Pre-requisites	**Computer Aided Drawing and Modelling,**

Course Learning Outcomes (CLOs)

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

i) **CLO1:** ***Explain*** the concepts of Computer Aided Manufacturing (CAM), Computer Integrated Manufacturing (CIM), product development methodologies, and CAD/CAM integration in modern manufacturing systems. ***(L2)***

ii) **CLO2:** ***Develop*** geometric models and ***apply*** CAD/CAM data exchange standards to prepare engineering models for manufacturing applications. ***(L3)***

iii) **CLO3:** ***Generate*** CNC part programs, tool paths, and machining simulations using manual programming techniques and CAM software for manufacturing components. ***(L3)***

iv) **CLO4:** ***Analyze*** computer-aided process planning, manufacturing automation, flexible manufacturing systems, and robotics to improve productivity and manufacturing efficiency. ***(L4)***

v) **CLO5:** ***Evaluate*** appropriate digital manufacturing technologies, including computer-aided inspection, Industry 4.0, Industrial Internet of Things (IIoT), Digital Twin, and additive manufacturing, for smart manufacturing applications. ***(L5)***

Theory Module (Internal and External Evaluation)

M.No:	Topic
Module 1.	Evolution and types of manufacturing systems, introduction to Computer Aided Manufacturing (CAM), Computer Integrated Manufacturing (CIM), CIM hardware and software, CAD, CAM and CAE integration, product development cycle, sequential engineering, concurrent engineering, product lifecycle management (PLM), design for manufacturability, and digital manufacturing.
Module 2.	Introduction to geometric modelling, wireframe modelling, surface modelling, solid modelling, feature-based modelling, parametric modelling, representation of curves and surfaces, Bézier curves, B-spline curves, non-uniform rational B-splines (NURBS), freeform surface design, CAD data exchange standards (IGES, STEP, STL, and DXF), reverse engineering, and CAD/CAM data transfer.
Module 3.	Numerical control (NC), computer numerical control (CNC), construction of CNC machines, machine coordinate systems, motion control, interpolation, tool compensation, automatic tool changers, CNC controllers, manual part programming, G-codes, M-codes, canned cycles, CNC turning programming, CNC milling programming, machining centres, CAM software architecture, tool path generation, cutter location data, post-processing, virtual machining, and machining simulation.
Module 4.	Process planning fundamentals, computer-aided process planning, variant process planning, generative process planning, group technology, coding and classification systems, flexible manufacturing systems, flexible manufacturing cells, manufacturing automation, automated material handling systems , programmable logic controllers, shop floor control, and manufacturing execution systems.
Module 5.	Intelligent manufacturing systems, industrial robotics, robot programming and simulation, computer-aided inspection, coordinate measuring machines, non-contact inspection, manufacturing simulation, digital twin, additive manufacturing, hybrid manufacturing, Industry 4.0, Industrial Internet of Things (IIoT), smart manufacturing, artificial intelligence in manufacturing, and cloud manufacturing.

Activity Module (Internal Evaluation Only-10 Marks)

Activity	Example Task
Using the tools learned on Module 1, design a variety of items, including:	Prepare a CAD/CAM product development workflow for a shaft, bracket, or gear and compare it with the conventional manufacturing process.
Using the tools learned on Module 2, design a variety of items, including:	Create the 3D model of a flange, coupling, or connecting rod and export it in STEP/IGES format for CAM.
Using the tools learned on Module 3, design a variety of items, including:	Generate CNC part programs and CAM tool paths for a stepped shaft, face milling, pocket milling, or drilling operation and verify them using simulation software.
Using the tools learned on Module 4, design a variety of items, including:	Prepare a process plan for a machined component and study (through demonstration/video/software) applications of pick-and-place robots, bowl feeders, FMS, or automated sorting systems.
Using the tools learned on Module 5, design a variety of items, including:	Analyse a smart manufacturing application involving robotic welding, CMM inspection, additive manufacturing, Digital Twin, IIoT-based machine monitoring, or adaptive machining through a case study or simulation.

CLO-PLO Mapping Matrix

CLO \ PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO10	PLO11	PLO12
CLO1	3	2	2	0	2	1	1	1	1	2	2	3
CLO2	3	2	3	2	3	0	1	0	1	2	1	2
CLO3	3	3	3	2	3	1	1	1	2	2	2	2
CLO4	3	3	3	3	3	2	2	1	2	2	3	3
CLO5	3	3	3	3	3	2	3	2	2	3	3	3

Recommended Books

S.No:	**Text Books**	**Author**	**Publisher**
1.	Automation, Production Systems, and Computer-Integrated Manufacturing	Groover, M. P.,	Pearson.
2.	CAD/CAM: Computer-Aided Design and Manufacturing	Groover, M. P. and Zimmers, E. W.,	Pearson.
3.	CAD/CAM/CIM,	Radhakrishnan, P., Subramanyan, S., and Raju, V.	New Age International.
4.	CAD/CAM: *Theory and Practice*	Zeid, I.	McGraw-Hill.
	References	**Author**	**Publisher**
1.	Computer-Aided Manufacturing	Chang, T. C., Wysk, R. A., and Wang, H. P.	Pearson
2.	Computer Control of Manufacturing Systems	Koren, Y.	McGraw-Hill
3.	CAD/CAM: Principles and Applications	Rao, P. N.	McGraw-Hill Education

---

Course Code	**BMECLWT725**				
Category	**Lab Course**				
Course Title	**Welding Technology**				
Scheme and Credits	**L** 0	**T** 0	**P** 4	**Credits** 2	**Semester- 7 (*Seven*)**
Pre-requisites	-				

Course Learning Outcomes (CLOs)

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

i) **CLO1:** ***Explain*** the principles, processes, metallurgy, and safety aspects of welding technology. ***(L2)***

ii) **CLO2:** ***Compare*** conventional and advanced welding processes based on their characteristics, applications, and limitations. ***(L2)***

iii) **CLO3:** ***Analyse*** welding symbols, weld defects, inspection results, and quality standards for welded joints. ***(L4)***

iv) **CLO4:** ***Evaluate*** welding parameters, joint design, and quality control techniques for engineering applications. ***(L2)***

v) **CLO5:** ***Select*** appropriate welding processes, consumables, and inspection methods for different engineering materials and industrial applications. ***(L3)***

Theory Module(Internal and External Evaluation)

M.No:	Topic
Module 1.	Introduction to welding and joining processes; classification of welding processes; heat sources; welding terminology and symbols; joint design and edge preparation; welding positions; weldability of engineering materials; welding consumables and shielding gases; welding safety and personal protective equipment.

Module 2.	Principles, equipment, characteristics, advantages, limitations, and applications of Shielded Metal Arc welding, gas metal arc welding, gas tungsten arc welding, submerged arc welding, flux-cored arc welding, oxy-acetylene gas welding, and resistance welding processes (spot, seam, projection, flash, and butt welding).
Module 3.	Principles and applications of plasma arc welding, laser beam welding, electron beam welding, friction welding, friction stir welding, ultrasonic welding, diffusion welding, and explosive welding, robotic and automated welding systems; welding automation and additive manufacturing.
Module 4.	Heat flow and solidification in welding; Heat Affected Zone (HAZ); residual stresses and distortion; weld defects and their prevention; destructive and non-destructive testing (visual, liquid penetrant, magnetic particle, ultrasonic, and radiographic testing); weld quality assurance and inspection.
Module 5.	Design of welded joints; welding procedure specifications, procedure and welder qualification; welding codes and standards (AWS, ASME, BIS); welding economics; welding of stainless steels, aluminium alloys, and dissimilar metals, industrial applications, emerging trends in welding automation, digital manufacturing, and Industry 4.0.

Activity Module (Internal Evaluation Only-10 Marks)

Activity	Example Task
Using the tools learned on Module 1, design a variety of items, including:	Develop 2D/3D CAD models of butt, lap, T-, corner, and edge joints with appropriate edge preparation and welding symbols. Prepare joint layouts and estimate weld length, weld volume, filler material requirement, and welding time using CAD software and Microsoft Excel.
Using the tools learned on Module 2, design a variety of items, including:	Develop a computational model to estimate welding parameters (current, voltage, travel speed, heat input, deposition rate, and electrode consumption) for SMAW, MIG, TIG, and resistance welding processes. Compare process efficiency and productivity using MATLAB or Python.
Using the tools learned on Module 3, design a variety of items, including:	Develop a computational model to estimate heat input, cooling rate, and weld efficiency for different welding processes (SMAW, MIG, TIG, and FSW). Compare the influence of welding parameters using MATLAB, or Python.
Using the tools learned on Module 4, design a variety of items, including:	Perform a basic thermal analysis of a welded joint to evaluate temperature distribution and heat affected zone under different welding heat inputs using SolidWorks Simulation, ANSYS, COMSOL Multiphysics, or equivalent software. Compare the influence of welding parameters on weld quality.
Using the tools learned on Module 5, design a variety of items, including:	Design and analyze a welded engineering component (e.g., bracket, frame, or support) using CAD software. Select suitable materials and welding processes, evaluate its structural performance using SolidWorks Simulation, ANSYS, or equivalent finite element analysis software, and compare alternative designs based on strength, weight, and manufacturing cost.

Practical Module (Internal and External Evaluation)

M.No:	Experiments
Module 1.	Study of welding equipment, accessories, safety practices, and welding symbols.
Module 2.	Preparation of butt and lap joints using shielded metal arc welding.
Module 3.	Preparation of fillet joints using gas metal arc welding (GMAW/MIG).
Module 4.	Preparation of butt joints using gas tungsten arc welding (GTAW/TIG).
Module 5.	Preparation of spot welds using resistance spot welding and evaluation of weld quality.
Module 6.	Study and demonstration of oxy-acetylene gas welding and flame adjustment.
Module 7.	Examination and identification of common welding defects by visual inspection.
Module 8.	Non-Destructive Testing (NDT) of welded joints using dye penetrant testing and magnetic particle testing.
Module 9.	Destructive testing of welded joints (tensile test, bend test, or fillet weld break test).
Module 10.	Macro-etch examination of welded joints to study weld penetration, fusion, and heat affected zone.

CLO-PLO Mapping Matrix

CLO \ PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO10	PLO11	PLO12
CLO1	3	2	1	1	1	0	1	1	0	0	0	1
CLO2	2	3	2	2	2	0	1	0	1	1	0	2
CLO3	2	3	2	3	3	1	2	1	1	1	0	2

CLO4	2	2	3	3	2	2	2	1	1	2	1	2
CLO5	2	2	3	2	3	2	2	1	2	2	2	3

Recommended Books

S.No:	Text Books	Author	Publisher
1.	A Textbook of Welding Technology	O. P. Khanna	Dhanpat Rai Publications.
2.	Elements of Workshop Technology (Vol. II)	S. K. Hajra Choudhury, A. K. Hajra Choudhury, and N. Roy	Media Promoters & Publishers.
	References	**Author**	**Publisher**
1.	Welding: Principles and Applications	Larry Jeffus	Cengage Learning.
2.	Modern Welding Technology	Cary, H. B. and Helzer, S. C.	Pearson Education
3.	Welding Metallurgy	Sindo Kou	Wiley.

Course Code	**BMECDFT725**				
Category	**Professional Elective Course**				
Course Title	**Fundamentals of Tribology**				
Scheme and Credits	**L**	**T**	**P**	**Credits**	**Semester- 7 *(Seven)***
	2	**0**	**2**	**3**	
Pre-requisites	**Material Science, Machine Design, Fluid Mechanics and Heat Transfer**				

Course Learning Outcomes (CLOs)

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

i) **CLO1:** ***Understand*** the fundamental concepts of tribology, including friction, wear, lubrication, surface topography, and contact mechanics. ***(L2)***

ii) CLO2: ***Compare*** the different laws, types, and theories of friction, and distinguish between various friction mechanisms and asperity deformation models. ***(L2)***

iii) CLO3: ***Interpret*** the principles of lubrication, lubrication regimes, lubricant properties, Reynolds equation, and the role of additives in engineering applications. ***(L5)***

iv) CLO4: ***Draw*** conclusions on wear mechanisms, wear theories, and wear testing methods to evaluate the tribological performance of engineering materials. ***(L3)***

v) CLO5: ***Assemble*** knowledge of advanced wear mechanisms to propose suitable material and tribological solutions for minimizing wear in engineering components. ***(L6)***

Theory Module(Internal and External Evaluation)

M.No:	Topic
Module 1.	Introduction: Definition of tribology, friction, wear and lubrication, importance of the Tribological studies. Surface Topography: Methods of assessment, measurement of surface roughness-different statistical parameters (Ra, Rz, Rmax, etc.), contact between surfaces, deformation between single and multiple asperity contact, contact theories involved.
Module 2.	Friction: Coulomb and Amontons laws of friction, its applicability and limitations, comparison between static, rolling and kinetic friction, friction theories, mechanical interlocking, molecular attraction, electrostatic forces and welding, shearing and ploughing, models for asperity deformation.
Module 3.	Lubrication: Types of lubrication, viscosity, characteristics of fluids as lubricant, hydrodynamic lubrication, Reynold's equation, elastohydrodynamic lubrication- partial and mixed, boundary lubrication, various additives, solid lubrication.
Module 4.	Wear: Sliding wear: Abrasion, adhesion and galling, testing methods pin-on-disc, block-on ring, etc., theory of sliding wear, un-lubricated wear of metals, lubricated wear of metals, fretting wear of metals
Module 5.	Advanced Wear of Engineering Materials: Wear of ceramics and polymers. Wear by plastic deformation and brittle fracture. Wear by hard particles: Two-body abrasive wear, three-body abrasive wear, erosion, effects of hardness shape and size of particles.

