# NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

# M.TECH – Machine Design

## SCHEME OF INSTRUCTION AND SYLLABI

**for M.Tech. Programme in Machine Design**

**(Effective from 2021-22)**

## DEPARTMENT OF MECHANICAL ENGINEERING

## Vision and Mission of the Institute
## National Institute of Technology Warangal

### VISION

Towards a Global Knowledge Hub, striving continuously in pursuit of excellence in Education, Research, Entrepreneurship and Technological services to the society

### MISSION

- Imparting total quality education to develop innovative, entrepreneurial and ethical future professionals fit for globally competitive environment.
- Allowing stake holders to share our reservoir of experience in education and knowledge for mutual enrichment in the field of technical education.
- Fostering product-oriented research for establishing a self-sustaining and wealth creating centre to serve the societal needs.

## Vision and Mission of the Department
## Department of Mechanical Engineering

### VISION

- To be a global knowledge hub in mechanical engineering education, research, entrepreneurship and industry outreach services.

### MISSION

- Impart quality education and training to nurture globally competitive mechanical engineers.

- Provide vital state-of-the-art research facilities to create, interpret, apply and disseminate knowledge.

- Develop linkages with world class educational institutions and R&D organizations for excellence in teaching, research and consultancy services.

## Department of Mechanical Engineering:

### Brief about the Department

The Department of Mechanical Engineering was established in the year 1959. The department presently offers one Under Graduate Programme, i.e., B.Tech in Mechanical Engineering with an intake of 170 students, seven M.Tech programs - Thermal Engineering, Manufacturing Engineering, Computer Integrated Manufacturing, Machine Design, Automobile Engineering, Materials and Systems Engineering Design, Additive Manufacturing, - one PG Diploma in Additive Manufacturing and Ph.D programs. At present, the Department has 48 faculty members with research expertise in different specializations of Mechanical Engineering. The Department has good research facilities for both experimental as well as simulation-based research. The department has liaison with reputed industries and R&D organizations such as NFTDC, DMRL, DRDL, ARCI, BHEL, CPRI, CMTI etc. All the faculty of the department are actively engaged in R&D and Consultancy. Presently the department is handling about 25 funded projects worth Rs. 3.00 Crores. The department has recently acquired Metal 3D Printer at a cost of Rs.1.4 Crores under TEQIP -III grants. The institute is establishing SIEMENS Centre of Excellence in Digital Manufacturing and Industry 4.o in which the department is playing a key role. The department produces a large number of publications, and offers solutions to the industry regularly and is also active with regular outreach activities like workshops, conferences and executive programs for industry personnel. The department has been recognized as QIP Centre for M.Tech and Ph. D. programmes.

**List of Programs offered by the Department:**

| Program | Title of the Program |
|---|---|
| B.Tech. | Mechanical Engineering |
| M.Tech. | Thermal Engineering |
| | Automobile Engineering |
| | Manufacturing Engineering |
| | Machine Design |
| | Computer Integrated Manufacturing |
| | Materials and Systems Engineering Design |
| | Additive Manufacturing |
| PG Diploma | Additive Manufacturing |
| Ph.D. | Mechanical Engineering |

**Note: Refer to the following weblink for Rules and Regulations of M.Tech. program:**
**https://www.nitw.ac.in/main/MTechProgram/rulesandregulations/**

# M.Tech. – Machine Design

## Programme Educational Objectives:

Programme Educational Objectives (PEOs) are broad statements that describe the career and professional accomplishments that the programme is preparing graduates to achieve. They are consistent with the mission of the Institution and Department. Department faculty members continuously worked with stakeholders (local employers, industry and R&D advisors and the alumni) to review and update them periodically.

| | |
|---|---|
| **PEO1** | Analyze the concepts and tools for design and development of machine components and systems. |
| **PEO2** | Analyze the physical systems and establish schematics and mathematical models |
| **PEO3** | Design, analyze and simulate mechanical components and systems. |
| **PEO4** | Develop life skills to become design professionals, administrators and Academicians**.** |
| **PEO5** | Engage in lifelong learning to adopt socio-economic -technological developments |

## M.Tech. – Machine Design Programme Programme Articulation Matrix

| PEO / Mission Statements | PEO1 | PEO2 | PEO3 | PEO4 | PEO5 |
|---|---|---|---|---|---|
| Impart quality education and training to nurture globally competitive mechanical engineers | 3 | 3 | 2 | 2 | 2 |
| Provide vital state-of-the-art research facilities to create, interpret, apply and disseminate knowledge | 3 | 3 | 2 | 2 | 2 |
| Develop linkages with world class educational institutions and R&D organizations for excellence teaching, research and consultancy services | 3 | 3 | 2 | 2 | 2 |

1-Slightly 2-Moderately 3-Substantially

# M.Tech. – Machine Design

## Programme Outcomes:

**Programme Outcomes** (POs) are narrower statements that describe what the students are expected to know and be able to do upon the graduation. These relate to the knowledge, skills and behavior the students acquire through the programme. The POs are specific to the programme and facilitate the attainment of PEOs.

At the end of the programme the student shall be able to:

| | |
|---|---|
| **PO1** | Carryout independent research/investigation and development work to solve practical problems |
| **PO2** | Write and present a substantial technical report/document |
| **PO3** | Demonstrate a degree of mastery in machine design at a level higher than the bachelors programme |
| **PO4** | Use state of art tools and techniques to model and analyze machine components |
| **PO5** | Design, develop and evaluate mechanical components and systems |
| **PO6** | Engage in lifelong learning adhering to professional, ethical, legal, safety, environmental and societal aspects for career excellence. |

## MAPPING OF PROGRAMME OUTCOMES WITH PROGRAMME EDUCATIONAL OBJECTIVES:

| Programme outcomes | PEO1 | PEO2 | PEO3 | PEO4 | PEO5 |
|---|---|---|---|---|---|
| **PO1** | 2 | 3 | 2 | 2 | 3 |
| **PO2** | 3 | 2 | | 2 | 2 |
| **PO3** | 2 | 2 | | 2 | 3 |
| **PO4** | 3 | 3 | 2 | 2 | 3 |
| **PO5** | 3 | 2 | 3 | 3 | 2 |
| **PO6** | 2 | 2 | 3 | 3 | 3 |

1: Slightly 2: Moderately 3: Substantially

## CREDITS IN EACH SEMESTER

| Category | I Year, Sem – I | I Year, Sem – II | II Year, Sem – I | II Year, Sem – II | Total No. of credits to be earned |
|---|---|---|---|---|---|
| Core courses | 12 | 06 | -- | -- | **18** |
| Electives | 06 | 12 | -- | -- | **18** |
| Lab Courses | 04 | 04 | -- | -- | **08** |
| ComprehensiveViva-Voce (CVV) | -- | -- | 02 | -- | **02** |
| Seminar (SEM) | 01 | 01 | -- | -- | **02** |
| Dissertation (DW) | -- | -- | 12 | 20 | **32** |
| **Total** | **23** | **23** | **14** | **20** | **80** |

# SCHEME OF INSTRUCTION

## M.Tech. Machine Design – Course Structure

### M. Tech I - Year, I – Semester

| S. No. | Course Code | Course Title | L | T | P | Credits | Cat. Code |
|---|---|---|---|---|---|---|---|
| 1. | ME 5401 | Advanced Mechanical Design | 3 | 0 | 0 | 3 | PCC |
| 2. | ME 5402 | Advanced Mechanics of Solids | 3 | 0 | 0 | 3 | PCC |
| 3. | ME 5403 | Mechanical Vibrations | 3 | 0 | 0 | 3 | PCC |
| 4. | ME 5404 | Computer Aided Geometric Design | 3 | 0 | 0 | 3 | PCC |
| 5. | | Elective-1 | 3 | 0 | 0 | 3 | PEC |
| 6. | | Elective-2 | 3 | 0 | 0 | 3 | PEC |
| 7. | ME 5408 | Numerical Simulation Lab | 0 | 0 | 3 | 2 | PCC |
| 8. | ME 5409 | Machine Dynamics Lab | 0 | 0 | 3 | 2 | PCC |
| 9. | ME 5448 | Seminar – 1 | 0 | 0 | 2 | 1 | SEM |
| | | | **Total** | | | **23** | |

### M. Tech I - Year, II – Semester

| S. No. | Course Code | Course Title | L | T | P | Credits | Cat. Code |
|---|---|---|---|---|---|---|---|
| 1. | ME 5451 | Product Design & Development | 3 | 0 | 0 | 3 | PCC |
| 2. | ME 5452 | Finite Element Analysis for Design | 3 | 0 | 0 | 3 | PCC |
| 3. | | Elective-3 | 3 | 0 | 0 | 3 | PEC |
| 4. | | Elective-4 | 3 | 0 | 0 | 3 | PEC |
| 5. | | Elective-5 | 3 | 0 | 0 | 3 | PEC |
| 6. | | Elective-6 | 3 | 0 | 0 | 3 | PEC |
| 7. | ME 5458 | Tribology and Composites Lab | 0 | 0 | 3 | 2 | PCC |
| 8. | ME 5459 | Modelling and Analysis Lab | 0 | 0 | 3 | 2 | PCC |
| 9. | ME 5498 | Seminar – 2 | 0 | 0 | 2 | 1 | SEM |
| | | | **Total** | | | **23** | |

## M. Tech II - Year, I – Semester

| S No | Course Code | Course Title | Credits | Cat. Code |
|---|---|---|---|---|
| 1 | ME6447 | Comprehensive Viva Voce | 2 | CVV |
| 2 | ME6449 | Dissertation Part A | 12 | DW |
| | | **Total** | **14** | |

## M. Tech II - Year, II – Semester

| S No | Course Code | Course Title | Credits | Cat. Code |
|---|---|---|---|---|
| 1 | ME6499 | Dissertation Part B | 20 | DW |
| | | **Total** | **20** | |

## Programme Elective Courses

| List of Electives (I Year, I Semester) | | |
|---|---|---|
| **S. No.** | **Course Code** | **Course** |
| 1 | ME5411 | Mechanics of Composite Materials |
| 2 | ME5412 | Characterization of Engineering Materials |
| 3 | ME5413 | Analysis and Synthesis of Mechanisms |
| 4 | ME5414 | Automatic Controls |
| 5 | ME5415 | Mathematical Methods in Engineering |
| 6 | ME5416 | Failure Analysis and Design |
| 7 | ME5417 | Mechanics and Processing of Polymer Materials |
| **List of Electives (I Year, II Semester)** | | |
| **S. No.** | **Course Code** | **Course** |
| 1 | ME5461 | Fracture Mechanics |
| 2 | ME5462 | Condition Monitoring and Fault Diagnostics |
| 3 | ME5463 | Rotor Dynamics |
| 4 | ME5464 | Theory of Plates and Shells |
| 5 | ME5465 | Smart Materials and Sensors |
| 6 | ME5466 | Tribology in Design |
| 7 | ME5467 | Advanced Composite Technologies |
| 8 | ME5468 | Robotics |
| 9 | ME5469 | Optimization Methods for Engineering Design |
| 10 | ME5552 | Vehicle Dynamics |
| 11 | ME5371 | AI and ML for Mechanical Systems |

# DETAILED SYLLABUS

## M.Tech. – Machine Design

# DETAILED SYLLABUS

# PROGRAMME CORE COURSES

# (I – YEAR, I – SEMESTER)

| Course Code: ME 5401 | ADVANCED MECHANICAL DESIGN | Credits 3-0-0: 3 |
|---|---|---|

Prerequisite: Nil

**Course Outcomes:**

At the end of the course, the student shall be able to:

| | |
|---|---|
| **CO1** | Design mechanical components by selecting a suitable material and failure criteria. |
| **CO2** | Evaluate fatigue life of mechanical components for ductile and brittle materials. |
| **CO3** | Analyze and predict the fracture strength of mechanical components under different fracture modes. |
| **CO4** | Design mechanical components involving contacts avoiding the surface failures. |

**Course Articulation Matrix:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 2 | 3 | 3 | 2 |
| **CO2** | 2 | | 2 | 3 | 3 | 2 |
| **CO3** | 2 | | 3 | 2 | 2 | 3 |
| **CO4** | 3 | 2 | 3 | 3 | 2 | 3 |

**Syllabus:**

**Material selection for design**

Engineering Design process and the role of materials; Materials classification and their properties; Types of Material Failure – Elastic & Plastic Deformation, Creep deformation, Fatigue fracture under static and impact loading, Fatigue under cyclic loading, Combined effects; Design and Materials Selection – Iterative and Stepwise nature design, Safety factors, Prototype and Component Testing, Service Experience, Examples of material selection for typical applications; Fundamentals of Plasticity – Theory of limit design, Bauschinger effect, Ludwik, Hollomon equations and voce equation.

