NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL



Honors in
DESIGN ENGINEERING

SCHEME OF INSTRUCTION AND SYLLABI

for B.Tech. Program

(Effective from 2021-22)

DEPARTMENT OF MECHANICAL ENGINEERING

Scheme of Instruction
Honors in Design Engineering

S.No.	Subject name	Semester
1	ME5401 Advanced Mechanical Design	Odd
2	ME5402 Advanced Mechanics of Solids	Odd
3	ME5413 Analysis and Synthesis of Mechanisms	Odd
4	ME5417 Mechanics and Processing of Polymer Materials	Odd
5	ME5451 Product Design & Development	Even
6	ME5552 Vehicle Dynamics	Even

Course Code: ME5401	ADVANCED MECHANICAL DESIGN	3-0-0: 3

Pre-Requisites: Design of machine elements, Design of transmission elements

Course Outcomes:

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

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; Griffith's 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:

Text Books:

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 Mc Graw Hill, 2011, 9th edition.
3. Mechanical Behavior of materials, Marc Meyers and Krishan Chawla, Cambridge University Press, 2009. 2nd edition.
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: ME5402	ADVANCED MECHANICS OF SOLIDS	3-0-0: 3

Pre-Requisites: Mechanics of Solids

Course Outcomes:

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

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:

Text Books:

1. Advanced Mechanics of Solids, L.S. Srinath, TMH, 2009, 3rd edition.
2. Mechanics of Deformable Solids, Irving H. Shames, Krieger Pub Co, 2008.

Reference Books:

1. Theory of Elasticity, Sadhu Singh, Khanna Publishers, 2015, 4th edition.
2. Theory of Elasticity, Timoshenko and Goodier, TMH, 2011, 3rd edition.

Course Code: ME5413	ANALYSIS AND SYNTHESIS OF MECHANISMS	3-0-0: 3

Pre-Requisites: Kinematics of Machinery, Dynamics of Machinery

Course Outcomes:

CO1	Understand basic mechanisms and machines and formulate the design problem
CO2	Develop analytical equations for relative position, velocity and acceleration of all 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.

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 for rocker output, precision points, comparison of analytical and graphical two position synthesis, 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 train and its analysis.

Learning Resources:

Text Books:

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 Analysis of Mechanisms and Machines, Robert L Norton, McGraw Hill reprint 2011, 2nd edition.
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, Oxford University Press, 2011, 4th edition.

Course Code: ME5451	PRODUCT DESIGN AND DEVELOPMENT	3-0-0: 3

Pre-Requisites: NIL

Course Outcomes:

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.

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:

Text Books:

1. Engineering Design, George E Dieter, Publisher, McGraw Hill, 4th edition.

Reference Books:

1. Kevin N. Otto, Kristin L. Wood, "Product Design", Pearson Education, 2004.
2. W. Ernest Eder, S. Hosendl., "Design Engineering", CRC Press, 2008.

Online Resources:

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

Course Code: ME5417	MECHANICS AND PROCESSING OF POLYMER MATERIALS	3-0-0: 3

Pre-Requisites: NIL

Course Outcomes:

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

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:

Text Books:

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

Course Code: ME5552	VEHICLE DYNAMICS	3-0-0: 3

Pre-Requisites: NIL

Course Outcomes:

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

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:

Text Books:

1. Tire and Vehicle Dynamics, Hans B Pacejka, Elsevier Ltd., 2012, 3rd Edition.
2. An Introduction to Modern Vehicle Design, J H Smith, Butterworth Heinemann, Oxford, 2010.

Reference Books:

1. Road Vehicle Dynamics, Rao V Dukkipati , Springer 2008.
2. Ground Vehicle Dynamics, Werner and Karl, Springer Berlin Heidelberg, 2008.
3. Theory of Ground Vehicles, Wong H, McGraw Hill, 2006, Second edition.
4. Fundaments of Vehicle Dynamics, Thomas D Gillespie, SAE Inc, 2002.