Activity Module (Internal Evaluation Only-10 Marks)

Activity	Example Task
Using the tools learned on Module 1, design a variety of items, including:	Simulation of single and multiple asperity contact Analysis (using ANSYS)
Using the tools learned on Module 2, design a variety of items, including:	Simulation of Static, rolling, and kinetic friction behavior (using ANSYS)
Using the tools learned on Module 3, design a variety of items, including:	Simulation of Elastohydrodynamic and Boundary Lubrication Performance (Using ANSYS)
Using the tools learned on Module 4, design a variety of items, including:	Simulation of sliding and fretting wear behavior of metals (using Abaqus / ANSYS)
Using the tools learned on Module 5, design a variety of items, including:	Simulation of abrasive and erosive wear of engineering materials (using ANSYS / EDEM)

Practical Module (Internal and External Evaluation)

M.No:	Experiments
Module 1.	Study of surface topography and wear tracks of engineering materials using an optical microscope
Module 2.	Determination of the coefficient of friction of different material pairs using the Pin-on-Disc Tribometer.
Module 3.	Effect of normal load on the coefficient of friction using the Pin-on-Disc Tribometer.
Module 4.	Effect of sliding speed on the coefficient of friction using the Ball-on-Disc (Rotary) Tribometer.
Module 5.	Study of dry and lubricated sliding conditions and comparison of frictional behaviour using the Ball-on-Disc Tribometer.
Module 6.	Evaluation of the effect of different lubricants (oil, grease, etc.) on friction and wear using the Pin-on-Disc Tribometer.
Module 7.	Determination of wear rate and specific wear rate of engineering materials using the Pin-on-Disc Tribometer under dry sliding conditions.
Module 8.	Analysis of wear debris generated during tribological testing and identification of probable wear mechanisms using an optical microscope.
Module 9.	Study of the influence of lubricant additives on tribological performance using a tribometer.
Module 10.	Performance of Journal bearing test rig.

CLO-PLO Mapping Matrix

CLO \ PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO10	PLO11	PLO12
CLO1	3	2	1	1	1	0	1	0	0	1	0	2
CLO2	3	3	2	1	1	0	0	0	0	1	0	2
CLO3	3	3	2	2	2	1	2	0	0	1	1	2
CLO4	3	3	2	3	3	1	2	1	1	2	0	2
CLO5	3	3	3	3	2	2	3	1	2	2	2	3

Recommended Books

S.No:	Text Books	Author	Publisher
1.	A system approach to science and Technology of Friction, Lubrication and Wear	Czichos, H.	Volume I, Tribology series, Elsevier Publicatons, 1978.
2.	Friction, Wear, Lubrication	Ludema, K.C.	CRC Press, NY., 1996
	References	**Author**	**Publisher**
1.	Wear control Handbook	PetersonM.B.,Winner W.O	Sponsored by The Research Committee on Lubrication, 1980.
2.	The principles of Lubrication	Cameron A.	Longman, London, 2000

Course Code	**BMECDMC725**				
Category	**Professional Elective courses**				
Course Title	**Microprocessors and Processor-based Systems**				
Scheme and Credits	**L**	**T**	**P**	**Credits**	Semester- **5** (*Fifth*) 7
	3	**0**	**2**	**4**	
Pre-requisites	Basic knowledge of computer operations, elementary programming concepts, and elementary mathematical concepts.				

Course Learning Outcomes (CLOs)

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

i) **CLO1:** ***Explain*** the fundamentals of processor-based systems, computer organization, processor operation, memory organization, system buses, and the role of microprocessors, microcontrollers, PLCs, and embedded systems in modern engineering applications. ***(L2)***

ii) **CLO2:** ***Illustrate*** the architecture, instruction execution mechanism, and functional organization of the 8085 microprocessor, including addressing modes, machine cycles, interrupts, and processor control signals. ***(L2)***

iii) **CLO3:** ***Develop*** assembly language programs using appropriate instruction sets, addressing modes, loops, subroutines, and decision-making techniques to solve basic engineering problems. ***(L3)***

iv) **CLO4:** ***Apply*** memory and I/O interfacing techniques, programmable peripheral interfaces, communication interfaces, and data conversion techniques for processor-based control systems. ***(L3)***

v) **CLO5:** ***Analyze*** modern processor-based and embedded systems for mechanical engineering applications, and compare different processor platforms based on architecture, functionality, and industrial applications. ***(L4)***

Theory Module (Internal and External Evaluation)

M. No:	**Topic**
Module 1.	Evolution of processor-based systems and their role in mechanical engineering, applications of processor-based systems in industrial automation, CNC machines, robotics, mechatronics, automotive systems and smart manufacturing, computer organization and functional units, CPU (ALU, Control Unit and Registers), memory unit and input/output unit, processor operation, clock, instruction cycle, machine cycle and fetch–decode–execute cycle, memory organization, RAM, ROM and secondary memory, system buses, address bus, data bus and control bus, fundamentals of microprocessors, microcontrollers, embedded systems and programmable logic controllers (PLCs), comparative study of processor-based platforms based on architecture, integration, performance and engineering applications.
Module 2.	8085 microprocessor architecture and functional organization, register organization, accumulator, general-purpose registers, program counter, stack pointer and flag register, arithmetic logic unit (ALU), timing and control unit, pin configuration and signal classification, memory organization and memory addressing, instruction format and addressing modes, instruction execution, machine cycles and timing diagrams, interrupt organization and processor control signals.
Module 3.	Machine language and assembly language, program development tools, assembler, linker and debugger, 8085 instruction set, data transfer, arithmetic, logical, branch and stack operations, assembly language programming methodology, programming techniques, decision making, looping, counters, delay generation and subroutines, programs for arithmetic operations, searching, sorting and simple data processing applications, program testing and debugging.
Module 4.	Memory interfacing and address decoding concepts, memory-mapped and I/O-mapped interfacing, programmable peripheral interface (8255), digital input/output interfacing using switches, LEDs, seven-segment displays and relays, interrupt-driven data transfer, analog interfacing using analog-to-digital converter (ADC) and digital-to-analog converter (DAC), fundamentals of processor communication interfaces, UART, SPI, I²C and CAN, sensor and actuator interfacing for processor-based control systems.
Module 5.	Evolution from microprocessors to microcontrollers and embedded systems, overview of modern processor platforms, 8051, ARM Cortex and ESP32, fundamentals of embedded system architecture, processor-based systems in industrial automation, CNC machines, robotics, mechatronics, automotive electronic control units, industrial instrumentation and smart manufacturing, emerging trends in processor-based engineering systems, Internet of Things (IoT)-enabled embedded systems, edge computing, Industry 4.0 and cyber-physical systems.

Activity Module (Internal Evaluation Only-10 Marks)

Activity	Example Task
Case Study	Study the processor architecture and control strategy used in a CNC machine, industrial robot, automotive ECU, or PLC-based automation system.
Mini Project	Design and demonstrate a simple processor-based application involving sensor interfacing, actuator control, or industrial automation using a suitable hardware or simulation platform.
Technical Seminar	Present a seminar on modern processor technologies, embedded systems, industrial automation, robotics, or smart manufacturing applications.
Programming Assignment	Develop, test and debug assembly language programs for basic engineering applications using an 8085 simulator or trainer kit.
Industrial Survey	Prepare a technical report on processor-based systems used in manufacturing industries, highlighting sensors, actuators, communication interfaces, and control architecture.

Practical Module (Internal and External Evaluation)

M. No:	Experiments
Module 1.	Study of processor-based systems used in Mechanical Engineering applications (CNC machine, industrial robot, PLC, automotive ECU and embedded controller).
Module 2.	Identification of the functional units of the 8085 microprocessor trainer kit and demonstration of processor operation (CPU, memory, buses and I/O devices).
Module 3.	Identification of processor signals, buses and timing waveforms using trainer kit and logic analyzer/oscilloscope.
Module 4.	Study of the 8085 architecture, register organization and instruction execution using a simulator/trainer kit.
Module 5.	Programs to verify arithmetic, logical and data transfer instructions.
Module 6.	Programs to observe flag register operation, addressing modes and branching instructions.
Module 7.	Programs using loops, counters and delay generation.
Module 8.	Programs using subroutines, stack operations and decision-making instructions.
Module 9.	Programs for searching, sorting and simple data processing applications.
Module 10.	Interfacing LEDs, switches and seven-segment displays using the 8255 Programmable Peripheral Interface.
Module 11.	Interfacing Analog-to-Digital Converter (ADC) and Digital-to-Analog Converter (DAC) for analog signal acquisition and generation.
Module 12.	Demonstration of serial communication using UART and study of SPI, I^2C and CAN communication interfaces.
Module 13.	Study of an embedded system platform (8051/ARM/ESP32/Arduino) and demonstration of processor-based control.
Module 14.	Mini application involving sensor interfacing and actuator control for a mechanical engineering application (temperature monitoring, motor control, speed measurement or automation).
Module 15.	Case study and demonstration of a processor-based system used in industrial automation, robotics, CNC or mechatronics.

CLO-PLO Mapping Matrix

CLO \ PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO10	PLO11	PLO12
CLO1	3	2	1	1	1	0	0	0	0	0	0	1
CLO2	3	3	2	2	2	0	0	0	0	0	0	1
CLO3	3	3	3	3	2	0	0	0	0	0	0	1
CLO4	3	3	3	3	3	1	0	0	0	0	0	1
CLO5	3	2	2	2	3	1	1	0	0	0	0	2

Recommended Books

Text Books

Text Books			
S. No.	Book Title	Author	Publisher
1.	Microprocessor Architecture, Programming, and Applications with the 8085	**Ramesh S. Gaonkar**	Penram International Publishing (India) / Prentice Hall

Text Books

S. No.	Book Title	Author	Publisher
2.	Embedded Systems: Architecture, Programming and Design	**Raj Kamal**	McGraw-Hill Education
Refresences			
1.	Introduction to Microprocessors	Aditya P. Mathur	Tata McGraw-Hill
2.	Fundamentals of Microprocessors and Microcomputers	B. Ram	Dhanpat Rai Publications
3.	Advanced Microprocessors and Peripherals	A. K. Ray and K. M. Bhurchandi	McGraw-Hill Education
4.	The 8051 Microcontroller and Embedded Systems	Muhammad Ali Mazidi, Janice Gillispie Mazidi and Rolin D. McKinlay	Pearson Education
5.	Computer Organization and Design: The Hardware/Software Interface	David A. Patterson and John L. Hennessy	Morgan Kaufmann

Course Code	**BMECDRF725**				
Category	**Professional Elective Course**				
Course Title	**Refrigeration**				
Scheme and Credits	L 2	T 0	P 2	Credits 3	**Semester- 7 (*Seven*)**
Pre-requisites	**Engineering Thermodynamics, Heat Transfer**				

Course Learning Outcomes (CLOs)

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

i) **CLO1:** ***Analyze*** the performance of vapour compression refrigeration cycles and their modifications using thermodynamic principles. ***(L4)***

ii) **CLO2:** ***Evaluate*** refrigerants and secondary coolants based on thermodynamic, environmental, and safety criteria. ***(L5)***

iii) **CLO3:*Analyze*** the operation and performance of vapour absorption refrigeration systems. ***(L4)***

iv) **CLO4:** ***Evaluate*** advanced refrigeration systems and cooling technologies for engineering applications. ***(L5)***

v) **CLO5:** ***Analyze*** the design and performance of refrigeration system components for effective system selection. ***(L4)***

Theory Module(Internal and External Evaluation)

M.No:	Topic
Module 1.	Principles of refrigeration and heat pumps, Second law of thermodynamics, Clausius and Kelvin–Planck statements, Reversed Carnot refrigeration cycle and its limitations, Standard vapour compression refrigeration system, Components and working principle, Representation on T–s and P–h diagrams, Actual vapour compression cycle, Coefficient of performance, Energy analysis of refrigeration systems, Effect of superheating and subcooling, Liquid–suction heat exchanger, Multistage compression, Flash intercooling, Cascade refrigeration systems.
Module 2.	Classification of refrigerants (ASHRAE nomenclature), designation of refrigerants, properties of refrigerants, selection criteria for refrigerants, primary and secondary refrigerants, natural and synthetic refrigerants, ozone depletion potential, global warming potential, Montreal protocol, Kigali amendment, secondary coolants, brines and glycols, basic psychrometric properties, applications of psychrometry in refrigeration.
Module 3.	Principles of vapour absorption refrigeration, simple vapour absorption refrigeration system, coefficient of performance of absorption systems, aqua–ammonia refrigeration system, Lithium bromide–water refrigeration system, comparison between vapour compression and vapour absorption systems, waste heat-driven refrigeration, applications of absorption refrigeration.
Module 4.	Reversed brayton refrigeration cycle, Bell-Coleman refrigeration system, aircraft cooling systems, performance analysis of gas refrigeration cycles, solar-assisted refrigeration systems, cooling towers, spray ponds, cooling tower performance, cooling tower losses, water treatment for cooling systems.

Module 5.	Types of refrigeration compressors, performance and selection of compressors, flooded evaporators, dry expansion evaporators, liquid chillers, boiling heat transfer, overall heat transfer coefficient, air-cooled condensers, water-cooled condensers, evaporative condensers, fouling factor, expansion devices, automatic expansion valve, thermostatic expansion valve, capillary tube, float valve, selection of refrigeration system components.

Activity Module (Internal Evaluation Only-10 Marks)

Activity	Example Task
Using the tools learned on Module 1, design a variety of items, including:	Model and simulate the ideal and actual vapour compression refrigeration cycles using MATLAB, Python, CoolProp, REFPROP, or any other equivalent computational platform, and investigate the effects of superheating, subcooling, and multistage compression on COP and compressor work.
Using the tools learned on Module 2, design a variety of items, including:	Evaluate and compare the performance of different refrigerants using MATLAB, Python, CoolProp, REFPROP, or any other equivalent computational platform by analysing thermodynamic properties, COP, refrigeration effect, and environmental impact (ODP and GWP).
Using the tools learned on Module 3, design a variety of items, including:	Develop and simulate a simple vapour absorption refrigeration system (NH_3–H_2O or LiBr–H_2O) using MATLAB, Python, EES, or any other equivalent computational platform, and study the effect of generator and absorber temperatures on system COP.
Using the tools learned on Module 4, design a variety of items, including:	Simulate and evaluate the performance of a Bell–Coleman refrigeration cycle or a cooling tower using MATLAB, Python, or any other equivalent computational platform, and analyse the effect of operating conditions on system performance.
Using the tools learned on Module 5, design a variety of items, including:	Model and analyse the performance of refrigeration system components (compressor, condenser, evaporator, and expansion device) using MATLAB, Python, ANSYS, OpenModelica, or any other equivalent computational platform, and evaluate heat transfer characteristics, pressure drop, compressor power, and overall system efficiency.

Practical Module (Internal and External Evaluation)

M.No:	Experiments
Module 1.	Determine the Coefficient of Performance (COP) of a VCR system under different operating conditions.
Module 2.	Plot the actual refrigeration cycle on T–s and p–h diagrams and evaluate cycle performance.
Module 3.	Study the construction and operation of a Vapour Absorption Refrigeration (VAR) system and determine its COP.
Module 4.	Study and performance evaluation of a thermoelectric (Peltier) refrigeration unit.
Module 5.	Performance test on a cooling tower to determine cooling range, approach, and effectiveness.
Module 6.	Performance evaluation of an evaporator under different load conditions.

