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
Final 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.

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Curriculum

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For

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Bachelor of Technology (B. Tech.) Degree in Mechanical Engineering

Credit Framework for UG Programme in Mechanical Engineering

(Level 6.0 - B.Tech. in Mechanical Engineering with Multidisciplinary Minor)

Semester - VII

Sr.	Course Type	Course Code	Course Name	L	T	P	Hr	Cr	Examination Weightage in %		
									TA	MST	ESE
1	PCC	R5ME4001T	Research Methodology	2	0	0	2	2	20	30	50
2	PCC	R5ME4002T	Renewable Energy Engineering	2	0	0	2	2	20	30	50
3	PEC		Program Elective –III	3	1	0	4	4	20	30	50
4	PEC		Program Elective –IV	3	1	0	4	4	20	30	50
5	MDM		Multi-disciplinary Minor-V	3	1	0	4	4	20	30	50
6	OE		Open Elective-II	3	1	0	4	4	20	30	50
7		R5ME4801P	Project	0	0	8	8	4	ISCE :60		40
			Total	16	4	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

Credit Framework for UG Programme in Mechanical Engineering

(Level 6.0 - B.Tech. in Mechanical Engineering with Multidisciplinary Minor)

Semester - VIII

Sr.	Course Type	Course Code	Course Name	L	T	P	Hr	Cr	Examination Weightage in %		
									TA	MST	ESE
1	OJT	R5ME4701I	Internship					12	ISCE: 60		40
2	PCC	R5ME4003T	Product Innovation & Entrepreneurship (Online)	2	0	0	2	2	20	30	50
			Total	2	0	0	2	14			

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

Program Electives-III in Semester VII

Sr. No.	Course Code	Name
1	R5ME4101T	Tribology
2	R5ME4102T	System Modeling
3	R5ME4103T	Smart Manufacturing
4	R5ME4104T	Supply Chain Management
5	R5ME4105T	Microfluidics
6	R5ME4106T	Air Conditioning Systems Design
7	R5ME4107T	Electric Vehicle

Program Electives-IV in Semester VII

Sr. No.	Course Code	Name
1	R5ME4111T	Pressure Vessel Design
2	R5ME4112T	Piping Engineering
3	R5ME4113T	Industrial Engineering & Management
4	R5ME4114T	Sustainable Manufacturing
5	R5ME4115T	Gas Dynamics
6	R5ME4116T	Design of Heat Exchange Equipment

Multi-Disciplinary Minors in Semester VII

Sr. No.	Course Code	Name
1	R5ME4201T	Wheeled Mobile Robots
2	R5ME4202T	Unmanned Vehicle Technology
3	R5ME4203T	Aerospace Propulsion Systems

SEMESTER-VII

Programme Name	Bachelor of Technology in Mechanical Engineering	Semester – VII
Course Code	**R5ME4001T**	
Course Title	**Research Methodology**	
Prerequisites		

COURSE OUTCOMES

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

1. Understand research problem formulation and approaches of investigation of solutions for research problems.
2. Learn ethical practices to be followed in research and apply research methodology in case studies and acquire skills required for presentation of research outcomes
3. Discover importance of Intellectual Property Rights.
4. Promote Intellectual Property Right and patenting.

Course Contents

Research Problem

Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem.

Approaches of investigation of solutions for research problem.

Literature Review

Effective literature studies approaches, analysis, Plagiarism, Research ethics,

Technical Writing

Effective technical writing, how to write report, Paper, Developing a Research Proposal, Format of research proposal, and presentation.

Nature of Intellectual Property

Patents, Designs, Trade and Copyright. Process of Patenting and Development technological research, Innovation, patenting. Procedure for grants of patents.

Patent Rights

Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications.

Recommended Reading

1. Ranjit Kumar, Research Methodology A Step-by-Step Guide for beginners, 2nd Edition
2. C.R. Kothari, Research Methodology Methods and Techniques
3. Halbert, Resisting Intellectual Property, Taylor & Francis Ltd., 2007.
4. Mayall, Industrial Design, McGraw Hill, 1992.
5. Niebel, Product Design, McGraw Hill, 1974.
6. T. Ramappa, Intellectual Property Rights under WTO, S. Chand, 2008

Programme Name	Bachelor of Technology in Mechanical Engineering	Semester – VII
Course Code	**R5ME4002T**	
Course Title	**Renewable Energy Engineering**	
Prerequisites		

COURSE OUTCOMES

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

1. Obtain a foundational understanding of renewable energy sources and their significance in the global energy landscape.
2. Explore the principles, technologies, and applications of renewable energy systems relevant to mechanical engineering.
3. Investigate the fundamentals of design, analysis, and integration of renewable energy systems.
4. Address the economic, environmental, and social aspects of renewable energy adoption.
5. Recognize hydrogen as a key renewable energy carrier and explore its production, storage, and utilization.

Course Contents

Introduction to Energy Systems and Renewable Energy

Global energy scenario: Fossil fuels vs. renewable energy; Classification of energy sources: Conventional and renewable; Importance of renewable energy in sustainable development; Overview of renewable energy policies in India (e.g., National Solar Mission, Wind Energy Policy, National Hydrogen Mission)

Solar Energy

Solar radiation and its measurement; Photovoltaic (PV) systems: Principles, components, and types of solar cells; Solar thermal systems: Flat plate collectors, evacuated tube collectors, and concentrated solar power (CSP); Applications of solar energy: Power generation, water heating, and space heating

Wind Energy

Wind energy principles and wind turbine technology; Types of wind turbines: Horizontal- axis and vertical-axis; Wind resource assessment and site selection; Applications of wind energy: Onshore and offshore wind farms

Biomass Energy

Biomass resources and their characterization; Biomass conversion technologies: Combustion, gasification, and anaerobic digestion; Biofuels: Biodiesel, bioethanol, and biogas; Applications of biomass energy: Power generation and transportation

Geothermal and Ocean Energy

Geothermal energy: Principles and technologies; Types of geothermal power plants: Dry steam, flash steam, and binary cycle; Ocean energy: Tidal, wave, and ocean thermal energy conversion (OTEC); Applications and challenges of geothermal and ocean energy

Hydrogen Energy

Hydrogen as an energy carrier: Properties and advantages; Methods of hydrogen production: Steam methane reforming (SMR), Electrolysis (alkaline, PEM, SOEC) powered by renewables, Thermochemical and biological methods; Hydrogen storage technologies: Compressed gas, liquid hydrogen, metal hydrides, and chemical storage; Hydrogen utilization: Fuel cells, hydrogen combustion, and industrial applications; Green hydrogen and its role in decarbonizing sectors like transportation, industry, and power generation

Energy Storage and Hybrid Systems

Energy storage technologies: Batteries, applications in electric vehicles, pumped hydro, and flywheels; Design and applications of hybrid renewable energy systems (e.g., solar-wind, solar-diesel); Role of energy storage in grid stability and renewable energy integration

Energy Policies

Government strategies, laws, and regulations governing the production, distribution, and consumption of energy to balance economic development, security, and environmental sustainability.

Text Books

1. G.D. Rai, Non-Conventional Energy Sources, 6th ed., Khanna Publishers, 2017.
2. Twidell, John, and Tony Weir, “Renewable Energy Resources”, 3rd ed., Routledge, 2015.
3. Ministry of New and Renewable Energy (MNRE), India. Annual Reports and Policy Documents. Available at https://mnre.gov.in.
4. National Renewable Energy Laboratory (NREL). Research Reports and Technical Papers. Available at https://www.nrel.gov.
5. International Renewable Energy Agency (IRENA). Renewable Energy Statistics and Reports. Available at https://www.irena.org.

