SYLLABUS

For

B.Tech. PROGRAMME

in

MECHANICAL ENGINEERING



UNIVERSITY OF KASHMIR
SRINAGAR

JULY – 2026

(Applicable to Batch 2025 & Onwards)

Coordinator (DOME)
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COURSE STRUCTURE, B.Tech MECHANICAL ENGINEERING

THIRD SEMESTER TO EIGHTH SEMESTER

Indicator Alphabit			
E	Engineering Science Courses	L	Experiential Learning Course/ Lab Course
B	Basic Science Courses	H	Humanities and Social Sciences including
C	Professional Core Course	Y	Seminar
D	Professional Elective Course	P	Project work/Internship
O	Open Elective Course	A	Audit Course

ISE	Internal Semester Evaluation (**50 *Marks***)	
	MSE	Mid Semester Evaluation (***35 Marks***)
	CA	Contineous Assessment (***Assignment + Quiz/ Viva Voce (10 Marks) + Attendence (5 Marks)***)
ESA	End Semester Evaluation	

Semester - 3 (*Three*)

Course Code	Course Title	L	T	P	Credits	Examination Scheme (*Distribution of Marks*)										
						ISE (*Theory*)			ISE (*Practical*)			Internal (*Total*)	ESE (*Theory*)	ESE (*Practical*)	External (*Total*)	Total
						MSE	CA	Total	MSE	CA	Total					
BMECCDR325	Dynamics of Rigid Bodies	2	1	0	3	35	15	50	0	0	0	50	50	0	50	100
BMECCCM325	Computer Aided Drawing and Modelling	0	0	4	2	0	0	0	35	15	50	50	0	50	50	100
BMECCME325	Materials Engineering	2	1	2	4	35	15	50	35	15	50	100	50	50	100	200
BMECCET325	Engineering Thermoynamics	2	1	0	3	35	15	50	0	0	0	50	50	0	50	100
BMECCFM325	Fluid Mechanics	2	1	2	4	35	15	50	35	15	50	100	50	50	100	200
BMECCMP325	Metal Cutting and Machining Processes	2	1	2	4	35	15	50	35	15	50	100	50	50	100	200
		10	**5**	**10**	20											**900**
	Total Hours		**25**													

Semester - 4 (*Four*)

Course Code	Course Title	L	T	P	Credits	Examination Scheme (*Distribution of Marks*)										
						ISE (*Theory*)			ISE (*Practical*)			Internal (*Total*)	ESE (*Theory*)	ESE (*Practical*)	External (*Total*)	Total
						MSE	CA	Tota	MSE	CA	Total					
BMECBPD425	Partial Differential Equations, Laplace and Z-transform	2	1	0	3	35	15	50	0	0	0	50	50	0	50	100
BMECCMS425	Mechanics of Solids	2	1	2	4	35	15	50	35	15	50	100	50	50	100	200
BMECD**425	Professional Elective-I	1	0	2	2	35	15	50	35	15	50	100	50	50	100	200
BMECCTM425	Theory of Machines	2	1	2	4	35	15	50	35	15	50	100	50	50	100	200
BMECLFM425	Fluid Machinery	0	2	2	3	0	0	0	35	15	50	50	0	50	50	100
BMECCMC425	Metal Casting and Forming Processes	2	1	2	4	35	15	50	35	15	50	100	50	50	100	200
		9	**6**	**10**	20											**1000**
	Total Hours		**25**													

Semester - 5 (*Five*)