CLO-PLO Mapping Matrix

CLO \ PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO10	PLO11	PLO12
CLO1	3	3	2	2	2	0	0	0	0	0	0	1
CLO2	3	2	2	1	2	2	3	0	0	0	0	1
CLO3	3	3	2	2	2	0	1	0	0	0	0	1
CLO4	2	2	2	2	3	1	3	0	1	1	0	2
CLO5	3	3	3	2	2	0	1	0	0	0	1	1

Recommended Books

S.No:	Text Books	Author	Publisher
1.	Refrigeration and Air-conditioning	C.P. Arora	McGraw Hill
2.	Principles of Refrigeration	Roy J. Dossat and Thomas J. Horan	Pearson Education
	References	**Author**	**Publisher**

1.	Fundamentals of Refrigeration Thermodynamics,	J. S. Brown	Butterworth-Heinemann
2.	Refrigeration and Air Conditioning	W. F. Stoecker and J. W. Jones	McGraw-Hill Education

Course Code	**BMECLOD725**				
Category	**Experiential Learning courses**				
Course Title	**Operations and Diagnostics of Rotary Machines**				
Scheme and Credits	**L** 0	**T** 2	**P** 2	**Credits** 3	**Semester- 7** *(Seven)*
Pre requisites	**Fluid Mechanics, Machine Design, Mechanical Vibrations, Fluid Machinery**				

Course Learning Outcomes (CLOs)

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

i) **CLO1:** ***Explain*** the construction, operation, and maintenance strategies of various rotary machines and identify suitable condition monitoring techniques for industrial applications. ***(L2)***

ii) **CLO2:** ***Measure***, ***analyze***, and ***interpret*** vibration data to diagnose faults in rotary machines using time-domain and frequency-domain analysis. ***(L4)***

iii) **CLO3:** ***Evaluate*** the condition of rotary machines using thermal imaging, lubrication analysis, and acoustic monitoring techniques. **(L4)**

iv) **CLO4:** ***Perform*** shaft alignment, rotor balancing, and performance evaluation to improve machine reliability and operational efficiency. ***(L5)***

v) **CLO5:** ***Develop*** an IoT-enabled condition monitoring or predictive maintenance solution for rotary machinery and communicate the findings through technical reports and presentations. **(L6)**

Theory Module(Internal and External Evaluation)

M.No:	**Topic**
Module 1.	Introduction to rotary machines, classification of turbomachines, rotodynamic and positive displacement machines, centrifugal pumps, reciprocating pumps, centrifugal compressors, axial compressors, reciprocating compressors, centrifugal fans, axial fans, blowers, and gas turbines, fluid flow through rotary machines, Euler's turbomachinery equation and energy transfer, performance characteristics, cavitation, surge, stall, operating limitations, safe operating procedures, maintenance strategies including breakdown, preventive, predictive, and reliability-centered maintenance, introduction to machine diagnostics and condition monitoring.
Module 2.	Fundamentals of machine condition monitoring, machine health indicators, sources of machine faults, fundamentals of vibration, vibration characteristics of rotary machines, measurement techniques, sensors and instrumentation, time-domain analysis, frequency-domain analysis, vibration spectrum interpretation, diagnosis of rotor imbalance, shaft misalignment, mechanical looseness, resonance, rolling element bearing defects, gear faults, and rotor faults.
Module 3.	Infrared thermography, thermal imaging techniques, bearing temperature monitoring, lubrication systems, lubricant properties and selection, lubricant condition monitoring, wear debris analysis, oil contamination analysis, acoustic emission monitoring, ultrasonic inspection techniques, bearing condition assessment, machine health evaluation using multiple diagnostic techniques.
Module 4.	Shaft alignment methods, dial gauge alignment, laser shaft alignment, static balancing, dynamic balancing, balancing standards, coupling inspection, rotor balancing, efficiency and energy consumption analysis.
Module 5.	Online condition monitoring systems, data acquisition systems, industrial Internet of Things (IIoT), smart sensors for vibration, temperature, pressure, flow, and speed measurement, cloud-based machine monitoring, predictive analytics, artificial intelligence for fault diagnosis, machine learning applications in predictive maintenance, digital twin concepts for rotary machines.

Activity Module (Internal Evaluation only-10 Marks)

Activity	Example Task
Identify and study the constructional features of rotary machines available in the laboratory.	Identify and study the constructional features of different rotary machines available in the laboratory, dismantle and assemble a centrifugal pump or blower to identify major components, measure operating parameters such as discharge, head, pressure, rotational speed, power input, and efficiency, plot characteristic curves of a centrifugal pump/fan under different operating conditions, prepare a standard operating procedure and preventive maintenance checklist.
Measure operating parameters and prepare a preventive maintenance checklist.	Measure vibration levels using a portable vibration analyzer/ High speed camera. Acquire vibration signals and perform FFT analysis using MATLAB or Python. Compare healthy and faulty machine signatures and develop a preventive maintenance schedule based on the analysis.
Perform vibration monitoring and fault diagnosis using vibration analyzer and FFT analysis.	Perform thermal inspection using an infrared camera, Inspect lubricating oil for contamination and wear particles, Conduct ultrasonic/acoustic monitoring, prepare a machine health assessment report.
Carry out thermal imaging, lubricant inspection, shaft alignment, balancing, and performance evaluation.	Perform shaft alignment using a dial gauge or laser alignment system, carry out static and dynamic balancing of a rotor, Conduct performance testing and plot characteristic curves, diagnose operational problems and recommend corrective actions using Microsoft Excel, MATLAB, or Python
Develop and demonstrate a mini project on smart condition monitoring or predictive maintenance.	Develop an IIoT-based condition monitoring system by integrating vibration, temperature, pressure, or speed sensors with a data acquisition platform. Collect and visualize real-time data using Arduino/ESP32 with ThingSpeak or Node-RED.

Practical Module (Internal and External Evaluation)

M.No:	Experiments
Module 1.	Dismantle and assemble a centrifugal pump or centrifugal blower. Identify major components and record operating parameters such as discharge, head, pressure, and speed.
Module 2.	Measure vibration levels of a rotating machine and identify common faults such as imbalance and misalignment using a portable vibration analyzer.
Module 3.	Inspect bearings and rotating components using an infrared thermal camera and ultrasonic inspection equipment. Examine lubricant condition and prepare a machine inspection report.
Module 4.	Perform shaft alignment using a dial gauge or laser alignment kit. Conduct static balancing of a rotor and evaluate machine performance before and after alignment.
Module 5.	Demonstrate condition monitoring of a rotary machine by measuring vibration, temperature, speed, and pressure. Assess machine health and prepare a preventive maintenance checklist.

CLO-PLO Mapping Matrix

CLO \ PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO10	PLO11	PLO12
CLO1	3	2	2	0	3	0	0	0	1	1	0	1
CLO2	3	3	3	0	3	1	0	0	1	1	0	2
CLO3	3	3	2	3	3	1	1	0	1	1	1	2
CLO4	3	3	3	3	3	1	1	1	1	2	2	3
CLO5	3	3	3	3	3	1	1	1	1	2	2	3

Recommended Books

S.No:	Text Books	Author	Publisher
1.	Fluid Mechanics and Thermodynamics of Turbomachinery	Dixon, S. L. and Hall, C. A.	Butterworth-Heinemann (Elsevier)
2.	Machinery Failure Analysis and Troubleshooting	Bloch, H. P. and Geitner, F. K.	Gulf Professional Publishing (Elsevier)
3.	Turbomachinery	Maneesh Dubey, BVSSS Prasad, Archana Nema	Mc Graw Hill Education
	References	**Author**	**Publisher**

1.	Principles of Turbomachinery	Shepherd, D. G.	Dover Publications (Reprint Edition).
2.	An Introduction to Predictive Maintenance	Mobley, R. K.,	Butterworth-Heinemann (Elsevier), 2002.
3.	Vibration-Based Condition Monitoring: Industrial, Aerospace and Automotive Applications	Randall, R. B.,	John Wiley & Sons
4.	Practical Machinery Vibration Analysis and Predictive Maintenance	Scheffer, C. and Girdhar, P.,	Elsevier
5.	Pump User's Handbook: Life Extension	Bloch, H. P. and Budris, A. R.,	Fairmont Press
6.	Mechanical Vibration—Evaluation of Machine Vibration by Measurements on Non-Rotating Parts	ISO 10816/20816 Series,	ISO 10816/20816 Series,
7.	Condition Monitoring and Diagnostics of Machines-Data Processing, Communication and Presentation	ISO 13374 Series	ISO 13374 Series
8.	Condition Monitoring and Diagnostics of Machines-General Guidelines	ISO 17359	ISO 17359

Course Code	**BMECCMD725**				
Category	**Professional Core Courses**				
Course Title	**Machine Design**				
Scheme and Credits	**L** / **2**	**T** / **1**	**P** / **0**	**Credits** / **3**	**Semester- 7 *(Seven)***
Pre-requisites	**Engineering Mechanics, Solid Mechanics**				

Course Learning Outcomes (CLOs)

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

i) **CLO1:** ***Understand*** the design principles, operating characteristics, and applications of couplings, bearings, power transmission drives, gears, clutches, and brakes. ***(L2)***

ii) **CLO2:** ***Compare*** different types of couplings, bearings, belt and chain drives, gears, clutches, and braking systems based on performance, design requirements, and applications. ***(L2)***

iii) **CLO3:** ***Interpret*** the performance, load-carrying capacity, lubrication characteristics, fatigue behaviour, and service life of machine elements using standard design criteria and manufacturer data. ***(L5)***

iv) **CLO4:** ***Develop*** engineering designs and detailed design calculations for couplings, bearings, power transmission drives, gears, clutches, and brakes under specified operating conditions. ***(L3)***

v) **CLO5:** ***Design*** and integrate power transmission and motion control components to develop reliable and efficient mechanical systems that satisfy functional and safety requirements. ***(L6)***

Theory Module (Internal and External Evaluation)

M.No:	**Topic**
Module 1.	Design of springs, helical compression springs, terminologies, static and fatigue loading. leaf springs.
Module 2.	Design of welding and fastening, joints subjected to axial and eccentric loads, threaded fasteners, types and design.
Module 3.	Design of flexible mechanical elements, belt, chain and rope
Module 4.	Design of gears, introduction to gears, materials for gears, design of spur gear, helical gear, bevel gears, worm and worm gear.
Module 5.	Clutches and brakes, single and multi-plate clutch, constant wear and constant pressure theories for plate clutches, materials, shoe drum brakes, internal and external shoe brakes.

Activity Module (Internal Evaluation Only-10 Marks)

Activity	Example Task

Using the tools learned on Module 1, design a variety of items, including:	Design and model a muff coupling, flange coupling, and flexible coupling using CAD software (SolidWorks/Creo/AutoCAD).
Using the tools learned on Module 2, design a variety of items, including:	Using SKF or Timken catalogues, select an appropriate rolling element bearing for a given shaft load and speed. Estimate bearing life (L10 life).
Using the tools learned on Module 3, design a variety of items, including:	Modeling and Comparative Analysis of Rope, Belt, and Chain Drives Using CAD Software
Using the tools learned on Module 4, design a variety of items, including:	CAD Modeling and Assembly of Spur, Helical, and Worm Gear Drives
Using the tools learned on Module 5, design a variety of items, including:	CAD Modeling and Assembly of Single-Plate, Multi-Plate Clutches and Shoe Drum Brakes

CLO-PLO Mapping Matrix

CLO \ PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO10	PLO11	PLO12
CLO1	3	2	2	1	2	0	0	0	0	1	0	1
CLO2	2	3	2	2	2	0	0	0	0	1	0	2
CLO3	3	3	2	3	3	0	1	1	0	2	0	1
CLO4	3	3	3	2	3	1	1	1	1	2	2	2
CLO5	3	3	3	2	3	2	2	2	2	2	2	3

Recommended Books

S.No:	Text Books	Author	Publisher
1.	Design of Machine Elements	V.B. Bhandari	Tata McGraw Hill, New Delhi
	References	**Author**	**Publisher**
1.	Machine Elements in Mechanical Design	Robert L. Mo	Pearson Education
2.	Mechanical Engineering Design	Shigley, Budynas, Nisbett	McGraw Hill, New York

---

Course Code	**BMECHOR725**				
Category	**Humanities and Social Sciences including Management course**				
Course Title	**Operations Research**				
Scheme and Credits	**L**	**T**	**P**	**Credits**	**Semester- 7 *(Seven)***
	2	**1**	**0**	**3**	
Pre-requisites	-				

Course Learning Outcomes (CLOs)

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

i) **CLO1:** ***Understand*** the fundamental concepts, methodology, scope, and applications of Operations Research and formulate Linear Programming Problems for decision-making situations. ***(L2)***

ii) **CLO2:** ***Compare*** optimization techniques such as Graphical Method, Simplex Method, Transportation Models, and Assignment Models to obtain optimal solutions for resource allocation problems. ***(L3)***

iii) **CLO3:** ***Analyze*** project scheduling and management problems using PERT and CPM techniques to determine critical paths, project duration, and resource requirements. ***(L4)***

iv) **CLO4:** ***Solve*** sequencing, queuing, and probability-based problems using appropriate Operations Research models and statistical distributions. ***(L3)***

v) **CLO5:** ***Evaluate*** complex engineering and managerial decision-making problems and recommend optimal solutions using suitable Operations Research techniques. ***(L5)***

Theory Module(Internal and External Evaluation)

M.No:	Topic
Module 1.	Introduction to operations research, concept, scope, methodology and applications, linear programming: concepts, assumptions, formulation of LPP, graphical method, simplex method and Big-M method.
Module 2.	Transportation problems, formulation, initial basic feasible solutions (North-West corner, least cost, Vogel's approximation method), optimality tests, transshipment problems, assignment problems and solutions using the Hungarian method.
Module 3.	Introduction to project management, project life cycle, network analysis, objectives, rules of network construction, PERT and CPM techniques, critical path analysis, resource allocation, project monitoring and control.
Module 4.	Sequencing, terminology, job sequencing problems, introduction to queuing theory.
Module 5.	Probability, basic theorems, conditional probability, theoretical frequency distributions, normal Distribution, binomial distribution and poisson distribution.