Recommended Reading

1. Kalogirou, Soteris, “Solar Energy Engineering: Processes and Systems”, 2nd ed., Academic Press, 2013.
2. Manwell, James F., Jon G. McGowan, and Anthony L. Rogers, “Wind Energy Explained: Theory, Design, and Applicatios:,. 2nd ed., Wiley, 2010.
3. Klass, Donald L, “Biomass for Renewable Energy, Fuels, and Chemicals:, Academic Press,

1998.
4. Sørensen, Bent, “Hydrogen and Fuel Cells: Emerging Technologies and Applications”, 2nd ed., Academic Press, 2011.

Programme Name	Bachelor of Technology in Mechanical Engineering	Semester – VII
Course Code	**R5ME4101T**	
Course Title	**Tribology**	
Prerequisites		

COURSE OUTCOMES

The student should be able to –

1. Apply friction/lubrication mechanism to the practical engineering problem.
2. Justify the use of metallic and non-metallic materials.
3. Design mechanical components against wear.
4. Employ different methods to reduce the friction for engineering surface

Course Contents

Introduction

Tribology definition.

Tribology in design- bearing material, its properties and construction, Tribological design of oil seals and gasket.

Tribology in industry (Maintenance).

Lubrication-Definition, basic modes of lubrication, properties of lubricants, additives, EP lubricants, Recycling of used oil, oil conservation, oil emulsion.

Bearing Terminology-Types of Sliding contact, rolling contact bearings.

Comparison between sliding and rolling contact bearing.

Hydrodynamic lubrication and bearing design

Theory of hydrodynamic lubrication, mechanism of pressure development in oil film.Two dimensional Reynold's equation and its limitations, Petroff's equation.

Hydrodynamic thrust bearing-Introduction, types.

Flat plate thrust bearing-Pressure equation, load, centre of pressure, frictional force equation.

hydrodynamic lubrication: design of plain fixed pad and tilting pad, slider bearing for steady and varying –loads. Full and partial journal bearing of infinite length, design of journal bearing for steady loads and varying loads. Introduction to design of hydrostatic and Aerostatic bearings. Thrust and radial.

Elastohydrodyanamic Lubrication

Elasto-hydrodynamic lubrication-Principle and applications to rolling contact bearings, cams and gears.

Lubricants

Selection for general application and special application such as low temperature, high temperature, extreme Pressure etc.

Rolling Contact Bearing

Static and dynamic load capacity, rated life, Contact stresses

Surface Engineering

Friction- Introduction, laws of friction, Friction classification, causes of friction.
Theories of dry friction.
Friction measurement.
Stick-slip motion and friction instabilities.
Types of wear and basic mechanism of wear. Wear properties of friction and anti-friction metallic and nonmetallic materials, experimental techniques in evaluation of materials. Design of mechanical components against wear. Design of friction surfaces used in clutches and brakes.
Engineered surfaces and novel coatings for protection against wear, erosion or corrosion.

Text Books

1. Cameron A., Basic Lubrication Theory, Wiley Eastern Ltd.
2. Mujumdar B. C., Introduction to Tribology and Bearings, S. Chand and Company Ltd. New Delhi, 2010
3. Andras Z. Szeri, Fluid film lubrication theory & design, First Edition, 2005
4. J. Bhatia, Advances in industrial Tribology, Tata McGraw-Hill Publishing Company, 1998

Programme Name	Bachelor of Technology in Mechanical Engineering	Semester – VII
Course Code	**R5ME4102T**	
Course Title	**System Modelling & Analysis**	
Prerequisites		

COURSE OUTCOMES

The student should be able to –

1. Develop mathematical model for various types of systems.
2. Use transfer function and state space approach for finding solutions.
3. Calculate transient and steady state response for various input conditions.

Course Contents

Mechanical systems

Mathematical modeling of mechanical elements – inertia, stiffness and damper and mathematical modeling of mechanical systems – vehicles, articulated vehicle and other mechanical systems.

Electrical systems and Electro-mechanical systems

Fundamentals of Electrical Circuits, Mathematical Modeling of Electrical Systems, Mathematical Modeling of Electromechanical Systems

Fluid Systems and Thermal Systems

Mathematical modeling of hydraulic elements and system – Pneumatic elements and system.

Transfer function and state space approach

Transfer function representation, block diagram, State variable representation, matrix equation. Solution of state equation. Equivalent state space model.

Time and Frequency domain analysis

Transient response of First and Second order system, Steady state response, Step Response, Ramp response, Impulse response, Sinusoidal response, Convolution integral, Stability and controllability of system.

Text Books

1. K.Ogata, System Dynamics, Pearson, Fourth Edition, 2003
2. I.J. Nagarath & M.Gopal, Control System Engineering, NEW AGE, Fifth Edition, 2009

Recommended Reading

1. Ronald C. Rosenberg, Introduction to physical systems dynamics, McGraw Hill, 1983
2. Hung V Vu & R.S.Esfandi, Dynamics System Modelling & Analysis, McGraw Hill
3. Thomas D Burton, Introduction top dynamic systems analysis, McGraw Hill, 1994

Programme Name	Bachelor of Technology in Mechanical Engineering	Semester – VII
Course Code	**R5ME4103T**	
Course Title	**Smart Manufacturing**	
Prerequisites		

COURSE OUTCOMES

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

1. Describe the basic concepts of Artificial Intelligence and its applications.
2. Identify suitable methods to collect data for Artificial Intelligence systems.
3. Apply various algorithms for developing machine learning models.
4. Apply Artificial Intelligence techniques for manufacturing applications.

Course Contents

Fundamentals of AI

Historical development, key concepts and terminology, ethical and societal considerations. Problem Solving by Search: Fundamentals, application to manufacturing scenarios, case studies in manufacturing. Key AI Technologies: Machine learning and deep learning. Applications in quality control, predictive maintenance, and process optimisation. Role of data in AI applications and its acquisition in manufacturing.

Data sources in manufacturing, sensors IoT devices

Techniques for data acquisition and real-time monitoring in industrial settings. Challenges in managing and storing manufacturing data. Data preprocessing techniques for cleaning and structuring data. Feature selection and engineering for AI model inputs. Data visualisation and analysis techniques for manufacturing insights.

Supervised and Unsupervised Learning

Fundamentals, Overview of supervised and unsupervised learning algorithms, Applications in quality control, anomaly detection, and process optimization, Model selection and evaluation for manufacture. Deep learning techniques, convolutional neural networks and recurrent neural networks, Integration of robotics and AI in manufacturing processes, Case studies of AI-driven improvements in manufacturing efficiency and quality.

Real-world Applications in Manufacturing

AI-driven process optimization and quality control, AI's role in supply chain management, demand forecasting, and production scheduling. Sustainable and green manufacturing through AI. Future Trends and Preparing for Industry 5.0: Challenges and opportunities in the evolving landscape of

AI in manufacturing. The role of AI in fostering innovation and competitiveness. Preparing for the future of manufacturing with AI skills and knowledge.

Text Books

1. Russell, S., and Norvig, “Artificial Intelligence: A Modern Approach”, Pearson India, 2022.
2. Geron, A., “Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow”, O Reilly, 2019.
3. Nilsson, N.J., “Artificial Intelligence – A New Synthesis”, Morgan Kaufmann Publishers, Inc., 1998.