**Review of fundamental concepts:** Load analysis - 2D and 3D static load analysis; Case studies of static load analysis - Bicycle hand brake lever, Bicycle with pedal arm, Plier-wrench; Understanding of static failure for ductile and brittle materials; Comparison of experimental data with failure theories; Significance of the theories of failure; Importance of factor of safety in design; Design case studies - Bracket, Bicycle hand brake lever, Bicycle with pedal arm, Plier-wrench.

**Fatigue failure theories:** Introduction to fatigue; Fatigue failure models; Fatigue life; Estimation of theoretical fatigue strength; Correction factors to the theoretical fatigue strength; Stress concentration; Cumulative damage and life exhaustion; Effect of mean stress on the fatigue failure; Designing for fully reversed uniaxial stresses; Designing for fluctuating uniaxial stresses; Designing for multi-axial stresses in fatigue.

**Introduction to fracture and creep:** Fundamentals of Fracture mechanics; Mechanism of fracture - Cleavage fracture, Ductile fracture and Inter-granular fracture; Griffiths theory; Orowan theory; Theoretical fracture strength; Irwin's fracture analysis; Design case studies - Bicycle with pedal arm, Plier-wrench.
Fundamentals of degradation; Creep mechanisms; Temperature dependence of creep; Correlations to determine rupture time under creep condition – Larson – Miller, Manson and Haferd, Orr-Sherby-Dorn.

**Design for failure prevention:** Surface Geometry; Mating surfaces; Friction; Surface failures - Adhesive wear, Abrasive wear, Corrosion wear, Surface fatigue wear; Static and Dynamic Contact stresses – Spherical contact, Cylindrical contact and General contact, Design Case Studies – Ball bearing, Cylindrical roller bearing, Cam-follower contact.

## Learning Resources:


1. Machine design an integrated approach, Robert L Norton, Pearson Education, Second edition, 2009.
2. Mechanical Engineering Design, Richard G. Budynas, J Keith Nisbett, Shigley's McGraw Hill, Ninth edition, 2011.
3. Mechanical Behavior of materials, Marc Meyers and Krishan Chawla, CambridgeUniversity Press, 2nd Edition, 2009.
4. Mechanical properties of engineered materials, Wolé Soboyejo, Marcel Dekker, Inc.,2002.
5. Elements of Fracture Mechanics, Prashant Kumar, McGraw Hill Education (India)Private Limited, 2014.
6. Materials Selection in Design, Ashby, M.F., Butterworth-Heinemann, 4/e, 2010.

| Course Code: ME 5402 | ADVANCED MECHANICS OF SOLIDS | Credits 3-0-0: 3 |
|---|---|---|

Prerequisite: Nil

**Course Outcomes:**

At the end of the course, the student shall be able to:

| | |
|---|---|
| **CO1** | Analyze state of stresses and strains in a 3-D continuum |
| **CO2** | Establish stress-strain relations for deformable solids |
| **CO3** | Analyze mechanical structures using energy methods. |
| **CO4** | Evaluate stresses in symmetrical and asymmetrical beams |
| **CO5** | Analyze thin wall beams, torsional bars and axisymmetric problems |

**Course Articulation Matrix:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 3 | 3 | 3 | 2 |
| **CO2** | 3 | | 3 | 2 | 3 | 2 |
| **CO3** | 3 | 2 | 2 | 2 | 3 | 2 |
| **CO4** | 3 | | 2 | | 2 | 2 |
| **CO5** | 3 | 2 | 2 | | 2 | 2 |

**Syllabus:**

**Analysis of Stress:** Introduction, Body Force, surface force and stress tensor, The state of stress at a point, Normal, Shear and Rectangular stress components, Stress components on an arbitrary plane, Equality of cross shears, A more general theorem, Principal stresses, Stress invariants, Principal planes, cubic equations, The state of stress referred to principal axes, Mohr's circles for the 3-D state of stress, Octahedral stresses, the state of pure shear, Lame's Ellipsoid, The plane state of stress, Differential equations of equilibrium, Equations of equilibrium in cylindrical coordinates, Axisymmetric case and plane stress case.

**Analysis of Strain**: Introduction, Deformations in the neighbourhood of a point, Change in length of a linear element, Change in length of a linear element-linear components, The state of strain at a point, Interpretation of shear strain components, Cubical dilatation, angle between two-line elements, Principal axes of strain and principal strains, Plane state of strain, Plane strains in polar coordinates, Compatibility conditions.

**Stress-Strain Relations for Linearly Elastic Solids:** Introduction, generalized statement of Hooke's law, Stress-strain relations for isotropic materials, Modulus of rigidity, bulk modulus, Young's modulus and poison's ratio, Relation between the elastic constants, Displacement equations of equilibrium.

**Energy Methods:** Hooke's law and the principle of superposition, Work done by forces and elastic strain energy, Maxwell-Betti-Rayleigh Reciprocal theorem,

First and second theorem of Castigliano, expressions for strain energy when an elastic member is subjected to axial force, Shear force, Bending moment and Torsion. Theorem of virtual work, Kirchhoff's theorem.

**Bending of Beams:** Straight beams and asymmetrical bending, shear center or center of flexure, shear stresses in thin walled open sections: Bending of curved beams (Winkler –Bach formula).

**Torsion:** Torsion of general prismatic bars-solid sections, Torsion of circular, elliptical, triangular bars, Torsion of thin walled tubes and multiple closed sections, center of twist and flexure center.

**Axi-symmetric Problems:** Thick walled cylinder subjected to internal and external pressures-Lames-problems, sphere with purely radial displacements, rotating disc of uniform thickness, rotating shafts and cylinders.

## Learning Resources:


1. Advanced Mechanics of Solids, L.S. Srinath, 3rd Edition, TMH, 2009.
2. Mechanics of Deformable Solids, Irving H. Shames, Krieger Pub Co, 2008.
3. Advanced Mechanics of Solids Otto T. Bruhns, Springer, 2003
4. Theory of Elasticity, Sadhu Singh, 4th edition, Khanna Publishers, 2015
5. Theory of Elasticity, Timoshenko and Goodier, 3rd Edition, TMH, 2011

| Course Code: ME 5403 | MECHANICAL VIBRATIONS | Credits 3-0-0: 3 |
|---|---|---|

Prerequisite: Nil

**Course Outcomes:**

At the end of the course, the student shall be able to:

| | |
|---|---|
| **CO1** | Analyze the causes and effects of vibrations in mechanical systems andidentify discrete and continuous systems. |
| **CO2** | Model the physical systems into schematic models and formulate thegoverning equations of motion. |
| **CO3** | Compute the free and forced vibration responses of multi degree of freedomsystems through modal analysis and interpret the results. |
| **CO4** | Analyze and design systems involving unbalances, transmissibility, vibrationisolation and absorption. |
| **CO5** | Analyze and design to control and reduce vibration effects in machinery. |

**Course Articulation Matrix:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 3 | 2 | | 2 | 2 |
| **CO2** | 3 | 3 | 3 | | 2 | 2 |
| **CO3** | 2 | 3 | 2 | 2 | 3 | 2 |
| **CO4** | 3 | 3 | 2 | | 3 | 2 |
| **CO5** | 2 | 3 | 2 | 2 | 3 | 2 |

**Syllabus:**

**Introduction**: Causes and effects of vibration, Classification of vibrating system, Discrete and continuous systems, degrees of freedom, Identification of variables and Parameters, Linear and nonlinear systems, linearization of nonlinear systems, Physical models, Schematic models and Mathematical models.

**Single Degree of Freedom (SDF) systems:** Formulation of equation of motion: Newton – Euler method, De Alembert's method, Energy method, Free Vibration: Undamped Free vibration response, Damped Free vibration response, Case studies on formulation and response calculation. Forced vibration response of SDF systems: Response to harmonic excitations, solution of differential equation of motion, Vector approach, Complex frequency response, Magnification factor Resonance, Rotating/reciprocating unbalances.

**Dynamics of Rotors**: Whirling of rotors, Computation of critical speeds, influence of bearings, Critical speeds of Multi rotor systems.

**Design case studies**: Design case studies dealing with Transmissibility of forces and motion, Vehicular suspension, Analysis of Vehicles as single degree of freedom systems -vibration transmitted due to unevenness of the roads, preliminary design of automobile suspension. Design of machine foundations and isolators.

**Two degree of freedom systems:** Introduction, Formulation of equation of motion: Equilibrium method, Lagrangian method, Case studies on formulation of equations of motion, Free vibration response, Eigen values and Eigen vectors, Normal modes and mode superposition, Coordinate coupling, decoupling of equations of motion, Natural coordinates, Response to initial conditions, coupled pendulum, free vibration response case studies, Forced vibration response, Automobile as a two degree of freedom system –bouncing and pitching modes undamped vibration absorbers, Case studies on identification of system parameters and design of undamped vibration absorbers. Analysis and design of damped vibration absorbers.

**Multi degree of freedom systems:** Introduction, Formulation of equations of motion, Free vibration response, Natural modes and mode shapes, Orthogonally of modal vectors, normalization of modal vectors, Decoupling of modes, modal analysis, mode superposition technique, Free vibration response through modal analysis, Forced vibration analysis through modal analysis, Modal damping, Rayleigh's damping, Introduction to experimental modal analysis.

**Continuous systems:** Introduction to continuous systems, discrete vs continuous systems, Exact and approximate solutions, free vibrations of bars and shafts, Free vibrations of beams, Forced vibrations of continuous systems Case studies, Approximate methods for continuous systems and introduction to Finite element method.

**Vibration control in structures**: Introduction, State space representation of equations of motion. Passive control, active control and semi active control, Free layer and constrained damping layers, Piezo electric sensors and actuators for active control, semi active control of automotive suspension systems.

## Learning Resources:


1. Elements of Vibration Analysis, L. Meirovich, 2nd Ed. Tata Mc-Grawhill, 2007
2. Mechanical Vibrations. S Rao, 4th Ed., Pearson education, 2011
3. Theory of Vibration, W.T, Thompson, CBS Publishers
4. Vibration: Fundamentals and Practice, Clarence W. De Silva , CRC Press LLC,2000
5. Mechanical Vibrations, Venkatachalam R., PHI Publications, 2018

| Course Code: ME 5404 | COMPUTER-AIDED GEOMETRIC DESIGN | Credits 3-0-0: 3 |
|---|---|---|

Prerequisite: Nil

**Course Outcomes:**

At the end of the course, the student shall be able to:

| | |
|---|---|
| **CO1** | Apply geometric transformations and projection methods in CAD |
| **CO2** | Develop geometric models to represent curves |
| **CO3** | Design surface and solid models for engineering design |
| **CO4** | Apply mesh generation techniques for engineering analysis |

**Course Articulation Matrix:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | | 3 | 3 | 2 | 2 |
| **CO2** | 3 | | 3 | 3 | 2 | 2 |
| **CO3** | 3 | 2 | 3 | 3 | 3 | 2 |
| **CO4** | 3 | 2 | 3 | 3 | 3 | 2 |

**Syllabus:**

**Introduction:** Introduction to CAE, CAD. Role of CAD in Mechanical Engineering, Design process, software tools for CAD, Geometric modelling.

**Transformations in Geometric Modeling**: Introduction, Translation, Scaling, Reflection, Rotation in 2D and 3D. Homogeneous representation of transformation, Concatenation of transformations. Computer-Aided assembly of rigid bodies, Applications of transformations in design and analysis of mechanisms, etc. Implementation of the transformations using computer codes.

**Projections:** Projective geometry, transformation matrices for Perspective, Axonometric projections, Orthographic and Oblique projections. Implementation of the projection formulations using computer codes.

**Introduction to Geometric Modeling for Design:** Introduction to CAGD, CAD input devices, CAD output devices, CAD Software, Display Visualization Aids, and Requirements of Modelling.

**Curves in Geometric Modeling for Design:** Differential geometry of curves, Analytic Curves, PC curve, Ferguson's Cubic Curve, Composite Ferguson, Curve Trimming and Blending. Bezier segments, de Casteljau's algorithm, Bernstein polynomials, Bezier-subdivision, Degree elevation, Composite Bezier. B-spline basis functions, Properties of basic functions, Knot Vector generation, NURBS, Conversionof one form of curve to other. Implementation of the all the curve models using computer codes in an interactive manner.

**Surfaces in Geometric Modeling for Design**: Differential geometry of surfaces, Parametric

representation, Curvatures, Developable surfaces. Surfaces entities (planar, surfac of revolution, lofted etc). Free-for surface models (Hermite, Bezier, B-spline surface). Boundary interpolating surfaces (Coon's). Implementation of the all the surface models using computer codes.

