VEERMATA JIJABAI TECHNOLOGICAL INSTITUTE

(VJTI)

MATUNGA, MUMBAI 400 019

(Autonomous Institute affiliated to University of Mumbai)

Curriculum

(Scheme of Instruction & Evaluation and Course contents)

For

Third Year

of

Four Year Undergraduate Programme

Leading to

Bachelor of Technology (B Tech) Degree in Mechanical Engineering

Implemented for the batch admitted in Academic Year 2023-24

B. Tech. Mechanical Engineering

Program Educational Objectives (PEOs)

1. To attain Analytical, Experimental and Computational expertise in Mathematics, Applied Sciences and Core Engineering subject domain.
2. To discharge responsibilities towards society by achieving high standards of professionalism, leadership and ethical behavior.
3. To comprehend the need for higher studies and lifelong learning so as to remain in competitive and sustainable environment.

Program Outcomes (POs)

PO1: Apply knowledge of mathematics, science and engineering to design, analyze and evaluate mechanical components & complex systems.

PO2: Analyze problems of mechanical engineering including design thermal and manufacturing industrial systems.

PO3: Design, implement, and evaluate mechanical systems and processes considering public health, safety, cultural, societal and environmental issues.

PO4: Design and conduct experiments using domain knowledge and analyze data to arrive at valid conclusions.

PO5: Apply recent techniques, skills, knowledge and computer based methods & tools to solve mechanical problems.

PO6: Analyze the local and global impact of modern technologies on individual organizations, society and culture.

PO7: Apply knowledge of contemporary issues to investigate and solve problems with a concern for sustainability and eco-friendly environment.

PO8: Exhibit responsibility in professional, ethical, legal and social issues.

PO9: Function effectively in teams, in diverse and multidisciplinary areas to accomplish common goal.

PO10: Effective written and verbal communication on complex engineering activities and exhibit leadership qualities.

PO11: Apply management principles to manage projects in multidisciplinary environment.

PO12: Pursue life-long and independent learning as a means to enhance knowledge and skills.

Program Specific Outcomes (PSOs)

Our Graduate should be able to apply principles of Mechanical Engineering to:

1. Specify, manufacture, test, operate and document basic mechanical systems and processes.
2. Analyse, design, develop and implement advanced mechanical systems and processes.
3. Select solutions to the mechanical engineering problems based on ethics, sustainability and long term benefits to society.

V J T I Veermata Jijabai Technological Institute
(Central Technological Institute, Maharashtra State, INDIA)
H. R. Mahajani Marg, Matunga, Mumbai 400019
Tel.No. +91 22 24198101-02 Fax +91 22 24102874
www.vjti.ac.in

(Autonomous Institute affiliated to University of Mumbai)

Curriculum

(Scheme of Instruction & Evaluation and Course contents)

For

Third Year

of

Four Year Undergraduate Programme

Leading to

Bachelor of Technology (B Tech) Degree in Mechanical Engineering

V J T I Veermata Jijabai Technological Institute
(Central Technological Institute, Maharashtra State, INDIA)
H. R. Mahajani Marg, Matunga, Mumbai 400019
Tel.No. +91 22 24198101-02 Fax +91 22 24102874
www.vjti.ac.in

Credit Framework for UG Programme in Mechanical Engineering

(Level 5.5- B. Voc. or B. Sc. (Tech.)) - Semester - V

Sr.	Course Type	Course Code	Course Name	L	T	P	Hr	Cr	Examination Weightage in %		
									TA	MST	ESE
1	PCC	R5ME3001T	Dynamics of Machines	3	0	0	3	3	20	30	50
2	PCC	R5ME3002T	Heat Transfer	3	0	0	3	3	20	30	50
3	PCC	R5ME3003T	Fluid Machinery	3	0	0	3	3	20	30	50
4	PCC	R5ME3004T	Design of Machine Elements	3	0	0	3	3	20	30	50
5	PEC		Program Elective –I	3	0	0	3	3	20	30	50
6	HSSM	R5ME3005T	Production Management	2	0	0	2	2	20	30	50
7	MDM		Multi-disciplinary Minor-III	3	0	0	3	3	20	30	50
8	PCC	R5ME3001L	Dynamics of Machines Laboratory	0	0	2	2	1	ISCE :60		40
9	PCC	R5ME3002L	Heat Transfer Laboratory	0	0	2	2	1	ISCE :60		40
10	PCC	R5ME3003L	Fluid Machinery Laboratory	0	0	2	2	1	ISCE :60		40
11	PEC		Program Elective –I Laboratory	0	0	2	2	1	ISCE :60		40
			Total	20	0	8	28	24			

Abbreviations: **L** Lecture, **T** Tutorial, **P** Practical, **TA** Teacher Assessment / Term work Assessment, **MST** Mid Semester Test, **ESE** End Semester Written Examination, **ISCE** In-semester Continuous Evaluation, **PCC** Program Core, **PEC** Program Elective **MDM** Multi-Disciplinary Minor **HSSM** Humanities Social Science and Management

V J T I Veermata Jijabai Technological Institute
(Central Technological Institute, Maharashtra State, INDIA)
H. R. Mahajani Marg, Matunga, Mumbai 400019
Tel.No. +91 22 24198101-02 Fax +91 22 24102874
www.vjti.ac.in

Credit Framework for UG Programme in Mechanical Engineering (Level 6.0 - B.Tech. In Mechanical Engineering with Multidisciplinary Minor) - Semester - VI

Sr.	Course Type	Course Code	Course Name	L	T	P	Hr	Cr	Examination Weightage in %		
									TA	MST	ESE
1	PCC	R5ME3006T	Design of Mechanical Systems	3	0	0	3	3	20	30	50
2	PCC	R5ME3007T	Computer Aided Design and Analysis	3	0	0	3	3	20	30	50
3	PCC	R5ME3008T	Thermal Engineering	3	0	0	3	3	20	30	50
4	PEC		Program Elective –II	3	0	0	3	3	20	30	50
5	HSSM	R5ME3009T	Operations Management	2	0	0	2	2	20	30	50
6	MDM		Multi-disciplinary Minor-IV	3	0	0	3	3	20	30	50
7	OE		Open Elective-I	3	1	0	4	4	20	30	50
8	VSEC	R5ME3007L	Computer Aided Design and Analysis Laboratory	0	0	2	2	1	ISCE :60		40
9	PCC	R5ME3008L	Thermal Engineering Laboratory	0	0	2	2	1	ISCE :60		40
10	PEC		Program Elective –II Laboratory	0	0	2	2	1	ISCE :60		40
			Total	20	1	6	27	24			

Abbreviations: **L** Lecture, **T** Tutorial, **P** Practical, **TA** Teacher Assessment / Term work Assessment, **MST** Mid Semester Test, **ESE** End Semester Written Examination, **ISCE** In-semester Continuous Evaluation, **PCC** Program Core, **PEC** Program Elective, **MDM** Multi-Disciplinary Minor, **VSEC** Vocational and Skill Enhancement Course, **HSSM** Humanities Social Science and Management

V J T I Veermata Jijabai Technological Institute
(Central Technological Institute, Maharashtra State, INDIA)
H. R. Mahajani Marg, Matunga, Mumbai 400019
Tel.No. +91 22 24198101-02 Fax +91 22 24102874
www.vjti.ac.in

List of Exit Courses after completion of Semester V and VI

1. Exit option is available for students those who have earned the total 132 credits at the End of Second Semester.
2. Student who wants to avail the exit option after first year have to earn additional 6-8 credits from the list of courses shown below.
3. These courses student have to complete within summer vacation after 3rd Year.
4. After fulfilment as mentioned in 1 to 3 above, Students can earn B. Voc. or B. Sc. (Tech.) and same will be issued by the Institute.

List of Exit Courses after completion of Semester V and VI: Mechanical Engineering

Sr.	Course Type	Course Code	Course Name	L	T	P	Hr	Cr	Examination Weightage in %		
									TA	MST	ESE
1	OJT	R5ME3901I	Internship					6	ISCE :60		40
2		R5ME3902P	Mini-Project	0	0	8	8	4	ISCE :60		40
3	PCC	R5ME3903L	Thermal Engineering Laboratory	0	0	4	4	4	ISCE :60		40
4	PCC	R5ME3904L	CNC Programming	0	0	4	4	4	ISCE :60		40

Abbreviations: **L** Lecture, **T** Tutorial, **P** Practical, **TA** Teacher Assessment / Term work Assessment, **MST** Mid Semester Test, **ESE** End Semester Written Examination, **ISCE** In-semester Continuous Evaluation, **PCC** Program Core, **OJT** On Nob Training

V J T I Veermata Jijabai Technological Institute
(Central Technological Institute, Maharashtra State, INDIA)
H. R. Mahajani Marg, Matunga, Mumbai 400019
Tel.No. +91 22 24198101-02 Fax +91 22 24102874
www.vjti.ac.in

Program Electives in Semester V

Sr. No.	Course Code	Name
1	R5ME3101T	Automotive Mechanics
	R5ME3101L	Automotive Mechanics Laboratory
2	R5ME3102T	Composite Materials
	R5ME3102L	Composite Materials Laboratory
3	R5ME3103T	Energy Conservation & Management
	R5ME3103L	Energy Conservation & Management Laboratory

Program Electives in Semester VI

Sr. No.	Course Code	Name
1	R5ME3111T	Mechanical Vibrations
	R5ME3111L	Mechanical Vibrations Laboratory
2	R5ME3112T	Robotics
	R5ME3112L	Robotics Laboratory
3	R5ME3113T	Computational Fluid Dynamics
	R5ME3113L	Computational Fluid Dynamics Laboratory

V J T I Veermata Jijabai Technological Institute
(Central Technological Institute, Maharashtra State, INDIA)
H. R. Mahajani Marg, Matunga, Mumbai 400019
Tel.No. +91 22 24198101-02 Fax +91 22 24102874
www.vjti.ac.in

Multi-Disciplinary Minors in Semester V

Sr. No.	Course Code	Name
1	R5EE3221T	Microprocessor & Embedded Systems
2	R5ME3201T	Navigation, Guidance & Control
3	R5ME3202T	Aircraft Structures

Multi-Disciplinary Minors in Semester VI

Sr. No.	Course Code	Name
1	R5EE3222T	Control of Robotic Systems
2	R5ME3203T	Communication systems and sensors
3	R5ME3204T	Aerodynamics

SEMESTER-V

Programme Name	*Bachelor of Technology in Mechanical Engineering*	*Semester – V*
Course Code	**R5ME3001T**	
Course Title	**Dynamics of Machinery**	
Prerequisites	**Kinematics of Machinery**	

COURSE OUTCOMES

Upon successful completion of the course, students should be able to -

1. Apply the knowledge of flywheel, governor and gyroscope to the field applications
2. Perform static and dynamics force analysis for machine components.
3. Analyze single degree of freedom systems using various methods.

Course contents

Gear Trains

Kinematics and dynamic analysis of – simple gear trains, compound gear trains, reverted gear trains, Epicyclic gear trains with spur or bevel gear combination.

Gyroscope

Introduction, Gyroscopic couple and its effect on spinning bodies, naval Ships during steering, pitching, rolling and their stabilization.

Flywheel

Turning moment diagram, Fluctuation of speed, fluctuation in energy, function of flywheel estimating inertia of flywheel

Static and Dynamic force analysis

Slider crank mechanism (neglecting mass of connecting rod and crank), Turning moment on crank shaft

Basic Concepts of Vibration

Vibration and oscillation, causes and effects of vibrations, Importance of study of vibrations, Vibration parameters - springs, mass, damper, Motion- periodic, non-periodic, degree of freedom, static equilibrium position, vibration classification, steps involved in vibration analysis

Free Undamped Single Degree of Freedom Vibration System

Longitudinal, transverse, torsional vibration system, Methods for formulation of differential equations by Newton, Energy method.