Recommended Reading

1. Tran, K.P., “Artificial Intelligence for Smart Manufacturing - Methods, Applications, and Challenges”, Springer, 2023.
2. Chen, T.T., “Explainable Artificial Intelligence (XAI) in Manufacturing - Methodology, Tools, and Applications”, Springer, 2023.

Programme Name	Bachelor of Technology in Mechanical Engineering	Semester – VII
Course Code	**R5ME4104T**	
Course Title	**Supply Chain Management**	
Prerequisites		

COURSE OUTCOMES

The student should be able to –

1. Evaluate the supply chain networks
2. Estimate the total cost of different logistic modes
3. Evaluate various performance measures of supply chain management
4. Obtain solutions for a variety of warehouse problems
5. Integrate the supply chain using the IT solution.

Course Contents

Basics of Supply Chains

Supply chain stages and decision phases, Process view of supply chain: Supply chain flows, Examples of supply chains, Competitive and supply chain strategies, Achieving strategic fit: Expanding strategic scope, Drivers of supply chain performance. Framework for structuring drivers: inventory, transportation facilities, information obstacles to achieving fit. Sustainable and green manufacturing and linkage with supply chains.

Designing the Supply Chain Network Distribution Networking

Designing distribution, networks and applications to business, network design in supply chain and uncertain environments. Demand forecasting supply chains, aggregate planning and managing variability. Managing inventory in supply chain. Optimal level of product availability. Cross functional drivers in a supply chain.

Dimensions of Logistics Introduction

A Macro and Micro Dimensions, Logistics interfaces with other areas, Approach to analyzing logistics system, Logistics and systems analyzing: Techniques of logistics system analysis, factors affecting the cost and Importance of logistics.

Warehouse and Transport Management

Concept of strategic storage, Warehouse functionality, Warehouse operating principles, Developing warehouse resources, Material handling and packaging in warehouses, Transportation Management, Transport functionality and principles, Transport infrastructure, transport economics and Pricing. Transport decision making.

IT in Supply Chain

IT framework, Customer Relationship Management (CRM), internal Supply chain management, Supplier Relationship Management (SRM) and Transaction Management. Coordination in a Supply Chain. Lack of supply chain coordination and the Bullwhip effect, Obstacle to Coordination, Managerial levers, Building partnerships and trust. Emerging Trends and Issues. Vendor managed inventory-3PL-4PL, Reverse logistics: Reasons, Role, Activities; RFID systems: Components, Applications, Implementation; Lean supply chain, Implementation of Six Sigma in supply chain, Green supply chain. Use of GPS and GPRS systems. Application areas of technology-enabled solutions - real-time monitoring of large fleet of trucks/tankers or marine vessels through GPS-enabled global network; online monitoring of fuel consumption patterns of fleet; real-time stock level monitoring of warehouses across geographies. Software used for supply chain management.

Decision Support Models of Supply Chain Management

Decision support systems in supply chains. Transportation Systems. Warehouse Design, Distribution Policies, Transshipment etc.

Text Books

1. Sunil Chopra and Peter Meindl, Supply Chain Management Strategy, Planning, and operations, Pearson, Sixth Edition, 2014
2. Ammer D.S. Taraporawala, Materials Management & Purchasing
3. David Simchi Levi, Philip Kaminsky& Edith Smichi Levi, Designing & Managing Supply chain, McGraw Hill Higher Education, 1999

Recommended Reading

1. Robert B Handfield, Ernest L Nicholas, Supply Chain Redesign: Transforming Supply Chains into Integrated Value Systems, Financial Times/ Prentice Hall, 2002
2. Coyle, Bardi, Langley, The Management of Business Logistics: A Supply Chain Perspective, South-Western, Seventh Edition, 2002

Programme Name	Bachelor of Technology in Mechanical Engineering	Semester – VII
Course Code	**R5ME4105T**	
Course Title	**Microfluidics**	
Prerequisites	**Fluid Mechanics**	

COURSE OUTCOMES

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

1. Apply the fundamental principles of fluid mechanics and conservation laws to analyze fluid behaviour in micro-scale systems.
2. Analyze low Reynolds number pressure-driven flows in microchannel.
3. Evaluate unsteady viscous flows in a microchannel and external flows.
4. Interpret interfacial phenomena, lubrication effects, and surface-tension-driven transport in microfluidic systems.
5. Explain the working principles and engineering applications in microfluidics related emerging technologies.

Course Contents

Introduction to Microfluidics

Basics of Fluid Mechanics: Lagrangian and Eulerian approaches, visualization of fluid flow (streamlines, streaklines, pathlines), strains in fluid flow (linear strain rate, shear strain rate, volumetric strain rate).

Reynolds Transport Theorem (RTT)

Equations of Conservation: Continuity Equation

Navier Stokes Equation

Energy Conservation Equation

Species Conservation Equation

Pressure driven flows through a microchannel

Unit 2: Pressure driven flows through a microchannel

Low Reynolds number hydrodynamics, and Scaling effect at microlevel.

Governing Equations, Boundary conditions, Entrance effects, Exact solutions

Couette Flow (Flow between Parallel plates)

Poiseuille flow (Flow through a cylinder)

Poiseuille flow (Flow through a rectangular channel)

Unsteady flows (internal and external)

Stokes 1st problem and Modified Stokes 1st problem (with confinement)
Stokes 2nd problem and Modified Stokes 2nd problem (with confinement)
Flows over external surface: Stokes drag on a Sphere.

Lubrication theory and Surface tension driven flows through a microchannel

Lubrication theory
Microchannel classification based on Knudsen number (Kn)
Slip Boundary conditions.
Interfacial equilibrium
Flow in a capillary
Modified surface tension flows
Thin Film dynamics

Real-life Applications of Microfluidics

Lab on a CD
Electrokinetics and Diffusion
Biomicrofluidics
Introduction to Microfabrication
Introduction to nanofluids

Recommended Reading:

1. Nguyen, N. T., Werely,S. T., Fundamentals and applications of Microfluidics, Artech house Inc., 2002.
2. Bruus, H., Theoretical Microfluidics, Oxford University Press Inc., 2008.
3. Madou, M. J., Fundamentals of Microfabrication, CRC press, 2002.
4. Tabeling, P., Introduction to microfluidics, Oxford University Press Inc., 2005.
5. Kirby, B.J., Micro- and Nanoscale Fluid Mechanics: Transport in Microfluidic Devices, Cambridge University Press, 2010.
6. Colin,S., Microfluidics, John Wiley & Sons, 2009.
7. Micro- and Nano-scale Fluid Mechanics: Transport in Microfluidic Devices, Brian J. Kirby, 2012.
8. Introduction to Microfluidics, Patrick Tabeling, 2023.

Programme Name	Bachelor of Technology in Mechanical Engineering	Semester – VII
Course Code	**R5ME4106T**	
Course Title	**Air Conditioning Systems Design**	
Prerequisites	**Thermodynamics, Fluid Mechanics, Thermal Engg.**	

COURSE OUTCOMES:

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

1. Analyze psychrometric properties and processes.
2. Estimate various loads for air conditioning.
3. Design various industrial air conditioning systems.
4. Design Air Handling Units for proper ventilation.

Course contents

Basic Psychrometric Processes

Psychrometric processes–Adiabatic mixing, Sensible heating/cooling, Humidification /Dehumidification, Bypass Factor, Apparatus Dew Point (ADP), Types of Sensible Heat Factors (SHF) like Room SHF, Grand SHF, effective SHF.