**Solids in Geometric Modeling for Design:** Solid entities, Boolean operations, Topological aspects, Invariants. Write-frame modeling, B-rep of Solid Modelling, CSG approach of solid modelling. Popular modeling methods in CAD softwares. Data Exchange Formats and CAD Applications:

**Meshing Methods for Engineering Analysis**: FEM, Meshing, Quality of meshing, Mesh generation methods.

## Learning Resources:


1. Geometric Modeling, Michael E. Mortenson, Tata McGraw Hill, 2013.
2. Computer-Aided Engineering Design, Saxena and B. Sahay, AnamayaPublishers, New Delhi, 2005.
3. An introduction to NURBS: with historical perspective, Rogers, David F.MorganKaufmann Publishers, USA, 2001.
4. Mathematical Elements for Computer Graphics, David F. Rogers, J. A. Adams, TMH,2008.
5. Principles of CAD/CAM/CAE systems, Kunwoo Lee, Addison-Wesley (1999).

| Course Code: ME 5408 | NUMERICAL SIMULATION LABORATORY | Credits 0-0-3: 2 |
|---|---|---|

Prerequisite: Nil

**Course Outcomes:**

At the end of the lab sessions, the student shall be able to:

| | |
|---|---|
| **CO1** | Apply built-in functions in MATLAB/ SCILAB to solve numerical problems. |
| **CO2** | Develop code for solving problems involving different types of mathematicalmodels and equations (ODE, PDE, Linear and nonlinear equations). |
| **CO3** | Solve simulation problems encountered in mechanical design, vibrationanalysis and CAD |
| **CO4** | Model a system and Develop a simulation code towards a mini project |

**Course Articulation Matrix:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 2 | | 3 | 2 | 1 | 2 |
| **CO2** | 3 | | 3 | 3 | 2 | 2 |
| **CO3** | 3 | | 3 | 3 | 3 | 2 |
| **CO4** | 3 | 2 | 3 | 3 | 3 | 2 |

**Syllabus:**

List of Experiments conducted in this laboratory:

| Week | Exercises |
|---|---|
| 1 | Introduction to MATLAB and practice |
| 2 | Practice session on handling basic arithmetic etc. |
| 3 | Writing codes with control loops, functions and scripts |
| 4 | Developing codes for visualization and plotting |
| 5 | Solving problems involving linear and nonlinear equations |
| 6 | Solving problems involving curve fitting and interpolations |
| 7 | Solving problems involving ordinary and partial differential equations |
| 8 | Solving problems related to optimization |
| 9 | Solving problems involving numerical differentiation and integrations |
| 10 | Practice session |
| 11 | Introduction to Simulink |
| 12 | Case studies and working on projects |
| 13 | Case studies and working on projects |
| 14 | Case studies and working on projects |

**Reading:**

1. laboratory Instruction Manual

| Course Code: ME 5409 | MACHINE DYNAMICS LABORATORY | Credits 0-0-3: 2 |
|---|---|---|

Prerequisite: Nil

**Course Outcomes:**

At the end of the lab sessions, the student shall be able to:

| | |
|---|---|
| **CO1** | Study and analyze the kinematics of different mechanisms. |
| **CO2** | Evaluate the vibration parameters using undamped and damped freeand forced vibrations. |
| **CO3** | Estimate the unbalance and balance the rotors. |
| **CO4** | Identify the natural modes and study the influence of initial conditions onthe response of a two degree of freedom systems. |
| **CO5** | Determine the critical speed of shafts with short and long bearings. |

**Course Articulation Matrix:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 3 | 3 | | 2 | |
| **CO2** | 3 | 3 | 3 | | 2 | |
| **CO3** | 3 | 3 | 3 | | 2 | |
| **CO4** | 3 | 3 | 3 | | 2 | |
| **CO5** | 3 | 3 | 3 | | 2 | |

**Syllabus**:

List of Experiments conducted in this laboratory:

1. Undamped Free Vibrations:
   a. Trifilar Pendulum
   b. A Slender Rod on a Cylindrical Surface
   c. A Semi Cylindrical Shell on aHorizontal surface.
   d. Compound Pendulum
2. Damped Free Vibrations:
   a. Viscous Damper
   b. Logarithmic Decrement
   c. Spring-Mass-Damper System Coulomb Damping
3. Damped Free Vibrations of Two Degree Freedom System: Coupled Pendulum 4. Vibrations of Continuous System: A Cantilever Beam
4. Balancing of Rotors: Rotor Balancing Machine
5. Balancing of Reciprocating Machines: Balancing a Twin Cylinder Engine (ALocomotive Engine)
6. Critical speeds of shafts with hinged and fixed end conditions
7. Tuning of Dynamic Absorber
8. Case studies on mechanisms and inversions.

**Reading:**

1. laboratory Instruction Manual

| Course Code: ME 5448 | SEMINAR-1 | Credits 0-0-2: 1 |
|---|---|---|

Prerequisite: Nil

**Course Outcomes:**

| | |
|---|---|
| **CO1** | Identify and compare technical and practical issues related to the area of course specialization. |
| **CO2** | Outline annotated bibliography of research demonstrating scholarly skills. |
| **CO3** | Prepare a well-organized report employing elements of technical writing and critical thinking |
| **CO4** | Demonstrate the ability to describe, interpret and analyze technical issues and develop competence in presenting. |

**Evaluation Scheme:**

| Task | Description | Weightage |
|---|---|---|
| I | Clarity on the topic | 10 |
| II | Literature survey | 30 |
| III | Content | 30 |
| IV | Presentation | 20 |
| V | Response to Questions | 10 |
| TOTAL | | 100 |

**Task-CO mapping:**

| Task/CO | CO1 | CO2 | CO3 | CO4 |
|---|---|---|---|---|
| I | X | | | |
| II | | X | | |
| III | | | X | |
| IV | | | | X |
| V | | | | X |

**Course Articulation Matrix:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 2 | | | 3 |
| **CO2** | 3 | 2 | 2 | | | 3 |
| **CO3** | 3 | 3 | 2 | | | 3 |
| **CO4** | 3 | 3 | 2 | | | 3 |

# DETAILED SYLLABUS

# PROGRAMME CORE COURSES

# (I – YEAR, II– SEMESTER)

| Course Code: ME 5451 | PRODUCT DESIGN AND DEVELOPMENT | Credits 3-0-0: 3 |
|---|---|---|

Prerequisite: Nil

**Course Outcomes:**

At the end of the course, the student shall be able to:

| | |
|---|---|
| **CO1** | Develop conceptual product models using creativity and product design techniques |
| **CO2** | Apply embodiment principles in product development process. |
| **CO3** | Develop products by considering the social, environmental and ethical concerns. |
| **CO4** | Experience by developing CAD/ physical models using the concepts of product design theory. |

**Course Articulation Matrix:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 2 | 3 | 3 | 3 | 3 | 2 |
| **CO2** | 2 | 3 | 3 | 3 | 2 | 2 |
| **CO3** | | | 1 | | | 3 |
| **CO4** | 3 | 3 | 3 | 3 | 3 | 3 |

**Syllabus:**

**Introduction:** Design thinking philosophy - Empathy, Define, Ideate, Prototype, Test. Product design context- types of designs, Asimov model, Design method vs scientific method, Considerations of a good design, Design activities/ Process, Product life and technological insertion cycles, organizational structures, business models, Design in teams-Team behavior and dynamics. Team formation and Course project assignment.

**Problem identification:** Need analysis, customer study and need identification tools, Product Quality and classification of Customer requirements, Kano Diagram. Establishing Engineering characteristics- Benchmarking, Quality Function Deployment- HOQ, Preparation of Initial PDS for the Course Project.

**Gathering Information**: Transformation from Data to knowledge, types and sources of information, intellectual property rights- classification, Patent searching, stages of patent filing. Importance of Codes and standards in Product Design

**Concept Generation/Improvement and Decision making:** Creative thinking models, creative thinking aids and barriers, structured and unstructured creative design methods/theories- Brainstorming techniques, Random input technique and Synectics, concept map, Functional decomposition, Morphological analysis, TRIZ, Axiomatic Design, practice exercises. Decision making theories- criteria based selection, Pugh's concept, AHP.

**Embodiment and Detailed Design:** Product Architecture, Configuration and Parametric design Concepts, Detailed design, Engineering Requirements- failure mode and effects analyses, Legal and ethical issues in design. DFX, Course Project Reviews

## Learning Resources:

1. Engineering Design, George E Dieter, Publisher, McGraw Hill, 4th edition
2. Product Design, Kevin N. Otto, Kristin L. Wood, Pearson Education, 2004.
3. Design Engineering, W. Ernest Eder, S. Hosendl, CRC Press, 2008.
4. The Mechanical Design Process, David G. Ullman, McGraw Hill, 2000.

## Online Resources:

1. https://nptel.ac.in/courses/107/103/107103082/

| Course Code: ME 5452 | FINITE ELEMENT ANALYSIS FOR DESIGN | Credits 3-0-0: 3 |
|---|---|---|

Prerequisite: Nil

**Course Outcomes:**

At the end of the course, the student shall be able to:

| | |
|---|---|
| **CO1** | Make use of the concept of finite element method for solving machine design problems |
| **CO2** | Solve problems in 1-D structural systems involving bars, trusses, beams and frames. |
| **CO3** | Develop 2-D and 3-D FE formulations involving triangular, quadrilateral elements and higher order elements. |
| **CO4** | Apply the knowledge of FEM for stress analysis, model analysis, heat transfer analysis and flow analysis. |
| **CO5** | Develop algorithms and FE code for solving design problems and adapt commercial packages for complex problems. |

**Course Articulation Matrix:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | | 2 | | 2 | 2 |
| **CO2** | 2 | | 2 | | 2 | |
| **CO3** | | | 2 | 2 | 3 | |
| **CO4** | 3 | | 3 | 2 | 3 | 2 |
| **CO5** | 3 | 2 | 3 | 3 | 3 | |

**Syllabus:**

**Introduction:** Historical Perspective of FEM and applicability to mechanical engineering design problems.

**Mathematical Models and Approximations:** Review of elasticity. Mathematical models for structural problems: Equilibrium of continuum-Differential formulation, Energy Approach- Integral formulation: Principle of Virtual work - Variational formulation. Overview of approximate methods for the solution of the mathematical models, Residual methods and weighted residual methods, Ritz, Rayleigh-Ritz and Gelarkin's methods. Philosophy of solving continuum problems using Finite Element Method.

**Finite Element Formulation:** Generalized FE formulation based on weightedresidual method and through minimization of potential, displacement based formulation,Concept of discretization, Interpolation, Formulation of Finite element characteristic matrices and vectors, Compatibility conditions, Assembly and boundary considerations.

**Finite Element Analysis for One Dimensional Structural problems**: Structuralproblems with one dimensional geometry. Bar element: formulation of stiffness matrix,consistent and lumped load vectors. Boundary conditions and their incorporation:Elimination method, Penalty Method, Introduction to higher order elements and their advantages and disadvantages. Formulation for Truss elements, Case studies involving hand calculations with an emphasis on Assembly,

boundary conditions,contact conditions and multipoint constraints.

**Beams and Frames**: Review of bending of beams, higher order continuity ($C^0$ and $C^1$ Continuity), interpolation for beam elements and formulation of FE characteristics, Plane and space frames and examples problems involving hand calculations. Algorithmic approach for developing computer codes involving 1-D elements.

**Two dimensional Problems:** Interpolation in two dimensions, natural coordinates, Isoparametric representation, Concept of Jacobian. Finite element formulation for plane stress plane strain and axi-symmetric problems; Triangular and Quadrilateral elements, higher order elements, sub-parametric, Isoparametric and superparametric elements. Formulation of plate bending elements using linear and higher order bending theories, Shell elements, General considerations in finite element analysis of design problems, Choosing an appropriate element and the solution strategies. Introduction to pre and post processing of the results and analysis.

**Three Dimensional Problems:** Finite element formulation for 3-D problems, mesh preparation, tetrahedral and hexahedral elements, case studies.

**Dynamic Analysis:** FE formulation in dynamic problems in structures using Lagrangian Method, Consistent and lumped mass models, Formulation of dynamic equations of motion, Modelling of structural damping and formulation of damping matrices, Model analysis, Mode superposition methods and reduction techniques.

**FEM in Heat Transfer and Fluid Mechanics problems:** Finite element solution for one dimensional heat conduction with convective boundaries. Formulation of element characteristics and simple numerical problems. Formulation for 2-D and 3-D heat conduction problems with convective boundaries. Introduction to thermo-elastic contact problems. Finite element applications in potential flows; Formulation based on Potential function and stream function. Case studies.

**Algorithmic Approach for problem solving:** Algorithmic approach for Finite element formulation of element characteristics, Assembly and incorporation of boundary conditions. Guidelines for code development. Introduction to commercial Finite Element software packages like ANSYS.