Free Damped Single Degree of Freedom Vibration System

Introduction to different methods of damping, Study and analysis of Viscous damped system, Under damped, critically damped, over damped; Logarithmic decrement

Text Books

1. Farazdak Haideri, Dynamics of Machinery, Nirali Publications, Pune, Thirteenth Edition, 2016
2. Thomas Bevan, Theory of Machines, C.B.S. Publishers, Third Edition, 2005
3. S.S.Rattan, Theory of Machines, McGraw-Hill Education (India) Private Limited, Fourth Edition, 2014
4. G. K. Grover, Mechanical Vibrations, Nem Chand & Bros, Eighth Edition, 2009

Recommended Reading

1. R. Norton, Kinematics and Dynamics of Machinery, McGraw-Hill Education (India) Private Limited, 1980
2. A.Ghosh and A.Malik, Theory of Mechanism and Machines, Affiliated East –West Press Pvt. Ltd., New Delhi, 2008
3. John J. Uicker Jr , Gordon R. Pennock , Joseph E. Shigley, Theory of Machines and Mechanisms, Oxford Press, Fifth Edition
4. J.Hannah and R.C.Stephens, Mechanics of Machines-Elementary Theory and Examples, Butterworth-Heinemann, Fourth Edition, 1984
5. Thomas Cane, Dynamics-Theory and Applications, McGraw Hill, First Edition
6. Grahm Kelly, Mechanical Vibrations, Schaum's outline series, Tata McGraw Hill, Special Edition, 2007
7. William Seto, Mechanical Vibrations, Schaum's outline series-McGraw Hill
8. J.S.Rao, K.Gupta, Theory and Practice of mechanical vibrations, New Age International Publications

Programme Name	*Bachelor of Technology in Mechanical Engineering*	*Semester – V*
Course Code	**R5ME3002T**	
Course Title	**Heat Transfer**	
Prerequisites	**Mathematics for Mechanical Engineers– I & II, Fluid Mechanics**	

COURSE OUTCOMES

The student should be able to –

1. Remember basic concepts, approaches and modes of Heat Transfer.
2. Understand and describe fundamental of natural and forced convection Heat Transfer.
3. Analyze different heat exchangers, fins and Insulation.
4. Explore application of radiation Heat Transfer.

Course Contents

Introduction and Modes of Heat Transfer

Importance of heat transfer in engineering, basic modes and fundamental laws of heat transfer, applications in industry such as nuclear, mechanical, electrical, electronics, chemical, metallurgy and MEMS engineering.

Conduction

Mechanism of hear transfer by Conduction, Fourier's Law, General three-dimensional differential equation for conduction with heat generation, for unsteady state; in Cartesian co-ordinates. Solution of Fourier's equation for one-dimensional steady state Conduction through isotropic materials of various configurations such as plane wall, cylinder and sphere, composite wall, composite cylinders and composite spheres. (For cylindrical and spherical walls, derivation of Fourier's three-dimensional equation is NOT included.)

Thermal Insulation-insulating materials, Critical thickness of insulation. Extended surfaces, Solutions for heat transfer through rectangular fins. Types of fins and their applications. Effectiveness and efficiency of fins. Unsteady state Conduction – Bodies with no internal resistance, thermocouples, Bodies with finite internal resistance.

Convection

Mechanism of heat transfer by convection – Conservation equation of Mass, Momentum, Energy for laminar flow, Hydrodynamic and thermal boundary layers, Similarity between velocity profile and temperature profile. Relation between the hydrodynamic and thermal boundary layer, Convective heat transfer coefficient (film coefficient), Effect of various parameters such

as physical properties of the fluid, system geometry, fluid flow etc. on heat transfer coefficient. Application of dimensional analysis to convective heat transfer. Empirical relations for free convection and forced convection, Physical significance of dimensionless numbers such as Nusselt's Number, Grashoffs Number, Prandtl's Number, Reynolds Number and Stanton Number. Reynolds analogy between momentum and heat transfer, Condensation and Boiling.

Heat Exchangers

Classification of heat exchangers. Applications, Overall heat transfer coefficient, Fouling factor, pressure drop in fluids across heat exchangers. Logarithmic Mean Temperature Difference in parallel flow, counter flow and cross flow heat exchangers, Multi pass heat exchangers. Effectiveness of a heat exchanger- Relation for the effectiveness in terms of Number of Transfer Units.

Radiation

Mechanism of heat transfer by Radiation. Concept of black body and grey body. Emissive power and Emissivity. Basic laws of Radiation: Planck's law, Kirchhoff's law, Stefan-Boltzmann law, Wien's displacement law and Lambert's Cosine law, Intensity of Radiation. Shape factors for simple geometrical shapes. Radiosity and Irradiation. Radiation heat exchange between two black bodies. Electrical network analogy.

Text Books

1. J. P. Holman, Heat Transfer, McGraw Hill Companies, Tenth Edition, 2009
2. R. K. Rajput, Heat and Mass Transfer, S. Chand & Company Ltd., Revised Edition, 2008
3. M. M. Rathore, Engineering Heat and Mass Transfer, University Science Press, Third Edition, 2015.
4. Sachdeva R.C., Fundamentals of Heat and Mass Transfer, 4th Edition, New Age International,2012.

Recommended Reading

1. Yunus A. Cengel, Heat Transfer: A Practical Approach, McGraw Hill International Edition, Second, 2002.
2. Eckert and Drake, Heat and Mass Transfer, Second Revised Edition, 1959
3. Ozisik, Heat Transfer, McGraw Hill, 1985.
4. Incropera and Dewitt, Heat Transfer, John Willey and Sons, 2002.
5. M. Thirumaleshwar, Fundamentals of Heat and Mass Transfer, Pearson Education India, 2009
6. A.F. Mills and V. Ganesan, Heat Transfer, Pearson Education, 2009
7. Sukhatme S. P., Heat transfer, McGraw Hill, 1985
8. Adrian Bejan, Convection Heat Transfer, Wiley-Interscience, Second Edition 1994
9. P.K. Nag Heat and Mass Transfer, Third Edition, McGraw Hill International, 2011.

Programme Name	*Bachelor of Technology in Mechanical Engineering*	*Semester – V*
Course Code	**R5ME3003T**	
Course Title	**Fluid Machinery**	
Prerequisites	**Fluid Mechanics**	

COURSE OUTCOMES

The student should be able to –

1. Analyze the performance of hydraulic turbines
2. Analyze the performance of pumps
3. Analyze the performance of compressors
4. Select the pump/compressor/turbine for a given application

Course Contents

Basic Principles

Introduction, Classification of Fluid Machines, The Linear-Momentum Equation: Force on fixed and moving Vanes, The Angular- Momentum Principle: The Euler Turbomachinery Equation, The Euler and Bernoulli Equations, Velocity Diagrams

Hydraulic Turbines

Hydro Electric Power Plants: Classification, Components of Hydro Electric Power Plants, Classification of Hydraulic Turbines, Pelton/Francis/Kaplan Turbines – Main Components and their Functions, Velocity Triangles, Force and Power, Losses and Efficiencies, Design of Component Parts, Draft Tube Analysis, Cavitation, Thoma's Cavitation parameter, Performance Characteristics, Model Testing and Similarity, Governing, Selection of Turbines. Operation and Maintenance of Turbines, Field Troubles

Pumps

Classification of Pumps: Positive & Non Positive Displacement Pumps, Types and Applications, Centrifugal Pumps – Introduction, Pump Construction, Components and their Functions, Materials Commonly Used, Terminology Used: Manometric Head, Total Static Head etc., Euler's Head, Theoretical Characteristics, Efficiencies, Hydraulic Performance, Losses: (Leakage, Disk Friction, Mechanical)System Characteristics, Operating Point, Duty Point, Performance Characteristics, Pumps in Series and Parallel, NPSH & Cavitation – NPSH(A) and NPSH (R), Selection of Pumps, Axial Thrust & Radial Thrust, Operation and Maintenance of Pumps, Field Troubles, Model Testing, Pump Testing – Procedure, Tolerances Allowed (reference to IS codes)

Reciprocating Pumps – Components, Working, Types, Work done, Indicator diagram, Effects of Acceleration of Piston, Air vessels, Rotary Pumps – Gear Pumps, Vane Pumps & Piston Pumps, Construction and Working, Performance Characteristics

Compressors

Introduction: Applications of Compressed Air, Classification of Air-Compressors,
Centrifugal Compressors and Fans – Principle of Operation, Work done and Pressure rise, The Diffuser, Compressibility Effects, Non Dimensional Quantities, Compressor Characteristics
Axial Flow Compressors and Fans– Introduction, Compressor Stage, Reaction Ratio, Stage Loading, Lift and Drag Coefficients, Blade Cascades, Blade Efficiency and Stage Efficiency, Three-dimensional Flow, Multistage Performance, Axial Compressor Characteristics, Operation and Maintenance of Pumps, Field Troubles, Introduction to Gas Turbines

Text Books

1. S.K.Som, G.Biswas, Suman Chakraborty, Introduction to Fluid Mechanics and Fluid Machines, Tata McGraw-Hill Education, Third Edition, 2013
2. A. J. Stepanoff, Centrifugal and Axial Flow Pumps, John Wiley & Sons, Inc., Second Edition, 1993
3. A. T. Sayers, Hydraulic and compressible flow turbomachines, McGraw-Hill, 1990

Recommended Reading

1. Miroslav Nechleba, Hydraulic Turbines, ARTIA Prague
2. S. M. Yahya, Turbines Compressors and Fans, Tata McGraw-Hill, Fourth Edition, 2002
3. David Japikse, Nicholas C. Baines, Introduction to Turbomachinery, Concepts ETI, Inc. and Oxford University Press, 1997
4. HIH Saravanamuttoo, GFC Rogers, H Cohen, Gas Turbine Theory, Pearson Education, Sixth Edition, 2008
5. Igor J Karassik & Roy Carter, Centrifugal Pumps, McGraw-Hill, Second Edition, 1998
6. George F. Round, Incompressible Flow Turbomachines, Elsevier, Butterworth and Heinmann, 2004
7. S. L. Dixon and C. A. Hall, Fluid Mechanics and Thermodynamics of Turbomachinery, Elsevier, Sixth Edition, 2010

Programme Name	*Bachelor of Technology in Mechanical Engineering*	*Semester – VI*
Course Code	**R5ME3004T**	
Course Title	**Design of Machine Elements**	
Prerequisites	**Strength of Materials, Dynamics of Machinery**	

COURSE OUTCOMES:

Upon successful completion of the course, students should be able to

1. Use various standards and other considerations in design.
2. Apply a suitable theory of failure.
3. Design of clutches and flexible drives.
4. Design machine elements subjected to static and dynamics loads.

Course contents

Basics of Machine Design

Mechanical Engineering Design, Design methods, Aesthetic and Ergonomics considerations in design, Material properties and their uses in design, Design for manufacturing, types of fits, selection of fits, Design for assembly. National and International standards used in design. Modes of failures, Factor of safety, Design stresses, Theories of failure, Preferred Series and Numbers. Green/ Lean Design concepts.

Design against static loads

Design of machine elements like Cotter joint, knuckle joint, strap end connecting rod.

Bolted and welded joints concentric and eccentric loading.

Power screws and its applications. Introduction to Re-circulating ball screw.

Design of springs

Helical compression, tension springs under static load, Laminated springs.

Clutches

Type of Clutches, Analysis of clutches, design of clutch friction clutch.

Design against fluctuating Load

Fatigue failure, Variable stresses, reversed, repeated, fluctuating stresses, Static and fatigue stress concentration factors. Estimation of endurance limit.

Design for finite and infinite life. Soderberg and Goodman design criteria.

Fatigue design under combined stresses.

Design of shaft, Key selection, rigid and flexible couplings.

Design of bolted joint subjected to internal pressure

Design of Helical spring subjected to variable loads.

Flexible curvature drive

Flat belt, V-belt, Rope, Selection of Roller Chain drive.