Heat Load Calculations

Heating / Cooling Load Calculations, Comfort Air Conditioning- Effective Temperature, Comfort Charts, Comfort Zone.

Air Conditioning Systems

Summer / Winter AC, Year-round AC, Room and Split Air-conditioners, Package and ductable air-conditioners, Central AC, Direct Expansion (DX) system, Chilled Water system, VRV / VRF systems.

Air Handling Unit & Duct Design

Air Handling Units and Fan Coil units, Flow through Ducts, Static & Dynamic Losses, Diffusers, Duct Design–Equal Friction Method, System Balancing, Fans & Duct system characteristics, fan arrangement, fan sizing & fan selection, Variable Air Volume systems.

Text Books

1. Arora & Domkundwar, "Course in Refrigeration & Air-Conditioning", Dhanpat Rai Publications, 8th ed., 2013.
2. Manohar Prasad, "Refrigeration & Air-Conditioning", New Age Intl. Publications, 3rd ed., 2010.

Recommended Reading

1. ASHRAE Handbook, 2013 ed.
2. W. P. Jones, Air Conditioning Engineering, Butterworth-Heinemann, 5th ed., 2000.
3. Richard C. Jordan and Gayle B. Priester, “Refrigeration and Air Conditioning”, Prentice-Hall, 1948.

Programme Name	Bachelor of Technology in Mechanical Engineering	Semester – VII
Course Code	**R5ME4107T**	
Course Title	**Electric Vehicle Technology**	
Prerequisites		

Course Outcomes

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

1. Explain the architecture, types, and performance characteristics of various Electric Vehicles compared to conventional IC engine vehicles.
2. Analyse and select electric motors, drives, and power electronics suitable for EV propulsion systems.
3. Evaluate different energy storage technologies, battery management systems and charging infrastructure for EVs.
4. Apply principles of vehicle dynamics, thermal management, and control systems in EV design and integration.
5. Demonstrate the ability to analyse, evaluate, and integrate power management strategies.

Course Contents

Introduction to Electric Vehicles

Evolution and history of EVs; Comparison of EVs with ICE vehicles (efficiency, emissions, performance). Types of EVs: Battery Electric Vehicles (BEV), Hybrid Electric Vehicles (HEV), Plug-in HEV (PHEV), Fuel Cell EVs (FCEV), Extended Range EVs. EV architecture, powertrain configurations (series, parallel, series-parallel), advantages, limitations, and market trends. Basics of EV performance parameters: range, efficiency, torque-speed characteristics.

Electric Propulsion Systems

Electric motors for EVs: DC motors, Induction motors, Permanent Magnet Synchronous Motors (PMSM), Brushless DC (BLDC), Switched Reluctance Motors – working principle, characteristics, selection criteria. Motor sizing, torque-speed curves, efficiency maps, and regenerative braking. Power electronics: Inverters, converters, choppers, and their role in motor control. Motor controllers and drive systems (vector control, field-oriented control). Mechanical integration: Gearboxes, differentials, and direct drive options.

Energy Storage and Battery Technology

Battery fundamentals: Chemistry, capacity, energy density, power density, C-rate, SOC, SOH. Battery packs: Cell configurations (series-parallel), thermal management systems (air, liquid, PCM). Battery Management System (BMS): Monitoring, balancing, protection, estimation algorithms. Other storage: Supercapacitors, flywheels, fuel cells – hybridization. Charging systems: On-board/off-board chargers, AC/DC charging levels, standards (CCS, CHAdeMO), wireless charging, V2G.

Vehicle Dynamics and Control for EVs

EV-specific dynamics: Weight distribution, centre of gravity, handling, stability (Braking systems: Regenerative braking, blending with friction brakes, energy recovery. Suspension, steering, and chassis design adaptations for EVs. Control systems: Vehicle Control Unit (VCU), traction control, stability control, ADAS integration.

Power Management, Thermal Systems, and Integration

Energy management strategies: Optimal power split in hybrids, range estimation. Thermal management: Cooling for batteries, motors, power electronics, cabin HVAC (heat pumps). Vehicle body, aerodynamics, lightweight materials, and structural considerations for EVs. Wiring harness, high-voltage safety, EMI/EMC issues. System integration and packaging challenges.

Reference Books

1. James Larminie and John Lowry, *Electric Vehicle Technology Explained*, 2nd Edition, Wiley, 2012. (Comprehensive on principles, design, and applications).
2. Mehrdad Ehsani, Yimin Gao, Stefano Longo, Kambiz Ebrahimi, *Modern Electric, Hybrid Electric, and Fuel Cell Vehicles: Fundamentals, Theory, and Design*, 3rd Edition, CRC Press, 2018. (Excellent for theory and design).
3. Iqbal Husain, *Electric and Hybrid Vehicles: Design Fundamentals*, 3rd Edition, CRC Press.
4. Chris Mi, M. Abul Masrur, David Wenzhong Gao, *Hybrid Electric Vehicles: Principles and Applications with Practical Perspectives*, Wiley.
5. National/Regional standards documents (e.g., AIS standards for India) and SAE papers for case studies.

Programme Name	Bachelor of Technology in Mechanical Engineering	Semester – VII
Course Code	**R5ME4111T**	
Course Title	**Pressure Vessel Design**	
Prerequisites		

COURSE OUTCOMES

The student should be able to –

1. Apply ASME code to design vessel for internal and external pressure.
2. Design/Select Nozzles and Flanges for the given conditions.
3. Design vessel for wind and seismic loads.
4. Analyze the requirements of transportation, Testing and erections.

Course Contents

Introduction to Pressure vessel

Classification, Components, Types of shell, Types of supports, nozzles, attachments, Procedure for pressure vessel design, Fabrication methods, Review of various country wide Pressure vessel codes

Theory of Pressure Vessel

Types of Design methods, various failure modes, stress evaluation, loads, stress theories, stiffener rings, stresses in various components.

Material of Construction

Selection of material for Pressure vessel, ASME Material codes for Pressure Vessel, Types of material treatment used for pressure vessel, Post heat weld treatment, Physical property selection of materials using ASME section-II part D.

Design for Internal Pressure

Thickness calculation of various components subjected to internal pressure. Analysis of thickness calculation for different head using ASME sections including vertical vessels, tall vessels, Columns, end closures.

Design for External Pressure

Thickness calculation of various components subjected to External pressure, requirement of stiffeners, unsupported length, section calculations for stiffeners, types of stiffeners.

Other requirements of Pressure vessel

Understanding Requirements of Part UG, UW, UCS of ASME Sec VIII Div 1, Design considerations , General rules for examination methods, inspector qualification, and mandatory hydrostatic/pneumatic testing procedures. Welding criteria.

Nozzles and Bolted Flange design

Types of openings, size of opening, nozzle reinforcement, Need of flanges, types of flanges, design considerations

Design for Wind/ Seismic loads

Design codes and practices, Load cases, comparison, steps in wind and seismic load calculations, effects of wind and seismic loads, Designing a Pressure vessel under wind and seismic load, both and anchor design.

Evaluation of Pressure Vessel for various conditions

Saddle design, design of Lifting attachments, types of transportation, Hydro test, external nozzle loads.