## Learning Resources:

1. Finite element Method in Engineering, Singiresu S.Rao, 5ed, Elsevier, 2012.
2. Textbook of Finite Element Analysis, Seshu P, PHI. 2004
3. Finite Element Method in Engineering, Reddy, J.N., Tata McGraw Hill, 2017
4. The Finite Element Method 4 Vol set, Zeincowicz, 4th Edition, Elsevier 2007.

| Course Code: ME 5458 | TRIBOLOGY AND COMPOSITES LABORATORY | Credits 0-0-3: 2 |
|---|---|---|

Prerequisite: Nil

**Course Outcomes:**

At the end of the lab sessions, the student shall be able to:

| | |
|---|---|
| **CO1** | Apply the knowledge of dynamics to determine the frequencies of component. |
| **CO2** | Estimate friction and wear between interacting material surfaces of given materials. |
| **CO3** | Estimate the lubricant characteristics and identify a suitable lubricant for thegiven application. |
| **CO4** | Analyze the influence of additives on the mechanical properties ofpolymer |
| **CO5** | Design and fabricate prototypes through rapid prototyping techniques. |

**Course Articulation Matrix:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 2 | 2 | 3 | 2 | 1 | 2 |
| **CO2** | 2 | 3 | 3 | 3 | 2 | 3 |
| **CO3** | 2 | 1 | 3 | 3 | 3 | 3 |
| **CO4** | 1 | 2 | 3 | 3 | 2 | 3 |
| **CO5** | 1 | 2 | 3 | 3 | 2 | 3 |

**Syllabus:**

List of Experiments conducted in this Laboratory:

1. Determination of critical speed of rotating shaft with centre mass approach.
2. Measurement of the natural frequencies of hinged-hinged and fixed-fixed configuration of rotating shaft.
3. Determination of friction and wear of dry sliding contacts using friction and wear testrig.
4. Measurement of the abrasive wear by using dry sand abrasion test rig.
5. Measurement of the erosive wear by using air jet erosion test rig.
6. Determination of lubricity of lubricants using four ball test rig.
7. Fabrication of polymer composites using hand layup technique.
8. Fabrication of a mechanical component using fused deposition modelling technique.
9. Measurement of kinematic and dynamic viscosities of an oil using redwood viscometer.
10. Determination of flash and fire point of an oil / lubricant.
11. Measurement of the emissions of vehicle using chassis dynamometer.
12. Measurement of stress due to bending using a strain gauge.
13. Determination of Modulus of Elasticity using Strain gages.
14. Determination of stress concentration factor for a plate with a hole (Photoelastic)

**Reading:**

1. laboratory Instruction Manual

| Course Code: ME 5459 | MODELING AND ANALYSIS LABORATORY | Credits 0-0-3: 2 |
|---|---|---|

Prerequisite: Nil

**Course Outcomes:**

At the end of the course, the student shall be able to:

| | |
|---|---|
| **CO1** | Develop programs for modeling the synthetic curves and surfaces. |
| **CO2** | Develop finite element code to solve problems involving Trusses,Beams and Frames |
| **CO3** | Build 2D and 3D objects using a modeling software |
| **CO4** | Solve structural problems using finite element software |
| **CO5** | Execute mini project involving both modeling and analysis |

**Course Articulation Matrix:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | | 3 | 3 | 2 | | 2 |
| **CO2** | | 3 | 3 | 2 | 3 | 2 |
| **CO3** | 2 | 3 | 3 | 2 | | |
| **CO4** | 3 | 3 | 3 | 2 | 3 | 2 |
| **CO5** | 3 | 3 | 3 | 2 | 3 | |

**Syllabus:**

List of Experiments conducted in this laboratory:

1. Develop Programs for Transformations in CAD
2. Develop programs for Synthetic Curves in CAD
3. Introduction to Pro/E and working with features like Extrude & Revolve insketch mode
4. Model solids with features like Hole, Round, Chamfer and Rib
5. Model solids with features like Pattern, Copy, Rotate, Move and Mirror
6. Advanced modeling tools (Sweep, Blend, Variable section Sweep etc)
7. Assembly modelling in Pro/E, Generating, editing and modifying drawings in Pro/E
8. Introduction to developing program for finite element analysis in MATLAB
9. Solution of Trusses problems using the developed code
10. Solution of Beams and Frames using the developed code
11. Solution of problems involving triangular element using the developed code
12. Introduction to FEA software, ANSYS
13. Solution of problems of Trusses using ANSYS
14. Solution of problems of Beams and Frames using ANSYS
15. Solution of problems involving triangular element etc. using ANSYS
16. Solution of 3D analysis problems using ANSYSReading:

**Reading:**

1. laboratory Instruction Manual

| Course Code: ME 5498 | SEMINAR-2 | Credits 0-0-2: 1 |
|---|---|---|

Prerequisite: Nil

**Course Outcomes:**

| | |
|---|---|
| **CO1** | Identify and compare technical and practical issues related to the area ofcourse specialization. |
| **CO2** | Outline annotated bibliography of research demonstrating scholarly skills. |
| **CO3** | Prepare a well-organized report employing elements of technical writing andcritical thinking |
| **CO4** | Demonstrate the ability to describe, interpret and analyze technical issues and develop competence in presenting. |

**Evaluation Scheme:**

| Task | Description | Weightage |
|---|---|---|
| I | Clarity on the topic | 10 |
| II | Literature survey | 30 |
| III | Content | 30 |
| IV | Presentation | 20 |
| V | Response to Questions | 10 |
| TOTAL | | 100 |

**Task-CO mapping:**

| Task/CO | CO1 | CO2 | CO3 | CO4 |
|---|---|---|---|---|
| I | X | | | |
| II | | X | | |
| III | | | X | |
| IV | | | | X |
| V | | | | X |

**Course Articulation Matrix:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 2 | | | 3 |
| **CO2** | 3 | 2 | 2 | | | 3 |
| **CO3** | 3 | 3 | 2 | | | 3 |
| **CO4** | 3 | 3 | 2 | | | 3 |

# DETAILED SYLLABUS

# PROGRAMME ELECTIVE COURSES

# (I – YEAR, I – SEMESTER)

| Course Code: ME 5411 | MECHANICS OF COMPOSITE MATERIALS | Credits 3-0-0: 3 |
|---|---|---|

Prerequisite: Nil

**Course Outcomes:**

At the end of the course, the student will be able to:

| | |
|---|---|
| **CO1** | Understand the characteristics of composite materials. |
| **CO2** | Select suitable manufacturing processes to develop fiber reinforced composites. |
| **CO3** | Analyze the micro and macro mechanical behavior of fiber reinforced composites. |
| **CO4** | Develop the governing equations for bending, buckling and vibration of laminated plates. |
| **CO5** | Design the composite structures for engineering applications. |

**Course Articulation Matrix:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | | | | | | 2 |
| **CO2** | 1 | | | | | 2 |
| **CO3** | 1 | | 3 | | 2 | |
| **CO4** | 2 | | 3 | | 2 | 2 |
| **CO5** | 3 | | 3 | | 2 | 2 |

**Syllabus:**

**General Introduction:** Introduction, Classification of Composites, Constituent materials in Composites, Composition of Fiber Reinforced Composites, Types and properties of Reinforcement, Types and properties of Resins, Types of additives, Mechanical behaviour of composite materials, Basic Terminology of Laminated fiber reinforced composite materials, Manufacture of Laminated fiber reinforced composite materials.

**Manufacturing Composite materials:** Tooling and Specialty Materials, Classification of Manufacturing Processes, Open mold Process, Closed mold Process, Continuous Process, Forming Structural Shapes, Processing of composite materials, Manufacturing Defects, Mechanical Testing of Composites, Joining of Composites, Environmental Effects on Composites

**Micromechanics of Laminae:** Introduction, Stress-strain relation for anisotropic materials, Stiffnesses, Behaviour of Laminae, Equations of Equilibrium, Anisotropic Elasticity, Hooke's Law in Compliance Form, Hooke's Law in Stiffness Form, Orthotropic and Transverse Isotropic materials compliances, Engineering constants, Restriction on Engineering constants, Stress-strain relation for plane stress in orthotropic materials.

**Macromechanical behaviour of laminates and plate theories:** Elastic approach to stiffness, Mechanics of materials approach to stiffness, Mechanics of materials approach to strength, Transformed reduced stiffnesses Classical Laminate theory, Special cases of laminate Stiffnesses, Strength of Laminates, Theories of failures related to FRP composires, Interlaminar stresses axisymmetric shells.

**Design of composite structures:** Design Issues, Structural Component Design Process, Macromechanical failure theories, Bending, Deflection of Simply supported laminated plates, Governing equation for Bending, Buckling, and Vibration of Laminated plates.

## Learning Resources:

1. Principles of composite material mechanics, Ronald F. Gibson, CRC Press, 2011.
2. Mechanics of Composite Materials, Robert M Jones, Taylor & Francis, 2000.
3. Mechanical Properties of Polymers and Composites, Lawrence E. Nielsen, Nielson, Paul NielsenSecond Edition, CRC press, 2000.

| Course Code: ME 5412 | CHARACTERIZATION OF ENGINEERING MATERIALS | Credits 3-0-0: 3 |
|---|---|---|

Prerequisite: Nil

**Course Outcomes:**

At the end of the course, the student shall be able to:

| | |
|---|---|
| **CO1** | Identify advanced techniques available for characterization of materials |
| **CO2** | Select a characterization technique to evaluate the behavior of materials |
| **CO3** | Analyze defects and failure surfaces of materials |
| **CO4** | Analyze the characterization results by various equipment |

**Course Articulation Matrix:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 2 | 2 | 3 | 3 |
| **CO2** | 3 | 2 | 2 | 2 | 2 | 2 |
| **CO3** | 3 | 3 | | 3 | | 2 |
| **CO4** | 3 | 3 | 2 | 2 | 2 | 3 |

**Syllabus:**

**Introduction:** Overview of the course; materials classification and their properties, Importance of materials selection, property classification, Criteria for selection of materials, Ashby charts for materials selection, Engineering Design process and the role of materials; material property charts; selection of materials based on function, objective, constraints and free variables; examples of material selection for typical applications;

**Computer aided materials selection:** Selection of process based on material classification; pencil curve approach; material selection for multiple constraints and multiple objective cases; multiple constraints and conflicting objectives. Co-selection of material and shape; concept of macroscopic and microscopic shape factors; Four quadrant method of material selection. General Properties of plastics, polymers and elastomers; visco-elastic properties; short-term and long-term properties of plastics;

**High temperature materials:** families of super alloys and their characteristics; creep and fatigue resistance of super alloys; role of precipitates in strengthening of super alloys; repair of super alloys after creep damage; coatings for high temperature materials.

**Fundamentals of ceramics:** general properties, applications of ceramics for critical applications. Design considerations. Surface treatment of materials using coatings; type of coatings; PVD and CVD coatings. Basics of electro-plating and electro-less plating.

**Physical characterization of materials:** Optical Microscopy, SEM,TEM, Density, Void content in materials, Electron Probe Micro Analyzer (EPMA), Atomic Force Microscopy (AFM), Thermogravimetric analysis (TGA), nano indentation, NMR spectroscopy, EDAX, FTIR, XRD

**Mechanical characterization:** Tensile test, flexural test, compression test, ILSS, creep, fatigue, Hardness, Impact test, Fracture toughness test, Principle, construction and operation working parameters, equipment operation. selection of plastics based on mechanical properties, degradation due to environment, of laminates.

**Tribological characterization:** Abrasive wear, Pin-on Disc, Erosion test, Corrosion test, sand abrasion, slurry erosion, scratch test, nano indent scratch test, wear; Design methods for snap fits; case studies. Fundamentals of fiber reinforced plastics; Stress, strain analysis of continuous fiber

composites, rule of mixtures, general deformation behavior

.

## Learning Resources:


1. Materials Selection in Mechanical Design, M.F. Ashby, Butterworth Heinemann, 4/e, 2010
2. Materials Characterization-Introduction to Microscopic and Spectroscopic Methods - Yang Leng, John Wiley & Sons (Asia) Pte Ltd, 2008
3. ASM Handbook: Materials Characterization, ASM International, 2008.
4. Experimental Techniques in Physical Metallurgy, V. T. Cherapin and A. K. Mallik, Asia Publishing House, 1967.
5. Mechanical Metallurgy, Dieter,George E. McGraw Hill, 2nd Edition, 2005
6. Plastics Engineering, Crawford, R. J., Butterworth-Heinemann, 3/e, 2002.
7. Super alloys: A technical guide, Donachie, M. J. and Donachie, S. J., ASM International, 2002.

| Course Code: ME 5413 | ANALYSIS AND SYNTHESIS OF MECHANISMS | Credits 3-0-0: 3 |
|---|---|---|

Prerequisite: Nil

## Course Outcomes:

At the end of the course, the student shall be able to:

| | |
|---|---|
| **CO1** | Understand basic mechanisms and machines and formulate the design problem. |
| **CO2** | Develop analytical equations for relative position, velocity and acceleration ofall moving links. |
| **CO3** | Analyze Simple and Complex mechanisms. |
| **CO4** | Apply the knowledge of Kinematic theories to practical problems of mechanism design and synthesis. |
| **CO5** | Design higher pair kinematic linkages for a given application. |

## Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 2 | 3 | 2 | 1 |
| **CO2** | 3 | 3 | 3 | 3 | 3 | 3 |
| **CO3** | 2 | 3 | 3 | 3 | 3 | 3 |
| **CO4** | 3 | 3 | 3 | 2 | 2 | 2 |
| **CO5** | 3 | 3 | 3 | 3 | 2 | 2 |

## Syllabus:

**Introduction:** review of kinematic chains, equivalent chains and their inversions.

**Position analysis:** position and systems, co-ordinate transformation, rotation, translation and combined motion, algebraic position analysis, loop closure equations, position of any point on a linkage, transmission angles and toggle positions, position based synthesis of planar mechanisms.