Text Books

1. V.B.Bhandari, Design of Machine Elements, Tata McGraw-Hill Education, Third Edition, 2010
2. J.E.Shigley, Mechanical Engineering Design, McGraw Hill, Sixth Edition, 2001
3. Merhyle Franklin Spotts, Terry E. Shoup, Lee EmreyHornberger, Design of Machine Elements, Pearson/Prentice Hall, Eighth Edition, 2004

Recommended Reading

1. Robert L. Norton, Machine Design- An Integrated Approach, Pearson Education Asia, Fifth Edition, 2013
2. M. F. Ashby, Materials Selection in Mechanical Design, Butterworth-Heinemann, Elesevier, 5th Edition, 2017
3. D N Reshetov, Machine Design, Mir Publishers
4. Black Adams, Machine Design, McGraw Hill, Third Edition
5. Hawrock, Jacobson, Fundamental of Machine Elements, McGraw Hill, Third Edition, 2014
6. V.M. Faires, Design of Machine Elements, The Macmillan Co., Fourth Edition
7. P. Orlov, Fundamentals of Machine Design, Mir Publishers,
8. Design Data Book, PSG, 2012
9. Design Data Book, Mahadevan, CBS Publishers and Distributors Pvt Ltd, Fourth Edition, 2013

Programme Name	*Bachelor of Technology in Mechanical Engineering*	*Semester – VI*
Course Code	**R5ME3101T**	
Course Title	**Automotive Mechanics**	
Prerequisites		

COURSE OUTCOMES

The student should be able to –

1. Outline the structure of the automobile
2. Analyze the various forces and torque reaction on front and rear axles.
3. Formulate steering, braking and suspension systems.
4. Identify the usage of Electrical vehicles/Hybrid electric vehicle and power plants.

Course Contents

Vehicle classifications and specifications

Introduction: Current Scenario of the global automobile industry and future challenges in vehicle manufacturing.

Vehicle classifications and specifications: Frames, Chassis Layout and constructional details. power plant locations and drive.

Axles, Steering System, Wheels and Tyres

Axles: Types of front axles and their constructions, Purpose and materials.

Steering System: Steering geometry, Steering requirements, Steering linkages and steering gears, over steer and under steer, Cornering power, Reversibility of steering gears.

Wheels and Tyres: Wheels construction, alloy wheel, wheel balancing, types of tyres, construction, materials, factors affecting tyre life.

Brakes

Requirement of brakes, Classification of brakes, Mechanical, Hydraulic, Pneumatic, Electro and vacuum brakes, Disc brakes, Weight transfer during braking and braking efficiency, braking of vehicle front wheel, Rear wheel and four wheel brakes, Introduction to antilock braking system and EBD (Electronic Brake force Distribution).

Suspension

Objectives of suspension, Basic requirements, Springs-Leaf and Coil springs, Air suspension and its features, Independent suspension, Sprung and un-sprung mass, Pitching, Rolling and bouncing, Shock absorbers.

Transmission and drive line

Requirements of clutches, Types of clutches and clutch materials, Fluid coupling- Gear box-types, Automatic Transmission, Continuously Variable Transmission (CVT), Propeller Shafts, Overdrive, final drive and differential.

Electrical System, Electric and Hybrid Electric Vehicles

Batteries: Principles and construction of Lead acid battery, characteristics of battery, rating, capacity and efficiency of batteries.

Electric Vehicle: Introduction, layout construction and working.

Hybrid Electric Vehicles: Introduction, types, hybridization factor. Challenges and future scope of EVs and HEVs.

Text Books

1. Kirpal Singh, Automobile Engineering, Vol. 1&2 Standard Publications.
2. N.K. Giri, Mechanics, Khanna Publishers, New Delhi, 8th Edition
3. C. P. Nakra, Basic Automobile Engineering, Dhanpat Rai Publishing Company.
4. P. S. Kohali, Automobile Electrical Equipment, Tata McGraw Hill Publication.

Reference books

1. William H. Crouse, Automotive Mechanics, Tata McGraw-Hill., 10th edition
2. J. Reimpell H. Stoll, J.W. Betzler, The Automotive Chassis, SAE International Publication.
3. Newton, Steed and Garrot, Motor Vehicles, Butterworth London, 13th Edition
4. SAE Manuals and Standards.
5. Joseph Heitner, Automotive Mechanics, C. B. S. Publishers and Distributers.
6. R. B.Gupta, Automobile Engineering, Satya Publication.

Programme Name	*Bachelor of Technology in Mechanical Engineering*	*Semester – V*
Course Code	**R5ME3102T**	
Course Title	**Composite Materials**	
Prerequisites	**Material Science**	

COURSE OUTCOMES

The student should be able to –

1. Identify the properties of fiber and matrix materials used in composites.
2. Select an appropriate manufacturing process for composite parts.
3. Analyze fiber composites based on the constituent properties.
4. Create and design engineering structures with fiber reinforced -composites.
5. To study nanocomposites processing and properties

Course Contents

Introduction to Composites

Material selection in design, Types of composite materials, general characteristics of composite materials, applications of composites

Constituents of Composite Materials

Reinforcement and fillers: glass fibers, carbon fibers, organic fibers, boron fibers, natural fibers, ceramic fibers Matrix: thermoset matrix and thermoplastic matrix, metal matrix materials, ceramic matrix materials

Manufacturing of Composites

Bag-molding, compression molding, pultrusion, filament winding, liquid composite molding, metal matrix composite manufacturing, ceramic matrix composite manufacturing, selection of manufacturing method

Mechanics of Fiber Reinforced Composite Materials

Fiber matrix interaction, micromechanics of composite materials, Laminate Analysis, Failure theories for composite materials

Characterization of Fiber Reinforced Composite Materials

Static mechanical properties, fatigue properties, impact properties, methods of characterization of fiber-matrix interphase, quality inspection methods, different ASTM standards

Fracture and Fatigue of Fiber Reinforced Composite Materials

Failure of composites, delamination in composites, modes of fracture, composite damage mechanics, S-N diagram for composite materials

Polymeric Nanocomposite Materials

Introduction to nanomaterials, nanoplatelete/nanoparticles/nanofibers reinforced composites, CNT/Graphene reinforced composites, challenges in processing of nanocomposites, prediction of properties of nanocomposites, applications of nanocomposites

Text Books

1. P.K. Mallick, Fiber-Reinforced Composites: Materials, Manufacturing, and Design, Third Edition, CRC Press, 2007
2. K. K. Chawla, Composite Materials: Science and Engineering, Springer, 2012

Recommended Reading

1. Bryan Harris, Engineering Composite Materials, The Institute of Materials, Landon
2. Hussain, Farzana, et al., Review article: polymer-matrix nanocomposites, processing, manufacturing, and application: an overview. Journal of composite materials 40.17, 2006: 1511-1575
3. M. Ashby, Material Selection in Mechanical Design, 4th Edition, Elsevier, 2010

Programme Name	*Bachelor of Technology in Mechanical Engineering*	*Semester – V*
Course Code	**R5ME3103T**	
Course Title	**Energy Conservation and Management**	
Prerequisites		

COURSE OUTCOMES

The student should be able to –

1. Illustrate the current energy scenario, challenge of climate change & peak oil, importance of energy conservation and need for alternative energy resources.
2. Examine various parameters in energy systems and energy auditing.
3. Apply Energy Planning and forecasting techniques for performing energy analysis.
4. Integrate energy economics and relevance of sound energy policies for sustainable development.

Course Contents

Introduction

Energy Scenario-world and India. Energy Resources Availability in India. Energy consumption pattern. Energy conservation potential in various Industries and commercial establishments. Energy intensive industries - an overview. Peak oil. Challenge of climate change - Energy conservation and energy efficiency – needs and advantages.

Pollution from energy generation

Coal and Nuclear based Power Plants – Fly Ash generation and environment impact, Fly ash utilization and disposal, nuclear fuel cycle, radioactive wastes – treatment and disposal- Environmental pollution limits guidelines for thermal power plant pollution control- Environmental emissions from extraction, conversion, transport and utilization of fossil fuels- Green house effect- Global warming.

Energy auditing

Energy Conservation Act 2001. Energy auditing - Definition, need, types of energy audit methodologies, barriers. Role, Duties and responsibilities of energy managers and auditors. Energy audit questionnaire. Energy management (audit) approach: Understanding energy costs, bench marking, energy performance, matching energy use to requirement, optimizing the input energy requirements; Fuel & energy substitution.

Energy conservation

Energy Efficiency in relevant utilities

Mechanical/Thermal – Boilers, Steam System, Furnaces, Insulation and Refractories, Cogeneration, Waste Heat Recovery, Heat Exchangers
Electrical – Electrical Systems, Electric motors, Compressed air system, HVAC and refrigeration system, Fans and Blowers, Pumps and pumping system, Cooling Tower, Lighting system, Diesel/Natural Gas Power generating system
Civil – Energy Conservation in buildings and ECBC
Textile – Textile industry

Energy economics

Investment - need, appraisal and criteria, financial analysis techniques - break even analysis-simple pay back period, return on investment, net present value, internal rate of return, cash flows, DSCR, financing options, ESCO concept.

Energy forecasting

Energy forecasting techniques - Energy demand – supply balancing, Energy models, Simulation and forecasting of future energy demand consistent with macroeconomic parameters in India. Basic concept of Econometrics (OLS) and statistical analysis (Multiple Regression), Econometrics techniques used for energy analysis and forecasting with case studies from India.

Energy policies

National energy policy in the last plan periods, Energy use and Energy supply, Overview of renewable energy policy and the Five Year Plan programmes, Basic concept of Input-Output analysis, Concept of energy multiplier and implication of energy multiplier for analysis of regional and national energy policy- Carbon Trading- Renewable Energy Certification – CDM. The Sustainable Energy Utility (SEU) Model.

Text Books:

1. General Aspects of Energy management and Audit, Guide book for energy manager and energy auditor, Bureau of energy efficiency
2. Energy Efficiency in Thermal Utilities, Guide book for energy manager and energy auditor, Bureau of energy efficiency
3. Energy Efficiency in Electrical Utilities, Guide book for energy manager and energy auditor, Bureau of energy efficiency
4. Energy Performance Assessment for Equipment and Utility Systems, Guide book for energy manager and energy auditor, Bureau of energy efficiency

Additional Reading:

1. YP Abbi and Shashank Jain, Handbook on Energy Audit and Environment Management, TERI Publications, 2009.
2. Steve Doty, Wayne C. Turner, Energy Management Handbook

3. Jason Houck, Wilson Rickerson, The Sustainable Energy Utility (SEU) Model for Energy Service Delivery, http://online.sagepub.com

Programme Name	*Bachelor of Technology in Mechanical Engineering*	*Semester – V*
Course Code	**R5ME3005T**	
Course Title	**Production Management**	
Prerequisites		

COURSE OUTCOMES

After completing this course, students will be able to:

1. Develop an understanding of production processes and strategies.
2. Apply techniques to find solutions to typical problems in inventory and forecasting faced by managers
3. Apply production planning and control techniques
4. Analyze and improve production efficiency
5. Understand the role of technology in production management.

Course Content

Introduction to Production Management

Production and Production Management, Production Management in Business, Scope of Production Management in Manufacturing. Focus areas of Production and Operations. Production System Types: Job Shop, Batch Production, Mass Production: Assembly Line, Continuous Flow, and Efficiency, Continuous Production.

Product Design and Development

Product Life Cycle: Stages: Introduction, Growth, Maturity, Decline. Standardization and Simplification: importance of Standardized Components, benefits of Product Simplification, cost reduction. Concurrent Engineering: Concepts, cross-Functional Team Approach. Importance of Time to Market and Improved Design Quality.

Production Planning and Control (PPC)

Objectives and Functions. PPC in Resource Utilization. Monitoring and Adjusting Production Plans. Aggregate Planning: Medium-Term Planning Techniques, strategies for aggregate planning; Chase, Level, and Hybrid Approaches. Master Production Schedule (MPS): MPS for Different Product Types, integration with Other Planning Tools. Material Requirements Planning (MRP): Bill of Materials, Lead Times, and Inventory Data, Lot Sizing Techniques and MRP II

Forecasting in Production

Importance of Forecasting; Role in Production Planning and Inventory Control. Managing Demand Uncertainty. Qualitative and Quantitative Methods. Qualitative: Delphi Method, Market Research. Quantitative: Moving Averages, Exponential Smoothing, Regression Analysis.

Forecasting Accuracy: Measures of Accuracy-Mean Absolute Error (MAE), Mean Squared Error (MSE), Mean Absolute Percentage Error (MAPE), Improving Forecasting Accuracy

Facility Location and Layout

Factors Influencing Plant Location. Proximity to Markets, Raw Materials, Labor Availability, and Transportation. Environmental and Regulatory Considerations. Process Layout: Flexible but Complex Routing, Product Layout: Assembly Lines and Flow Lines, Fixed Position Layout: Suitable for Large or Immobile Products.