Activity Module (Internal Evaluation Only-10 Marks)

Activity	Example Task
Using the tools learned on Module 1, design a variety of items, including:	Develop a computational model of a real-life linear programming problem, obtain the optimal solution, and perform sensitivity analysis using Microsoft Excel Solver, MATLAB, Python (PuLP/OR-Tools), or LINGO.
Using the tools learned on Module 2, design a variety of items, including:	Implement transportation and assignment models, compare different solution methods, and determine the optimal allocation of resources using Microsoft Excel Solver, MATLAB, Python (SciPy/OR-Tools), or LINGO.
Using the tools learned on Module 3, design a variety of items, including:	Create a PERT/CPM network, identify the critical path, estimate project completion time, and analyze schedule variations using Microsoft Project, Microsoft Excel, MATLAB, or Python (NetworkX).
Using the tools learned on Module 4, design a variety of items, including:	Develop computational models for sequencing and queuing problems, evaluate system performance measures, and compare alternative scheduling policies using MATLAB, Python (SimPy), Microsoft Excel, or R.
Using the tools learned on Module 5, design a variety of items, including:	Simulate Binomial, Poisson, and Normal probability distributions, perform Monte Carlo simulation, and analyze uncertainty using MATLAB, Python (NumPy, SciPy), Microsoft Excel, or R.

CLO-PLO Mapping Matrix

CLO \ PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO10	PLO11	PLO12
CLO1	3	3	2	0	1	0	0	0	0	1	2	1
CLO2	3	3	2	2	2	0	0	0	0	1	3	2
CLO3	2	3	2	2	2	0	0	0	1	1	3	2
CLO4	3	3	2	2	2	0	0	0	0	1	2	2
CLO5	3	3	3	2	2	2	1	1	1	2	3	3

Recommended books:

S.No:	Text Books	Author	Publisher
1.	Quantitative Techniques in Management	N.D. Vohra	McGraw Hill Education.
2.	Operations Research	Hamdy A. Taha	Pearson Education
	References	**Author**	**Publisher**
1.	Operations Research	S. R. Yadav, A. K. Malik	Oxford Higher Education
2.	Introduction to Operations Research	Frederick S. Hillier, Gerald J. Lieberman.	Tata McGraw Hill
3.	Operations Research	P. K. Gupta, D. S. Hira.	S. Chand & Company, New Delhi.

Course Code	**BMECPPP725**				
Category	**Project work, Seminar and Internship**				
Course Title	**Final Year Pre-Project**				
Scheme and Credits	**L**	**T**	**P**	**Credits**	Semester- 7 *(Seven)*
	0	**0**	6	3	
Pre-requisites	-				

Course Learning Outcomes (CLOs)

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

i) **CLO1:** Identify a mechanical engineering problem through literature review and problem analysis. ***(L3)***

ii) **CLO2:** Formulate project objectives, methodology, and expected outcomes. ***(L3)***

iii) **CLO3:** Analyze the technical feasibility of the proposed project. ***(L4)***

iv) **CLO4:** Develop preliminary designs, models, simulations, or experimental plans using appropriate engineering tools. ***(L5)***

v) **CLO5:** Prepare and present a project proposal demonstrating technical communication, teamwork, and project planning skills. ***(L5)***

Plan for Conducting the Course

The plan of conducting this course is given below:

Students shall work individually or in teams of 2–5 members under faculty supervision. Each team shall identify a project topic, conduct a literature review, define objectives and methodology, prepare preliminary designs or simulations, and submit a project proposal with a work plan. The course concludes with a proposal presentation and viva-voce before the departmental committee.

Evaluation Scheme

Internal Evaluation (50%)

Project proposal and literature review-**25%**

Progress review and implementation- **50%**

Documentation and presentation- **25%**

External Evaluation (80%)

Project demonstration and viva-voce - **50%**

Technical quality, innovation, implementation, and performance - **38%**

Project report and presentation - **12%**

CLO-PLO Mapping Matrix

CLO \ PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO10	PLO11	PLO12
CLO1	3	2	0	0	1	1	0	0	0	0	0	1
CLO2	3	3	2	2	3	1	0	0	0	1	0	1
CLO3	2	3	3	3	3	1	0	0	0	1	0	1
CLO4	2	2	3	3	3	1	0	0	2	2	0	2
CLO5	2	2	3	3	3	1	1	1	3	2	1	3

Recommended Books

S.No.	References	Author	Publisher
	Research Methodology for Engineers,	CR. Ganesan,	MJP Publishers.
	Research Design: Qualitative, Quantitative, and Mixed Methods Approaches,	John W. Creswell	Sage Publications.

Course Code	BMECHPM825				
Category	Humanities and Social Sciences including Management course				
Course Title	Introduction to Project Management				
Scheme and Credits	L 2	T 1	P 0	Credits 3	Semester- 8 (*Eight*)
Pre-requisites	-				

Course Learning Outcomes (CLOs)

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

i) **CLO1:** Explain project management concepts, project life cycle stages, project identification methods, and project selection processes. ***(L2)***

ii) **CLO2:** Analyze the feasibility of projects through market, technical, financial, and economic studies, and assess project risks and uncertainties. ***(L4)***

iii) **CLO3:** Apply capital budgeting techniques such as Payback Period, ROI, NPV, PI, IRR, and DCF Analysis for project investment decisions. ***(L3)***

iv) **CLO4:** Conduct project appraisal using market surveys, demand forecasting methods, technical analysis, plant location decisions, and facility layout planning. ***(L4)***

v) **CLO5:** Develop and manage project implementation plans using Work Breakdown Structures (WBS), coordination and control mechanisms, project management software, and contemporary AI-enabled project management practices. ***(L6)***

Theory Module(Internal and External Evaluation)

M.No:	Topic
Module 1.	Project definition, characteristics, classification, and performance dimensions, project life cycle, life cycle paths, project management concepts and benefits, identification of investment opportunities, project screening, selection, and formulation.
Module 2.	Feasibility studies including economic, market, financial, and technical analysis, concepts of risk and uncertainty, risk identification, assessment, and mitigation in project planning and decision-making.
Module 3.	Financial analysis of projects and investment decision-making using capital budgeting techniques, pay-back period, return on investment, net present value, profitability index/ benefit-cost ratio, internal rate of return, and discounted cash flow analysis
Module 4.	Project appraisal covering market and demand analysis, market surveys, and demand forecasting methods. Technical analysis including manufacturing processes, materials–product mix, plant location decisions, project charts, and facility layouts.
Module 5.	Organization systems for project implementation, work breakdown structure, coordination and control mechanisms, project management software, selection of appropriate software tools, role of artificial intelligence in project management, and case studies on contemporary project management practices.

Activity Module (Internal Evaluation Only-10 Marks)

Activity	Example Task
Using the techniques/methods learned on Module 1, design a variety of items, including:	Prepare a project identification and formulation report for a startup, manufacturing unit, or engineering project by performing opportunity analysis, project screening, and SWOT analysis using Microsoft Excel or project planning templates.
Using the techniques/methods learned on Module 2, design a variety of items, including:	Develop a comprehensive feasibility study and risk assessment matrix for the selected project, perform sensitivity analysis and evaluate project risks using Microsoft Excel or equivalent analytical tools.
Using the techniques/methods learned on Module 3, design a variety of items, including:	Perform project financial appraisal by calculating Payback Period, NPV, IRR, ROI, PI/BCR, and DCF using Microsoft Excel, financial calculators, or MATLAB/Python.
Using the techniques/methods learned on Module 4, design a variety of items, including:	Prepare a market demand forecasting report and develop a plant/facility layout for the selected project. Use Microsoft Excel for forecasting and AutoCAD, Microsoft Visio, or equivalent software for facility layout planning.
Using the techniques/methods learned on Module 5, design a variety of items, including:	Develop a complete project implementation plan including work breakdown structure, Gantt chart, resource allocation, project monitoring dashboard, and AI-assisted project scheduling using Microsoft Project, Primavera P6, Trello, Asana, or equivalent project management software.

CLO-PLO Mapping Matrix

CLO \ PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO10	PLO11	PLO12
CLO1	2	2	1	0	1	0	0	0	1	2	3	1
CLO2	2	3	2	3	2	2	2	1	1	2	3	2
CLO3	2	3	2	2	2	0	1	1	0	1	3	2
CLO4	2	3	3	3	2	2	2	0	2	2	3	2
CLO5	2	3	3	2	3	2	2	2	3	3	3	3

Recommended Books

S.No:	Text Books	Author	Publisher
1.	Project Management for Business and Technology: Principles and Practice	John M. Nicholas	Pearson Prentice Hall, New Delhi
2.	Projects: Preparation, Appraisal, Budgeting and Implementation	Prasanna Chandra	Tata McGraw Hill Publishing Company Ltd., New Delhi
	References	Author	Publisher
1.	Project Management – Case Studies	Harold Kerzner	John Wiley & Sons, New Jersey
2.	Project Management: A Systems Approach to Planning, Scheduling, and Controlling	Harold Kerzner	John Wiley & Sons, New Jersey
3.	Project and Production Management (NPTEL Course)	Arun Kanda and S. G. Deshmukh	National Programme on Technology Enhanced Learning (NPTEL), IIT Delhi

Course Code	**BMECONT825**				
Category	**Open Elective Course**				
Course Title	**Non-Destructive Testing**				
Scheme and Credits	**L** 2	**T** 0	**P** 2	**Credits** 3	**Semester- 8 (*Eight*)**
Pre-requisites	-				

Course Learning Outcomes (CLOs)

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

i) **CLO1:** ***Explain*** the principles, classification, advantages, limitations, standards, and selection criteria of various non-destructive testing (NDT) methods. ***(L2)***

ii) **CLO2:** ***Apply*** appropriate surface and volumetric NDT techniques, including liquid penetrant, magnetic particle, ultrasonic, radiographic, and eddy current testing, for defect detection in engineering materials. ***(L3)***

iii) **CLO3:** ***Analyze*** inspection data obtained from ultrasonic, radiographic, and advanced NDT techniques to identify, characterize, and evaluate material defects. ***(L4)***

iv) **CLO4:** ***Evaluate*** and select suitable NDT methods for inspection of engineering components based on material properties, defect type, service conditions, applicable standards, and safety requirements. ***(L5)***

v) **CLO5:** ***Design*** an inspection plan by integrating appropriate NDT techniques for quality assurance and structural integrity assessment of industrial components and engineering systems. ***(L6)***

Theory Module(Internal and External Evaluation)

M.No:	Topic

Module 1.	Introduction to quality control and inspection, destructive testing and non-destructive testing, Advantages and limitations of NDT, classification of NDT methods, types of defects in engineering materials, selection criteria for NDT methods, standards and codes for NDT, personnel qualification and certification.
Module 2.	Visual testing, optical inspection methods, liquid penetrant testing, magnetic particle testing, eddy current testing, probe types in eddy current testing.
Module 3.	Ultrasonic testing, wave propagation in ultrasonic testing, pulse-echo method, through transmission method, ultrasonic equipment, A-scan, B-scan and C-scan, defect characterization, phased array ultrasonic testing, time of flight diffraction.
Module 4.	Radiographic testing, X-ray radiography, gamma-ray radiography, film radiography, digital radiography, radiographic image interpretation, radiation safety, acoustic emission testing, infrared thermography, leak testing, laser and optical NDT, structural health monitoring.
Module 5.	NDT of welded joints, Inspection of castings and forgings, NDT for aerospace components, NDT in power plants, NDT for railway and automotive components, pipeline and pressure vessel inspection, composite material inspection, Industry 4.0 in NDT, artificial intelligence in NDT, industrial case studies.

Activity Module (Internal Evaluation Only-10 Marks)

Activity	Example Task
Using the tools learned on Module 1, design a variety of items, including:	Select suitable NDT methods for a welded pressure vessel, cast pump housing, forged crankshaft, railway axle, or aluminium aircraft panel. Justify the choice based on defect type and material.
Using the tools learned on Module 2, design a variety of items, including:	Conduct visual testing of welded joints, liquid penetrant testing on an aluminium component with surface cracks, magnetic particle testing on a steel shaft or gear, and eddy current testing for crack detection in heat exchanger tubes.
Using the tools learned on Module 3, design a variety of items, including:	Detect internal flaws in a steel plate, locate defects in welded joints using pulse-echo UT, measure pipe wall thickness, interpret A-scan signals, or inspect forged components for internal discontinuities.
Using the tools learned on Module 4, design a variety of items, including:	Interpret radiographs of welded joints to identify porosity, slag inclusion, lack of fusion, and cracks, analyze infrared thermography images for electrical hot spots; evaluate acoustic emission testing data for pressure vessels; or demonstrate structural health monitoring of a beam using sensors.
Using the tools learned on Module 5, design a variety of items, including:	Prepare an inspection plan for a pressure vessel, oil and gas pipeline, wind turbine blade, aircraft wing, railway axle, or automotive suspension component by selecting suitable NDT methods, inspection sequence, acceptance criteria, and reporting format.

Practical Module (Internal and External Evaluation)

M.No:	Experiments
Module 1.	Visual inspection of welded joints.
Module 2.	Liquid Penetrant Testing of surface cracks.
Module 3.	Magnetic Particle Inspection of ferromagnetic components.
Module 4.	Ultrasonic flaw detection in plates.
Module 5.	Thickness measurement using Ultrasonic Testing.
Module 6.	Radiographic image interpretation (demonstration/simulation).
Module 7.	Eddy Current Testing of conductive materials.
Module 8.	Infrared thermography demonstration.
Module 9.	Defect analysis using multiple NDT methods.
Module 10.	Industrial case study and report.