Creep and fatigue in Pressure vessel

Creep: Phenomenon, Creep Behaviour, Governing Parameters, Creep Testing, Design Considerations

Fatigue: Background, Phenomenon, fatigue behaviour, design considerations

Text Books

1. Somnath Chattopadhyay, Pressure vessels design and practice, CRC Press, Third Edition, 2004
2. John F Harvey, Theory & Design of Pressure Vessels, Van Nostrand Reinhold Company Ltd, Fifteenth Edition

Recommended Reading

1. Vincent A. Carucci, Overview of pressure vessel design, ASME International
2. Brownell and Young, Process equipment design, Wiley, 2009
3. N K Roy, Review of code for pressure vessels, IS 2825 as compared to ASME/BS/ADMerkblatter, Journal for Process Equipment & Piping Technology, Vol 1, No 1, June 1994
4. A special report : Worldwide pressure vessel codes, Hydrocarbon Processing, Dec 1978.
5. ASME Section VIII Div-1, 2 & 3, 2010, Addenda 2011a.
6. H. Bednar, Pressure Vessel Design Handbook, Krieger Publishing Company, Second Edition, 1990
7. Dennis Moss, Pressure Vessel Design Manual, Butterworth-Heinemann, Fourth Edition, 2013

Programme Name	Bachelor of Technology in Mechanical Engineering	Semester – VII
Course Code	**R5ME4112T**	
Course Title	**Piping Engineering**	
Prerequisites		

COURSE OUTCOMES

The student should be able to –

1. Prepare piping system layout.
2. Design piping system as per the requirement.
3. Apply various national and international standards.

Course Contents

Introduction

Scope of Piping, Code and Standards, Mechanical Design Fundamentals, Mechanical design of piping system, Wall thickness, Piping size selection, Piping elements and specialties, Pipe representation, Welded and flanged fittings.

Piping system layout and drawing

Piping layout, Equipment Layout, Process Piping Layout, Pipe flow sheets, plan and isometric representation of piping system, plot plan

Pipe Supports

Load on structural supports, supporting structures on pipelines, pipe supports – design considerations, platforms and ladders, foundations, supporting span of overhead pipelines, stiffening ribs, flexible hanger support.

Valves and Auxiliaries

Valve material and method of construction, Pressure drop in valves, valve size, type of valves, fittings, Pressure relief devices, Design of pressure relief system.

Mechanical Piping Design

Nominal pipe size, Pipe sizing by internal diameter, Choosing the final pipe size, Piping drawings, Piping stress design, Internal or external fluid pressure stresses, expansion effect and compensation methods.

Stress analysis

Type of loads, code compliance, thermal effects, fatigue loads, flexibility analysis and introduction to dynamic analysis, software for stress analysis.

System-level engineering

Design of piping network connected to several equipment. Composite thermal expansion-related stresses, piping strain due to misalignment at equipment flanges, Flow-induced Vibration (FIV) and Acoustic-induced Vibration (AIV) in piping systems. Piping & Instrumentation Diagram (P&ID) and Piping Isometrics. Exposure to any commercial Piping Design. Energy institute guidelines for controlling noise.

Text Books

1. G K Sahu, Handbook of piping design, New Age international publisher, Second Edition, 2009
2. Sabin Crocker, Piping Handbook, McGraw Hill Publication, Fifth Edition, 1968
3. Ed. Bausbacher and Roger Hunt, Process Plant Layout and Piping Design, Pearson Prentice Hall, 1993

Recommended Reading

1. Mohinder L. Nayyar, Piping Handbook, McGraw Hill, Seventh Edition, 1999
2. ASME Piping Code B 31 (Power piping) and 33 (Process piping)
3. Pipe Supports, Catalog PH-82A NHK Spring Co. Limited, Yokohoma, JAPAN

Programme Name	***Bachelor of Technology in Mechanical Engineering***	***Semester – VII***
Course Code	**R5ME4113T**	
Course Title	**Industrial Engineering and Management**	
Prerequisites		

COURSE OUTCOMES

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

1. Examine various organizational behaviours and management principles.
2. Apply statistical techniques for inspection.
3. Elaborate and application of work study, Time study.
4. Optimize resources with the use of ERP technology.

Course Contents

Introduction

Introduction to industrial engineering, history and contribution to industrial engineering, industrial engineering approach, techniques of industrial engineering, objectives of industrial engineering, system approach and industrial engineering. Organization Structure and Behavior Definition, Need, Types, Hierarchy, Functional matrix relationship, Responsibility, Authority delegation, Span of control, Recent developments (Lean, network, virtual, SBU'S), Theories of motivations and leadership.

Industrial Acts Introduction, necessity of industrial acts, Indian Boiler Act 1923, Indian Factories At 1948, Minimum Wage Act 1948, Industrial Disputes Act1947. Current Amendments.

Work Study & Time study

Definition and Objectives, Work content – Basic work content, Total work content – Ineffective time method of their reduction, Method study; Definition – Objectives and asic procedure – Different techniques used in method improvement – Process chart symbol – Process chart for operator or Material process chart – Process chart for assemblies, Flow diagram – analysis and critical examination of operations and development of improved methods, Man machine chart, Multiple activity chart, Use of micromotion and memotion study, Work measurements, Significance and procedures of work measurements, Techniques of time study; Steps in making time study – Selection of operator, Breakup of an operation into elements, Different timing method – Recording time study data – Form used, Different rating practices , Normal time, Different types of allowances, Standard time. Maynard Operation Sequence Technique (MOST). Facility Planning Objectives and scope, location of facilities, types of layouts, layout design techniques, assembly line balancing, and computer packages for layout analysis. Quantitative methods of Plant layout: CRAFT and CORELAP, Relationship diagrams.

Statistics in Industrial Engineering

Control chart techniques, Quality characteristics, trial control limits, revised control limits of mean, range and standard deviation chart, state of control, control chart for moving average and run chart, Control charts of attributes – Control chart for fraction defectives (p), Control chart for number of defectives (np), Control for number of defects (c), Control harts for number of defects per unit (u). Concept of variation, central tendency theorem, acceptance sampling.

Enterprise Resource Planning ERP

Conceptual overview, Critical components, Structure, Evolution and Architecture of ERP, Best Practices and Business process reengineering issues in ERP, ERP- Overview of functional modules (i) Manufacturing and Purchase Module: A functional overview (ii) Finance Module-A functional overview (iii) Sales & Distribution Module-A functional Overview ERP-Implementation methodologies, Success and failure cases, ERP Audit, Future of ERP, ERP systems in India, Introduction to ERP software. Lean Manufacturing, Six Sigma.

Text Books

1. Heinz Weihrich, Harold, Koontz, “Management A Global Perspective”, McGraw-Hill, 10th ed., 1994.
2. R. Panneerselvam, “Production and Operations Management”, PHI Learning, 3rd ed., 2012.
3. Martand Telsang, “Industrial Engineering and Production Management”, S. Chand, 2nd ed., 2006.
4. T.R.Banga and S.C.Sharma, “Industrial Engineering and Production Management”, Khanna Publishers, 11th ed., 2014.
5. Dr. B. Kumar, “Industrial Engineering and Management”, Khanna Publishers, 10th ed., 2010.
6. International Labour Organisation (ILO), “Introduction to Work Study”, 3rd ed., 1983.
7. Gang A. Langenwalter, “ERP and Beyond Integrating Your Entire organization”, The St. Lucas Press/ Apics Series on Resources Management, 1999.

Recommended Reading

1. Harold Amrine, John Ritchey, Moodie, Kmec, “Manufacturing Organisation and Management”, Pearson, 6th ed., 2004
2. J.L. Riggs, “Production System, Planning, Analysis and Control”, John Wiley & Sons Inc., 4th ed., 1987.
3. International Journal of Business Performance Management.

