOR MANUFACTURE	L	T	P	S	CIE	SEE
Code	16MEMDPEDF	3	0	0	0	50	50

Course Content:

UNIT - I

Effect of Materials And Manufacturing Process On Design: Major phases of design. Effect of material properties on design Effect of manufacturing processes on design. Material selection process-cost per unit property, Weighted properties and limits on properties methods.

Tolerance Analysis: Process capability, mean, variance, skewness, kurtosis, Process capability metrics, Cp, Cpk, Cost aspects, Feature tolerances, Geometries tolerances, Geometric tolerances, Surface finish, Review of relationship between attainable tolerance grades and different machining process. Cumulative effect of tolerance- Sure fit law and truncated normal law. **10 Hours**

UNIT - II

Selective Assembly: Interchangeable part manufacture and selective assembly, Deciding the number of groups -Model-1: Group tolerance of mating parts equal, Model total and group tolerances of shaft equal. Control of axial play-Introducing secondary machining operations, Laminated shims, examples. Datum Features: Functional datum, Datum for manufacturing, Changing the datum. Examples.

8 Hours

UNIT - III

Design Considerations: Design of components with casting consideration. Pattern, Mould, and Parting line. Cored holes and Machined holes. Identifying the possible and probable parting line. Casting requiring special sand cores. Designing to obviate sand cores. Component Design: Component design with machining considerations link design for turning components-milling, Drilling and other related processes including finish- machining operations. **10 Hours**

UNIT - IV

True positional theory: Comparison between co-ordinate and convention method of feature location. Tolerance and true position tolerancing virtual size concept, Floating and fixed fasteners. Projected tolerance zone. Assembly with gasket, zero position tolerance. Functional gauges, Paper layout gauging.

6 Hours

UNIT - V

Design of Gauges: Design of gauges for checking components in assemble with emphasis on various types of limit gauges for both hole and shaft. **5 Hours**

Text Books:

1. Harry Peck, "Designing for Manufacturing", Pitman Publications, 1983.
2. Dieter , "Machine Design" - McGraw-Hill Higher Educ ation, -2008.
3. R.K. Jain, "Engineering Metrology", Khanna Publishers, 1986.
4. Geoffrey Boothroyd, Peter dewhurst, Winston Knight, "Product design for manufacture and assembly", Merceldekker. Inc. CRC Press, Third Edition
5. Material selection and Design, Vol. 20 - ASM Hand book.

Course Outcomes:

Upon completion of this course, the student will be able to

CO1	Understand the role of manufacture and assembly in development of mechanical parts and their assemblies.
CO2	Apply manufacturing considerations in the design and development of components made of casting and machining.
CO3	Apply geometrical dimensioning and tolerances issues in mechanical design.

Scheme of Examination for Semester End Examination:

Answer Five Full questions selecting one from each unit.
To set One question each from unit II, IV, V and Two questions each from units I & III.

Course		Credits : 03				Marks	
Name	ROBOTICS	L	T	P	S	CIE	SEE
Code	16MEMDPERB	3	0	0	0	50	50

Course Content:

UNIT - I

Introduction and Mathematical Representation of Robots: History of Robots, Types of Robots, Notation, Position and Orientation of a Rigid Body, Properties of Rotation Matrices, Successive Rotations, Representation by X-Y-Z, Z-Y-Z Euler Angles, Transformation between coordinate system, Homogeneous coordinates, Properties of , T A B Types of Joints: Rotary, Prismatic joint, Cylindrical joint, Spherical joint, Representation of links using Denvit-Hartenberg parameters: Link parameters for intermediate, first and last links, Link transformation matrices, Transformation matrices of 3R manipulator, PUMA560 manipulator, SCARA manipulator, The planar four bar mechanisms, Three DOF parallel manipulator, A six-DOF parallel(hybrid) manipulator.

Kinematics of Serial and Parallel Manipulators: Degrees of freedom of a manipulator, Loop constraint equations. Direct kinematics of 2R and 3R manipulator, Puma560 manipulator, SCARA manipulator, Stanford arm, The Planar four bar mechanism, Direct kinematics of Stewart-Gough Platform. Inverse kinematics of 2R, 3R manipulator, Inverse kinematics of Stewart- Gough Platform. **11 Hours**

UNIT - II

Velocity and Statics of Manipulators: Differential relationships, Jacobian, Differential motions of a frame (translation and rotation), Linear and angular velocity of a rigid body, Linear and angular velocities of links in serial manipulators, 2R, 3R manipulators, Jacobian of serial manipulator, Three DOF parallel manipulator. Velocity ellipse of 2R manipulator, Singularities of serial and parallel manipulators 2R, 3R, four bar mechanism, three DOF parallel manipulator, Statics of serial manipulators, Static force and torque analysis of 3R manipulator, Statics of parallel manipulator, Singularity in force domain.