CLO-PLO Mapping Matrix

CLO \ PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO10	PLO11	PLO12
CLO1	3	3	0	0	0	0	0	2	0	0	0	1
CLO2	3	3	2	2	2	0	0	2	0	0	0	1
CLO3	3	3	2	3	2	0	0	2	0	0	0	2
CLO4	2	3	2	3	3	0	2	2	0	0	0	2

CLO5	2	3	3	3	3	2	2	3	2	2	2	3

Recommended Books

S.No:	Text Books	Author	Publisher
1.	Practical Non-Destructive Testing	Baldev Raj, T. Jayakumar and M. Thavasimuthu	Narosa Publishing House
2.	Introduction to Nondestructive Testing: A Training Guide	Paul E. Mix	John Wiley & Sons
	References	**Author**	**Publisher**
1.	Non-Destructive Test and Evaluation of Materials	J. Prasad and C. G. K. Nair,	McGraw Hill Education
2.	Non-Destructive Testing,	R. Halmshaw	Edward Arnold Publishers, London,
3.	Handbook of Nondestructive Evaluation	Charles J. Hellier,	McGraw-Hill Education
4.	ASM Handbook, Volume 17: Nondestructive Evaluation and Quality Control	ASM International,	ASM International

---

Course Code	**BMECOMS825**				
Category	**Open Elective Course**				
Course Title	**Mechatronic Systems**				
Scheme and Credits	L	T	P	Credits	**Semester- 8 (Eight)**
	2	0	2	3	
Pre-requisites	-				

Course Learning Outcomes (CLOs)

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

i) **CLO1:** ***Explain*** the fundamental concepts, components, and interdisciplinary design approach of mechatronic systems. ***(L2)***

ii) **CLO2:** ***Develop*** mathematical models of mechanical and electromechanical systems and analyze their dynamic behaviour for engineering applications. ***(L4)***

iii) **CLO3:** ***Apply*** and ***integrate*** appropriate sensors, actuators, and transducers for the design of mechatronic systems. ***(L3)***.

iv) **CLO4:** ***Analyze*** and implement basic control, embedded, and logic-based systems for mechatronic applications. *(L4)*

v) **CLO5:** ***Design*** and ***implement*** automated mechatronic systems using microcontrollers, programmable logic controllers (PLCs), communication interfaces, and data acquisition systems. ***(L6)***

Theory Module(Internal and External Evaluation)

M.No:	Topic
Module 1.	Introduction to mechatronics, mechatronic design approach, interdisciplinary engineering concepts, system interfacing, instrumentation and control systems, microprocessor-based controllers and microelectronics, mechatronics as a new direction in nano-, micro-, and mini-scale systems, applications of mechatronics.
Module 2.	Electromechanical system design, physical system modelling, electromechanical system structures and materials, modelling of mechanical systems for mechatronic applications, dynamic behaviour of mechanical systems, introduction to system modelling techniques.
Module 3.	Fundamentals of time and frequency, sensor and actuator characteristics, linear and rotational position sensors, acceleration sensors, force, torque and power measurement, flow measurement, temperature measurement, distance and proximity sensors, light detection, image and vision systems, integrated microsensors, electromechanical actuators, electrical machines, piezoelectric actuators, hydraulic and pneumatic actuation systems.

Module 4.	Microtransducer analysis, design and fabrication, role of control systems in mechatronics, modelling for mechatronic system design, response of dynamic systems, introduction to digital computers, logic systems, embedded systems, and real-time control concepts.
Module 5.	Logic concepts, combinational and sequential logic design, system interfaces, communication protocols, industrial computer networks, fault analysis in mechatronic systems, programmable logic controllers, software for automation, data acquisition systems, industrial monitoring and control applications.

Activity Module (Internal Evaluation Only-10 Marks)

Activity	Example Task
Using the tools learned on Module 1, design a variety of items, including:	Develop and simulate simple mechatronic systems to understand the interaction between mechanical, electrical, electronic, and control components using suitable modelling and simulation tools such as MATLAB/Simulink, Simscape, or equivalent software.
Using the tools learned on Module 2, design a variety of items, including:	Develop mathematical and simulation models of electromechanical systems and analyse their dynamic behaviour using MATLAB/Simulink, Simscape, SolidWorks Motion, or equivalent engineering simulation software.
Using the tools learned on Module 3, design a variety of items, including:	Interface sensors and actuators with a microcontroller, acquire experimental data, and evaluate system performance using suitable platforms such as Arduino, MATLAB, LabVIEW, Proteus, or equivalent software.
Using the tools learned on Module 4, design a variety of items, including:	Model and simulate open-loop and closed-loop control systems, analyse transient response, and implement basic embedded control algorithms using MATLAB/Simulink, Python, Proteus, or equivalent simulation software.
Using the tools learned on Module 4, design a variety of items, including:	Develop PLC ladder logic programs and implement automation for simple industrial processes involving sensor interfacing, actuator control, and data acquisition using Siemens TIA Portal, Factory I/O, CODESYS, or equivalent PLC programming software.

Practical Module (Internal and External Evaluation)

M.No:	**Experiments**
Module 1.	Study the components of a mechatronic system and identify sensors, actuators, controllers, and interfacing devices used in industrial applications.
Module 2.	Develop a mathematical model and simulate the dynamic response of a simple electromechanical system using MATLAB/Simulink or equivalent software.
Module 3.	Interface a linear or rotary position sensor with a microcontroller and acquire measurement data.
Module 4.	Interface temperature, proximity, or ultrasonic sensors and analyse their performance characteristics.
Module 5.	Control DC and stepper motors using a microcontroller and evaluate speed and position control.
Module 6.	Study the characteristics and applications of pneumatic and hydraulic actuators through simulation or laboratory setup.
Module 7.	Interface force, pressure, or flow sensors with a data acquisition system and analyse the measured signals
Module 8.	Design and simulate a basic feedback control system for a mechatronic application using MATLAB/Simulink or equivalent software.
Module 9.	Develop and test digital logic circuits using logic gates and flip-flops for mechatronic control applications.
Module 10	Interface sensors and actuators with a PLC and implement an automated industrial process with fault diagnosis.

CLO-PLO Mapping Matrix

CLO \ PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO10	PLO11	PLO12
CLO1	3	2	1	0	0	0	0	0	0	0	0	1
CLO2	2	3	2	2	2	2	0	0	0	0	2	0
CLO3	2	2	3	2	3	0	0	0	0	2	0	2
CLO4	2	3	3	3	2	0	0	0	2	0	2	0
CLO5	2	2	3	3	3	0	0	0	2	2	3	1

Recommended Books

S.No:	Text Books	Author	Publisher
	Mechatronic system design	Shetty. D and Richard A. K	Cengage learning, 2011
S.No:	References		
	Mechatronics	Dan. S. N	Prentice Hall, 2002

Course Code	BMECOME825				
Category	Open Elective Course				
Course Title	Micro-Electro-Mechanical Systems				
Scheme and Credits	L	T	P	Credits	Semester- 8 (*Eight*)
	2	0	2	3	
Pre-requisites	-				

Course Learning Outcomes (CLOs)

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

i) **CLO1:** Understand the fundamentals, materials, fabrication processes, and operating principles of MEMS devices. *(L2)*
ii) **CLO2:** Compare various MEMS sensors, actuators, micromachining techniques, and material systems. ***(L3)***
iii) **CLO3:** Interpret the mechanical, electrical, thermal, magnetic, and piezoelectric behaviour of MEMS devices. ***(L3)***
iv) **CLO4:** Analyze MEMS fabrication processes and device performance for engineering applications. **(L5)**
v) **CLO5:** Evaluate and select suitable MEMS technologies for applications in biomedical, automotive, aerospace, communication, and industrial systems. ***(L6)***

Theory Module(Internal and External Evaluation)

M.No:	Topic
Module 1.	Introduction to microelectromechanical systems (MEMS), intrinsic characteristics of MEMS, energy domains and transduction principles, sensors and actuators, overview of microfabrication, silicon-based MEMS fabrication processes, emerging MEMS materials, review of electrical and mechanical concepts, semiconductor fundamentals, stress and strain analysis, flexural beam bending, and torsional deflection.
Module 2.	Electrostatic sensing and actuation, parallel-plate and interdigitated capacitive sensors, comb-drive actuators, microgrippers, micromotors, thermal sensing and actuation, thermal expansion, thermocouples, thermal resistors, thermal bimorph actuators, magnetic actuation, micromagnetic components, shape memory alloy actuators, and engineering applications of electrostatic, thermal, and magnetic MEMS devices.
Module 3.	Piezoresistive and piezoelectric MEMS sensors and actuators, piezoresistive and piezoelectric materials, mechanical stress analysis, inertial sensing, pressure sensors, tactile sensors, flow sensors, acoustic sensors, accelerometers, gyroscopes, microsensors for biomedical and industrial applications, and performance evaluation of MEMS sensing devices.
Module 4.	Micromachining technologies, silicon anisotropic and isotropic wet etching, dry etching, plasma etching, deep reactive ion etching (DRIE), gas-phase etching, surface micromachining, structural and sacrificial materials, sacrificial layer removal, stiction and anti-stiction techniques, LIGA process, wafer bonding, three-dimensional MEMS assembly, MEMS packaging, foundry processes, and reliability considerations.
Module 5.	Polymer and optical MEMS, polymer materials for MEMS including polyimide, SU-8, liquid crystal polymer (LCP), PDMS, PMMA, parylene, and fluorocarbons, polymer MEMS fabrication techniques, optical MEMS components, microlenses, micromirrors, optical switches, optical actuators, RF MEMS, BioMEMS, Lab-on-a-Chip systems, microsystem integration, emerging trends, and industrial case studies.

Activity Module (Internal Evaluation Only-10 Marks)

Activity	Example Task
Using the tools learned on Module 1, design a variety of items, including:	Study and demonstrate the working principles of commercially available MEMS sensors and actuators.
Using the tools learned on Module 2, design a variety of items, including:	Simulate the performance of electrostatic, thermal, or magnetic MEMS actuators using appropriate software.

Using the tools learned on Module 3, design a variety of items, including:	Analyze the applications of piezoresistive and piezoelectric MEMS sensors through a case study or technical presentation.
Using the tools learned on Module 4, design a variety of items, including:	Develop a process flow diagram for the fabrication of a silicon-based MEMS device using micromachining techniques.
Using the tools learned on Module 5, design a variety of items, including:	Design and present a conceptual polymer or optical MEMS device for a selected engineering application.

Practical Module (Internal and External Evaluation)

M.No:	Experiments
Module 1.	To study the construction, working principle, and applications of common MEMS sensors and actuators.
Module 2.	To characterize the performance of a MEMS accelerometer under varying acceleration conditions.
Module 3.	To calibrate and evaluate the response characteristics of a MEMS pressure sensor.
Module 4.	To investigate the temperature-dependent behaviour of a MEMS temperature sensor.
Module 5.	To simulate and analyze the displacement characteristics of an electrostatic comb-drive actuator.
Module 6.	To study the actuation mechanism and performance of a thermal MEMS actuator.
Module 7.	To examine the piezoresistive effect and its application in MEMS sensing devices.
Module 8.	To understand bulk and surface micromachining processes used in MEMS fabrication.
Module 9.	To develop and analyze the fabrication process flow of a silicon-based MEMS device.
Module 10.	To design and evaluate a basic MEMS structure using CAD/MEMS simulation tools.

CLO-PLO Mapping Matrix

CLO \ PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO10	PLO11	PLO12
CLO1	3	2	1	1	2	0	0	0	0	0	0	1
CLO2	2	3	2	2	2	0	0	0	1	1	0	1
CLO3	2	3	2	3	2	0	0	0	0	1	0	1
CLO4	2	3	3	3	3	0	1	0	1	1	0	2
CLO5	2	2	3	2	3	2	2	1	1	2	1	3

Recommended Books

S.No:	Text Books	Author	Edition & Publisher
1.	An Introduction to Microelectromechanical Systems Engineering,	Nadim Maluf and Kirt Williams,	2nd/3rd Edition, Artech House.
2.	MEMS and Microsystems: Design, Manufacture, and Nanoscale Engineering	Tai-Ran Hsu	2nd Edition, Wiley.
	References	**Author**	**Publisher**
1.	MEMS: Design and Fabrication,	Mohamed Gad-el-Hak	CRC Press.
2.	Microsmart Systems: Technologies and Applications	S. Gopalakrishnan	Springer

---

Course Code	BMECORB825				
Category	Open Elective Course				
Course Title	Robotics				
Scheme and Credits	L 2	T 0	P 2	Credits 3	Semester- 8 (*Eight*)
Pre-requisites	-				

Course Learning Outcomes (CLOs)

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

i) **CLO1:** ***Explain*** the fundamentals of robotics and automation, including robot anatomy, classification, coordinate systems, performance parameters, and industrial applications. ***(L2)***

ii) **CLO2:** ***Apply*** kinematic principles, Denavit–Hartenberg (D–H) convention, homogeneous transformation matrices, and Jacobian analysis to model and simulate robotic manipulators. ***(L3)***

iii) **CLO3:** ***Analyze*** the dynamics, motion control, sensors, actuators, and vision-based robotic systems to evaluate robotic performance for engineering applications. ***(L4)***

iv) **CLO4:** ***Develop*** and simulate basic robotic applications using ROS/ROS2, Gazebo, CoppeliaSim, RoboDK, Webots, or ABB RobotStudio, incorporating robot programming, path planning, and autonomous navigation. ***(L6)***

v) **CLO5:** ***Design*** and implement intelligent robotic applications by integrating ROS-Python, computer vision, artificial intelligence techniques, and autonomous systems for industrial robots, mobile robots, or UAVs through simulation. ***(L6)***

Theory Module(Internal and External E valuation)

M.No:	Topic
Module 1.	Introduction to Robotics, history and evolution of robots, classification of robots, robot Anatomy and components, Degrees of Freedom (DOF), robot coordinate systems, homogeneous transformation matrix, robot configurations (cartesian, cylindrical, spherical, SCARA, articulated, parallel), robot workspace, applications of robotics
Module 2.	Forward Kinematics, inverse Kinematics, Denavit-Hartenberg (D-H) Convention, rotation and, transformation Matrices, Jacobian matrix, differential Motion, velocity Analysis, singularities, workspace analysis
Module 3.	Lagrangian dynamics, Newton–Euler formulation, robot trajectory planning, joint space and Cartesian space motion, actuators: DC motors, servo motors, stepper motors, pneumatic actuators, hydraulic actuators, sensors: encoders, force/torque sensors, proximity sensors, vision sensors and cameras, machine vision fundamentals, image acquisition, image processing for robot guidance, visual servoing (vision-based control), object detection and tracking, camera calibration, PID control, computed torque control, motion control.
Module 4.	Robot programming languages, Robot Operating System (ROS/ROS2), path planning, motion planning, localization, simultaneous localization and mapping, mobile robots, autonomous navigation, human–robot interaction, artificial intelligence for robotics, machine learning fundamentals, deep learning for robotic perception, reinforcement learning, autonomous decision making, AI-enabled robot planning and control, cloud robotics, edge AI in robotics.
Module 5.	Industrial robot programming, end effectors and grippers, flexible manufacturing systems, collaborative robots (cobots), industrial automation, automated guided vehicles, autonomous mobile robots, unmanned aerial vehicles and drones, drone kinematics and flight control, drone navigation and mission planning, drone sensors and payloads, drone applications in inspection, surveillance, agriculture and logistics, medical robotics, space robotics, underwater robotics, agricultural robotics, Industry 4.0, digital twin, ethics and safety standards in robotics.