Course Code	Course Title	L	T	P	Credits	Examination Scheme (*Distribution of Marks*)										
						ISE (*Theory*)			ISE (*Practical*)			Internal (*Total*)	ESE (*Theory*)	ESE (*Practical*)	External (*Total*)	Total
						MSE	CA	Total	MSE	CA	Total					
BMECBCA525	Complex Analysis and Special Functions	2	1	0	3	35	15	50	0	0	0	50	50	0	50	100
BMECCAC525	Automatic Control	2	0	2	3	15	35	50	35	15	50	100	0	50	50	150
BMECCHT525	Heat Transfer	2	1	2	4	35	15	50	35	15	50	100	50	50	100	200
BMECCAT525	Applied Thermodynamics	2	1	2	4	35	15	50	35	15	50	100	50	50	100	200
BMECCSM525	Structural Mechanics	2	1	0	3	35	15	50	0	0	0	50	50	50	100	150
BMECLMI525	Metrology & Instrumentation	0	2	2	3	0	0	0	35	15	50	50	0	50	50	100
		10	**6**	**8**	20											**900**
	Total Hours		**24**													

Semester - 6 (*Six*)

Course Code	Course Title	L	T	P	Credits	Examination Scheme (*Distribution of Marks*)										
						ISE (*Theory*)			ISE (*Practical*)			Internal (*Total*)	ESE (*Theory*)	ESE (*Practical*)	External (*Total*)	Total
						MSE	CA	Total	MSE	CA	Total					
BMECHIE625	Industrial Engineering	2	0	2	3	35	15	50	35	15	50	100	50	50	100	200
BMECCMV625	Mechanical Vibrations	2	1	2	4	35	15	50	35	15	50	100	50	50	100	200
BMECLIC625	Internal Combustion Engines	0	2	2	3	0	0	0	35	15	50	50	0	50	50	100
BMECO**625	Open Elective-I	2	0	2	3	35	15	50	35	15	50	100	50	50	100	200
BMECCDM625	Design of Machine Elements	2	1	0	3	35	15	50	0	0	0	50	50	0	50	100
BMECCCF625	Compressible Fluid Flow	2	1	2	4	35	15	50	35	15	50	100	50	50	100	200
		10	**5**	**10**	20											**1000**
	Total Hours		**25**													

Semester - 7 (*Seven*)						Examination Scheme (*Distribution of Marks*)										
Course Code	Course Title	L	T	P	Credits	ISE (Theory)			ISE (Practical)			Internal (Total)	ESE (Theory)	ESE (Practical)	External (Total)	Total
						MSE	CA	Total	MSE	CA	Total					
BMECLCM725	Computer Aided Manufacturing	0	0	6	3	0	0	0	35	15	50	50	0	50	50	100
BMECLWT725	Welding Technology	0	0	4	2	0	0	0	35	15	50	50	0	50	50	100
BMECD**725	Professional Elective II	2	0	2	3	35	15	50	35	15	50	100	50	50	100	200
BMECLOD725	Operation and Diagnostics of Machines	0	2	2	3	0	0	0	35	15	50	50	0	50	50	100
BMECCMD725	Machine Design	2	1	0	3	35	15	50	0	0	0	50	50	0	50	100
BMECHOR725	Operations Research	2	1	0	3	35	15	50	0	0	0	50	50	0	50	100
BMECPPP725	Final Year Pre-Project	0	0	6	3	0	0	0	35	15	50	50	0	50	50	100
		6	4	20	20											800
	Total Hours	30														

Semester - 8 (*Eight*)						Examination Scheme (*Distribution of Marks*)										
Course Code	Course Title	L	T	P	Credits	ISE (Theory)			ISE (Practical)			Internal (Total)	ESE (Theory)	ESE (Practical)	External (Total)	Total
						MSE	CA	Total	MSE	CA	Total					
BMECHPM825	Introduction to Project Management	2	1	0	3	35	15	50	35	15	50	100	50	50	100	200
BMECO**825	Open Elective-II	2	0	2	3	35	15	50	0	0	0	50	50	0	50	100
BMECD**725	Professional Elective-III	2	0	2	3	35	15	50	35	15	50	100	50	50	100	200
BMECD**825	Professional Elective-IV	2	1	0	3	35	15	50	0	0	0	50	50	0	50	100
BMECPFP825	Final Year Project	0	0	14	7	0	0	0	35	15	50	50	0	50	50	100
BMECPIN825	Internship	0	0	0	1	0	0	0	35	15	50	50	0	50	50	100
		8	2	18	20											1000
	Total Hours	28														