Programme Name	*Bachelor of Technology in Mechanical Engineering*	*Semester – VII*
Course Code	**R5ME4114T**	
Course Title	**SUSTAINABLE MANUFACTURING**	
Prerequisites		

COURSE OUTCOMES

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

1. Identify key requirements in sustainable manufacturing
2. Apply sustainability concepts in manufacturing systems
3. Demonstrate the life cycle analysis and costing in the production process
4. Map the possibilities in remanufacturing and circular economy in manufacturing

Course Contents

Concept of sustainability, Sustainable Development goals, manufacturing operations, resources in manufacturing. Concept of the triple bottom line, environmental, economic, and social dimensions of sustainability. Need for sustainable manufacturing. Environmental impact assessment methods - CML, EI 95 and 99, ISO 14001, EMS and PAS 2050 standards, environmental impact parameters. Sustainability assessment-concept models and various approaches, product sustainability and risk assessment-corporate social responsibility.

Life cycle analysis tools, optimization for achieving sustainability in manufacturing, value analysis, analysis for carbon footprint-software packages for sustainability analysis, Life Cycle Cost Analysis. Remanufacture and disposal - Environmental conscious- quality function deployment- R3 and R6 cycles – Remanufacturing case studies, EoL Waste valorization techniques, Industrial symbiosis, Circular economy strategies. Environmental Impacts of Manufacturing, Cutting Tool Sustainability, Minimum Quantity Lubrication in Machining.

Environmentally conscious quality function deployment (ECQFD), Life Cycle Design, Facilitating Disassembly, System Design for Eco-efficiency, Environmental Complexity and Designing Activity, and Product Lifetime Optimisation. Sustainable smart manufacturing in Industry 4.0-recent developments in metal joining techniques, machining, Green and Sustainable Manufacturing Processes for Motor Cores in EV- Industrial case studies on sustainable

Text Books

1. S.Vinodh, “Sustainable Manufacturing Concepts, Tools, Methods and Case Studies”, CRC Press, 2020
2. Kapil Gupta, “Sustainable Manufacturing”, Elsevier Science Publishing Co Inc, Springer, 2021
3. Dornfeld, David, Green Manufacturing, Springer-Verlag, New York, 2012
4. Rainer Stark, Günther Seliger, Jérémy Bonvoisin, “ Sustainable Manufacturing: Challenges, solutions and implementation perspectives, Springer, 2017.
5. Gupta, S.M. and Lambert, A.J.D., “Environment Conscious Manufacturing”, CRC Press, 2008

Programme Name	***Bachelor of Technology in Mechanical Engineering***	***Semester – VII***
Course Code	**R5ME4115T**	
Course Title	**Gas Dynamics**	
Prerequisites	**Thermodynamics, Fluid Mechanics**	

COURSE OUTCOMES:

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

1. Analyze one -dimensional steady compressible flow.
2. Analyze the conditions for flow through a normal shock, oblique shock and Prandtl-Meyer expansion wave.
3. Solve an unsteady one-dimensional flow problem numerically.

Course contents

Basic concepts

Introduction to compressible flow, A brief review of thermodynamics and fluid mechanics, Acoustic speed and Mach number, Governing equations for compressible flows.

One-dimensional compressible flow

One dimensional flow concept, Isentropic flows, Stagnation/Total conditions, Characteristics speeds of gas dynamics, Dynamic pressure and pressure coefficients, Normal shock waves, Rankine-Hugonoit equations, Rayleigh flow (constant area frictionless flow with heat transfer), Fanno flow (constant area adiabatic flow with friction), Crocco's theorem, Gas tables.

Quasi-one dimensional flows

Governing equations, Area velocity relations, Isentropic flow through variable-area ducts, Convergent-divergent (or De Laval) nozzles, Over-expanded and under-expanded nozzles, Diffusers.

Unsteady wave motions

Moving normal shock waves, Reflected shock waves, Physical features of wave propagation, Elements of acoustic theory, Incident and reflected waves, Piston analogy, Finite compression waves, Shock tube relations, Method of Characteristics.

Two-dimensional flows

Oblique shock wave and its governing equations, θ-B-M relations, Supersonic flow over wedges and cones, Mach line, Attached and Detached shock, Reflections and interaction of oblique shock waves, Expansion waves, Prandtl-Meyer flow and its governing equations, Supersonic flow over convex and concave corners, Approximation of continuous expansion waves by discrete waves.

Introduction to numerical techniques in inviscid Gas Dynamics

Classical finite difference procedures; Application to one-dimensional unsteady flows.

Introduction to Experimental Facilities

Shock Tube, Subsonic wind tunnels, Supersonic wind tunnels, Shock tunnels, Free-piston shock tunnel, Detonation-driven shock tunnels, and Expansion tubes. Flow visualization

Applications

Gas Compressors used in Process Industries, Gas Turbine Engines used in Aviation etc.

Text Books

1. J D Anderson, “Modern Compressible Flow with Historical Perspective”, 3rd ed., McGraw-Hill, 2003.
2. P H Oosthuizen and W E Carscallen, “Compressible Fluid Flow”, McGraw-Hill, 1997.

Recommended Reading

1. H W Liepmann and A Roshko, “Elements of Gas Dynamics”, Dover, 2003
2. Ascher H. Shapiro, “Dynamics and Thermodynamics of Compressible Fluid Flow” (Vol. I and II), John Wiley & Sons, 1977.

Programme Name	Bachelor of Technology in Mechanical Engineering	Semester – VII
Course Code	**R5ME4116T**	
Course Title	**Design of Heat Exchange Equipment**	
Prerequisites		

COURSE OUTCOMES

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

1. Analyse theory and working of various heat exchangers.
2. Investigate the design methodology of a Hairpin and Shell-&-Tube heat exchangers.
3. Evaluate the performance of governing parameters for Plate heat exchangers.
4. Design Regenerative compact heat exchangers.

Course Contents

Classification & Basic Design of Heat Exchangers

Basic types of heat exchange devices, Classification of heat exchangers, Advantages / limitations of various types of heat exchangers, Guidelines for selection of heat exchangers, Performance enhancement of heat exchangers, fouling and corrosion, Testing, Maintenance of heat exchangers. Basic design methods, Theoretical analysis of parallel flow, counter flow, crossflow and multi-pass heat exchangers, LMTD Approach, Effectiveness-NTU Approach, Use of various charts for calculation of performance factors.

Design of Hairpin (Double Pipe) Heat Exchangers

Counterflow double pipe heat exchangers, calculation of Fouling Factor, calculation of Pressure Drop in pipes and annuli, Kern method for design of Double Pipe heat exchangers, Double Pipe heat exchangers in series-parallel arrangements.

Design of Shell-&-Tube Heat Exchangers

Heat exchanger tubes, joints, baffles, and their various configurations, TEMA Standards and nomenclatures, Heat Transfer Coefficients and Pressure Drop calculations using Kern method, Bell-Delaware method, Willis-Johnston method.

Design of Plate Heat Exchangers

Plate heat exchangers – Gasketted, Spiral, Lamella, applications, advantages & limitations, Theoretical design of Plate heat exchangers, ASME Pressure Vessel Standards.

Regenerative Heat Exchangers

Compact heat exchangers, Regenerative heat exchangers, Basic design methodologies for regenerative heat exchangers.

Introduction to Heat exchanger design software

Text Books

1. Donald Q. Kern, Process Heat Transfer, McGraw-Hill Inc., 1st ed., 1978.
2. Sadik Kakac and Hongtan Liu, Heat Exchanger Selection, Rating and Thermal Design, CRC Press, 3rd ed., 2012.
3. Arthur P. Frass, Heat Exchanger Design Handbook, Hemisphere Publishing Corporation, 2nd ed., 2012.