Activity Module (Internal Evaluation Only-10 Marks)

Activity	Example Task
Using the tools learned on Module 1, design a variety of items, including:	Develop a simple robotic manipulator or workcell model by identifying robot configurations, assigning coordinate frames and degrees of freedom (DOF), and visualizing the robot workspace using SolidWorks, Autodesk Fusion, RoboDK, or RobotStudio.
Using the tools learned on Module 2, design a variety of items, including:	Develop kinematic models of robotic manipulators, perform forward and inverse kinematics, Jacobian and workspace analysis, and simulate robot motion using MATLAB, Python, RoboDK, or CoppeliaSim.
Using the tools learned on Module 3, design a variety of items, including:	Develop robot dynamic models, generate trajectories, integrate actuators and sensors, implement motion control algorithms, and perform vision-based object detection or pick-and-place simulation using MATLAB/Simulink, Python, OpenCV, ROS, or Gazebo.
Using the tools learned on Module 4, design a variety of items, including:	Develop robot programs for localization, path planning, SLAM, autonomous navigation, and AI-enabled robotic perception using ROS/ROS2, Gazebo, Python, OpenCV, TensorFlow, or PyTorch.
Using the tools learned on Module 5, design a variety of items, including:	Develop industrial robotic automation systems involving robot programming, gripper integration, AGV/AMR navigation, or UAV mission planning and

	simulate Industry 4.0-enabled robotic applications using RoboDK, RobotStudio, ROS2, Gazebo, PX4, QGroundControl, or AirSim.

Practical Module (Internal and External Evaluation)

M.No:	Experiments
Module 1.	Study the construction, joints, DOF, workspace, end effectors, sensors, and actuators of the robotic arm(s), and demonstrate basic teach-and-repeat operation.
Module 2.	Develop and simulate forward and inverse kinematics of a 2-DOF/3-DOF robotic manipulator using MATLAB Robotics Toolbox or Python, and verify the motion on the laboratory robotic arm (where applicable).
Module 3.	Perform trajectory planning and PID-based motion control of the robotic arm; demonstrate basic pick-and-place or point-to-point motion using the available robotic arm.
Module 4.	Develop a simple vision-guided robotic application using the AI-based robotic arm or an external camera for object detection, colour/shape recognition, and object sorting using Python/OpenCV.
Module 5.	Develop basic ROS 2 applications using publishers, subscribers, and topics to interface with a simulated or laboratory robot
Module 6.	Implement robot localization or obstacle avoidance for a mobile robot using WEBOTS, Gazebo, or CoppeliaSim.
Module 7.	Program the robotic arm to perform automated pick-and-place, sorting, or stacking operations using the manufacturer's software or ROS interface.
Module 8.	Develop a simple AI-enabled robotic application using TensorFlow/PyTorch or the built-in AI features of the robotic arm for object classification or object tracking.
Module 9.	Simulate an industrial robotic workcell using RoboDK or ABB RobotStudio, including material handling or assembly operations.
Module 10.	Demonstrate waypoint navigation or autonomous mission planning for a simulated AGV/AMR or UAV using Gazebo, WEBOTS, or PX4/AirSim, and prepare a brief performance report.

CLO-PLO Mapping Matrix

CLO \ PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO10	PLO11	PLO12
CLO1	3	2	0	0	1	1	0	0	0	1	0	1
CLO2	3	3	2	2	3	0	0	0	0	0	0	1
CLO3	2	3	2	3	3	1	0	0	0	1	0	1
CLO4	2	2	3	2	3	0	0	0	2	2	0	3
CLO5	2	2	3	3	3	1	1	1	3	2	1	3

Recommended Books

S.No:	Text Books	Author	Publisher
1.	Introduction to Robotics: Analysis, Control, Applications	Saeed B. Niku	John Wiley & Sons
2.	Introduction to Robotics: Mechanics and Control	John J. Craig	Pearson Education,
S.No.	**References**	**Author**	**Publisher**
1.	Robotics: Modelling, Planning and Control	Bruno Siciliano, Lorenzo Sciavicco, Luigi Villani, and Giuseppe Oriolo,	Springer
2.	Introduction to Autonomous Mobile Robots	Roland Siegwart, Illah R. Nourbakhsh, and Davide Scaramuzza	MIT Press
3.	Programming Robots with ROS: A Practical Introduction to the Robot Operating System	Morgan Quigley, Brian Gerkey, and William D. Smart,	O'Reilly Media
4.	Robotics, Vision and Control: Fundamental Algorithms in MATLAB®	Peter Corke,	Springer

Course Code	**BMECDCE825**				
Category	**Professional Elective Course**				
Course Title	**Cryogenic Engineering**				
Scheme and Credits	**L**	**T**	**P**	**Credits**	Semester- 8 (*Eight*)
	2	0	2	3	
Pre-requisites	**Refrigeration , Thermodynamics, Heat Transfer**				

Course Learning Outcomes (CLOs)

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

i) **CLO1:** ***Explain*** the fundamentals of cryogenic engineering and the thermophysical behaviour of cryogenic fluids. ***(L2)***

ii) **CLO2:** ***Analyze*** cryogenic refrigeration and gas liquefaction cycles for performance evaluation. ***(L4)***

iii) **CLO3:** ***Analyze*** heat transfer, insulation techniques, and storage systems used in cryogenic engineering. ***(L4)***

iv) **CLO4:** ***Evaluate*** the design, operation, and instrumentation of cryogenic equipment and systems. ***(L5)***

v) **CLO5:** ***Evaluate*** industrial and emerging applications of cryogenic engineering in energy, aerospace, healthcare, and advanced technologies. ***(L5)***

Theory Module(Internal and External Evaluation)

M.No:	Topic
Module 1.	Introduction to cryogenic engineering; cryogenic temperature range; applications of cryogenics, thermodynamic and transport properties of cryogenic fluids, properties of liquid nitrogen, oxygen, hydrogen, helium, and LNG, gas laws at low temperatures, Joule–Thomson effect; inversion temperature; isentropic expansion, phase equilibrium and P–T diagrams; safety aspects in handling cryogenic fluids.
Module 2.	Principles of gas liquefaction, minimum work of liquefaction, Figure of Merit (FOM), Linde–Hampson cycle, Claude cycle, Collins cycle, Brayton cryogenic refrigeration cycle, regenerative and recuperative heat exchangers, cryogenic refrigerators and cryocoolers (Stirling, Gifford–McMahon, Pulse Tube), performance evaluation and COP.
Module 3.	Heat transfer at cryogenic temperatures, conduction, convection, radiation, boiling, and condensation; thermal conductivity of insulation materials; vacuum insulation; multilayer insulation (MLI), radiation shields, cryostats and Dewar flasks, boil-off losses; storage, handling, and transportation of cryogenic liquids, transfer lines and piping.
Module 4.	Cryogenic pumps, compressors, turbo-expanders, valves, and heat exchangers, cryogenic piping systems; pressure relief devices, instrumentation for measurement of temperature, pressure, flow, and liquid level, cryogenic sensors, process control, material selection for cryogenic service, mechanical properties of materials at low temperatures, embrittlement and thermal stresses, design considerations and safety standards.
Module 5.	Air separation plants; liquefied natural gas (LNG) production, storage, and transportation, superconductivity and superconducting magnets, cryogenic applications in space technology and rocket propulsion, cryogenic preservation and biomedical applications, food freezing and preservation; hydrogen liquefaction and storage, emerging applications in quantum computing, fusion technology, and sustainable energy systems.

Activity Module (Internal Evaluation Only-10 Marks)

Activity	Example Task
Using the tools learned on Module 1, design a variety of items, including:	Study the thermophysical properties of liquid nitrogen, oxygen, hydrogen, and helium using published data, and plot the variation of density or specific heat with temperature using spreadsheet software or MATLAB.
Using the tools learned on Module 2, design a variety of items, including:	Draw the schematic and T–s diagram of the Linde–Hampson and Claude liquefaction cycles, and compare their operating principles and applications.
Using the tools learned on Module 3, design a variety of items, including:	Estimate the heat leak and boil-off rate of a cryogenic storage vessel using standard equations, and compare the effectiveness of different insulation materials.
Using the tools learned on Module 4, design a variety of items, including:	Prepare a CAD model of a Dewar flask or cryogenic storage vessel, identify its major components, and explain the function of cryogenic instrumentation and safety devices.

Using the tools learned on Module 5, design a variety of items, including:	Prepare a case study or presentation on the application of cryogenics in LNG storage, superconducting magnets, space technology, biomedical preservation, or hydrogen energy systems, highlighting the engineering challenges and benefits.

Practical Module (Internal and External Evaluation)

M.No:	Experiments
Module 1.	Study of cryogenic fluids and identification of cryogenic system components.
Module 2.	Determination of thermophysical properties of cryogenic fluids using REFPROP/EES or equivalent software.
Module 3.	Simulation of the Joule–Thomson expansion process and determination of inversion temperature.
Module 4.	Experimental determination/simulation of heat leak through cryogenic insulation materials.
Module 5.	Study of cryogenic pumps, valves, and pressure relief devices (demonstration/virtual laboratory).
Module 6.	Simulation of an Air Separation Unit (ASU) for oxygen and nitrogen production.

CLO-PLO Mapping Matrix

CLO \ PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO10	PLO11	PLO12
CLO1	3	2	0	1	1	0	1	0	0	0	0	1
CLO2	3	3	2	2	3	0	1	0	0	0	0	1
CLO3	3	3	2	2	2	0	2	0	0	0	0	1
CLO4	3	2	3	2	3	1	1	0	1	1	1	1
CLO5	2	2	2	1	2	2	3	0	1	1	0	2

Recommended Books

S.No:	Text Books	Author	Publisher
1.	Cryogenic Process Engineering	Klaus D. Timmerhaus and Thomas M. Flynn	Springer
2.	Cryogenic Systems	Randall F. Barron,	Oxford University Press
	References	**Author**	**Publisher**
1.	Cryogenic Engineering,	Russell B. Scott	D. Van Nostrand Company,
2.	Cryogenic Heat Transfer	R. F. Barron	Taylor & Francis

Course Code	**BMECDHV825**					
Category	**Professional Elective courses**					
Course Title	**Heating Ventilation and Air Conditioning**					
Scheme and Credits	**L**	**T**	**P**	**Credits**	**Semester- 8 (*Eight*)**	
	2	0	2	3		
Pre-requisites	**Basic Engineering, Thermodynamics, Refrigeration Systems, Heat Transfer**					

Course Learning Outcomes (CLOs)

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

i) **CLO1:** Explain psychrometric processes, human comfort, and ventilation principles for HVAC applications. ***(L2)***

ii) **CLO2:** Analyze refrigeration systems and evaluate refrigerants based on performance and environmental considerations. ***(L4)***

iii) **CLO3:** Analyze air conditioning systems and perform cooling and heating load calculations for buildings. ***(L4)***

iv) **CLO4:** Analyze the design and performance of air distribution systems and HVAC equipment ***(L4)*** *v)* **CLO5:**Evaluate HVAC piping, control systems, and energy management strategies for efficient building operation. *(L5)*

Theory Module(Internal and External Evaluation)

M.No:	Topic
Module 1.	Introduction to HVAC and its applications, human thermal comfort and indoor environmental quality, thermal comfort principles, properties of moist air, psychrometric chart, psychrometric processes, sensible heat factor, ventilation requirements, outdoor air requirements, air filtration and indoor contaminants
Module 2.	Refrigeration principles, vapour compression refrigeration system, vapour absorption refrigeration system, heat pumps, refrigerants, environmental impact of refrigerants (ODP and GWP), compressors, condensers, evaporators, expansion devices, cooling towers, Air Handling Units (AHUs), Fan Coil Units (FCUs), chillers
Module 3.	Building heat transfer, solar heat gain, internal heat gains, ventilation and infiltration loads, residential cooling load calculation, commercial cooling load calculation, heating load estimation, peak load determination, building energy balance, HVAC equipment selection
Module 4.	Air distribution principles, duct design, duct sizing methods, pressure losses, fan selection, air terminals, diffusers, grilles, hydronic piping systems, pumps, chilled water systems, DX systems, Variable Air Volume (VAV), Constant Air Volume (CAV), Building Management Systems (BMS), HVAC control strategies
Module 5.	Energy-efficient HVAC design, Variable Refrigerant Flow (VRF/VRV), Heat recovery systems, green buildings and HVAC, ASHRAE standards, building energy codes, thermal energy storage, renewable energy-based HVAC, maintenance, testing, balancing, and commissioning of HVAC systems, smart HVAC systems, IoT-enabled monitoring, AI and predictive HVAC control, HVAC simulation and optimization

Activity Module (Internal Evaluation Only-10 Marks)

Activity	Example Task
Using the tools learned on Module 1, design a variety of items, including:	Perform psychrometric analysis to determine air-conditioning processes, thermal comfort conditions, ventilation requirements, and indoor air quality using a psychrometric chart, CoolPack, or Python.
Using the tools learned on Module 2, design a variety of items, including:	Simulate a vapour compression refrigeration system using CoolPack, MATLAB, or Python, and evaluate the effects of refrigerant selection, superheating, and subcooling on system COP and performance.
Using the tools learned on Module 3, design a variety of items, including:	Estimate the cooling and heating loads of a classroom, office, or residential building using the CLTD/CLF method or HVAC load calculation software such as HAP, CoolCalc, and select suitable HVAC equipment.
Using the tools learned on Module 4, design a variety of items, including:	Design and simulate an air distribution duct network using the equal-friction or static-regain method, perform duct sizing, select fans, diffusers, and grilles, and analyze airflow using DuctSizer or Revit MEP.
Using the tools learned on Module 5, design a variety of items, including:	Perform an energy assessment of an HVAC system, compare conventional and energy-efficient HVAC configurations, and recommend energy-saving measures through building energy simulation and smart control strategies using HAP, EnergyPlus or TRNSYS.

Practical Module (Internal and External Evaluation)

M.No:	Experiments
Module 1.	Determine the psychrometric properties of moist air and analyze air-conditioning processes using a psychrometric chart or software
Module 2.	Conduct a performance test on a vapour compression refrigeration (VCR) test rig and determine the Coefficient of Performance (COP).
Module 3.	Perform an energy performance test on a domestic refrigerator and determine the Energy Efficiency Ratio (EER) or COP under different operating conditions.
Module 4.	Study the performance characteristics of an air-conditioning test rig by varying operating parameters and evaluating cooling capacity.
Module 5.	Estimate the cooling and heating loads of a classroom or office building using the Carrier HAP software.
Module 6.	Design an air distribution duct system using the equal-friction or static-regain method and select suitable fans, diffusers, and grilles.