**Kinematics of rigid bodies:** plane motion of a rigid body, graphical velocity and acceleration analysis, instantaneous centers of velocity, centrodes, velocity of rub, analytical solutions for velocity analysis – velocity of any point on a linkage, acceleration of any point on a linkage, coriollis acceleration, analytical solutions for
velocity and acceleration analysis, case studies – four-bar pin joined linkage, four link slider-crank.

**Analytical linkage synthesis:** types of kinematic synthesis – motion and path generation, number synthesis, dimensional synthesis, two position synthesis forrocker output, precision points, comparison of analytical and graphical two positionsynthesis, three position synthesis.

**Graphical linkage synthesis:** two position synthesis for rocker output, three position synthesis, position synthesis for more than three positions (four and six bar quick return), coupler curves, exact and approximate straight line mechanisms.

**Cam:** terminology, types of follower, follower motions, cams, svaj diagrams, law of cam design, single and double dwell cam design using shm, cycloidal displacement, combined functions, critical path motion, practical design considerations.

**Gears and gear trains**: law of gearing, involute tooth form, pressure angle, backlash, contact ratio, interference and method to avoid interference, gear trainand its analysis.

## Learning Resources:


1. Kinematics Analysis and Synthesis of Mechanisms, A K Mallik, Amitabha Ghosh and Guntur, D CRC Press, 2011
2. Planar Multibody Dynamics, Parviz E Nikravesh, CRC Press, 2016
3. Design of Machinery An Introduction to the Synthesis and Analysisof Mechanisms and Machines, Robert L Norton, 2nd Edition, McGraw Hill reprint 2011
4. Advanced Mechanism Design: Analysis and Synthesis, Sandor and Erdman, vol II,PHI, New Delhi, 2010
5. Theory of Machines and Mechanisms, Shigley, Pennock and Uicker, 4th Edition,Oxford University Press, 2011

| Course Code: ME 5414 | AUTOMATIC CONTROLS | Credits 3-0-0: 3 |
|---|---|---|

Prerequisite: Nil

**Course Outcomes:**

At the end of the course, the student shall be able to:

| | |
|---|---|
| **CO1** | Analyze electromechanical systems by mathematical modelling. |
| **CO2** | Determine Transient and Steady State behavior of systems using standard test signals. |
| **CO3** | Analyze linear systems for steady state errors, absolute stability and relative stability using time domain and frequency domain techniques. |
| **CO4** | Identify and design a control system satisfying specified requirements. |

**Course Articulation Matrix:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 3 | 3 | 2 | 2 | |
| **CO2** | 3 | 3 | 3 | 2 | 2 | |
| **CO3** | 3 | 3 | 3 | 2 | 2 | |
| **CO4** | 3 | 3 | 3 | 2 | 2 | |

**Syllabus:**

**Introduction:** System, control system, types of control systems, open-loop and closed loop systems, types of feedback, feedback and its effects. Concept of linearization with incremental changes.

**Mathematical Modelling Of Physical Systems:** Mathematical modelling of Electrical, Mechanical and Electro-mechanical elements, D.C. motors, flapper amplifiers, pneumatic amplifiers. Block diagram representation. Concept and use of Transfer function.

**Transfer Function From Block Diagrams And Signal Flow Graphs:** Introduction, impulse response and its relation with transfer function of linear systems. Block diagram reduction technique and signal flow graph, Mason's gain formula.

**State Variable Analysis Of Linear Dynamic Systems:** State variables, state variable representation of system, dynamic equations, merits for higher order differential equations and solution. Concept of controllability and observability and techniques to test them.

**Time Domain Analysis Of Control Systems:** Introduction- typical Test signals, time domain indices, steady state error constants, concept of BIBO stability, absolute stability, Routh Hurwitz Criterion. Effect of P, PI & PID controllers.

**Root Locus Techniques:** Introduction, Root loci theory, Application to system stability studies. Illustration of the effect of addition of a zero and a pole.

**Frequency Domain Analysis Of Control Systems:** Introduction, polar plots, Nyquist stability criterion, Frequency domain indices (gain margin, phase margin, bandwidth), Bode plots, application of Bode plots, Introduction to lag and lead compensation.

**Qualitative Analysis Of Controllers:** Introduction, Additions of Poles and Zeros, compensation – Phase Lag, Phase lead, feedback compensation, introduction to state space analysis – generalized state equation, techniques for deriving system state-space equations.

**Control Applications:** Active vibration control – Principle of active control, structural vibration control, Active vibration isolation system, Engine Governing – Mechanical governors, Electronic governors, carburetor control, Diesel fuel Ignition control, Boiler control – combustion control, feed water control, steam temperature control.

## Learning Resources:


1. Automatic Control Systems, Benjamin C Kuo and Golnaraghi, 10th Edition, Mc Graw Hill, 2017.
2. Control Systems Engineering, J. Nagarath, M. Gopal, New Age Pub. Co, 6th Edition, 2017.
3. Automatic control engineering, Francis Harvey Raven, McGraw-Hill, 2008.
4. Modern Control Engineering, Katsuhiko Ogata, Pearson Education India, 5th Edition, 2015.
5. Theory and Application of Automatic Controls, B. C. Nakra and S. P. Singh, 3rd Edition, New Age International Publishers., 2017.
6. Vibration and Acoustics, C Sujatha, Tata McGraw Hill, 2017

| Course Code: ME 5415 | MATHEMATICAL METHODS IN ENGINEERING | Credits 3-0-0: 3 |
|---|---|---|

Prerequisite: Nil

**Course Outcomes:**

At the end of the course, the student shall be able to:

| | |
|---|---|
| **CO1** | Formulate a design task as an optimization problem |
| **CO2** | Identify constrained and unconstrained optimization problems and solve using corresponding methods |
| **CO3** | Solve nonlinear optimization problems with evolutionary methods |
| **CO4** | Apply data driven methods to solve engineering problems |

**Course Articulation Matrix:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 3 | 3 | 1 | 2 |
| **CO2** | 2 | 2 | 3 | 3 | 2 | 2 |
| **CO3** | 3 | | 3 | 3 | 3 | 2 |
| **CO4** | 3 | | 3 | 3 | 3 | 2 |

**Syllabus:**

**Mathematical Modeling:** Modeling of systems related to mechanical engineering, assumptions, appropriate methods and fundamental of a computer implementation

**Numerical Linear Equations**: Introduction, Basic Ideas of Applied Linear Algebra, Systems of Linear Equations, Square, Non-Singular Systems, the Algebraic Eigenvalue Problem, Matrix Decompositions, Computer implementation of the methods for applications in engineering analysis.

**Outline of Optimization Techniques**: Introduction to Optimization, Multivariate Optimization, Constrained Optimization, Optimality Criteria, Computer implementation of the methods for applications in design optimization, manufacturing and thermal process optimization.

**Topics in Numerical Analysis**: Interpolation, Regression, Numerical Integration, Numerical Solution of ODE's as IVP Boundary Value Problems. Application of numerical methods for research in mechanical engineering.

**Overviews: PDE's and Variational Calculus:** Separation of Variables in PDE's, Hyperbolic Equations, Parabolic and Elliptic Equations, Membrane Equation, and Calculus of Variations. Applications in mechanical engineering research.

**Learning Resources:**

1. Advanced Engineering Mathematics, E. Kreyszig , Wiley, 2010.
2. Applied Mathematical Methods, B. Dasgupta , Pearson Education, 2006.
3. Scientific Computing, M. T. Heath, McGraw-Hill Education, 2001.
4. Applied Numerical Methods with Matlab, Steven Chapra, McGraw-Hill Education, 2011.

| Course Code: ME 5416 | FAILURE ANALYSIS AND DESIGN | Credits 3-0-0: 3 |
|---|---|---|

Prerequisite: Nil

**Course Outcomes:**

At the end of the course, the student shall be able to:

| | |
|---|---|
| **CO1** | Analyze material failure prevention in mechanical design |
| **CO2** | Establish various stresses and failure theories on static and dynamic loading |
| **CO3** | Analyze high, low cycle fatigue and interpretation of data by combined loading. |
| **CO4** | Design various mechanical components and prevent the failure by proper analysis |

**Course Articulation Matrix:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 2 | 2 | 2 | 2 |
| **CO2** | 3 | 3 | 2 | 2 | 2 | 2 |
| **CO3** | 3 | 2 | 2 | 3 | 2 | 2 |
| **CO4** | 3 | 2 | 2 | 2 | 3 | 2 |

**Syllabus:**

**Introduction:** The role of failure prevention analysis in Mechanical Design, Material failure modes and their identification.

**Combined stress, theories of failure and their use in Design:** State of stress and relation between stress and strain. Static loading, Fatigue loading

**High cycle fatigue:** Fatigue testing, S-N-P curves, endurance diagrams, influence factors, stress concentration factors and notch sensitivity, fatigue design for combined stress, cumulative damage and life prediction.

**Fatigue testing procedures and statistical interpretation of data:** Loading regimes for testing and statistical interpretation, low cycle fatigue, fretting. Fracture mechanics principles in design practice, contact fatigue, high temperatures, corrosion. Shock and impact loading.

**Failure Analysis Techniques and Preventive Measures:** Non-Destructive Testing Techniques and Metallographic Techniques.

**Component Failures:** Bearings, Gears, Chain and Belt Drives, Lifting Equipment's, Welded constructions and Screw fastenings, Pressure Vessel, Seals, Shafts, Springs.

**Learning Resources:**


1. Failure of Materials in Mechanical Design: Analysis, Prediction and Prevention, Jacks A. Collins, 2nd Edition, John Wiley & Sons, 1993.
2. Mechanical behaviour of Materials, Norman E. Dowling, 4th edition, Pearson, 2013.
3. Fatigue of Materials, S.Suresh, 2nd Edition, Cambridge University Press, 2012.
4. Elements of Fracture Mechanics, Prashanth kumar, Mc-Graw Hill, 2014
5. Failure Analysis and Prevention (ASM Hand Book), Metals Hand Book 9th Edition,Vol.11.

| Course Code: ME 5417 | MECHANICS AND PROCESSING OF POLYMER MATERIALS | Credits 3-0:0: 3 |
|---|---|---|

Prerequisite: Nil

**Course Outcomes:**

At the end of the course, the student will be able to

| | |
|---|---|
| **CO1** | Understand the structures of polymers |
| **CO2** | Select a characterization technique to evaluate the polymers |
| **CO3** | Analyze and Characterize polymers. |
| **CO4** | Understanding the polymer processing |

**Course Articulation Matrix:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 2 | 2 | 2 | 3 |
| **CO2** | 3 | 3 | 3 | 2 | 3 | 3 |
| **CO3** | 3 | 2 | 2 | 3 | 2 | 2 |
| **CO4** | 3 | 2 | 2 | 2 | 3 | 2 |

**Syllabus:**

**Introduction to polymers, applications and processing:** Introduction and Classification of Polymers. History of Polymers, Thermosets, Factors influencing the polymer properties, Monomers used for polymer synthesis, Polymer Manufacturing and Processing, Polymer Mechanics Creep, stress relaxation, Boltzmann superposition principle, mechanical models, dynamic behavior of polymers, Impact and fatigue in polymers

**Synthesis and properties:** Commodity and general purpose thermoplastics: PE, PP, PS, PVC, Polyesters, Acrylic, PU polymers. Engineering Plastics: Nylon, PC, PBT, PSU, PPO, ABS, Fluoropolymers Thermosetting polymers: PF, MF, UF, Epoxy, Unsaturated polyester, Alkyds. Natural and synthetic rubbers: Recovery of NR hydrocarbon from latex, SBR, Nitrile, CR, CSM, EPDM, IIR, BR, Silicone, TPE.

**Polymer processing:** Compression molding, transfer molding, injection molding, blow molding, reaction injection molding, extrusion, pultrusion, calendaring, rotational molding, thermoforming, rubber processing in two-roll mill, internal mixer.

**Experimental methods to measure properties of solid polymers:** Mechanical-static and dynamic tensile, flexural, compressive, abrasion, endurance, fatigue, hardness, tear, resilience, impact, toughness. Conductivity-thermal and electrical, dielectric constant, dissipation factor, power factor, electric resistance, surface resistivity, volume resistivity, swelling, ageing resistance, environmental stress cracking resistance.