Recommended Reading

1. G. F. Hewitt, G. L. Shires and T. R. Bott, Process Heat Transfer, CRC Press, 1st ed., 1994.
2. ASME Section VIII Div-1, 2 & 3 ed. 2010 Addenda 2011A.
3. W. M. Kays and A. L. London, Compact Heat Exchangers, McGraw-Hill Inc., 1st ed., 1964.

Programme Name	***Bachelor of Technology in Mechanical Engineering***	***Semester – VII***
Course Code	**R5ME4201T**	
Course Title	**Wheeled Mobile Robots**	
Prerequisites		

COURSE OUTCOMES

The student should be able to –

1. Interpret sensor systems for state measurement, navigation, and localization in mobile robots.
2. Apply motion planning and navigation schemes for autonomous operation of mobile robotic systems.
3. Analyze the mechanical and electrical subsystems involved in robot locomotion and manipulation.
4. Design basic mobile robotic systems by integrating sensing, control, navigation, and actuation techniques.

Course Contents

Introduction to Mobile Robotics and Locomotion

Introduction to mobile robots and mobile manipulators. Principles of locomotion and types of locomotion. Types of mobile robots: ground robots (wheeled and legged robots), aerial robots, underwater robots and water surface robots. Kinematics of wheeled mobile robot, degree of freedom and maneuverability, generalized wheel model, different wheel configurations, holonomic and non-holonomic robots.

Dynamics of mobile robot

Lagrange-Euler and Newton-Euler methods. Computer based dynamic (numerical) simulation of different wheeled mobile robots.

Sensors for mobile robot navigation

Magnetic and optical position sensor, gyroscope, accelerometer, magnetic compass, inclinometer, tactile and proximity sensors, ultrasound rangefinder, laser scanner, infrared rangefinder, visual and motion sensing systems. Robot navigation: Localization, Error propagation model, Probabilistic map based loclaisation, Autonomous map building, Simultaneous localization and mapping (SLAM).

Motion and path planning

collision free path planning and sensor-based obstacle avoidance.

Motion control of mobile robots

Motion controlling methods, kinematic control, dynamic control and cascaded control.

Introduction to modern mobile robots

Swarm robots, cooperative and collaborative robots, mobile manipulators, autonomous mobile robots.

Textbooks

1. Siegwart R, Nourbakhsh I R and Scaramuzza D, Introduction to Autonomous Mobile Robots, 2nd Edition, MIT Press 2011.
2. Tzafestas S G, Introduction to Mobile Robot Control, 1st Edition, Elsevier 2014.
3. Peter Corke, Robotics, Vision and Control: Fundamental Algorithms in MATLAB, Springer Tracts in Advanced Robotics, 2011.
4. S. M. LaValle, “Planning Algorithms”, Cambridge University Press, 2006. (Available online http://planning.cs.uiuc.edu/)
5. Thrun, S., Burgard,W., and Fox, D., Probabilistic Robotics. MIT Press, Cambridge, MA, 2005.

Recommended Readings

1. Melgar, E. R., Diez, C. C., Arduino and Kinect Projects: Design, Build, Blow Their Minds, 2012.
2. H. Choset, K. M. Lynch, S. Hutchinson, G. Kantor, W. Burgard, L. E. Kavraki, and S. Thrun, Principles of Robot Motion: Theory, Algorithms and Implementations, PHI Ltd., 2005.
3. Dudek G and Jenkin M, Computational Principles of Mobile Robotics, 2nd Edition, Cambridge University Press, 2010.
4. Kelly A, Mobile Robotics: Mathematics, Models, and Methods, 1st Edition, Cambridge University Press, 2013.

Programme Name	Bachelor of Technology in Mechanical Engineering	Semester – VII
Course Code	**R5ME4202T**	
Course Title	**Unmanned Vehicle Technology**	
Prerequisites	Basics of Engineering Mechanics, Introduction to Aerodynamics and Control Systems, Fundamentals of Electronics and Communication	

COURSE OUTCOMES,

After completing this course, students will be able to -

1. Explain the fundamentals of unmanned vehicle systems used in defence applications.
2. Analyze the aerodynamic, propulsion, and control characteristics of unmanned aerial and ground vehicles.
3. Apply mission planning and autonomous operation concepts for defence applications.
4. Evaluate unmanned vehicle performance, endurance, and mission capability.
5. Design unmanned systems for Ground, Aerial and Naval platforms.

Course Contents

Fundamentals of Unmanned Vehicle Systems

Introduction to unmanned systems, Evolution and history of unmanned vehicles, Classification of unmanned systems, Architecture of unmanned Systems, Performance parameters, Mission profile and operations, Advantages and limitations of unmanned systems.

Unmanned Ground Vehicles (UGVs)

Classification of UGV Systems, Mobility and Terrain Adaptability, Stability and Operational Characteristics, Mobility versus stability trade-off, Autonomous Ground Operations. Future trends in robotic mobility systems.

Unmanned Surface Vehicles (USVs)

Introduction to marine unmanned systems, Classification of USV Systems, Floating body, Buoyancy and equilibrium, Static and dynamic stability, Hydrodynamic Resistance, Conceptual USV design.

Unmanned Underwater Vehicles (UUVs)

Deep-sea and shallow-water systems, Stability of underwater systems, Pressure-Resistant Structures, Battery systems and Energy management.

Unmanned Aerial Vehicles (UAVs)

Classification of UAV Systems, Airframe Configuration, Weight and Endurance Estimation, Launch and Recovery of UAVs, Stealth and Low-Observable UAV, Swarm Systems and Emerging Technologies.

Text Books:

1. Andall K. Nichols, Julie Ryan, Hans Mumm, Wayne Lonstein, Candice Carter, Jeremy Shay, Randall Mai, John P Hood, and Mark Jackson “Unmanned Vehicle Systems & Operations on Air, Sea, Land,” New Prairie Press.
2. Reg Austin, “Unmanned Aircraft Systems: UAVS Design, Development and Deployment”, Oxford University Press.
3. Mohammad Sadraey, “Unmanned Aircraft Design: A review of fundamentals”, Morgan & Claypool Publishers.
4. Sabiha Wadoo, Pushkin Kachro, “Autonomous Underwater Vehicles: Modeling, Control Design, and Simulation”, CRC Press.
5. K. K Sharma, “Radar, Sonar and Navigation Engineering”, S K Kataria & Sons.

Recommended Readings

1. Matthew Harrison, “Vehicle Refinement: Controlling Noise and Vibration in Road Vehicles,” Wiley.
2. Narayan Panigrahi, Smita Tripath, “Design Principles of Autonomous Systems UAV, UGV, and AUV”, CRC Press.
3. Thor I. Fossen, Kristin Y. Pettersen, Henk Nijmeijer, “Sensing and Control for Autonomous Vehicles: Applications to Land, Water and Air Vehicles”, Springer Cham.
4. Roland Siegwart, Illah Nourbakhsh, and Davide Scaramuzza, “Introduction to Autonomous Mobile Robots”, MIT Press.
5. Steven W. Moore, Harry Bohm, and Vickie Jensen, “Underwater Robotics: Science, Design and Fabrication”, Marine Advanced Technology Education.
6. Huarong Zheng & Chen-Guang Liu, “Towards Unmanned Surface Vehicles: Methods and Practices”, CRC Press.