Dynamics of Manipulators: Inertia of a link, Recursive formulation of dynamics using Newton Euler equation, Equation of motion of 2R and 3R manipulators using Lagrangian, Newton-Euler formulation. **12 Hours**

UNIT - III

Trajectory Planning: Joint space schemes, cubic trajectory, Joint space schemes with via points, Cubic trajectory with a via point, Third order polynomial trajectory planning, Linear segments with parabolic blends, Cartesian space schemes, Cartesian straight line and circular motion planning, Trajectory planning for orientation. **5 Hours**

UNIT - IV

Control: Feedback control of a single link manipulator- first order, second order system, PID control, PID control of multi-link manipulator, Non-linear control of manipulators-computed torque method, Force control of manipulator, Cartesian control of manipulators, Force control of manipulators-force control of single mass, Partitioning a task for force and position control- lever, peg in hole Hybrid force and position controller. **5 Hours**

UNIT - V

Actuators: Types, Characteristics of actuating system: weight, Power to- weight ratio, Operating pressure, Stiffness vs. compliance, Use of reduction gears, Comparison of hydraulic, Electric, pneumatic, actuators, Hydraulic actuators, Proportional feedback control, Electric Motors: DC motors, Reversible AC motors, Brushless DC motors, Stepper motors- structure and principle of operation, Stepper motor speed-torque characteristics.

Sensors: Sensor characteristics, Position sensors- potentiometers, Encoders, LVDT, Resolvers, Displacement sensor, Velocity sensor- encoders, tachometers, Acceleration sensors, Force and Pressure sensors - piezoelectric, force sensing resistor, Torque sensors, Touch and tactile sensor, Proximity sensors-magnetic, Optical, Ultrasonic, Inductive, Capacitive, Eddy-current proximity sensors. **6 Hours**

Text Books:

1. Ghosal A., "Fundamental Concepts and Analysis – Robotics", Oxford, 2006.
2. Niku, S. B., "Introduction to Robotics Analysis - Systems Applications", Pearson Education, 2008.

Reference Books:

1. Craig, J. J., "Introduction to Robotics: Mechanica and Control - 2nd ed, Addison-Welsey, 1989.
2. Schilling R. J., "Fundamentals of Robotics, Analysis and Control", PHI, 2006.
3. Fu, K, S., Gonzalez R. C., Lee C.S. G., "Robotics Control, Sensing, Vision and Intelligence", McGraw Hill, 1987.

Course Outcomes:

Upon completion of this course, the student will be able to

CO1	Formulate a representation for links using Denvit-Hartenberg parameters.
CO2	Derive and analyze the velocity and statics of a manipulator.
CO3	Plan and develop trajectory with different schemes.
CO4	Characterize and choose different actuators and sensors for robotic applications.

Scheme of Examination for Semester End Examination:

Answer Five Full questions selecting one from each unit.
To set One question each from unit III, IV, V and Two questions each from units I & II.

Course		Credits : 01				Marks	
Name	**DESIGN LABORATORY – 2**	**L**	**T**	**P**	**S**	**CIE**	**SEE**
Code	16MEMDPCD2	**0**	**0**	**1**	**0**	**50**	**50**

Course Content:

Experiment #1
Structural Analysis
Part A: FE Modeling of a stiffened Panel using a commercial preprocessor.
Part B: Buckling, Bending and Modal analysis of stiffened Panels.
Part C: Parametric Studies.

Experiment #2
Design Optimization
Part A: Shape Optimization of a rotating annular disk.
Part B: Weight Minimization of a Rail Car Suspension Spring.
Part C: Topology Optimization of a Bracket.

Experiment #3
Thermal analysis
Part A: Square Plate with Temperature Prescribed on one edge and Opposite edge insulated.
Part B: A Thick Square Plate with the Top Surface exposed to a Fluid at high temperature, Bottom Surface at room temperature, Lateral Surfaces Insulated.

Experiment #4
Thermal Stress Analysis
Part A: A Thick Walled Cylinder with specified Temperature at inner and outer Surfaces.
Part B: A Thick Walled Cylinder filled with a Fluid at high temperature and Outer Surface exposed to atmosphere.

Experiment#5
CFD Analysis
Part A: CFD Analysis of a Hydro Dynamic Bearing using commercial code.
Part B: Comparison of predicted Pressure and Velocity distributions with Target solutions.
Part C: Experimental Investigations using a Journal Bearing Test Rig.
Part D: Correlation Studies.

Experiment #6
Analysis of Welded Joints.
Part A: Fabrication and Testing.
Part B: FE Modeling and Failure Analysis.
Part C: Correlation Studies.

Experiment #7
Analysis of Bolted Joints.
Part A: Fabrication and Testing.
Part B: FE Modeling and Failure Analysis.
Part C: Correlation Studies.