**Learning Resources:**

1. Robert O. Ebewele , Polymer Science and Technology, CRC press, 2000
2. Tesoro, G. (1984), Textbook of polymer science, 3rd ed., Fred W. Billmeyer, Jr., Wiley-Interscience, New York, 1984
3. I L.H. Sperling, N. Introduction To Physical Polymer Science 2006 By John Wiley & Sons, Inc, Fourth Edition

# DETAILED SYLLABUS

# PROGRAMME ELECTIVE COURSES

# (I – YEAR, II – SEMESTER)

| Course Code: ME 5461 | FRACTURE MECHANICS | Credits 3-0-0: 3 |
|---|---|---|

Prerequisite: Nil

**Course Outcomes:**

At the end of the course, the student will be able to:

| | |
|---|---|
| **CO1** | Understand the concept of crack subsequently leading to fracture failure Further analyze the mechanical components against fracture. |
| **CO2** | Analyze and predict the fracture strength of mechanical components under different fracture modes. |
| **CO3** | Application of fracture mechanics principles by Determining Fracture Parameters using Experimental Methods. |
| **CO4** | Designing of mechanical components against fracture by Determining Fracture Parameters for the analysis of cracks in solids. |
| **CO5** | Analyze the mechanical components against fracture by Detection of crack and its growth through Non-Destructive Testing. |

**Course Articulation Matrix:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 3 | 3 | 3 | 2 | 2 |
| **CO2** | 3 | 3 | 3 | 2 | 2 | 2 |
| **CO3** | 3 | 3 | 2 | 2 | 3 | 2 |
| **CO4** | 3 | 3 | 3 | 3 | 3 | 2 |
| **CO5** | 2 | 2 | 3 | 3 | 2 | 3 |

**Syllabus:**

**Introduction:** Brittle and Ductile Fracture, Modes of Fracture Failure, Surface Energy, Griffith's Dilemma, Realization and Analysis. Energy Release Rate, Energy Release Rate of DCB Specimen, Anelastic Deformation at Crack-tip, Crack Resistance, Stable and Unstable Crack Growth, Critical Energy Release Rate.

**Stress Intensity Factor:** Linear Elastic Fracture Mechanics (LEFM), Westergaard's Approach, Applications of Westergaard Approach, Crack in a Plate of Finite Dimensions, Edge Cracks, Embedded Cracks, The Relation between $G_I$ and $K_I$, Critical Stress Intensity Factor, Bending and Twisting of Cracked Plates. Approximate Shape and Size of the Plastic Zone, Effective Crack Length, Effect of Plate Thickness.

**J-Integral:** Definition of the J-Integral, Path Independence, Stress-Strain Relation, Experiments to Determine the CriticalJ-Integral, Comments on the Numerical Evaluation ofJ-Integral, A Simplified Relation for the J-Integral, Applications to Engineering Problems. Crack Tip Opening Displacement, Relationship between CTOD, Kr and Gr for Small Scale Yielding, Equivalence between CTOD and J.

**Test Methods:** $K_{IC}$-Test Technique, Test Methods to Determine $J_{IC}$, Test Methods to Determine $G_{IC}$ and $G_{IIC}$, Determination of Critical CTOD.

**Fracture Parameters:** Direct Methods to Determine Fracture Parameters. Indirect Methods to Determine Fracture Parameters. Mixed Mode Crack Initiation and Growth.

**Crack Detection through Non-Destructive Testing:** Examination through Human Senses, Liquid Penetration Inspection, Ultrasonic Testing, Radiographic Imaging, Magnetic Particle Inspection.

## Learning Resources:


1. Elements of fracture mechanics, Kumar, Prashant, Tata McGraw-Hill Education, 2009.
2. Fracture mechanics: fundamentals and applications. Anderson, Ted L., CRC press, 2017.
3. Elementary engineering fracture mechanics, Broek, David, Springer Science & Business Media, 2012.
4. Fracture and Fatigue control in Structures, S.T. Rolfe and J.M. Barson, Prentice Hall Inc. New Jersy, 1977.
5. Advanced Fracture Mechanics, M.F. Kanninen and C.H. Popelar, Oxford University Press, 1985.

| Course Code: ME 5462 | CONDITION MONITORING AND FAULT DIAGNOSTICS | Credits 3-0-0: 3 |
|---|---|---|

## Course Outcomes:

At the end of the course, the student will be able to:

| | |
|---|---|
| **CO1** | Understand effective maintenance schemes in industries. |
| **CO2** | Apply vibration monitoring techniques for system diagnoses. |
| **CO3** | Apply oil analysis technique to diagnose the wear debris. |
| **CO4** | Identify nonconventional methods for machine diagnoses. |
| **CO5** | Develop modern technologies for effective plant maintenance. |

## Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | | | | | 2 | 3 |
| **CO2** | 3 | | 3 | | 2 | |
| **CO3** | 3 | | 3 | | 2 | |
| **CO4** | 3 | | 3 | | 2 | |
| **CO5** | 3 | | 3 | | 2 | 3 |

## Syllabus:

**Vibration based condition monitoring:** Introduction, Type of failures, investigation and occurrences, Service failures, Principles of predictive maintenance, Predictive maintenance techniques, sensors for fault detection, Vibration transducers, Vibration basics, Spring-mass system: mass, stiffness, damping, System response, Nature of vibration, Harmonics, Limits and standards of vibration.

**Data acquisition and analysis:** Introduction, Vibration sensors, characteristics and mountings Collection of vibration signal, Vibration signature of active systems, Vibration monitoring equipment, Critical vibration levels, Conversion of vibrations to electrical signal, The fast Fourier transform (FFT) analysis, Frequency analysis techniques, Derived functions, Time waveform analysis, Phase signal analysis.

**Machinery fault diagnosis and correcting faults:** Introduction, Commonly witnessed machinery faults diagnosed, Simple vibration, Belt drives, Gear excitation, Rolling elements bearing, Balancing, Alignment, Resonance vibration control with dynamic absorbers.

**Wear debris analysis:** Introduction, Oil fundamentals, sampling methods, lubricant properties, Contaminants in used lubricating oils, Contaminants monitoring techniques, Spectrometric oil analysis, Magnetic chip detectors, Ferrograph particle precipitation, XRF, Temperature analysis.

**Other predictive maintenance techniques:** Performance trend monitoring, Performance monitoring systems, Introduction to non-destructive techniques, Ultrasound, Infrared thermography, Eddy current, Introduction to structural health monitoring

## Learning Resources:

1. Rao J. S., Vibration Condition Monitoring, Narosa Publishing House, 2/e 2000.
2. Isermann R., Fault Diagnosis Application, Springer-Verlag Berlin, 2011.
3. Allan Davis, Hand book of Condition Monitoring, Chapman and Hall, 2000.
4. Choudary K K., Instrumentation, Measurement and Analysis, Tata McGraw Hill.
5. Collacott, R. A., Mechanical Faults Diagnosis, Chapman and Hall, London, 1990
6. Vibration and Acoustics, C Sujatha, Tata McGraw Hill, 2017

| Course Code: ME 5463 | ROTOR DYNAMICS | Credits 3-0-0: 3 |
|---|---|---|

## Course Outcomes:

At the end of the course, the student shall be able to:

| | |
|---|---|
| **CO1** | Model the Rotor bearing systems and formulate the governing equations. |
| **CO2** | Understand the role of damping, gyroscopic, centrifugal, stiffness and inertialeffects on rotors. |
| **CO3** | Compute the critical speeds and stability limits for rotors under axial, transverseand torsional modes. |
| **CO4** | Analyse the rotor bearing systems using transfer matrix method and FiniteElement Method. |
| **CO5** | Compute the transient response of rotors. |

## Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | | 3 | | 3 | 2 |
| **CO2** | 2 | | 3 | | | 2 |
| **CO3** | 3 | | 3 | 2 | 3 | 2 |
| **CO4** | 3 | | 3 | 2 | 3 | 2 |
| **CO5** | 2 | | 3 | | 3 | 2 |

## Syllabus:

**Introduction:** Introduction to rotor dynamics, Rotating and reciprocating unbalances, Classification of Discrete and continuous systems, Review of free and forced vibrations of single and multi-degree of freedom systems.

**Linear Rotor Dynamics :** Equation of motion, Rotating systems, Complex coordinate representation, Undamped Jeffcott Rotor – Free whirling, Unbalance response, Shaft Bow Jeffcott Rotor with viscous damping – Free whirling, Unbalance response, Shaft Bow With structural damping – Free whirling, Unbalance response, frequency dependent loss factors with non-synchronous damping, Effect of Bearing Compliance,Stability in supercritical region.

**Modelling with Four Degrees of Freedom:** Generalised coordinates and equations of motion in real and complex coordinates, Static and couple unbalance and their effects, uncoupled gyroscopic systems, Free whirling of coupled undamped systems, Unbalance response and Shaft bow. Model uncoupling of gyroscopic systems, Configuration and state space approaches.

**Discrete multi-degree of freedom:** Introduction, Transfer matrix approach for undamped systems, Damped systems, The finite element method for rotors, Beam elements, spring elements, Mass elements, Assembly and constraints, Damping matrices, Choice of coordinates: fixed Vs Rotating and Real Vs Complex coordinates, Computation of critical speeds, Computation of unbalance response. Campbell and root locus diagrams, Reduction of DOF: Nodal reduction, model reduction and component mode synthesis.

**Transmission Shafts:** Modelling of rotors as continuous systems, Euler-Bernoulli and Timoshenko beam models, Dynamic stiffness, Analytical and approximate solutions.
**Anisotropy of rotors and supports:** Isotropic rotors on Anisotropic supports – Influence of damping, non-isotropic rotors on isotropic supports.

**Rotor-Bearing Interaction:** Rigid body and flexural modes, Linearization of bearing Characteristics, Rolling element bearings, Fluid film bearings, Magnetic bearings, bearing alignment in multi rotor bearings

## Learning Resources:

1. Dynamics of Rotating Systems, Giancarlo Genta, Springer, 2009
2. Rotor Dynamics, Rao, J.S., 3 Ed. New Age International, 2003
3. Rotating Machinery Vibrations, Marcel Dekker, Inc., New York, 2001
4. Vibration Analysis of Rotors, Chong-Won Lee, Kluwer Academic Publishers, London, 1995
5. Rotor dynamics, Muszynska A, Taylor & Francis, New York, 2005

| Course Code: ME 5464 | THEORY OF PLATES AND SHELLS | Credits 3-0-0: 3 |
|---|---|---|

Prerequisite: Nil

**Course Outcomes**:

At the end of the course, the student shall be able to:

| | |
|---|---|
| **CO1** | Formulate the Constitutive Relations and Equilibrium conditions applicable to plates |
| **CO2** | Analyze the forces and bending moments in plates and shells |
| **CO3** | Analyze Natural Frequencies and Modes in plates and shells under freevibrations |
| **CO4** | Solve problems of Plates and Shells on Elastic Foundations |

**Course Articulation Matrix:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 2 | | 3 | | | |
| **CO2** | 3 | 2 | 3 | 2 | 3 | 2 |
| **CO3** | 3 | 2 | 3 | 2 | 3 | |
| **CO4** | 3 | 2 | 3 | 2 | 3 | 2 |

**Syllabus:**

**Introduction:** Fundamental Relations, Equilibrium equations Kinematic Relations and Constitutive Relations.

**Plate Theories:** Thin plate concept, Kirchhoff-Differential Equation for studying the plates' stress strain, moments force, Variational Formulation, Boundary conditions: Fixed edges, clamped edges, simply supported plates with various load conditions (Analytical concepts) and mixed boundary conditions. Thick plate concepts, Reissner-Mindlin–Differential Equation, Finite Element/variational formulations for plate bending studies, Potential energy method for plate analysis.

**Deep Shell Equations:** Introduction**,** Shell Coordinates and Infinitesimal Distances in Shell Layers, Stress–Strain Relationships, Membrane Forces and Bending Moments, Energy Expressions, Boundary Conditions, Hamilton's Principle, Other Deep Shell Theories.

**Natural Frequencies and Modes:** General Approach, Rectangular Plates that are simply supported Along Two Opposing Edges, Circular Plates Vibrating Transversely, In-Plane Vibrations of Rectangular Plates.

**Vibration of Shells and Membranes under the Influence of Initial Stresses**: Strain-Displacement Relationships, Equations of Motion, Pure Membranes, Equations of Motion for Shells on Elastic Foundations, Plates on Elastic Foundations.

**Learning Resources:**

1. Vibration of Shells and Plates, Werner. S Marcel Publishing House, 2004.
2. Stresses in Beams, Plates, and Shells, Third Edition Ugural, Ansel C, CRC Press 2009.
3. Theory Applications and Plate analysis, RudolphSzilard, Whiley Publisher 2004
4. Saouma. V.E, Finite Elemnt II Solid Mechanics, Springer- 2001.
5. Theory of Plates and Shells, Arthur. W. L, Vibration of Plates, 1970.Timoshenko, Mc Graw Hill.