Module 7.	Develop a building energy model in Carrier HAP and calculate cooling and heating loads for a residential or commercial building.
Module 8.	Design a complete HVAC system by selecting chillers, AHUs, FCUs, ducts, and air distribution components based on calculated building loads using Carrier HAP.
Module 9.	Conduct a case study and energy audit of an existing HVAC installation and recommend energy conservation measures based on ASHRAE guidelines.
Module 10.	Visit a commercial HVAC facility (central air-conditioning plant, cold storage, or chilled water plant) and prepare a technical report on system configuration, operation, controls, and maintenance practices.

CLO-PLO Mapping Matrix

CLO \ PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO10	PLO11	PLO12
CLO1	3	2	0	1	1	1	2	0	0	0	0	1
CLO2	3	3	2	2	3	0	3	0	0	0	0	1
CLO3	3	3	3	2	2	1	2	0	0	0	1	1
CLO4	3	3	3	2	3	0	1	0	1	1	1	1
CLO5	2	2	2	2	3	2	3	0	1	1	2	2

Recommended Books

S.No:	Text Books	Author	Publisher
1.	Refrigeration and Air Conditioning Tata	Arora.C.P	McGraw Hill
2.	Refrigeration and Air Conditioning	W. F. Stoecker and J. W. Jones	McGraw-Hill Education
3.	Heating, Ventilating, and Air Conditioning: Analysis and Design	F. C. McQuiston, J. D. Parker, and J. D. Spitler,	John Wiley & Sons, Latest Edition.
	References	**Author**	**Publisher**
1.	Handbook – Fundamentals	ASHRAE	ASHRAE
2.	Handbook – HVAC Systems and Equipment,	ASHRAE	ASHRAE
3.	Handbook – HVAC Applications	ASHRAE	ASHRAE
4.	Heating and Cooling of Buildings: Design for Efficiency	Jan F. Kreider	CRC Press.
5.	Handbook of Air Conditioning System Design	Carrier Air Conditioning Company	McGraw-Hill.
6.	Principles of Heating, Ventilating, and Air Conditioning	H. J. Sauer, R. H. Howell, and W. J. Coad	ASHRAE.
7.	Principles of Refrigeration,	Roy J. Dossat and Thomas J. Horan	Pearson Education.
8.	Fundamentals of Refrigeration Thermodynamics,	J. S. Brown	Butterworth-Heinemann

---

Course Code	**BMECDCM825**				
Category	**Professional Elective Course**				
Course Title	**Composite Materials**				
Scheme and Credits	L 2	T 0	P 2	Credits 3	Semester- 8 (*Eight*)
Pre-requisites	**Material Engineering**				

Course Learning Outcomes (CLOs)

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

i) **CLO1:** ***Understand*** the classification, constituents, properties, and functions of engineering composite materials, including different matrix and reinforcement materials. ***(L2)***

ii) **CLO2:** ***Compare*** various types of matrices, reinforcements, fibers, and composite materials based on their properties, performance, advantages, and engineering applications. ***(L2)***

iii) **CLO3:** ***Interpret*** the influence of reinforcement, matrix selection, and fabrication methods on the mechanical behavior and engineering performance of composite materials. ***(L5)***

iv) **CLO4**: ***Illustrate*** and draw the manufacturing processes and testing procedures used for composite materials, including autoclave curing, compression moulding, filament winding, and mechanical testing methods. ***(L3)***

v) **CLO5:** ***Select*** and assemble suitable matrix materials, reinforcements, and fabrication techniques to design composite materials for specific engineering applications. ***(L5)***

Theory Module(Internal and External Evaluation)

M.No:	Topic
Module 1.	Classifications of engineering materials, concept of composite materials, matrix materials, functions of a matrix, desired properties of a matrix, polymer matrices (thermosets and thermoplastics), metal matrices, ceramic matrices, carbon matrices, glass matrices.
Module 2.	Types of matrices and reinforcements, classification based on matrix materials, organic matrix, polymer matrix, carbon matrix, metal matrix, ceramic matrix, classification based on reinforcements, types of fibres, glass fibres, carbon fibres, aramid fibres, metal fibres, alumina fibres, boron fibres, silicon carbide fibres, quartz and silica fibres, multiphase fibres, whiskers, flakes, mechanical properties of fibres, material properties improved by composite materials, engineering potential of composite materials.
Module 3.	Types of composites, fibre reinforced composites, fibre reinforced polymer (FRP) composites, laminar composites, particulate composites, comparison with metals, advantages and limitations of composite materials.
Module 4.	Fabrication methods of composite materials, processing considerations, autoclave curing, filament winding, compression moulding, resin transfer moulding, prepreg lay-up, fibre-only preforms, combined fibre-matrix preforms, tooling and specialty materials, release agents, peel plies, release films and fabrics, bleeder and breather plies, bagging films.
Module 5.	Testing of composite materials, mechanical testing of composites, tensile testing, compressive testing, intra-laminar shear testing, inter-laminar shear testing, fracture testing.

Activity Module (Internal Evaluation Only-10 Marks)

Activity	Example Task
Using the tools learned on Module 1, design a variety of items, including:	Comparison of mechanical properties of different matrix materials using Material Data (using Excel/MATLAB)
Using the tools learned on Module 2, design a variety of items, including:	Effect of fiber volume fraction on composite strength calculation (Using Excel/MATLAB)
Using the tools learned on Module 3, design a variety of items, including:	Calculation of Elastic properties of fiber reinforced polymer composites (using Excel/MATLAB)
Using the tools learned on Module 4, design a variety of items, including:	Simulation of composite laminate stacking sequence and orientation effect (using MATLAB/ANSYS Student)
Using the tools learned on Module 5 design a variety of items, including:	Calculation of interlaminar shear strength and failure analysis of composite laminates (using Excel/MATLAB)

Practical Module (Internal and External Evaluation)

M.No:	Experiments
Module 1.	Study of the Vacuum-Assisted Infusion Molding (VAIM) setup and identification of its components.
Module 2.	Fabrication of a Glass Fiber Reinforced Polymer (GFRP) laminate using Vacuum-Assisted Infusion Molding.
Module 3.	Fabrication of Fiber Reinforced Polymer (FRP) composite laminate using hand lay-up molding technique.
Module 4.	Evaluation of void content and laminate quality produced by VAIM.
Module 5.	Effect of fiber orientation on mechanical properties of composites.
Module 6.	Microscopic examination of fiber orientation, laminate structure, and fracture surfaces.
Module 7.	Determination of fiber volume fraction, resin content, density, and void content of composite laminates.
Module 8.	Study of moisture absorption behavior of polymer matrix composites and its effect on mechanical properties.
Module 9.	Study of composite manufacturing processes using virtual laboratories.
Module 10.	Study of curing parameters (temperature and time) on the properties of polymer matrix composites.

CLO-PLO Mapping Matrix												
CLO \ PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO10	PLO11	PLO12
CLO1	3	2	0	0	0	0	0	0	0	0	0	1
CLO2	2	3	2	0	0	0	0	0	0	0	0	1
CLO3	2	3	3	2	1	0	1	0	0	0	0	1
CLO4	2	2	2	3	3	0	0	0	0	1	0	0
CLO5	2	2	3	2	2	1	2	1	2	1	2	3

Recommended Books

S.No:	Text Books	Author	Publisher
1.	Introduction to Composite Materials Design	Ever J. Barbero	CRC Press
2	Engineering Materials: Polymers, Ceramics and Composites	A.K Bhargava	Prentice Hall India.
3.	Composite Materials Science and Engineering	K. K. Chawla	Springer-Verlag New York.
	References	**Author**	**Publisher**
1.	Composite Materials: Science and Applications	Deborah D. L. Chung	Springer
2.	Fundamentals of Materials Science and Engineering	William D. Callister, Jr., David G. Rethwisch	John Wiley & Sons

---

Course Code	**BMECDPP825**				
Category	**Professional Elective Courses**				
Course Title	**Power Plant Engineering**				
Scheme and Credits	**L** 2	**T** 1	**P** 0	**Credits** 3	**Semester- 8 (*Eight*)**
Pre-requisites	**Engineering Thermodynamics and Heat Transfer**				

Course Learning Outcomes (CLOs)

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

i) **CLO1:** Explain the principles, components, and operation of thermal, hydro, nuclear, gas turbine, and diesel power plants. *(L2)*

ii) **CLO2:** Compare different power plants based on efficiency, economics, reliability, environmental impact, and applications. ***(L1)***

iii) **CLO3:** Analyze power plant performance using energy conversion processes, heat balance, and operating parameters. *(L2)*

iv) **CLO4** : Design and interpret schematic layouts of power plants, including major components, auxiliary systems, and pollution control equipment. ***(L3)***

v) **CLO5:** Apply engineering principles to solve problems related to power generation, plant performance, energy conservation, and environmental sustainability. ***(L5)***

Theory Module(Internal and External Evaluation)

M.No	Topic
Module 1.	Fuels and combustion, thermodynamic cycles of steam power plants, Rankine cycle, actual Rankine cycle, reheat cycle, Carnot cycle, heat rate, classification of fuels, calorific value and its determination,

	combustion equations, stoichiometric air-fuel ratio, excess air requirement, actual air-fuel ratio, flue gas analysis, pulverized coal firing system, fluidized bed combustion.
Module 2.	Thermal power plants, introduction, layout of modern coal-fired power plants, supercritical boilers, fluidized bed combustion boilers, steam turbines, condensers, steam rate and heat rate, fuel handling system, ash handling system, draught system, feedwater treatment, binary cycles, cogeneration systems.
Module 3.	Hydroelectric power plants, general layout and arrangement, types of hydraulic turbines, principles of impulse and reaction turbines, turbine characteristics, selection of turbines, governing of turbines, performance characteristics of hydroelectric power plants.
Module 4.	Diesel power plants, layout and main components, working principle, diesel plant efficiency, heat balance, performance characteristics, selection of diesel power plants, applications and limitations.
Module 5.	Basics of nuclear engineering, layout and subsystems of nuclear power plants, working principles of nuclear reactors, boiling water reactor, pressurized water reactor, Canada deuterium uranium reactor, breeder reactor, gas-cooled reactor, liquid metal-cooled reactor, safety measures for nuclear power plants.

Activity Module (Internal Evaluation Only-10 Marks)

Activity	Example Task
Using the tools learned on Module 1, design a variety of items, including:	Develop a computational model to determine the calorific value, theoretical air requirement, excess air, air–fuel ratio, and flue gas composition for different fuels. Compare combustion performance under varying operating conditions using MATLAB or Python.
Using the tools learned on Module 2, design a variety of items, including:	Develop a computational model of the Rankine cycle to determine thermal efficiency, heat rate, steam rate, and condenser performance. Investigate the effects of boiler pressure, condenser pressure, and degree of superheating on plant performance using MATLAB, or Python.
Using the tools learned on Module 3, design a variety of items, including:	Develop a computational model to estimate turbine power output and efficiency for different head and discharge conditions. Select a suitable hydraulic turbine and compare the performance characteristics of impulse and reaction turbines using MATLAB, or Python.
Using the tools learned on Module 4, design a variety of items, including:	Develop a computational model to calculate the heat balance sheet, brake thermal efficiency, specific fuel consumption, and overall plant efficiency of a diesel power plant. Investigate the influence of operating parameters on plant performance using MATLAB, or Python.
Using the tools learned on Module 5, design a variety of items, including:	Develop a computational model to estimate reactor thermal efficiency and power output under different operating conditions. Compare the performance characteristics of BWR, PWR, PHWR (CANDU), Fast Breeder, and Gas-Cooled reactors, and analyze basic reactor safety parameters using MATLAB, or Python.

CLO-PLO Mapping Matrix

CLO \ PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO10	PLO11	PLO12
CLO1	3	1	0	0	0	1	1	0	0	0	0	1
CLO2	2	3	1	2	0	2	3	1	0	1	0	1
CLO3	2	3	1	3	2	1	2	0	0	1	0	1
CLO4	2	2	3	1	2	1	2	0	1	1	2	1
CLO5	3	3	2	2	2	2	3	1	1	1	2	2

Recommended Books

S.No:	**Text Books**	**Author**	**Publisher**
1.	Power Plant Engineering	P. K. Nag,	McGraw Hill
2.	HA Textbook of Power Plant Engineering	R. K. Rajput	McGraw Hill
	References	**Author**	**Publisher**
1.	Power Plant Technology	El-Wakil. M.M.	McGraw Hill

2.	Power Plant Engineering	C. Thomas, Elliott, Kao Chen and C. Robert Swanekamp	McGraw Hill

Course Code	**BMECDIC825**				
Category	**Professional Elective Course**				
Course Title	**Introduction to Computational Mechanics**				
Scheme and Credits	**L** 2	**T** 0	**P** 2	**Credits** 2	**Semester- 8 (*Eight*)**
Pre-requisites	**Engineering Mathematics**				

Course Learning Outcomes (CLOs)

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

i) **CLO1:** ***Understand*** the fundamentals of computational mechanics, mathematical modelling, and numerical methods for engineering analysis.(L2)

ii) **CLO2:** ***Apply*** computational tools to model and solve solid mechanics, heat transfer, and fluid flow problems.(L1)

iii) **CLO3:** ***Analyze*** computational results through visualization, validation, and interpretation of engineering simulations.(L3)

iv) **CLO4:** ***Develop*** computational models using modern engineering software for multidisciplinary engineering applications. *(L4)*

v) **CLO5:** ***Evaluate*** engineering systems using computational mechanics and AI-assisted simulation tools for design and optimization. *(L6)*

Theory Module(Internal and External Evaluation)

M.No:	Topic
Module 1.	Introduction to computational mechanics, role and scope in engineering, engineering systems and mathematical modelling, governing equations, input and output variables, boundary and initial conditions, computational workflow, overview of computational platforms (MATLAB, Python, ANSYS, OpenFOAM or equivalent).
Module 2.	Dimensional analysis and non-dimensionalization, introduction to numerical methods, concepts of finite difference, finite volume and finite element methods, discretization of engineering problems, structured and unstructured meshes, convergence and error concepts.
Module 3.	Introduction to computational solid mechanics, stress and strain analysis, deformation of engineering components, displacement and stress visualization, verification of computational results using analytical solutions, engineering applications.
Module 4.	Introduction to computational heat transfer and fluid flow, steady-state heat conduction, basic concepts of computational fluid dynamics, temperature, pressure and velocity distributions, contour plots, streamlines, engineering applications.
Module 5.	Introduction to multiphysics analysis, computational modelling in manufacturing, machine design, automotive, aerospace and energy systems, interpretation and validation of computational results, limitations of computational methods, emerging trends in computational mechanics and artificial intelligence.