Programme Name	***Bachelor of Technology in Mechanical Engineering***	***Semester – VII***
Course Code	**R5ME4203T**	
Course Title	**Aerospace Propulsion Systems**	
Prerequisites		

COURSE OUTCOMES

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

1. Explain the fundamental principles of air-breathing and rocket propulsion systems.
2. Analyze the performance characteristics of turbojets, turbofans, ramjets, and chemical rocket engines.
3. Evaluate advanced and futuristic propulsion technologies.
4. Apply propulsion system design principles to solve practical engineering problems, conduct preliminary design studies, and assess mission-specific propulsion requirements for aircraft and spacecraft.

Course Contents

Fundamentals of Propulsion

Introduction to aerospace propulsion: historical overview and modern classifications. Basic thrust equation and propulsive efficiency. Comparison of air-breathing and non-air-breathing engines. Review of relevant thermodynamics (First and Second Laws, isentropic flow) and compressible fluid mechanics (shock waves, Mach number, stagnation properties). Performance parameters: specific thrust, specific impulse, total efficiency, and specific fuel consumption.

Air-breathing Engine Cycles

The Brayton cycle: ideal and real cycle analysis for gas turbine engines, including effects of irreversibilities and component losses. Detailed thermodynamic cycle analysis for: Ramjet engines (ideal and real cycles, performance at high Mach numbers); Turbojet engines (with and without afterburner, specific thrust optimization); Turbofan engines (separate and mixed exhaust streams, bypass ratio selection); Turboprop and turboshaft engines (power balance, propeller efficiency); Operating principle and thermodynamic cycle of scramjet engines with stress on supersonic mixing and flameholding, thermal management, high-temperature materials, and ground testing. Performance comparison across engine types and flight regimes.

Engine Component Analysis

Air Intakes: subsonic and supersonic diffuser design, pressure recovery, performance parameters, and modes of operation (critical, subcritical, supercritical). Combustion Chambers: gas turbine combustor types (can, annular, can-annular), flame stabilization mechanisms, combustion efficiency, pressure loss, and exit temperature distribution. Afterburners: design principles, thrust augmentation, and operational limitations. Nozzles: convergent and convergent-divergent (C-D) nozzles, flow choking, under-expanded and over-expanded flows, nozzle efficiency, and thrust vectoring concepts.

Fundamentals of Combustion

Combustion thermochemistry: stoichiometry, fuel-air ratio, enthalpy of formation, and adiabatic flame temperature calculations. Introduction to propellants: conventional aviation fuels, cryogenic fuels, and emerging sustainable alternatives.

Chemical and Electric Propulsion

Introduction to rocket propulsion systems and their classification. Rocket thrust equation, effective exhaust velocity, specific impulse, characteristic velocity (c*), and thrust coefficient (Cf). Nozzle flow theory for rockets: isentropic expansion, area-Mach number relationship, and optimum expansion ratio. Solid & Liquid propellant rockets; Electrostatic & Electromagnetic thrusters;

Preliminary Design Applications

Case studies: Turbofan engine for a business jet, solid rocket motor for a small satellite launch vehicle, electric propulsion subsystem for a geostationary communication satellite.

Reference Books

1. J.D. Mattingly, Elements of Propulsion: Gas Turbines and Rockets, AIAA Education Series, 2nd Edition, 2016.
2. S. Farokhi, Aircraft Propulsion, John Wiley & Sons, 2nd Edition, 2014.
3. M.J.L. Turner, Rocket and Spacecraft Propulsion: Principles, Practice and New Developments, Springer, 3rd Edition, 2009.
4. P.G. Hill and C.R. Peterson, Mechanics and Thermodynamics of Propulsion, Pearson, 2nd Edition, 1992.
5. G.P. Sutton and O. Biblarz, Rocket Propulsion Elements, John Wiley & Sons, 9th Edition, 2016.
6. D. Musielak, Scramjet Propulsion: A Practical Introduction, John Wiley & Sons, 2022.
7. D.M. Goebel and I. Katz, Fundamentals of Electric Propulsion: Ion and Hall Thrusters, Wiley/JPL/NASA, 2008.

Recommended Reading

1. N. Cumpsty and A. Heyes, Jet Propulsion: A Simple Guide to the Aerodynamics and Thermodynamic Design and Performance of Jet Engines, Cambridge University Press, 3rd Edition, 2015.
2. G.C. Oates, Aerothermodynamics of Gas Turbine and Rocket Propulsion, AIAA Education Series, 3rd Edition, 1997.

3. R.D. Flack, Fundamentals of Jet Propulsion with Applications, Cambridge University Press, 1st Edition, 2005.
4. V. Yang, Liquid Rocket Thrust Chambers: Aspects of Modeling, Analysis, and Design, AIAA Progress in Astronautics and Aeronautics, Vol. 200, 2004.
5. Prof. A. Kushari, Jet and Rocket Propulsion, NPTEL Lecture Notes, IIT Kanpur.
6. Prof. D.P. Mishra, Fundamentals of Combustion, NPTEL Lecture Notes, IIT Kanpur, 2018.
7. R.G. Jahn, Physics of Electric Propulsion, Dover Publications.
8. E.T. Curran and S.N.B. Murthy, Scramjet Propulsion, AIAA Progress in Astronautics and Aeronautics, Vol. 189, 2000

SEMESTER-VIII

Programme Name	Bachelor of Technology in Mechanical Engineering	Semester – VIII
Course Code	**R5ME4003T**	
Course Title	**Product Innovation & Entrepreneurship**	
Prerequisites		

COURSE OUTCOMES

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

1. Identify an unmet need through market research
2. Create an innovative solution and check problem-solution fit
3. Practice business planning, including marketing, fund-raising and start-up incubation.

Course contents

Entrepreneurship

Role of entrepreneurship in economic development; Entrepreneurial mindset, motivation and competencies; Market pull and technology push factors; New product development lifecycle; Technology readiness levels; Product-market fit validation; Commercialization pathways; Business vision & leadership; Team composition & management.

Product Innovation

Opportunity scanning, market survey, need identification and problem definition; Creative design thinking for concept generation; Detailed design & prototyping; Functionality & manufacturability; Bill of materials & components supply chain; Manufacturing & assembly plan; Product testing & quality assurance; Intellectual property rights management. IP protection and licensing/monetizing opportunities

Marketing & Finance

Market segmentation & market sizing; Customer persona & value proposition; Marketing (Go-to-market) strategy; Distribution channels and sales network; Funding requirement (based on stage); Source of funding for startup ventures; Financial projections and accounting; Startup to scale up financing.

Venture Creation

Sustainable business options & pathways; Business model & business canvas; Startup team & business partners; Startup ecosystem and stakeholders; Technology business incubators & parks; Proposal pitching & agreements; Startup company incorporation; Social impact & responsibility.

Course Project

Need identification, innovative solution, business plan, go-to-market strategy.

Text Books

1. Chelat Bhuvanachandran, “Innovision”, Khanna Book Publishing, 2022.
2. T.V. Rao, “Entrepreneurship - A South Asian Perspective”, Cengage Learning, New Delhi, 2012.

Recommended Reading

1. Bill Aulet, “Technology Entrepreneurship”, 4th ed., Tata McGraw Hill, 2014.
2. Peter F. Drucker, “Innovation and Entrepreneurship”, 1st ed., Harper Business, 2006.
3. Byers, Dorf, and Nelson, “Technology Ventures: From Ideas to Enterprise”, McGraw Hill, 2010.
4. Steve Blank, “The Startup Owner's Manual”, John Wiley & Sons Inc., 2012.