Capacity Planning

Capacity Strategies-Lead Strategy, Lag Strategy, and Match Strategy. Measurement of Capacity-Capacity Measurement Units, Effective vs. Design Capacity. Capacity Utilization. Bottleneck Management and Resource Optimization

Inventory Management

Types of Inventory-Raw Materials, Work-in-Progress (WIP), Finished Goods. Safety Stock and Cycle Stock. Economic Order Quantity (EOQ)-Assumptions and EOQ Formula, Sensitivity Analysis and Limitations. ABC and VED Analysis. Production, shortage and discount-based inventory models.

Quality Management in Production

Total Quality Management (TQM)-Core Concepts: Customer Focus, Continuous Improvement, and Employee Involvement. Basic quality tools. Charts for quality control. Process Capability Analysis. Six Sigma and ISO Standards. Lean Manufacturing, value stream mapping, and Just-in-Time (JIT**)**

Emerging Trends in Production Management

Automation and Robotics, Role of Automation in Increasing Efficiency, Collaborative Robots (Cobots) and Smart Factories. Industry 4.0 and Smart Manufacturing-Integration of IoT, Big Data, and AI in Production. Cyber-Physical Systems and Digital Twins. Sustainability in Production

Text Books

1. Jay Heizer, Barry Render, Jagadeesh Rajashekhar. Operation Management, Person Publication, 3rd Edition, 2011.
2. M.Telsng, Industrial Engineering and Production Management, S.Chand and Compant Publications, 3rd edition, 2018.
3. Krajewski, L. J., Ritzman, L. P. and Malhotra, M. K., Operations Management, Prentice Hall, New Delhi, 2009.
4. Ebert, J and Adams, D.J., Production/Operations Management, Prentice Hall of India, New Delhi, 2007.
5. Thomas Vollmann, William Berry, Manufacturing planning and control Systems, McGraw Hill Education, Fifth Edition, 2004.

6. Premkumar Gupta and Hira, Operation Research, S. Chand Company Ltd., New Delhi, 2007.

Programme Name	*Bachelor of Technology in Mechanical Engineering*	*Semester – V*
Course Code	**R5EE3221T**	
Course Title	**Microprocessor and Embedded Systems**	
Prerequisites		

COURSE OUTCOMES:

After completion of course, students would be able to:

1. Prepare block diagrams for any robotic control-hardware design,
2. Choose appropriate flow of embedded systems for a specific application.
3. Write code for micro controller devices.
4. Use advanced embedded processor and software.

COURSE CONTENTS

Introduction to Embedded Systems and microcomputers

Introductionto Embedded Systems, Embedded System Applications, Block diagram of embeddedsystems, Trends in Embedded Industry, Basic Embedded System Models, Embedded System development cycle, Challenges for Embedded System Design, Evolution of computing systems and applications. Basic Computer architecture: Von-Neumann and Harvard Architecture. Basics on Computer organizations. Computing performance, Throughput and Latency, Basic high performance CPU architectures, Microcomputer applications to Embedded systems and Mechatronics.

Microprocessor

8086 Microprocessor and its Internal Architecture, PinConfiguration and their functions, Mode of Operation, Introduction to I/O and Memory, Timing Diagrams, Introduction to Interrupts. Introduction to C language, Instruction format, C language programming format, Addressing mode, Instruction Sets, Programming 8086 microprocessor.

Microprocessor Interfacing

Introduction to interfacing, Memory Interfacing, Programmable Peripheral Interfacing, Programmable I/O, Programmable Interrupt Controller, Programmable Timers, Programmable DMA Controller, Programmable Key Board Controller, Data acquisition Interfacing: ADC, DAC, Serial and parallel data Communication interfacing. Microcontroller: Introduction to Microcontroller and its families, Criteria for Choosing Microcontroller. Microcontroller Architecture, Programming model, addressing modes, Instruction sets, Assembly and C

programming for Microcontroller, I/O programming using assembly and C language, Interrupt Controller, I/O interfacing, Timers, Real Time Clock, Serial and parallel Communication protocols, SPI Controllers. LCD Controller.

Microcontroller Interfacing

Introduction to Microcontroller Interfacingand applications: case studies: Display Devices, controllers and Drivers for DC, Servoand Stepper Motor.

Introduction to Advanced Embedded Processor and Software

ARM Processor, Unified Model Language (UML), Embedded OS, Real Time Operating System (RTOS), Embedded C.

Microprocessor and Embedded System Laboratories

Basic C language programming implementation on Microprocessor and Microcontroller. Interfacing Displays, Key boards and sensors with Microprocessors and Microcontrollers, Data Acquisition using Microprocessor and Microcontroller, Implementation of Controlling schemes for DC, Servo, Stepper motor using C programming in microprocessors and Microcontrollers.

Text Books/References:

1. K. V. Shibu, Introduction to Embedded Systems, McGRAW Hill Publications (2009).
2. Raj Kamal, Embedded Systems, TATA McGRAW Hill Publications (2003).
3. M. Morris Mano, Computer System Architecture, 3ed, Pearson Publication, (2007).
4. D. V. Hall, 8086 Microprocessors and Interfacings, TATA McGRAW Hill, (2005).

Additional Reading

1. B. B. Brey, The Intel Microprocessors, Prentice Hall Publications, 8th ed, (2018).
2. M. A. Mazidi, R.D. Mckinlay and D. Casey, PIC Microcontrollers and Embedded Systems, Pearson Publications, (2008).
3. M. Predko, Programming and Customizing the PIC Microcontroller, McGRAW Hill Publications. 3ed, (2017).
4. R. Barnett, L. O'Cull and S. Cox, Embedded C Programming and Microchip PIC,Cengage Learning, (2003).
5. https://nptel.ac.in/courses/108102045
   Embedded Systems, Prof. Santanu Chaudhary, IIT Delhi

Programme Name	*Bachelor of Technology in Mechanical Engineering*	*Semester – V*
Course Code	**R5ME3203T**	
Course Title	**Aircraft Structures**	
Prerequisites		

COURSE OUTCOMES

After completion of course, the student should be able to -

1. Grasp the fundamental concepts of aircraft structural design and analysis.
2. Understand the behavior of aircraft structures under various loading conditions.
3. Develop skills in analyzing and designing aircraft components and systems.
4. Familiarize students with the materials and manufacturing techniques used in aircraft structures.

Course Contents

Introduction to Aircraft Structures

Overview of aircraft structural components: fuselage, wings, empennage, landing gear, etc; types of aircraft structures: semi-monocoque, monocoque, and truss structures; Loads acting on aircraft structures: aerodynamic, inertial, ground, and pressure loads; Material selection for aircraft structures: aluminum alloys, composites, titanium, and steel.

Stress and Strain Analysis

Review of stress and strain concepts; Bending, shear, and torsion in beams; Stress-strain relationships for isotropic and anisotropic materials; Mohr's circle for stress and strain transformation.

Structural Load Analysis

Airworthiness requirements and design criteria; V-n diagram (flight envelope); Load factors and limit loads; Shear force and bending moment diagrams for aircraft wings and fuselage.

Analysis of Thin-Walled Structures

Thin-walled pressure vessels; Shear flow in thin-walled beams; Torsion of thin-walled closed and open sections; Bending and shear stress distribution in thin-walled beams.

Structural Stability and Buckling

Euler's buckling theory; Buckling of columns and plates; Local and global buckling in aircraft structures; Post-buckling behavior and design considerations.

Fatigue and Fracture Mechanics

Fatigue loading and S-N curves; Crack initiation and propagation; Stress concentration factors; Damage tolerance and fail-safe design principles.

Composite Materials in Aircraft Structures

Introduction to composite materials: fibers, matrices, and laminates; Mechanical properties of composites; Failure theories for composite materials; Design and analysis of composite structures.

Structural Dynamics and Vibration

Free and forced vibrations of aircraft structures; Natural frequencies and mode shapes; Aeroelasticity: flutter, divergence, and control reversal; Vibration testing and analysis.

Aircraft Structural Design

Design philosophy: safe-life, fail-safe, and damage-tolerant design; Structural joints: riveted, bolted, and bonded joints; Finite Element Analysis (FEA) in aircraft structural design; Case studies of aircraft structural failures and lessons learned.

Manufacturing and Maintenance of Aircraft Structures

Manufacturing techniques for metallic and composite structures; Non-destructive testing (NDT) methods: ultrasonic, radiographic, and eddy current testing; Repair and maintenance of aircraft structures; Corrosion prevention and control.

Reference Books

1. Megson, T.H.G., Aircraft Structures for Engineering Students, Elsevier, 7th Edition, 2020.
2. Sun, C.T., Mechanics of Aircraft Structures, Wiley, 2nd Edition, 2006.
3. Donaldson, Bruce K.**,** Analysis of Aircraft Structures: *An Introduction*, Cambridge University Press, 2nd Edition, 2008.

Recommended Reading

1. Baker, Alan; Dutton, Stuart; Kelly, Donald, Composite Materials for Aircraft Structures, AIAA Education Series, 2nd Edition, 2004.
2. Alderliesten, René**,** Introduction to Aerospace Structures and Materials, Delft University Press, 1st Edition, 2018.

Programme Name	*Bachelor of Technology in Mechanical Engineering*	*Semester* – V
Course Code	**R5ME3202T**	
Course Title	**Navigation, Guidance, and Control**	
Prerequisites	**Basic knowledge of control systems, dynamics, and differential equations**	

COURSE OUTCOMES

After completing this course, students will be able to:

1. Understand the principles of navigation and various navigation systems.
2. Analyze and apply different guidance laws for accurate missile and UAV trajectories.
3. Design control strategies for stabilizing and controlling dynamic systems.
4. Evaluate the performance of NGC systems through simulations and real-world applications.
5. Implement NGC algorithms using computational tools.

Course Contents

Introduction to Navigation, Guidance, and Control

Overview of NGC systems, Role of NGC in modern warfare, Applications in aerospace, robotics, and automotive systems, Historical advancements and modern developments.

Navigation Systems

Inertial Navigation Systems (INS), Global Navigation Satellite Systems (GNSS) (e.g., GPS, GLONASS, Galileo), Dead Reckoning and Terrain Referenced Navigation (TRN), Kalman Filtering for Sensor Fusion, Error sources and correction techniques.

Guidance Principles

Concept of guidance and types (e.g., Line-of-Sight, Proportional Navigation), Classical guidance laws: Pursuit, Proportional Navigation, and Waypoint Navigation, Terminal guidance and homing methods (Active, Passive, Semi-Active Homing), Optimal guidance strategies for missiles and UAVs, Swarm guidance and cooperative engagement of UAVs.

Control Mechanisms

Linear and Nonlinear Control Systems, PID Control for trajectory stabilization, State-space representation and feedback control, Adaptive and Robust Control Techniques, Application of AI/ML in control systems.

Implementation and Case Studies

Hardware and software tools for defence NGC systems. Case studies on autonomous vehicles, drones, missile guidance, and UAV swarm intelligence. Hands-on projects and simulations

Reference Books

1. Hofmann-Wellenhof, B., Lichtenegger, H., Verlag Wien, Collins, J. Global Positioning System Theory and Practice, Publisher: Springer 2001.
2. Grewal, M. S., Weill, L. R., A. P., Global Positioning Systems, Inertial Navigation, and Integration, Publisher: John Wiley & Sons, New York, 2006.
3. Verlag Wien. Hofmann-Wellenhof, B., Lichtenegger, H., Wasle, E., GNSS – Global Navigation Satellite Systems, Publisher: Springer 2008.
4. Anthony Lawrence, Modern Inertial Technology Navigation, Guidance, and Control, Publisher: Springer New York.2012.
5. Eugene Kagan, Nir Shvalb, Irad Ben-Gal, Autonomous Mobile Robots and Multi-Robot Systems: Motion-Planning, Communication, and Swarming Publisher: Wiley, 2019.