**Online Resources:** https://nptel.ac.in/noc/courses/noc18/SEM2/noc18-me65/

| Course Code: ME 5465 | SMART MATERIALS AND SENSORS | Credits 3-0-0: 3 |
|---|---|---|

Prerequisite: Nil

**Course Outcomes:**

At the end of the course, student will be able to:

| | |
|---|---|
| **CO1** | Identify smart materials based on the engineering applications |
| **CO2** | Develop constitutive equations and mathematical models for the smart materials |
| **CO3** | Design sensing devices and structures using smart materials |
| **CO4** | Adapt smart sensors for measurement of physical properties and structural health monitoring |

**Course Articulation Matrix:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 2 | | 3 | | | |
| **CO2** | 3 | 2 | 3 | 2 | 3 | 2 |
| **CO3** | 3 | 2 | 3 | 2 | 3 | |
| **CO4** | 3 | 2 | 3 | 2 | 3 | 2 |

**Syllabus:**

**Introduction:** Introduction of smart materials- Piezoelectric materials, magneto-strictive materials and magneto-resistance effect, electroactive materials and polymers, Shape memory alloys and polymers, electro and magneto rheological fluids, intelligent materials.

**Piezoelectric Materials:** Piezoelectric effect, Constitutive equations, properties of piezoelectric materials, variation of coupling coefficients for PZT materials, Mathematical modelling- Electro mechanical performance.

**Magneto-strictive Materials and Shape memory alloys:** Magneto-strictive Sensing Magneto mechanical coupling coefficients of magneto-strictive materials, constitutive relationships, Villari Effect, Matteuci Effect and Nagoka-Honda Effect, Magnetic Delay Line Sensing, Magneto strictive mini actuators. Classification of shape memory alloys, methods of fabrication, Control design for shape memory alloys and polymers, Electroactive polymers and its applications, LBHS and HBLS smart actuators.

**Smart sensors:** Selection of sensors and its monitoring techniques for monitoring force, position, vibration, noise, temperature for the mechanical systems-Integrated and distributed temperature sensing, strain measurements, fluid rheological properties measurements using FBG and ultrasonic sensors, Application of accelerometers, EAP, SMAs, vision sensors, MEMS based actuators, robot sensors, micro sensors, Nano sensors, Case studies and student presentations

**Structural Health Monitoring using Smart Sensors**: Structural integrity using fiber optic, acoustic/ultrasonic, and piezoelectric active sensors/patches, piezoelectric smart structures-numerical and experimental methods. Delamination sensing using magneto-strictive and Piezoelectric sensors. Case studies and student presentations.

## Learning Resources:


1. Structural Health monitoring with Piezoelectric Wafer Active sensors, by Victor Giurgiutiu, Academic Press, 2008, I st edition
2. Smart Materials and Structures, Thompson and Gandhi, Chapman and Hall, 1992
3. Piezoelectric energy harvesting, Alper Erturk and Daniel J Inmann, Wiley Publications, 2011, Ist edition
4. Structural Health monitoring with Piezoelectric Wafer Active sensors, by Victor Giurgiutiu, Academic Press, 2008
5. Smart sensors for industrial applications by Krzysztof Iniewski, CRC Press Taylor and Francis group, 2013
6. Micro and Smart Systems: Technology and Modeling, Ananthasuresh, G. K., Vinoy, K. J., Gopalakrishnan, S., Bhat, K. N., and Aatre, V. KWiley, New York, 2012.


## Online Resources:

https://nptel.ac.in/courses/112/104/112104173/

| Course Code: ME 5466 | TRIBOLOGY IN DESIGN | Credits 3-0-0: 3 |
|---|---|---|

Prerequisite: Nil

**Course Outcomes:**

At the end of the course, the student shall be able to:

| | |
|---|---|
| **CO1** | Analyze friction, wear, lubrication and their interactions for a given application |
| **CO2** | Identify tribological performance parameters on Tribological components |
| **CO3** | Predict the type of failure in metallic, ceramic and polymeric surfaces |
| **CO4** | Design and select appropriate tribo components for a given application |

**Course Articulation Matrix:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 2 | 2 | | 2 |
| **CO2** | 3 | 3 | 3 | 3 | 2 | |
| **CO3** | 3 | 2 | 3 | 2 | 3 | 2 |
| **CO4** | 3 | | 3 | 2 | 3 | 2 |

**Syllabus:**

**Basic concepts of Tribology**: Friction, Wear and Lubrication - Friction and Wear of metal, ceramics and polymeric materials.

**Friction and Wear:** Origins of sliding friction-Friction due to adhesion, ploughing, deformation by conical & spherical asperity; Determine the coefficient of friction by solid mechanics; limiting junction growth. Wear processes and their mechanisms - Adhesive wear, Abrasive wear, Erosive wear, Corrosive wear, Surface fatigue wear, Fretting wear.

**Lubrication modes and theories of hydrodynamic lubrication:** Types of lubricants, Modes of lubrication - hydrodynamic, hydrostatic, Elasto-hydrodynamic, mixed and boundary lubrication, Reynolds' equation, Applications of hydrodynamic lubrication theory.

**Surface Engineering,** Interactions and Coating for tribo components; Contact mechanics.

**Tribological components:** Theory, Design and applications of tribological components – sliding and rolling element bearings, seals, gears, cams, chains, brakes and clutches. Tribological issues in cutting tools and automotive engines.

**Tribo failures and analysis**: case studies

**Special topics:** Bio-tribology, Introduction to MEMS, Nano Tribology and Space Tribology.

**Learning Resources:**

1. Engineering Tribology, Stachowaik, G.W., Batchelor, A.W., 3rd Ed., Elsevier, 2010.
2. Tribology in Machine Design, TA Stolarski, Butterworth-Heinemann, 2000.
3. Engineering Tribology, Williams JA, Oxford Univ. Press, 2001.
4. Introduction to bearings, Majumdar B.C, S. Chand & Co., Wheeler publishing, 1999.
5. Fluid film lubrication theory and design, Andras Z. Szeri, Cambridge Universitypress, 1998.
6. Basic lubrication theory, Cameron A, Ellis Horwood Ltd., 2002.
7. Tribology Hand Book, Neale MJ, CBS Publications, 2012.

| Course Code: ME 5467 | ADVANCED COMPOSITE TECHNOLOGIES | Credits 3-0-0: 3 |
|---|---|---|

Prerequisite: Nil

**Course Outcomes:**

At the end of the course the student will be able to:

| | |
|---|---|
| **CO1** | Understand composite material and their reinforcements |
| **CO2** | Select constituent materials to develop appropriate composites |
| **CO3** | Analyze interfaces of composites for predicting their mechanical properties. |
| **CO4** | Develop metal matrix, ceramic matrix and polymer matrix composites with calculated values of constituents |
| **CO5** | Analyze the performance of automobile component material |

**Course Articulation Matrix:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 2 | 2 | 3 | 3 |
| **CO2** | 3 | 2 | 2 | 2 | 2 | 2 |
| **CO3** | 3 | 3 | | 3 | | 2 |
| **CO4** | 3 | 3 | 2 | 2 | 2 | 3 |
| **CO5** | 3 | 3 | 2 | 2 | 2 | 3 |

**Syllabus:**

**Introduction:** Overview of the course, history and basic concept of composites, Types and constituents, reinforcement and matrices, interface and mechanism of strengthening.

**Fundamental concepts:** Definition and Classification of Composites, particulate and dispersion hardened composites, continuous and discontinuous fibre reinforced composites MMC, PMC, CMC. Automobile component materials

**Metal Matrix Composites Processing:** Liquid state processes, solid state processes and insitu processes.

**Interface:** Role, reactions, bonding mechanisms and bond strength.

**Properties and applications:** Strength, stiffness, creep, fatigue and fracture; thermal, damping and tribological properties.

**Polymer Matrix Composites Processing:** Hand layup and spray technique, filament winding, pultrusion, resin transfer molding, bag and injection molding, sheet molding compound.
Matrix resins-thermoplastics and thermosetting matrix resins. Reinforcing fibers- Natural fibers (cellulose, jute, coir etc.), carbon fiber, glass fiber, Kevlar fiber, etc. Particulate fillers-importance of particle shape and size. Coupling agents-surface treatment of fillers and fibers, significance of interface in composites. short and continuous fibre reinforced composites, critical fibre length, and anisotropic behavior. Polymer composites applications in Automobile industry.

**Ceramic Matrix Composites Processing:** Cold pressing & sintering, hot pressing reaction bonding processes, infiltration, in-situ chemical reaction, Sol-Gel and polymer pyrolysis, self-propagating high

temperature synthesis. Carbon- carbon composites, Interfaces.

**Rule of mixtures.** Stress, strain transformations.
**Nanocomposites:** introduction to Nanocomposites, advantages disadvantages

**Materials for Automobile bodies:** Materials for considerations and use in automobile body structure- Steels, Aluminium alloys, Magnesium alloys, polymers and composites. Component manufacturing: material joining, Casting and forming techniques.
**Heat Treatment processes:** Annealing, Normalising, Ageing, solutionising, hardening, tempering
**Surface Heat treatment :** Carburising, zinc coating, Nitriding , cyaniding

**Test methods:** Quality assessment, physical and mechanical property characterization.

## Learning Resources:

1. Composite Materials Science and Engineering, Chawla, Springer
2. An introduction to composite materials, Hull, Cambridge
3. ASM Handbook Composites, Steven L. Donaldson, Volume 21, 2001.
4. Composite Materials, Science and Engineering, Krishan K. Chawla, Springer, 2001.
5. Process Modelling in Composites Manufacturing,Suresh G. Advani, E. Murat Sozer, 2nd Ed. CRC Press, 2009
6. Materials for Automobile Bodies-Geoffrey Davies, 2nd Ed. Elsevier Science, 2003.

| Course Code: ME 5468 | ROBOTICS | Credits 3-0-0: 3 |
|---|---|---|

Prerequisite: Nil

## Course Outcomes:

At the end of the course, the student shall be able to:

| | |
|---|---|
| **CO1** | Classify robots based on joints and arm configurations. |
| **CO2** | Design application specific End Effectors for robots. |
| **CO3** | Compute forward and inverse kinematics of robots and determine trajectory plan. |
| **CO4** | Program robot to perform typical tasks including Pick and Place, Stacking and Welding |
| **CO5** | Design and select robots for Industrial and Non-Industrial applications. |

## Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | | | 2 | 2 | 3 | 2 |
| **CO2** | 2 | | 3 | 2 | 3 | 2 |
| **CO3** | 2 | | 2 | 2 | 2 | 2 |
| **CO4** | 2 | | 2 | 2 | 2 | 2 |
| **CO5** | 3 | 1 | 3 | 3 | 3 | 2 |

## Syllabus:

**Introduction:** Multibody systems, Automation, Classification of robots, Anatomy, Sensors (velocity, proximity, touch, torque etc), Grippers, selection of Robot based on the Application. Demonstration of different types of Robots & tools using Robot Simulator Software like ROBODK.

**Kinematics:** Manipulators Kinematics, Rotation Matrix, Homogenous TransformationMatrix, Direct and Inverse Kinematics for industrial robots for Position and orientation. Demonstrate FK and IK using simulation tools.

**Differential Kinematics, statics and Dynamics:** Jacobian, Lagrangian Formulation, Newton-Euler Formulation for RR & RP Manipulators. Demonstrate differential kinematics using simulation tools.

**Trajectory planning & Control:** Motion Control- Interaction control, Rigid Body mechanics, Control architecture- position, path velocity and force control systems, computed torque control, adaptive control, and Servo system for robot control. Demonstrate trajectory planning using simulation tools.

**Advanced Topics in Robotics:** Motion Planning (Methods of Path planners), Robot Vision (Feature Detection & Matching, Motion Tracking, Machine Learning methods).

**Programming of Robots:** Overview of various programming languages.

**Application of Robots in production systems**: Application of robot in welding, machine tools, material handling, and assembly operations parts sorting and parts inspection.

## Learning Resources:

1. Robotics control, Sensing, Vision and Intelligence, Fu, K.S., Gonzalez, R.C., and Lee, C.S.G., McGraw-Hill Publishing company, New Delhi, 2003.

2. Engineering: An IntegratedApproach, Prentice Hall of India, Klafter, R.D., Chmielewski, T.A., and Negin. M, Robot New Delhi, 2002.
3. Introduction to Robotics Mechanics and Control, Craig, J.J., Addison Wesley, 1999.
4. Modern Robotics: Mechanics, Kevin M. Lynch, Frank C. Park, Planning, and Control, Cambridge University Press, 2017.