Activity Module (Internal Evaluation Only-10 Marks)

Activity	Example Task
Using the tools learned on Module 1, design a variety of items, including:	Develop a mathematical model of an engineering problem and implement it using MATLAB/Python.
Using the tools learned on Module 2, design a variety of items, including:	: Generate structured and unstructured meshes and perform numerical discretization using ANSYS/OpenFOAM.
Using the tools learned on Module 3, design a variety of items, including:	Simulate stress, strain, and deformation of a mechanical component using ANSYS Mechanical and validate the results with analytical solutions.

Using the tools learned on Module 4, design a variety of items, including:	Perform heat transfer and fluid flow simulations using ANSYS Fluent/OpenFOAM and interpret temperature, pressure, velocity contours, and streamlines.
Using the tools learned on Module 5, design a variety of items, including	Carry out a multidisciplinary computational analysis and apply AI-assisted optimization or MATLAB/Python tools to improve engineering design performance.

Practical Module (Internal and External Evaluation)

M.No:	Experiments
Module 1.	Familiarization with a computational mechanics platform; create a simple 3D mechanical component (beam, plate, or bracket) and assign material properties.
Module 2.	Generate a computational mesh for a simple component and study the effect of mesh size on the quality of the numerical solution.
Module 3.	Apply boundary conditions and external loads to a simple structural component and perform a basic static structural analysis.
Module 4.	Perform a steady-state heat conduction analysis of a plate or fin and visualize the temperature distribution and heat flux.
Module 5.	Simulate two-dimensional internal or external fluid flow and visualize pressure, velocity, and streamline contours.
Module 6.	Compare computational results with analytical solutions for a simple engineering problem such as axial deformation of a bar or heat conduction through a wall.
Module 7.	Investigate the influence of material properties, loading conditions, or geometric dimensions on the computational response of an engineering component.
Module 8.	Develop a simple engineering model integrating geometry creation, meshing, analysis, post-processing, and interpretation of results using a computational platform, and present the findings in the form of a technical report.

CLO-PLO Mapping Matrix

CLO \ PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO10	PLO11	PLO12
CLO1	3	2	1	1	2	0	0	0	0	1	0	1
CLO2	2	3	2	2	3	0	0	0	0	1	0	1
CLO3	2	3	2	3	3	0	0	0	0	1	0	1
CLO4	2	3	3	3	2	0	0	0	0	2	0	1
CLO5	3	3	3	2	3	1	1	0	1	2	0	2

Recommended Books

S.No:	Text Books	Author	Publisher
1.	Computational Fluid Dynamics	T. J. Chung,	Cambridge University Press.
2.	Introduction to Finite Element Analysis and Design	Nam-Ho Kim & Bhavani V. Sankar	Wiley
3.	Engineering Analysis with SOLIDWORKS Simulation	Paul Kurowski	SDC Publications
	References	**Author**	**Publisher**
1.	Finite Element Procedures,	K. J. Bathe,	Prentice Hall.
2.	Numerical Heat Transfer and Fluid Flow,	S. V. Patankar,	CRC Press.

Course Code	**BMECDSP825**				
Category	**Professional Elective**				
Course Title	**Solar PV Installation & Design**				
Scheme and Credits	L 2	T 1	P 0	Credits 3	Semester- **8** (*Eight*)
Pre-requisites	**Basic Electrical Engineering and Electrical Measurements.**				

Course Learning Outcomes (CLOs)

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

i) **CLO1:** ***Understand*** the fundamentals, components, working principles, and applications of Solar Photovoltaic (PV) systems. ***(L1)***

ii) **CLO2:** ***Compare*** different Solar PV technologies, modules, inverters, batteries, and mounting systems based on performance and applications. ***(L2)***

iii) **CLO3:** ***Interpret*** solar resource data, PV system characteristics, performance parameters, and site assessment results for system planning. ***(L3)***

iv) **CLO4:** ***Design*** grid-connected and stand-alone Solar PV systems, including system sizing, component selection, and electrical layouts. ***(L4)***

v) **CLO5:** ***Apply*** engineering principles and safety practices for the installation, commissioning, testing, and troubleshooting of Solar PV systems. ***(L5)***

Theory Module(Internal and External Evaluation)

M.No:	Topic
Module 1.	Introduction to PV systems, basics of photovoltaic cells, modules and arrays, materials for solar cells, photovoltaic technologies, photovoltaic modules, electrical parameters of PV modules, factors influencing the output of PV modules.
Module 2.	Photovoltaic module characteristics, V–I characteristics of solar panels, temperature effects on module characteristics, effects of electrical load mismatching, specifications of solar panels, series and parallel connections of solar panels.
Module 3.	PV system sizing (load estimation), daily load sizing, weekly average load sizing, daily load demand, estimation of continuous surge power for complex systems, calculation of ampere-hours for AC loads, efficient loads, types of lamps, electrical efficiency, lamp efficacy.
Module 4.	System sizing (array and battery), array and battery sizing principles, complete battery sizing calculations, basic array sizing calculations, complete array sizing calculations, loss estimation (shading and temperature), array sizing software.
Module 5.	System wiring, wire sizing based on ampacity, wire sizing based on voltage drop, electrical configurations for array wiring, overcurrent protection devices, equipment grounding for photovoltaic systems, lightning and surge protection, grounding methods, losses affecting the yield of solar PV systems, components of grid-connected PV systems.

Activity Module (Internal Evaluation Only-10 Marks)

Activity	Example Task
Using the tools learned on Module 1, design a variety of items, including:	Identify and characterize different PV cells, modules, and solar technologies through laboratory demonstrations.
Using the tools learned on Module 2, design a variety of items, including:	Plot and analyze the V–I and P–V characteristics of a photovoltaic module under varying irradiance and temperature conditions.
Using the tools learned on Module 3, design a variety of items, including:	Estimate electrical load demand and perform PV array and battery sizing for a residential or commercial application using manual calculations or PVsyst/MATLAB.
Using the tools learned on Module 4, design a variety of items, including:	Design a stand-alone or grid-connected Solar PV system, including array configuration, battery bank sizing, and component selection using PV design software.
Using the tools learned on Module 5, design a variety of items, including:	Prepare the electrical wiring layout of a Solar PV system, including cable sizing, grounding, overcurrent protection, surge protection, and grid interconnection in accordance with relevant standards.

CLO-PLO Mapping Matrix

CLO \ PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO10	PLO11	PLO12

CLO1	3	1	0	0	0	2	3	0	0	0	0	1
CLO2	2	3	1	2	1	1	3	0	0	1	0	1
CLO3	2	3	1	3	3	1	2	0	0	1	0	1
CLO4	2	2	3	1	3	2	3	1	1	1	2	1
CLO5	3	3	3	2	3	2	3	3	2	1	2	2

Recommended Books

S.No:	Text Books	Author	Publisher
1.	Solar Photovoltaics: Fundamentals, Technologies and Applications,	Chetan Singh Solanki,	PHI Learning Pvt. Ltd.
2.	Solar Energy: Principles of Thermal Collection and Storage,	S. P. Sukhatme and J. K. Nayak,	McGraw-Hill Education.
3.	Fundamentals of Photovoltaic Modules and Their Applications,	G. N. Tiwari and Swapnil Dubey,	Royal Society of Chemistry.
	References	**Author**	**Publisher**
1.	Handbook of Photovoltaic Science and Engineering	Antonio Luque and Steven Hegedus (Eds.),	Wiley Publication
2.	Photovoltaic Systems	James P. Dunlop	American Technical Publishers.

Course Code	**BMECPFP825**				
Category	**Project work, Seminar and Internship**				
Course Title	**Final Year Project**				
Scheme and Credits	**L** 0	**T** 0	**P** 14	**Credits** 7	**Semester- 8 (*Eight*)**
Pre-requisites	-				

Course Learning Outcomes (CLOs)

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

i) **CLO1:** ***Identify*** and formulate a mechanical engineering problem through literature review, problem analysis, and requirement specification. (L3)

ii) **CLO2:** ***Apply*** engineering principles, computational tools, experimental techniques, and design methodologies to develop solutions for mechanical engineering problems. (L3)

iii) **CLO3:** ***Analyze*** and validate the performance of mechanical systems through simulation, experimentation, and interpretation of results. (L4)

iv) **CLO4:** ***Develop*** a prototype, product, process, or simulation model by integrating appropriate design, manufacturing, testing, and optimization techniques. (L6)

v) **CLO5:** ***Design*** and present an innovative mechanical engineering solution by demonstrating technical competence, teamwork, project management, professional ethics, and effective communication. (L6)

Plan for Conducting the Course

The plan of conducting this course is given below:

1. Participants will be divided into groups of two/four members within the first week of the starting of the course by the course coordinators/managers depending upon the number of participants registered in the course.
2. The groups will have a group leader, who will be identified by the course coordinators of the course (may be the first name in the list of a student team).
3. Projects may be selected from the following areas:

   a) Research and Literature Survey: Critical review of recent developments in design engineering, manufacturing, thermal engineering, renewable energy, robotics, tribology, computational mechanics, CAD/CAM, finite element analysis, CFD, materials engineering, additive manufacturing, and industrial engineering.

b) Design and Analysis: Design, modelling, simulation, and optimization of mechanical components or systems using CAD/CAE software such as SolidWorks, CATIA, ANSYS, Abaqus, MATLAB, or OpenFOAM.

c) Experimental Investigation: Development and testing of experimental setups, performance evaluation of thermal and mechanical systems, vibration analysis, tribological investigations, renewable energy systems, or manufacturing processes.

d) Product Development: Design and fabrication of innovative mechanical systems, automation devices, renewable energy products, assistive devices, smart manufacturing systems, or Industry 4.0 solutions.

4. Each team shall submit a project proposal containing within two weeks of commencement.:
    01. Problem statement
    02. Objectives
    03. Literature review
    04. Methodology
    05. Expected outcomes
    06. Hardware/software requirements
    07. Work plan

The project supervisor shall periodically monitor progress through review meetings.

5. At the end of the semester, each team shall submit:
    01. Project Report
    02. CAD models and engineering drawings
    03. Simulation files/programs
    04. Experimental data
    05. Prototype (if applicable)
    06. Presentation (10–15 slides)

6. Evaluation Scheme

01. Internal Evaluation (50%)

Project proposal and literature review-**25%**
Progress review and implementation- **50%**
Documentation and presentation- **25%**

02. External Evaluation (80%)

Project demonstration and viva-voce - **50%**
Technical quality, innovation, implementation, and performance - **37%**
Project report and presentation - **12%**

CLO-PLO Mapping Matrix

CLO \ PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO10	PLO11	PLO12
CLO1	3	2	0	0	1	1	0	0	0	0	0	1
CLO2	3	3	2	2	3	1	0	0	0	1	0	1
CLO3	2	3	3	3	3	1	0	0	0	1	0	1
CLO4	2	2	3	3	3	1	0	0	2	2	0	2
CLO5	2	2	3	3	3	1	1	1	3	2	1	3

Recommended Books

S.No.	References	Author	Publisher
1.	Research Methodology for Engineers,	CR. Ganesan,	MJP Publishers.
2.	Research Design: Qualitative, Quantitative, and Mixed Methods Approaches,	John W. Creswell	Sage Publications.

Course Code	BMECPIN825				
Category	Project work, Seminar and Internship				
Course Title	Internship				
Scheme and Credits	L 0	T 0	P 0	Credits 1	Semester - 8 (*Eight*)
Pre-requisites	-				

Course Learning Outcomes (CLOs)

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

i) **CLO1:** Understand industrial practices, organizational structure, engineering processes, and professional ethics. *(L2)*

ii) **CLO2:** Apply mechanical engineering principles and modern engineering tools to industrial tasks and problem-solving. *(L3)*

iii) **CLO3:** Analyze manufacturing, maintenance, quality, design, or thermal engineering operations in an industrial environment. *(L4)*

iv) **CLO4:** Demonstrate technical competency by completing assigned industrial tasks and documenting observations and outcomes. *(L3)*

v) **CLO5:** Prepare and present a comprehensive internship report demonstrating technical knowledge, communication skills, teamwork, and professional responsibility. *(L5)*

Plan for Conducting the Course

Schedule	Duration	Activities
During Vacation after 5th Semester	4-6 weeks	Industrial/Govt./ NGO/MSME/ Rural Internship/ Innovation / Entrepreneurship
During Vacation after 7th Semester	4-6 weeks	Industrial/Govt./ NGO/ MSME/ Rural Internship/ Innovation / Entrepreneurship

1. Monitoring/ surprise visit by Training and Project Incharge (TPI)/ staff

TPI/ Staff of the institutes will make a surprise visit to the internship site, to check the student's presence physically, if the student is found absent without prior intimation to the TPI, entire training will be cancelled. Students should inform the TPI, as well as the industry supervisor at least one day prior to availing leave by email. Students are eligible to avail 1-day leave in 4 weeks and 2 days leave in 6 weeks of the internship period apart from holidays and weekly offs.

2. Evaluation through Seminar Presentation/ Viva-Voce

The student will give a seminar based on his training report, before an expert committee constituted by the concerned department on the basis of:

1. Quality of content presented
2. Proper planning for presentation.
3. Effectiveness of presentation.
4. Depth of knowledge and skills.
5. Attendance record, daily diary.

3. Evaluation Scheme

3.1 Internal Evaluation (50%)

Internship proposal and literature review-**25%**
Progress review and implementation- **50%**
Documentation and presentation- **25%**

3.2 External Evaluation (80%)

Internship demonstration and viva-voce - **50%**
Technical quality, innovation, implementation, and performance - **38%**
Project report and presentation - **12%**

CLO-PLO Mapping Matrix

CLO \ PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO10	PLO11	PLO12
CLO1	2	2	0	1	1	2	2	3	1	1	0	1
CLO2	3	3	2	2	3	1	1	1	2	1	0	2
CLO3	2	3	2	3	2	2	2	1	2	1	0	2
CLO4	2	2	3	3	3	1	1	1	3	2	1	2
CLO5	2	2	2	2	2	2	2	2	3	3	2	3

Recommended Books

S.No.	References	Author	Publisher
1.	Research Methodology for Engineers,	CR. Ganesan,	MJP Publishers.
2.	Research Design: Qualitative, Quantitative, and Mixed Methods Approaches,	John W. Creswell	Sage Publications.