Recommended Readings

1. Jay Farrell, The Global Positioning System & Inertial Navigation, Publisher: McGraw-Hill Education, 1998.
2. Groves, P. D., Principles of GNSS, inertial and multi-sensor integrated navigation systems, Publisher: Artech House.
3. Thor I. Fossen, Marine Control Systems Guidance, Navigation, and Control of Ships, Rigs, and Underwater Vehicles, Marine Cybernetics, Trondheim, Norway.
4. Devendra K. Chaturvedi, Modeling and Simulation of Systems Using MATLAB and Simulink, Publisher: CRC Press, 2010.
5. E. Kaplan and C. Hegarty, Understanding of GPS/GNSS: Principles and Applications, Artech House Publishers.

Programme Name	*Bachelor of Technology in Mechanical Engineering*	*Semester – V*
Course Code	**R5ME3001L**	
Course Title	**Dynamics of Machinery Laboratory**	
Prerequisites	**Kinematics of Machinery**	

COURSE OUTCOMES

Upon successful completion of the course, students should be able to -

1. Examine the behavior of various applications like governors, gyroscope, etc.
2. Calculate frictional power using brake dynamometer.
3. Calculate the transmission ratio for various gearing mechanism.
4. Estimate different properties of a dynamics system.

List of Experiments (Min. 8 expt to be performed)

1. Performance Characteristics of Porter Governors
2. Performance Characteristics of Proell Governor
3. Determine gyroscopic couple on Motorized Gyroscope.
4. Measure braking torque of Dynamometer
5. Study of Gear Trains
6. Determination of centre of gravity/moment of inertia of connecting rod.
7. Experimental determination of Corioli's acceleration
8. Experimental prediction of unknown mass and stiffness.
9. Experimental investigation of longitudinal vibrations of helical springs connected in series and parallel
10. Experimental prediction of damping constant of a given fluid.

Programme Name	*Bachelor of Technology in Mechanical Engineering*	*Semester – V*
Course Code	**R5ME3002L**	
Course Title	**Heat Transfer Laboratory**	
Prerequisites	**Mathematics for Mechanical Engineers– I & II, Fluid Mechanics**	

COURSE OUTCOMES

The student should be able to –

1. Identify various heat transfer phenomenon of conduction, convection and radiation using experimentation.
2. Understand and analyze free and forced convection heat transfer.
3. Analyze the performance of different heat exchangers and fins.
4. Evaluate the performance of radiation through grey and black body.

List of Experiments

1. To determine the thermal conductivity of a Metal Rod
2. To determine the thermal conductivity of an Insulating material
3. To determine the thermal conductivity and thermal resistance of a composite slab
4. To determine the convective heat transfer coefficient -'*h*' for

a. Free convection
b. Forced convection

5. To determine experimentally the value of Stefan-Boltzmann constant
6. To determine the emissivity of a circular disc.
7. To determine LMTD & overall heat transfer coefficient 'U' for ' a tube in tube ' type of heat exchangers for-

a. Parallel flow conditions
b. Counter flow conditions

8. To examine the phenomenon of Boiling and Condensation
9. To compare heat exchangers (shell and tube, concentric tube, tube-in-tube and plate type heat exchanger) using computerized interface.
10. To determine heat transfer coefficient and heat transfer rate of pin fin arrangement.
11. Assignment or Mini project on coding based numerical methods in heat flow devices using Python/ Matlab/ISRO-FEAST /Ansys workbench.
12. Assignment or Mini project on real life problem, bio-heat transfer, solar thermal, jet cooling and/or industrial heat exchanger problem considering probabilistic decision making and multi-disciplinary based numerical optimization of heat transfer equipment's.

Programme Name	*Bachelor of Technology in Mechanical Engineering*	*Semester – V*
Course Code	**R5ME3003L**	
Course Title	**Fluid Machinery Laboratory**	
Prerequisites	**Fluid Mechanics**	

COURSE OUTCOMES

The student should be able to –

1. Test the fluid machines for their Performance
2. Evaluate the Performance of Fluid Machines
3. Analyse the Performance Characteristic of Turbines, Pumps and Compressors

List of Experiments: [any 10]

1. Impact of Jet
2. Constant head characteristics of Pelton Turbine
3. Constant speed characteristics of Pelton Turbine
4. Constant head characteristics of Francis/Kaplan Turbine
5. Constant speed characteristics of Francis/Kaplan Turbine
6. Performance Characteristics of Centrifugal Pump with Iso- Efficiency curves
7. Performance Characteristics of Reciprocating Pump
8. Performance Characteristics of Gear Pump
9. Pumps in Series and Parallel
10. Characteristics of centrifugal blower
11. Cavitation
12. Water Hammer & Pipe Surge

Programme Name	*Bachelor of Technology in Mechanical Engineering*	*Semester – V*
Course Code	**R5ME3101L**	
Course Title	**Automotive Mechanics Laboratory**	
Prerequisites		

COURSE OUTCOMES

The student should be able to –

1. Understand the structure of the automobile.
2. Analyze the transmission systems, wheels and tyres.
3. Study of different automotive systems

Course Contents

1. Study of the following automotive systems

a. Chassis Layout,
b. Steering systems.
c. Drum and disc brakes.
d. Suspension systems.
e. Different types of clutches.
f. Gear Boxes.
g. Transmission systems.
h. Wiring layout.

2. Experimental study of the following systems

a. Spark ignition systems.
b. Differential gear boxes.
c. Clutch systems.
d. Gear boxes.
e. Power steering.
f. Pneumatic Braking System.

Programme Name	*Bachelor of Technology in Mechanical Engineering*	*Semester – V*
Course Code	**R5ME3102L**	
Course Title	**Composite Materials Laboratory**	
Prerequisites	**Material Science**	

COURSE OUTCOMES

The student should be able to –

1. Develop composite manufacturing process for the given part
2. Evaluate the performance of composite structure
3. Design the optimal composite structure

List of experiments

1. Resin Preparation and cure cycle
2. Manufacture of composite material using hand layup process
3. Manufacture of natural fibers composite materials
4. Open mold composite manufacturing process
5. Vacuum assisted resin transfer molding process
6. Manufacture of sandwich composite
7. Testing of polymeric composite materials
8. Finite element analysis of composite materials
9. Design optimization of composite structure
10. Manufacture of electrospun nanofibers reinforced composites

Text Books

1. P.K. Mallick, Fiber-Reinforced Composites: Materials, Manufacturing, and Design, CRC Press, Third Edition, 2007
2. K. K. Chawla, Composite Materials: Science and Engineering, Springer, Third Edition, 2012

Recommended Reading

1. Bryan Harris, Engineering Composite Materials, The Institute of Materials, Landon
2. Hussain, Farzana, et al., Review article: polymer-matrix nanocomposites, processing, manufacturing, and application: an overview. Journal of composite materials 40.17, 2006: 1511-1575
3. M. Ashby, Material Selection in Mechanical Design, Elsevier, Fourth Edition, 2010

Programme Name	*Bachelor of Technology in Mechanical Engineering*	*Semester – V*
Course Code	**R5ME3103L**	
Course Title	**Energy Conservation and Management Laboratory**	
Prerequisites		

COURSE OUTCOMES

The student should be able to –

1. Examine various parameters in energy systems and energy auditing.
2. Estimate energy needs of family, institution, country and world, energy consumption by sector
3. Examine the causes and consequences of climate change.

List of Experiments

1. Estimate the monthly energy consumption of your own family, include energy consumption from electricity, petrol, diesel, LPG, public transportation, etc. Make a brief report on it
2. Measure energy consumption of a light and a fan (or any other appliance) in your lab using power meter / energy meter over the duration of experiment. Also do the theoretical estimation of possible energy consumption by the appliances over the same time. Compare both and comment.
3. Figure out from which point electricity is entering your campus, how it is being measured (visit the site), check if you can take any reading, discuss the electrical supervisor on daily, monthly electricity consumption of the campus, discuss the variation of electricity consumption with season and reason behind it. Make summary of your observations.
4. Estimate the energy consumption of an industry / start-up /institution in your area, include energy consumption from electricity, petrol, diesel, LPG, public transportation, etc. Make a brief report on it.
5. Write a brief 2-page report on total annual energy consumption of any country, other than India. Include energy consumed from all resources, and draw its Sankey diagram.
6. Write a brief 2-page report on annual renewably energy consumption of any country, other than India. Include energy consumed from all resources, and draw its Sankey diagram.
7. Find out the records (measurements from meteorology stations) of average temperature changes of the past 20-30 years in your region. Observe the patterns of temperature change and make critical comments on patterns and reasons behind.
8. Find out the records (measurements from meteorology stations) of average precipitation of the past 20-30 years in your region. Observe the patterns of temperature change and make critical comments on patterns and reasons behind.
9. Estimate the carbon footprint of your institute based on energy consumption of the institute. Also make an estimate of carbon emission of your institute (even if it is very approximate) that includes travelling by students and staff, carbon footprint due to residents, etc.

10. Prepare a report on what is your and your family's possible role in contribution to climate change and its mitigation. As far as possible quantify the contributions.
11. Prepare a report on the possible role of your institutions in the mitigation of climate change. Do this based on discussion with people in society. Frame a set of 5 to 6 questions, interview people and based on the interview prepare a report.
12. Visit a nearby river / pond /forest, discuss with people living around it and figure out the changes people have observed since the last 20-30 years. Prepare a report.
13. Prepare a report on newspaper coverage of climate change and related happenings of your region and country since last one year. Make your remarks on newspaper coverage.

SEMESTER-VI

Programme Name	*Bachelor of Technology in Mechanical Engineering*	*Semester – VI*
Course Code	**R5ME3006T**	
Course Title	**Design of Mechanical Systems**	
Prerequisites	**Design of Machine Elements**	

COURSE OUTCOMES

The student should be able to –

1. Design various sub-systems of crane, pump and conveyors.
2. Design single and multispeed gear boxes.
3. Select suitable bearing for a given application.

Course Contents

Design of Gears and gear box

Design of spur, helical, bevels and worm gears using strength and wear, Derive Lewis equation, AGMA standards, Design of single speed gear box consisting of spur and helical gear pair, gear box housing layout and housing design (Maximum two stages), Design of gear box (multi speed) for machine tool applications(Maximum three stages and twelve speeds)

Design of Bearings

Basic terminology in Rolling Contact bearings, Selection of rolling contact bearings based on constant /Variable Load & speed conditions. Design of hydro dynamically lubricated bearings. Introduction to hydro Static bearings. Selection of Mechanical Seals

Design of Cranes

Classification, Criteria for selection. Types of cranes and their Layouts. Design of Hoisting Mechanism of Overhead crane.

Design of components of Gear Pump (External)

Classification, Working Principle, Construction. Design of External Gear Pump: Motor selection, Gears, Cover and casing. Bolts.

Design of components of Conveyors

Classification, Merits and Demerits. Design of Belt Conveyor: Belt, Roller Assembly, Drum & Drum Shaft, Bearings. Motor selection. Take-up arrangements.

Text Books

1. S.N. Trikha, Machine Design Exercises, Khanna Publishers
2. N. Rudenko, Material Handling Equipment, Peace Publication

Reference Books

1. M. F. Ashby, Materials Selection in Mechanical Design, Butterworth-Heinemann, Elesevier, 5th Edition, 2017
2. Spivakosky & Dyachkov, Conveying Machines Vol.2, Mir Publishers, Moscow, 1985
3. Anthony Esposito, Fluid power with applications, Prentice Hall, Seventh Edition, 2008
4. Indian Standards- IS: 807, IS: 3443, IS: 3777, IS: 3815, IS: 3973
5. Vickers Industrial Hydraulic Manual, 2013
6. CMTI : Machine Tool Design Handbook, Tata Mc-graw Hill, 2012
7. Design data - Data Book for Engineers, PSG, Coimbatore, 2012
8. Alexandrov M.P., Materials Handling Equipment, MIR Publishers, Moscow, 1981
9. N. K. Mehta, Machine Tool Design, Tata McGraw-Hill Education, Third Edition, 2012

Programme Name	***Bachelor of Technology in Mechanical Engineering***	***Semester – VI***
Course Code	**R5ME3007T**	
Course Title	**Computer Aided Design and Analysis**	
Prerequisites	**Strength of Materials, Heat Transfer, Mechanical Vibrations**	

COURSE OUTCOMES

The student should be able to –

1. Transform geometric objects.
2. Employ various techniques of geometric modeling.
3. Solve differential equations using approximate methods.
2. Formulate one and two dimensional problems using FEM for structural and thermal engineering problems.
3. Apply FEM to vibration and nonlinear problems

Course Contents

Introduction to CAD

Conventional design Vs computer aided design

Transformations

2D and 3D Transformations (Translation, Rotation, Scaling, Reflection),

Projections-Taxonomy of projection, parallel projection (orthographic- Iso, di, tri-metric projections)

Geometric Modeling

Curves – Introduction, Analytical curves (Line, circle, ellipse, parabola, hyperbola), Synthetic curves (Hermite Cubic Spline, Bezier, B-Spline Curve)

Surfaces – Introduction, Surface representation, Analytic surfaces, Synthetic Surfaces, Hermite bicubic, Bezier, B-Spline, Coons patch surface, Applications in freeform surfaces

Solids - Introduction, Geometry and Topology, Solid Representation, Boundary Representation, Euler's equation, Constructive Solid Geometry (CSG), Boolean operation for CSG

Introduction to Finite Element Method (FEM)

Basic concept of finite element method, Problem classification, Introduction of elements, nodes and dof, Example applications, Discretization, Stiffness matrix and boundary conditions, Introduction to elasticity, Plane Stress and Plain strain.