Experiment #8
Adhesive Bonded Joints.
Part A: Fabrication and Testing.
Part B: FE Modeling and Failure Analysis.
Part C: Correlation Studies.

Course Outcomes:
Upon completion of this course, the student will be able to

CO1	Get basic knowledge of Buckling, bending, CFD, Bolted and Welded joints.
CO2	Fabricate and test Bolted, Welded and Adhesive bonded joints.
CO3	Perform FE modelling and optimization of simple panels, joints and rotating discs.
CO4	Demonstrate Failure, Thermal and CFD analysis of FE models using different software packages

Course		Credits : 21				Marks	
Name	**INTERNSHIP / INDUSTRIAL TRAINING**	**L**	**T**	**P**	**S**	**CIE**	**SEE**
Code	16MEMDPCIN	**0**	**0**	**21**	**0**	**100**	**100**

Course Objectives:
To satisfy the requirements for the internship, students will:

- explain the operation of the industrial facility in which they worked
- describe the professional skills they developed during their internship
- demonstrate communication skills (written and oral)

Course Outcomes:
Upon completion of this course, the student will be able to

CO1	Design/ appraise the working of a system/organization, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
CO2	Function in multi-disciplinary teams
CO3	Identify, formulate, and solve engineering problems
CO4	Understand professional and ethical responsibility
CO5	Gain knowledge of contemporary issues
CO6	Use the techniques, skills, and modern engineering tools necessary for engineering practice

Course		Credits : 02				Marks	
Name	**TECHNICAL SEMINAR**	**L**	**T**	**P**	**S**	**CIE**	**SEE**
Code	16MEMDPCS2	**0**	**0**	**2**	**0**	**100**	**100**

Course Outcomes:
Upon completion of this course, the student will be able to

CO1	Identify and understand current trends and real-world issues related to topics in Machine Design.
CO2	Classify appropriate content and sources, through literature survey, that can be summarised and integrated into presentation
CO3	Review, analyse, and interpret data & results using critical thinking skills
CO4	Revise and present scientific case studies in presentation
CO5	Collaborate effectively with other students in analysing results and preparing oral presentations
CO6	Prepare a technical seminar report and communicate effectively through oral presentation using multimedia tools

Course		Credits : 27				Marks	
Name	**PROJECT WORK**	**L**	**T**	**P**	**S**	**CIE**	**SEE**
Code	16MEMDPCP1 & 16MEMDPCPR	**0**	**0**	**27**	**0**	**200**	**200**

Course Outcomes:

Upon completion of this course, the student will be able to

CO1	Apply relevant knowledge and skills acquired during the course in the domain to the problem on hand
CO2	Formulate the specifications of the project work, identify a set of feasible solutions and prepare and execute project plan considering professional, cultural and societal factors
CO3	Extract information pertinent to problem using literature survey
CO4	Analyze independently and discuss complex issues
CO5	Use appropriate techniques and tools to conduct experiments, analyze data
CO6	Evaluate and critically examine the outcomes of one's own work and others' work
CO7	Draw suitable conclusions based on the results and identify relevant applications
CO8	Document the findings and prepare a report in the prescribed format
CO9	Demonstrate working knowledge of ethics and professional responsibility at different stages such as formulation, design, implementation, and presentation
CO10	Publish the outcomes of the project work in a reputed journal, make effective presentation of the work and communicate confidently in defending the work

ASSESSMENT:

Continuous Internal Evaluation (CIE) includes mid-term tests, weekly/fortnightly class tests, homework assignments, problem solving, group discussions, quiz, seminar, mini- project and other Alternate Assessment Tools (AAT) prescribed by the faculty handling a course prior to beginning of the classes.

Semester End Examination (SEE) - A written examination for theory courses and practical/design examination with built-in oral part (Viva-Voce).

Both CIE and SEE have equal (50:50) weightage. The Student's performance in a course shall be judged individually and together based on the results of CIE and SEE.

Breakup of CIE Components for Courses in General:

Component	Test-1	Test-2	AAT	Total Marks
Maximum Marks	15	15	20	50

Breakup of CIE Components for Integrated Courses:

Component	Theory			Practical		Total Marks
	Test-1	Test-2	AAT	Records & Performance	Lab Test Viva-Voce	
Maximum Marks	10	10	05	10	15	50

Breakup of CIE Components for Comprehensive Courses:

Component	Theory			Practical	Self-Study	Total Marks
	Test-1	Test-2	AAT	Lab Performance / Record Lab Test		
Maximum Marks	10	10	05	15	10	50

Note:

Alternate Assessment Tools, if any, will be announced by concerned Faculty at the beginning of the semester.

In case of Alternative Assessment Tools (such as term papers, assignments, problem solving, micro-projects, seminars, MOOCs etc.) being used by a faculty for a particular course, a maximum of 40% of the total CIE marks can be utilized.