**Online Resources:**

1. nptel Courses: https://nptel.ac.in/courses/107/106/107106090/ , https://nptel.ac.in/courses/112/101/112101098/, https://nptel.ac.in/courses/112/107/112107289/, https://nptel.ac.in/courses/112/104/112104298/
2. Stanford Lecture Series: https://see.stanford.edu/Course/CS223A
3. MIT OCW: https://ocw.mit.edu/courses/mechanical-engineering/2-12-introduction-to-robotics-fall-2005/

| Course Code: ME 5469 | OPTIMIZATION METHODS FOR ENGINEERING DESIGN | Credits 3-0-0: 3 |
|---|---|---|

Prerequisite: Nil

**Course Outcomes:**

At the end of the course, the student shall be able to:

| | |
|---|---|
| **CO1** | Formulate a design task as an optimization problem |
| **CO2** | Identify constrained and unconstrained optimization problems and solve using corresponding methods |
| **CO3** | Solve discontinuous optimization problems using special methods |
| **CO4** | Solve nonlinear optimization problems with evolutionary methods |

**Course Articulation Matrix:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 3 | 3 | 1 | 2 |
| **CO2** | 2 | 2 | 3 | 3 | 2 | 2 |
| **CO3** | 3 | | 3 | 3 | 3 | 2 |
| **CO4** | 3 | | 3 | 3 | 3 | 2 |

**Syllabus:**

**Introduction to Optimization in Design:** Problem formulation, Optimization problems in Mechanical Engineering, Classification of methods for optimization

**Single-variable Optimization:** Optimal criteria, Derivative-free methods (bracketing, region elimination), Derivative based methods, root-finding methods.

**Multiple-variable Optimization:** Optimal criteria, Direct search methods (Box's,Simplex, Hooke-Jeeves, Conjugate methods), Gradient-based methods (Steepest Descent, Newton's, Marquardt's, DFP method). Formulation and Case studies.

**Constrained Optimization:** KKT conditions, Penalty method, Sensitivity analysis, Direct search methods for constrained optimization, quadratic programming, GRG method, Formulation and Case studies.
**Specialized algorithms:** Integer programming (Penalty function and branch-and- bound method), Geometric programming.

**Evolutionary Optimization algorithm:** Genetic algorithms, simulated annealing, Anti-colony optimization, Particle swarm optimization.

**Multi-objective Optimization:** Terminology and concepts, the concepts of Pareto optimality and Pareto optimal set, formulation of multi-objective optimization problem, NSGA.

**Case studies and Computer Implementation:** Representative case studies for important methods and development of computer code for the same to solve problems.

**Learning Resources:**

1. Introduction to Optimum Design, Jasbir Arora, Academic Press, 2004
2. Optimization For Engineering Design: Algorithms and Examples, Kalyanmoy Deb, PHI, 2004.
3. Multi-Objective Optimization using Evolutionary Algorithms, Kalyanmoy Deb, Wiley,2001.

| Course Code: ME 5552 | VEHICLE DYNAMICS | Credits 3-0-0: 3 |
|---|---|---|

Prerequisite: Nil

## Course Outcomes:

At the end of the course, the student shall be able to:

| | |
|---|---|
| **CO1** | Understand the principles underlying the development and design of road vehicles under the influence of dynamic loads. |
| **CO2** | Analyze the performance and establish the design specifications for the acceleration and braking conditions. |
| **CO3** | Model, simulate and analyze the conventional road vehicles for better ride comfort. |
| **CO4** | Analyze the cornering forces and effects of tractive forces on cornering. |
| **CO5** | Design suspension systems for better damping and comfort. |

## Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | | | 2 | 2 | 2 | 1 |
| **CO2** | 2 | 2 | 3 | 2 | 3 | 2 |
| **CO3** | 2 | | 3 | 3 | 2 | 2 |
| **CO4** | 2 | 2 | 3 | 3 | 3 | 2 |
| **CO5** | 3 | | 3 | 3 | 3 | 2 |

## Syllabus:

**Introduction:** Hypothetical vehicle control loop, Fundamental Approach, Vehicle coordinates, motion variables. Forces – Dynamic axle loads, Static loads on level ground, aerodynamic forces on body, hitch forces, tire construction, size and load rating, terminology, mechanics of force generation, Tire wear, tire life, factors affecting tire life – problems

**Road Loads:** Aerodynamic, Mechanics of pressure distribution – Aerodynamic forces: lift & drag, Spoilers, Lift force, side force and roll, pitch and yaw moments, Crosswind sensitivity. Rolling Resistance, Factors affecting pressure, velocity, slip temperature, etc – Total road loads – Fuel Economy Effects.

**Acceleration & Braking Performance:** Power limited, Traction limited acceleration, Static loads on level ground, aerodynamic forces on body, Fundamental Expressions, Constant retardation, Wind Resistance, Power, Braking forces, Brakes: disc and drum, front, rear and four-wheel braking, Braking Torque, Road friction rolling resistance, problems.

**Vehicle Vibration and Ride characteristics:** Excitation sources – road roughness, wheel assembly, driveline excitation, engine transmission. Wheel Hop Resonance. Rigid body bounce, pitch motion. Effect of vibration on vehicle riding. Influence of pressure in tyre, alignment toe in and toe out, tire wear and tire life.

**Suspension:** Solid axes – Independent suspension, Anti-squat and anti- pitch suspension geometry, roll center analysis, Active suspension, suspension load – vehicle loading, load due to gyroscopic force on suspension, total load on suspension.

**Steady–State Cornering:** Introduction, Low and high speed turning –Tire cornering forces, governing expressions, under steer gradient, over steer and neutral conditions. Characteristic speed, critical speed, yaw velocity gain, sideslip angle, static margin. Suspension effects on cornering.

**Learning Resources:**

1. Tire and Vehicle Dynamics, Hans B Pacejka, 3rd Edition, Elsevier Ltd., 2012.
2. An Introduction to Modern Vehicle Design, J H Smith, Butterworth Heinemann, Oxford, 2010
3. Road Vehicle Dynamics, Rao V Dukkipati, Springer 2008
4. Ground Vehicle Dynamics, Werner and Karl, Springer Berlin Heidelberg, 2008.
5. Theory of Ground Vehicles, Wong H, McGraw Hill, Second edition, 2006.
6. Fundaments of Vehicle Dynamics. Thomas D Gillespie, SAE Inc, 2002

| ME 5371 | ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING FOR MECHANICAL SYTEMS | 3-0-0: 3 |
|---|---|---|

Pre-Requisites: Nil

**Course Outcomes:**

At the end of the course, the student will be able to

| | |
|---|---|
| **CO1** | Understand the core concepts of Mechanical Systems in the context of Industry 4.0 |
| **CO2** | Apply AI, ML and Deep Learning concepts on Various Mechanical Systems |
| **CO3** | Apply the statistical and optimization techniques on Mechanical Systems |
| **CO4** | Evaluate the Mechanical System performance using simulation and experimental analysis |

**Course Articulation Matrix:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 2 | 3 | 3 | | 3 | 3 |
| **CO2** | | | 3 | 3 | | 3 |
| **CO3** | 3 | 3 | 3 | 3 | | 3 |
| **CO4** | | 3 | | 3 | 3 | 3 |

1 - Slightly; 2 - Moderately; 3 – Substantially

**Syllabus:**

**Introduction to Mechanical Systems** evolution in the context of Industry 4.0, Key issues: Adaptability, Intelligence, Autonomy, Safety, Sustainability, Interoperability, Flexibility of Mechanical Systems.

**Introduction of Statistics;** Descriptive statistics: Central tendency measures, Dispersion measures, data distributions, centre limit theorem, sampling, sampling methods; Inferential Statistics: Hypothesis testing, confidence level, degree of freedom, P-value, Chi-square test, ANOVA, Correlation V's Regression, Uses of Correlation and regression.

**Artificial Intelligence:** Brief review of AI history, Problem formulation: Graph structure, Graph implementation, state space representation, search graph and search tree, Search Algorithms: random search, Depth-first, breadth-first search and uniform-cost search. Heuristic: Best first search, A* and AO* algorithm, generalization of search problems. Ontology; Fuzzy; Meta-heuristics.

**Machine Learning:** Overview of supervised and unsupervised learning; Supervised Learning: Linear Regression, Non-linear Regression Model evaluation methods, Logistic Regression, Neural Networks; Unsupervised Learning: K-means clustering, C-means Clustering. Convolutional Neural Networks (CNN), Pooling, Padding Operations, Interpretability in CNNs, Limitations in CNN. Cases with respect to different mechanical systems.

**Introduction to Raspberry** Pi; Installation of Raspbian OS on Raspberry Pi; Controlling LED using Raspberry Pi; Integrating IR Sensor with Raspberry Pi; Controlling LED with IR Sensor; Integrating Temperature and amp; Humidity Sensor with Raspberry Pi read Current Environment Values, Collecting the sensor data using Raspberry Pi; Matlab toolboxes - Simulink, Mechanical

Systems implementation: From features to software components, Mapping software components to ECUs.

## Learning Resources


1. Rajkumar, Dionisio De Niz ,and Mark Klein, *Cyber-Physical Systems*, Wesley Professional.
2. Rajeev Alur, Principles of Cyber-Physical Systems, MIT Press, 2015.
3. Robert Levine et al., “A Comprehensive guide to AI and Expert Systems”, McGraw Hill Inc, 1986.
4. E. A. Lee and S. A. Seshia, “Introduction to Embedded Systems: A Cyber-Physical Systems Approach”, 2011.
5. C. Cassandras, S. Lafortune, “Introduction to Discrete Event Systems”, Springer 2007.
6. Constance Heitmeyer and Dino Mandrioli, “Formal methods for real-time computing”, Wiley publisher, 1996.
7. Montgomery Douglas, 2017. Design of Experiments, John Wiley and Sons, Inc.

| ME6447 | COMPREHENSIVE VIVA – VOCE | Credits: 2 |
|---|---|---|

**COMPREHENSIVE VIVA – VOCE OUTCOMES:** At the end of the comprehensive viva-voce, the student shall be able to:

| | |
|---|---|
| CO1 | Comprehend the knowledge gained in the course work |
| CO2 | Identify principles of design of mechanical systems and controls |
| CO3 | Demonstrate the ability in problem solving and to communicate effectively. |

**CO-PO MAPPING:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | | 3 | 2 | | 3 |
| **CO2** | 3 | | 3 | 3 | 2 | 3 |
| **CO3** | 3 | | 3 | 3 | 3 | 3 |

| ME6449 | DISSERTATION PART – A | Credits: 12 |
|---|---|---|

**DISSERTATION OUTCOMES:** At the end of the part – A of dissertation, the student shall be able to:

| | |
|---|---|
| **CO1** | Identify a topic in advanced areas of additive manufacturing |
| **CO2** | Review literature to identify gaps and define objectives and scope of the work |
| **CO3** | Employ the ideas from literature and develop research methodology |
| **CO4** | Develop a model, experimental set-up and/or computational techniques necessary to meet the objectives. |

**M.Tech Dissertation Rubric Analysis:**

| Task | Description |
|---|---|
| I | Selection of Topic |
| II | Literature Survey |
| III | Defining the Objectives and Solution Methodology |
| IV | Performance of the Task |
| V | Dissertation Preparation |
| VI | Review (Presentation & Understanding) |
| VII | Viva-Voce |
| VIII | Publications /Possibility of publication |

| | ME 6449 | | | |
|---|---|---|---|---|
| **Task (% Weightage)** | **CO1** | **CO2** | **CO3** | **CO4** |
| I (10) | X | | | |
| II (20) | X | X | | |
| III (30) | | | X | |
| IV (40) | | | | X |

**CO-PO MAPPING:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 3 | 1 | | 3 |
| **CO2** | 3 | 2 | 3 | 1 | | 3 |
| **CO3** | 3 | 3 | 3 | 3 | 3 | 3 |
| **CO4** | 3 | 3 | 3 | 3 | 3 | 3 |

| ME6499 | DISSERTATION PART – B | 20 Credits |
|---|---|---|

**DISSERTATION OUTCOMES:** At the end of the part – B of dissertation, the student shall be able to:

| | |
|---|---|
| **CO1** | Identify the materials and methods for carrying out experiments/develop a code |
| **CO2** | Execute the research methodology with a concern for society, environment and ethics |
| **CO3** | Analyse, discuss and justify the results/trends and draw valid conclusions |
| **CO4** | Prepare the report as per recommended format and present the work orally adhering to stipulated time |
| **CO5** | Explore the possibility to publish/present a paper in peer reviewed journals/conference without plagiarism |

**Task – CO Mapping:**

| | ME 6499 | | | | |
|---|---|---|---|---|---|
| **Task (% Weightage)** | **CO1** | **CO2** | **CO3** | **CO4** | **CO5** |
| IV (40) | X | X | | | |
| V (20) | | | | X | |
| VI (10) | | | X | | |
| VII (20) | | | | X | |
| VIII (10) | | | | | X |

**CO-PO MAPPING:**

| | **PO1** | **PO2** | **PO3** | **PO4** | **PO5** | **PO6** |
|---|---|---|---|---|---|---|
| **CO1** | 2 | | 3 | 3 | 2 | 3 |
| **CO2** | 2 | | 3 | 3 | 2 | 3 |
| **CO3** | 3 | | 3 | 3 | 2 | 3 |
| **CO4** | 3 | 3 | 3 | 3 | 3 | 3 |
| **CO5** | 3 | 3 | 3 | | | 3 |

**NOTE: Refer to the following link for the guidelines to prepare dissertation report: https://www.nitw.ac.in/main/PGForms/NITW/**