FEM Formulations

Variational method-Weighted residual method, Rayleigh-Ritz method, Virtual work method. Shape functions, Elemental matrix.

One Dimensional FEM

Element matrices, bar element (two-noded, and three-noded), Truss element, Frame elements, One dimensional heat transfer problem, Convergence of FE solutions.

Two Dimensional FEM

Three-noded triangular element, Six-noded triangular element, Four-noded quadrilateral element, Natural coordinates, Isoparametric Formulation, Numerical Integration.

Vibration Analysis using Finite Elements

Equations of motion, Bar vibration, Beam vibration.

Introduction to Three Dimensional and Non Linear FEM

Basic ideas and equations from two dimensions to three dimensional analysis, Geometric and material non-linearity, Examples of problems.

Text Books

1. 1. Roger & Adams, Mathematical elements for computer graphics, McGraw Hill Education, 2nd Edition, 2017
2. Ibrahim Zeid, R. Sivasubramanian, CAD/CAM-Theory & Practice, Tata McGraw Hill Publications, Special Indian Edition, 2009
3. T. R. Chandrupatla and A. D. Belegundu, Introduction to Finite Element in Engineering, Pearson, Fourth Edition, 2012.
4. P. Seshu, Textbook of Finite Element Analysis, PHI Learning Pvt. Limited, 2012.
5. R. D. Cook, D. S. Malkus, M. E. Pleasha and R. J. Witt, Concepts and Applications of Finite Element Analysis, John Wiley & Sons, Fourth Edition, 2005.

Recommended Reading

1. Foley Van Dam, Computer Graphics: Principles and Practice, Third Edition, 2013
2. J.N. Reddy, An Introduction to the Finite Element Method, McGraw Hill Book Co., Third Edition, 2016.
3. C. S. Desai and J. F. Abel, Introduction to the Finite Element Method, CBS Publishers, New Delhi, 2005.

Programme Name	***Bachelor of Technology in Mechanical Engineering***	***Semester – VI***
Course Code	**R5ME3008T**	
Course Title	**Thermal Engineering**	
Prerequisites	**Applied Thermodynamics, Fluid Mechanics, Heat Transfer**	

Course Outcomes:

After completion of course, the student should be able to –

1. Evaluate the performance of Steam & Gas Turbine Power Plants.
2. Examine the governing parameters affecting combustion.
3. Analyse the performance of various Jet Propulsion systems.
4. Investigate the factors affecting the performance of an Internal Combustion engine.
5. Evaluate the performance of refrigeration cycles and psychrometric processes.

Course Contents

Steam & Gas Power Plants

Steam Power Plant – Ideal Rankine Cycle, Actual Rankine Cycle, plant efficiency, Reheat, Regeneration.

Gas Turbine Power Plant – Ideal Brayton Cycle, Actual Brayton Cycle, plant efficiency, Intercooler, Reheat, Regeneration.

Comparison of Rankine and Brayton Cycles with Carnot Cycle.

Reacting Mixtures & Combustion

Fuels, combustion fundamentals; products of combustion; Stoichiometric Ratio; conservation of energy – reacting systems; Adiabatic Flame Temperature; evaluating entropy for reacting systems; entropy balances for reacting Systems.

Jet Propulsion

Jet Propulsion – Thrust, Turbojet engine, Thrust Augmentation, Turbofan engine, Turboprop engine, Regenerative engine, Turboshaft engine, Ramjet Engine, Pulse Jet engine, Scramjet engine, comparison of various jet propulsion devices.

Rocket Propulsion – Ideal chemical rocket, Optimal expansion ratio, liquid propellant, solid propellant, Free Radical Propulsion, Nuclear Propulsion, Ion Propulsion, Plasma Propulsion, Photon Propulsion.

Internal Combustion Engines

Classification of IC engines, Two-Stroke and Four-Stroke Cycles, Petrol and Diesel engines,

Comparisons of different engines and their efficiencies, Combustion in Petrol and Diesel engines.

Refrigeration & Psychrometry

Air Refrigeration Cycle, Aircraft Refrigeration, advantages and limitations of Air Refrigeration. Ideal Vapour Compression Cycle (VCC), Analysis of ideal VCC, Effect of various parameters on COP, ASHRAE Nomenclature of refrigerants.

Psychrometry, Calculation of various properties of moist air.

Psychrometric processes – Adiabatic mixing, Sensible cooling/heating, Cooling/heating with humidification/dehumidification, Evaporative cooling, etc.

Comfort Chart, Comfort Air Conditioning.

Text Books

1. Domkundwar, Kothandaraman & Domkundwar, A course in Thermal Engineering, Dhanpat Rai & Co., 6th edition, 2022.
2. P. L. Ballaney, Thermal Engineering - Engineering Thermodynamics & Energy Conversion Techniques, Khanna Publishers, 25th edition, 2022.
3. P. K. Nag, Basic & Applied Thermodynamics, McGraw-Hill Education, Second Edition, 2009.
4. M. L. Mathur and R. P. Sharma, Gas Turbines and Jet and Rocket Propulsion, Standard Publishers & Distributors, Delhi, 4th edition, 2014.

Recommended Reading

1. Moran & Shapiro, Fundamentals of Engineering Thermodynamics, John Wiley & Sons Inc., Ninth Edition, 2018.
2. Sonntag, Borgnakke & Van Wylen, Fundamentals of Thermodynamics, John Wiley & Sons Inc., Ninth Edition, 2017.
3. HIH Saravanamuttoo, GFC Rogers and H Cohen, Gas Turbine Theory, Pearson Education Ltd., India, 2nd edition, 2013.
4. Henning Struchtrup, Thermodynamics and Energy Conversion, Springer, 2nd edition, 2014.

Programme Name	*Bachelor of Technology in Mechanical Engineering*	*Semester – VI*
Course Code	**R5ME3111T**	
Course Title	**Mechanical Vibrations**	
Prerequisites	**Dynamics of Machinery**	

COURSE OUTCOMES:

Upon successful completion of the course, students should be able to

1. Analyze single degree of freedom systems using various methods.
2. Estimate the parameters required for vibration control.
3. Analyze multi-degree of freedom problems using various methods.
4. Assess parameters required for balancing of system.

Course contents

Introduction

Basic concepts of vibrations, Steps to solve vibration problems. Classification of Vibrations, Discrete and continuous systems, degrees of freedom, Identification of variables and Parameters, Linear and nonlinear systems, static equilibrium position. Transfer function approach, State space modelling,

Single Degree of Freedom systems

Conversion of multi-springs, multi masses, multi-dampers into a single spring and damper with linear or rotational co-ordinate system. Coulomb damping. Comparison with viscous damping.

Forced Vibration of Single Degree of Freedom System

Analysis of linear and torsional systems subjected to harmonic force excitation and harmonic motion excitation (excluding elastic damper), Force & motion transmissibility, typical isolators & mounts. Principle of vibration measuring instruments, vibrometer, velocity pick-up, accelerometer - undamped and damped.

Multi-degree of freedom (MDOF) systems

Modelling of MDOF systems (Damped & Undamped). Lagrange's method, Exact and approximate solution methods for MDOF. Concept of vibration absorber.

Continuous Systems

Introduction to continuous systems, discrete vs continuous systems, application to real life examples.

Balancing

Basic concepts of balancing, Active and Passive balancing, Static and Dynamic balancing of single & multi rotor system, Concept of partial balancing in reciprocating masses, balancing of reciprocating masses in In-line engines, Balancing of V-engines (excluding other radial engines)

Text Books

1. G. K. Grover, Mechanical Vibrations, Nem Chand & Bros, Eighth Edition, 2009
2. Graham Kelly, Fundamentals of Mechanical Vibration, Tata McGraw Hill, 2000
3. P.L. Ballaney, Theory of Machines, Khanna Publishers, Delhi.

Recommended Reading

1. S. S. Rao, Mechanical Vibrations, Pearson Education, Fourth edition, 2009
2. P. Srinivasan, Mechanical Vibration Analysis, Tata McGraw Hill, 1982
3. Den, Chambil, Hinckle, Mechanical Vibrations
4. J.P. Den Hartog, Mechanical Vibrations, McGraw hill Book Company Inc.
5. Leonard Meirovitch, Elements of Vibration Analysis, Tata McGraw Hill, Special Indian Edition, 2007
6. Grahm Kelly, Mechanical Vibrations, Schaum's outline series, Tata McGraw Hill, Special Edition, 2007
7. William Seto, Mechanical Vibrations, Schaum's outline series-McGraw Hill
8. J.S.Rao, K.Gupta, Theory and Practice of mechanical vibrations, New Age International Publications
9. W.T. Thomson, Theory of vibrations with applications, CBS Publishers, Delhi, 2003

Programme Name	*Bachelor of Technology in Mechanical Engineering*	*Semester – VI*
Course Code	**R5ME3112T**	
Course Title	**Robotics**	
Prerequisites	**Mathematics for Mechanical Engineers I and II, Kinematics of Machinery, Mechanical Measurements**	

COURSE OUTCOMES:

After completion of course, students would be able -

1. Analyze various types Robots and their applications
2. To understand terminologies related to Kinematics of Robotics.
3. To analyze basics of motion programming as per kinematics
4. To apply logic for selection of robotic sub systems and systems.

COURSE CONTENTS:

Introduction to robotics

Brief History, Basic Concepts of Robotics such as Definition , Three laws, Elements of Robotic Systems i.e. Robot anatomy, DOF, Misunderstood devices etc., Classification of Robotic systems on the basis of various parameters such as work volume, type of drive, etc., Associated parameters i.e. resolution, accuracy, repeatability, dexterity, compliance, RCC device etc., Introduction to Principles & Strategies of Automation, Types & Levels of Automations, Need of automation, Industrial applications of robot. Robotics application: current and future.

Grippers and Sensors for Robotics

Grippers for Robotics - Types of Grippers, Guidelines for design for robotic gripper, Force analysis for various basic gripper systems. Sensors for Robots - Types of Sensors used in Robotics, Classification and applications of sensors, Characteristics of sensing devices, Selections of sensors. Need for sensors and vision system in the working and control of a robot.

Drives and Control for Robotics

Drive - Types of Drives, Types of transmission systems, Actuators and its selection while designing a robot system. Control Systems: Types of Controllers, Introduction to closed loop control

Robot Kinematics and Dynamics

Spatial Descriptions: positions, orientations, and frame, mappings: changing description from frame to frame, Operators: translations, rotations and transformations, transformation arithmetic, compound Transformations, inverting a transform, transform equations, Euler Angles, Fixed Angles, Euler Parameters. Manipulator Kinematics, Link Description, Link to reference frame

connections, Denavit-Hartenberg Approach, D-H Parameters, Position Representations, Homogeneous Transformation Matrix, Forward Kinematics. Inverse Kinematics, Geometric and analytical approach, Basics of Robot Dynamics.

Trajectory Planning

Introduction, path vs trajectory, joint space vs Cartesian space description, basics of tractor planning, joint space trajectory planning: Third order polynomial, Fifth order polynomial, linear segment with parabolic blends, linear segment with parabolic blends and via points, higher order trajectories, etc.

Computer vision for robotic system

Imaging Components, Image Representation, Hardware Considerations, Picture Coding, Object Recognition and Categorization, Software Considerations, Need for Vision Training and Adaptations, Review of Existing Systems, etc.

Computer Considerations for Robotic Systems

Objectives, Motivation, Architectural Considerations, Hardware Considerations, Computational Elements in Robotic Applications, Real-Time Considerations, Robot Programming, Path Planning, etc.

Related Topics in Robotics

Socio-Economic aspect of robotisation. Economical aspects for robot design, Safety for robot and standards, Introduction to Artificial Intelligence, AI techniques, Need and application of AI, New trends & recent updates in robotics.

Text Books:

1. S. B. Niku, Introduction to Robotics – Analysis, Contro, Applications, 3rd edition, John Wiley & Sons Ltd., (2020)
2. R. D. Klafter, Thomas A. Chmielewski, and Mechael Negin, Robotic Engineering – An Integrated Approach, EEE, Prentice Hall India, Pearson Education Inc. (2009)

Reference Books

1. R. K. Mittal, I. J. Nagrath, Robotics and Control, TATA McGraw Hill Publishing Co Ltd, New Delhi (2003)
2. J. Angeles, Fundamentals of Robotic Mechanical Systems Theory Methods and Algorithms, Springer (1997)
3. Mikell Groover, Mitchell Weiss, Roger N. Nagel, Nicholas Odrey, Ashish Dutta, Industrial Robotics 2nd edition, SIE, McGraw Hill Education (India) Pvt Ltd (2012)
4. S. K. Saha, Introduction to Robotics 2e, TATA McGraw Hills Education (2014)
5. Dilip Kumar Pratihar, Fundamentals of Robotics, Narosa Publishing House, (2019)

Programme Name	*Bachelor of Technology in Mechanical Engineering*	*Semester – VI*
Course Code	**R5ME3113T**	
Course Title	**Computational Fluid Dynamics**	
Prerequisites	**Fluid Mechanics, Heat Transfer**	

COURSE OUTCOMES

The student should be able to –

1. Analyze methodologies used in CFD.
2. Apply finite volume method to heat transfer and fluid flow problems.
3. Develop computer codes for simulation of heat transfer and fluid flow problems.

Course Contents

Fundamentals of CFD

Overview of CFD, need, Advantages of CFD, Numerical vs. Analytical vs. Experimental, Applications of CFD, CFD methodology, grid independence, Verification and validation

Governing equations of mass, momentum and energy

Derivation, Discussion of physical meanings and presentation of forms particularly suitable to CFD, Boundary Conditions – Dirichlet, Neumann, Robbins, initial conditions, mathematical behavior of partial differential equations – Elliptic, parabolic & hyperbolic equations, impact on CFD

Discretisation methods

Introduction to Finite Difference Method, Finite Volume Method, Finite Element Method. Concepts of Convergence, consistency, stability. Solution of discretised equations, Direct methods and iterative methods, Tri Diagonal Matrix Algorithm, iterative convergence

Finite volume method for diffusion problems (Conduction)

Steady state one dimensional heat conduction with or without heat generation, Dirichlet, Neumann, and Robins type boundary conditions, Multi-solid heat conduction, Non-linear Heat Conduction, Unsteady heat conduction-Explicit, Crank-Nicolson, Implicit schemes, stability of solutions, two dimensional steady and unsteady heat conduction. Gauss-Seidal point by point and line by line TDMA methods.

Finite volume method for Convection-diffusion problems

One dimensional convection-diffusion- Advection schemes-Central, first order upwind, exponential, hybrid, power law, Second order upwind, QUICK etc., Conservativeness,

boundedness, transportiveness, False diffusion, Extension to two dimensional steady and unsteady convection – diffusion

Solution algorithms for pressure velocity coupling

Staggered grids and co-located grids, SIMPLE, SIMPLER, SIMPLEC, PISO algorithms, unsteady flows

Turbulence modeling

Turbulence, Reynolds Averaged Navier-Stokes (RANS) equations, introduction to turbulence modeling - DNS, LES, k-ε , k-ω, RSM models

Introduction to Grid Generation

Structured and Unstructured Grids, General transformations of the equations, body fitted coordinate systems, Algebraic and Elliptic Methods, multi block structured grids, adaptive grids

Text Books

1. S V Patankar, Numerical Heat Transfer and Fluid Flow, ANE BOOKS-NEW DELHI, Special Indian Edition, 2017
2. H K Versteeg and W. Malalasekera, An Introduction to Computational Fluid Dynamics-The Finite Volume Method, Pearson Education, Second Indian Edition, 2010

Recommended Reading

1. John. D. Anderson, Jr., Computational Fluid Dynamics - The basics with applications, McGraw-Hill, Indian Edition, 2017
2. Atul Sharma, Introduction to Computational Fluid Dynamics –Development, Application and Analysis, Ane-books Pvt. Ltd., 2017
3. Jiyuan Tu, Guan Heng Yeoh, Chaoqun Liu, Computational Fluid Dynamics: A Practical Approach, Elsevier, Third Edition, 2018
4. A.W. Date, Introduction to Computational Fluid Dynamics, Cambridge University Press, 2005
5. Ferziger and Peric, Computational Methods for Fluid Dynamics, Springer, Third Edition, 2008

Programme Name	*Bachelor of Technology in Mechanical Engineering*	*Semester – VI*
Course Code	**R5ME3009T**	
Course Title	**Operations Management**	
Prerequisites		

COURSE OUTCOMES

The student should be able to –

1. Develop process-oriented thinking for operational efficiency.
2. Apply operational decision-making models.
3. Analyze supply chains and logistics operations.
4. Apply statistical tools and techniques for solving managerial problems

Course Content

Introduction to Operations Management

Nature, Scope, and Importance- Core Functions of Operations Management, Role of Operations Management in Business Strategy. Evolution from Craft Production to Mass Production. Scientific Management and the Contributions of Taylor. Modern Trends in Operations Management.

Operations Strategy

Competitive Priorities- Cost, Quality, Time, Flexibility, Innovation. Trade-offs Between Priorities. Operations as a Source of Competitive Advantage-Role of Operational Efficiency in Gaining a Market Edge, Case Studies of Operational Excellence. Strategic Role of Operations-Operations as a Core Competency, Aligning Operations Strategy with Corporate Strategy.

Supply Chain Management (SCM)

Components of Supply Chain: Procurement, Production, Distribution, and Customer Service, Upstream and Downstream Relationships.

Supply Chain Integration: Internal and External Integration, Information Sharing and Collaboration

Bullwhip Effect and Mitigation: Causes of Demand Amplification, Techniques to Minimize the Bullwhip Effect

Procurement and Sourcing

Procurement Strategies: Centralized vs. Decentralized Procurement, strategic Sourcing. Make-or-Buy Decisions: Factors Influencing Decisions, Cost-Benefit Analysis. Supplier Relationship

Management (SRM): Vendor Evaluation and Selection, Building Long-Term Supplier Partnerships

Logistics and Distribution Management

Transportation Modes and Strategies: Road, Rail, Air, Sea transport. Cost and Service Trade-offs. Warehousing and Inventory Strategies: Cross-Docking and Consolidation, Inventory Positioning and Warehouse Layouts. Third-Party Logistics (3PL): Benefits and Limitations of 3PL Providers, Criteria for Selecting a 3PL

Technology and Innovation in Operations

Role of ERP Systems: Integration of Business Processes through ERP, Benefits and Challenges of ERP Implementation. Artificial Intelligence in Operations: AI Applications in Forecasting, Scheduling, and Quality Control. Blockchain and IoT in Operations: Blockchain for Supply Chain Transparency, IoT for Real-Time Monitoring\

Operation Research Techniques for Operations Management Problems

Linear programming problem, Formulation, Simplex method, concept of duality. Assignment models, Transportation models. Need for simulation, Monte Carlo technique. Theory of constraints. Sequencing problems. Project management.

Text Books

1. Jay Heizer, Barry Render, Jagadeesh Rajashekhar. Operation Management, Person Publication, 3rd Edition, 2011.
2. Krajewski, L. J., Ritzman, L. P. and Malhotra, M. K., Operations Management, Prentice Hall, New Delhi, 2009
3. Ebert, J and Adams, D.J., Production/Operations Management, Prentice Hall of India, New Delhi, 2007
4. Thomas Vollmann, William Berry, Manufacturing planning and control Systems, McGraw Hill Education, Fifth Edition, 2004
5. Premkumar Gupta and Hira, Operation Research, S. Chand Company Ltd., New Delhi, 2007.

Programme Name	*Bachelor of Technology in Mechanical Engineering*	*Semester – VI*
Course Code	**R5EE3222T**	
Course Title	**Control of Robotic Systems**	
Prerequisites		

COURSE OUTCOMES

After completion of course, students would have thorough understanding of linear, non-linear control systems and Motion Control.

COURSE CONTENTS

Basics of Control

Differential Equation, Transfer function, Frequency response, Routh-Hurwitz test, relative stability, Root locus design, construction of root loci, phase lead and phase-lag design, lag-lead design, Bode, polar, Nyquist plot.

Linear Control

Concept of states, state space model, different form, controllability, observability; pole placement by state feedback, observer design, P, PI & PID Controller, control law partitioning, modelling and control of a single joint.

Non-Linear Control System

Common physical non-linear system, phase plane method, system analysis by phase plane method, stability of non-linear system, stability analysis by describing function method, Liapunov's stability criterion, the control problems for manipulators.

Motion Control

Point to Point Control, trajectory generation, Continuous Path Control, Joint based control, Cartesian Control, Force Control, hybrid position/force control system.

Text Books

1. M. Gopal, Control Systems, McGraw-Hill (2012)
2. K. Ogata, "Modern Control Engineering", Prentice Hall India (2009).
3. M. Spong, M. Vidyasagar, S. Hutchinson, Robot Modeling and Control, Wiley & Sons, (2005).

Additional Reading

1. J. J. Craig, "Introduction to Robotics: Mechanics and Control", 3rd edition,Addison-Wesley (2003).
2. S. K. Saha, Introduction to Robotics 2e, TATA McGraw Hills Education (2014).
3. Thomas Kailath, "Linear Systems", Prentice Hall (1980).
4. Alok Sinha, "Linear Systems: Optimal and Robust Control", Taylor & Francis(2007).
5. https://nptel.ac.in/courses/112107289,
   Robotics and Control : Theory and Practice, Prof. N. Sukavanam, Prof. M. Felix Orlando, IIT Roorkee
6. https://nptel.ac.in/courses/107106081
   Control systems, Prof. C.S.Shankar Ram, IIT Madras

Programme Name	*Bachelor of Technology in Mechanical Engineering*	*Semester – VI*
Course Code	**R5ME3203T**	
Course Title	**Aerodynamics**	
Prerequisites		

Course Outcomes

The student should be able to –

1. Grasp the fundamental principles of fluid mechanics and aerodynamics.
2. Understand the generation of lift, drag, and moments on aerodynamic bodies.
3. Analyze subsonic, supersonic, and hypersonic flows.
4. Apply aerodynamic theories to the design and analysis of aircraft and spacecraft.

Course Contents

Introduction to Aerodynamics

Basic fluid properties: density, viscosity, compressibility, and thermal conductivity; Flow characteristics: laminar and turbulent flow, steady and unsteady flow; Continuity, momentum, and energy equations; Dimensional analysis and Buckingham Pi theorem.

Incompressible Flow Over Airfoils

Airfoil nomenclature and geometry; Pressure distribution over airfoils; Lift, drag, and moment coefficients; Thin airfoil theory; Kutta condition and circulation.

Finite Wing Theory

Vortex filament and Biot-Savart law; Downwash and induced drag; Prandtl's lifting line theory; Elliptical lift distribution and wing efficiency.

Compressible Flow

Thermodynamics of compressible flow; Speed of sound and Mach number; Isentropic flow relations; Normal and oblique shock waves; Expansion waves (Prandtl-Meyer flow).

High-Speed Aerodynamics

Subsonic, transonic, supersonic, and hypersonic flow regimes; Critical Mach number and drag divergence; Wave drag and area rule; Shock-expansion theory for supersonic airfoils.

Boundary Layer Theory

Boundary layer concept and characteristics; Laminar and turbulent boundary layers; Boundary layer separation and control; Drag due to skin friction and pressure drag.

Wind Tunnel Testing

Wind tunnel types and their applications; Similarity parameters: Reynolds number, Mach number, and Strouhal number; Measurement techniques for lift, drag, and pressure distribution; Flow visualization techniques.

Reference Books

1. J.D. Anderson Jr., Introduction to Flight, McGraw-Hill, 8th Edition, 2012.
2. Anderson, John D., Fundamentals of Aerodynamics, McGraw-Hill Education, 6th Edition, 2017.
3. Katz, Joseph; Plotkin, Allen, Low-Speed Aerodynamics, Cambridge University Press, 2nd Edition, 2001.
4. Houghton, E.L.; Carpenter, P.W.; Collicott, S.H.; Valentine, D.T., Aerodynamics for Engineering Students, Elsevier, 7th Edition, 2020.
5. Bertin, John J.; Cummings, Russell M., Aerodynamics for Engineers, Pearson, 6th Edition, 2013.

Recommended Reading

1. P.K. Kundu and I.M. Cohen, Fluid Mechanics, Elsevier Academic Press, 3rd Edition, 2004
2. Robert W. Fox, Alan T. McDonald, Philip. P. Pritchard, Introduction to Fluid Mechanics, 6th Edition, Wiley, 2003.
3. Frank M. White, Fluid Mechanics, Tata McGraw-Hill, 7th Edition, 2012

Programme Name	*Bachelor of Technology in Mechanical Engineering*	*Semester* – **VI**
Course Code	**R5ME3204T**	
Course Title	**Communication Systems and Sensors**	
Prerequisites	**Basic knowledge of electronic circuits, signal processing, and electromagnetics**	

COURSE OUTCOMES

After completing this course, students will be able to -

1. Understand the fundamentals of military communication systems and their applications.
2. Analyze different sensor technologies used for surveillance, targeting, and reconnaissance.
3. Evaluate the effectiveness of secure communication protocols in defense technology.
4. Design and simulate radar and sonar systems for battlefield applications.
5. Implement signal processing techniques for sensor fusion and data analysis.

Course Contents

Introduction to Defense Communication Systems

Overview of military communication networks, Secure and encrypted communication, Tactical data links and protocols, electronic warfare, and countermeasures.

Radio and Satellite Communications

Principles of RF and microwave communication, Satellite-based communication for defense applications, Software-defined radios (SDR), cognitive radio systems, Anti-jamming and frequency-hopping techniques.

Radar and Sonar Systems

Fundamentals of radar technology, Types of radars: Pulse-Doppler, Synthetic Aperture Radar (SAR), Phased Array Radar, Sonar principles and underwater detection systems, Applications in missile defense and naval warfare.

Infrared and Optical Sensor Systems

Infrared (IR) and thermal imaging, Laser-based communication and LiDAR, Night vision technologies, Optical sensors for missile guidance and surveillance.

Sensor Fusion and Signal Processing

Introduction to multisensor data fusion, Kalman Filtering and tracking algorithms, Image and signal processing techniques, AI, and machine learning applications in defense sensing.

Reference Books

1. Proakis and Salehi, Fundamentals of communication systems, Pearson.
2. B.P. Lathi and Zhi Ding, Modern digital and analog communication systems, Oxford University Press.
3. G. Maral, M. Bousquet, Z. Sun., Satellite Communications Systems: systems, techniques and technology, John Willy and Sons.
4. M.I. Skolnik, Introduction to Radar Systems, Tata Mcgraw Hill edition, 2001.
5. K. K Sharma, Radar, Sonar and Navigation Engineering, S K Kataria& Sons.

Recommended Readings

1. Simon Haykin and Michael Moher, Communication Systems, Wiley.
2. B.R.Mahafza, Radar Systems Analysis and Design Using MATLAB, CRC Press, 2013.
3. T. Pratt, C. W. Bostian, J. E.Allnut, Satellite communication, John Willey and Sons.
4. Anil K. Maini, Handbook of Defence Electronics and Optronics: Fundamentals, Technologies and Systems, John Wiley & Sons Ltd., 2018.
5. Samuel O. Agbo, Matthew N. O. Sadiku, Principles of Modern Communication Systems, Cambridge University Press, 2017.

Programme Name	***Bachelor of Technology in Mechanical Engineering***	***Semester – VI***
Course Code	**R5ME3007L**	
Course Title	**Computer Aided Design and Analysis Laboratory**	
Prerequisites	**Strength of Materials, Heat Transfer, Mechanical Vibrations**	

COURSE OUTCOMES

The student should be able to -

1. Develop part models and assemblies using CAD software
2. Formulate numerical model for a given system.
3. Solve mechanical engineering problems using FEA techniques.

COURSE CONTENTS

Part and Assembly Modeling

- Component and assembly modeling of mechanical components and assemblies (CATIA/Pro-E/Solidworks or similar)

Use of a FEM package

Solve the following problems using a commercial software like Ansys, (to practice the tasks like modeling, mesh generation, simulation, solution, interpretation of results and discussion)

1. Static analysis of bar and truss.
2. Steady state thermal analysis of a composite wall.
3. Static analysis using beam element.
4. Static Analysis of axisymmetric element.
5. Stress of a mechanical component like plate, spanner etc. plane stress/plane strain conditions.
6. Modal analysis of a mechanical component.

Recommended Reading

1. Paleti Shrinivas, Krisha Chaitnay Sambana, Rajesh Kumar Datti, Finite Element Analysis using Ansys 11.0, Prentice Hall, 2010
2. Saeed Moaveni, Finite Element Analysis Theory and Applications with ANSYS, Prentice Hall, Third Edition, 2007
3. Y. Nakasone and S. Yoshimoto, Engineering Analysis with ANSYS Software, Butterworth-Heinemann, 2007

4. Erdogan Madenci, Ibrahim Guven, The finite element method and applications in Engineering using Ansys, Springer, Third Edition, 2007
5. N.S. Gokhale, S S Deshpande, S.V. Bedekar and A.N. Thite, Practical Finite Element Analysis, Finite to Infinite, First Edition, 2008

Programme Name	***Bachelor of Technology in Mechanical Engineering***	***Semester – VI***
Course Code	**R5ME3008L**	
Course Title	**Thermal Engineering Laboratory**	
Prerequisites	**Applied Thermodynamics, Fluid Mechanics, Heat Transfer**	

Course Outcomes:

After completion of course, the student should be able to –

1. Evaluate the performance of Steam & Gas Turbine Power Plants.
2. Examine the governing parameters affecting combustion.
3. Analyse the performance of various Jet Propulsion systems.
4. Investigate the factors affecting the performance of an Internal Combustion engine..
5. Evaluate the performance of refrigeration cycles and psychrometric processes.

List of Experiments:

1. Modelling and simulation of stoichiometric Air:Fuel ratio.
2. Modelling and simulation of any of the jet propulsion systems.
3. Trial on a Petrol engine.
4. Trial on a Diesel engine.
5. Morse Test to find frictional power losses.
6. Trial on Vapour Compression Refrigerator Tutor
7. Evaluation of Psychrometric Properties of moist air.
8. Trial on Air Conditioning Tutor (minimum 2 Psychrometric processes).
9. Visit to any thermal industry (Gas turbine power plant / Automobile / HVAC).

Programme Name	*Bachelor of Technology in Mechanical Engineering*	*Semester – VI*
Course Code	**R5ME3111L**	
Course Title	**Mechanical Vibrations Laboratory**	
Prerequisites	**Dynamics of Machinery**	

COURSE OUTCOMES:

Upon successful completion of the course, students should be able to

1. Estimate response for single degree of freedom system.
2. Evaluate response for multi degree of freedom system.
3. Evaluate parameters required for balancing of system.

List of Experiments (Min. 8 experiments)

1. Experimental prediction of radius of gyration for a given bar.
2. Write a code for finding exact solution of MDOF system. (Eigen values)
3. Write a code for finding natural frequencies by Holzer method.
4. Experimental investigation of Transverse vibrations of beam (Dunkerlay Rule)
5. Measurement of Natural Frequency of Simply Supported Beam (Method of Sine Wave Sweep)
6. Estimating response of a MDOF system for various inputs using Simulink model.
7. Natural Frequency and Modal Shape of Two or Three Degree of Freedom String
8. Natural Frequency and Modal Shape of Multi Degree of Freedom String
9. Experimental prediction of frequency of shaft using whirling principle.
10. Vibration with Single / Double Absorber.
11. Experimental Investigation of Static and dynamic Balancing of multi-rotor system.

Programme Name	*Bachelor of Technology in Mechanical Engineering*	*Semester – VI*
Course Code	**R5ME3112L**	
Course Title	**Robotics Laboratory**	
Prerequisites	**Mathematics for Mechanical Engineers I and II, Kinematics of Machinery, Mechanical Measurements**	

COURSE OUTCOMES

The student should be able to –

1. Understand terminologies related to Kinematics of Robotics.
2. Understand manipulator positioning and motion planning using ROBO ANYLYZER
3. Estimate the forward and inverse transformation using MATLAB program.

List of Practicals

1. Introduction to RoboAnalyzer
2. Virtual Models of Industrial Robots
3. Understanding coordinate frames and transformations
4. Forward kinematics of robots
5. Inverse kinematics of robots
6. Case Study: Kinematics of MTAB Mini Robot
7. Case Study: Workspace Analysis of a 6 axis robot
8. Inverse and Forward dynamics of robots
9. Creating robot joint trajectories
10. Minimum 03 hands on experiment on 5 Axis articulated robot should be covered

Text Books/References:

1. S. K. Saha, Introduction to Robotics 2e, TATA McGraw Hills Education (2014).
2. Dilip Kumar Pratihar, Fundamentals of Robotics, Narosa Publishing House, (2019)
3. J. J. Craig, “Introduction to Robotics: Mechanics and Control”, 3rd edition, Addison- Wesley (2003).

Programme Name	*Bachelor of Technology in Mechanical Engineering*	*Semester – VI*
Course Code	**R5ME3113L**	
Course Title	**Computational Fluid Dynamics Laboratory**	
Prerequisites	**Fluid Mechanics, Heat Transfer**	

COURSE OUTCOMES

The student should be able to –

1. Develop computer codes for simulation of heat transfer and fluid flow problems.
2. Implement CFD process by using CFD software.
3. Interpret data obtained from the numerical solution

List of Experiments

Development of computer codes

1. To develop computer codes for steady state one dimensional heat conduction with or without heat generation, different boundary conditions, Multi-solid heat conduction, Non-linear Heat conduction, Unsteady heat conduction, two dimensional steady and unsteady heat conduction, comparison with analytical solution
2. To develop computer codes for one dimensional convection-diffusion problem to implement various advection schemes like - Central, first order upwind, hybrid, power law, Second order upwind, QUICK etc., two dimensional steady and unsteady convection – diffusion, comparison with analytical solution
3. To develop computer codes for implementation of pressure velocity couplings like SIMPLE for benchmark problems like Lid driven cavity, backward facing step etc., comparison with analytical/numerical solution.

Project

A small group of 2/3 students will use CFD software (commercial/open source) for solution of a problem (sample problems given in the list, however students can select their own project topic) and present their results.

1. Flow between two parallel plates (laminar/turbulent) (with or without heat transfer)
2. Flow in pipe (laminar/turbulent)
3. Boundary layer on a flat plate
4. Flow in a bend
5. Flow over an aerofoil
6. Convection in a pipe (laminar/turbulent)

7. Flow past a cylinder
8. Flow over backward facing step (laminar/turbulent)
9. Flow over Ahmed body
10. Fluid flow and heat transfer in a wavy channel
11. Lid driven cavity
12. Flow over pick-up truck
13. Cooling electronic components in a computer

Recommended Reading

1. Jiyuan Tu, Guan Heng Yeoh, Chaoqun Liu, Computational Fluid Dynamics: A Practical Approach, Elsevier, Second Edition, 2012
2. https://confluence.cornell.edu/display/SIMULATION/FLUENT+Learning+Modules
3. https://www.openfoam.com/documentation/