Professional Elective Courses					
Course Code	Course Title	L	T	P	Credits
	Professional Elective I				
BMECDPE425	Programming for Engineers	1	0	2	2
BMECDRE425	Renewable Energy Systems	2	0	0	2
BMECDMC425	Material Characterization Method	1	0	2	2
	Professional Elective II				
BMECDFT725	Fundamentals of Tribology	2	0	2	3
BMECDMC725	Microprocessors and Processor-Based Systems	2	0	2	3
BMECDRF725	Refrigeration	2	0	2	3
	Professional Elective III				
BMECDCE825	Cryogenic Engineering	2	0	2	3
BMECDHV825	Heating Ventilation and Air Conditioning	2	0	2	3
BMECDCM825	Composite Materials	2	0	2	3
	Professional Elective IV				
BMECDPP825	Power Plant Engineering	2	1	0	3
BMECDIC825	Introduction to Computational Mechanics	2	0	2	3
BMECDSP825	Solar PV Installation & Design	2	1	0	3

Open Elective Courses					
Course Code	Course Title	L	T	P	Credits
	Open Elective I				
BMECOAM625	Additive Manufacturing	2	0	2	3
BMECODE625	Design of Experiment	2	1	0	3
BMECONM625	Numerical Methods for Engineers	2	0	2	3
	Open Elective II				
BMECONT825	Non-Destructive Testing	2	0	2	3
BMECOMS825	Mechatronic Systems	2	0	2	3
BMECOME825	Micro-Electro-Mechanical Systems	2	0	2	3
BMECORB825	Robotics	2	0	2	3

Note: Students can also choose Professional Electives courses from Swayam (Moocs) plateform. The list of MOOCs courses will be notified at the start of each semester.

Course Code	BMECCDR325				
Category	Professional Core courses				
Course Title	Dynamics of Rigid Bodies				
Scheme and Credits	L	T	P	Credits	Semester- **3** (*Three*)
	2	1	0	3	
Pre requisites	Engineering Mechanics				

Course Learning Outcomes (CLOs)

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

i) **CLO1:** ***Understand*** the planar motion of rigid bodies by determining displacement, velocity, acceleration, relative motion, and instantaneous center of rotation for bodies undergoing translation, rotation, and general plane motion *(L2)*

ii) **CLO2:** ***Compare*** the principles of three-dimensional rigid body kinematics to determine orientation, angular velocity, and angular acceleration using translating and rotating reference frames and Euler angles. *(L2)*

iii) **CLO3:** ***Interpret*** the motion of planar rigid bodies by applying Newton–Euler equations, D'Alembert's principle, and inertia properties to solve force and acceleration problems involving translation, rotation, and general plane motion. *(L5)*

iv) **CLO4:** ***Draw*** work–energy and impulse–momentum principles to analyze planar rigid body motion and solve engineering problems involving conservation of energy and momentum. *(L3)*

v) **CLO5:** ***Assemble*** the three-dimensional dynamic behavior of rigid bodies using angular momentum, inertia tensor, Euler's equations of motion, and gyroscopic principles for engineering applications. *(L6)*

Theory Module(Internal and External Evaluation)

M.No:	Topic
Module 1.	Kinematics of rigid bodies, translation and rotation about a fixed axis, Relative velocity and acceleration (rotating axes), Instantaneous center of rotation.
Module 2.	Translating and rotating reference frames, Euler angles, angular velocity, and acceleration.
Module 3.	Introduction to Kinetics of rigid bodies, force and acceleration, Moments and products of inertia, D'Alembert's principle, equations of motion, translation, fixed-axis rotation, and general plane motion.
Module 4.	Energy and Momentum Methods, Work and kinetic energy for a rigid body, Impulse and momentum for a rigid body, Conservation of momentum and energy.
Module 5.	Angular momentum, kinetic energy, and inertia tensor, Euler's equations of motion, Gyroscope motion and torque-free motion.

Activity Module (Internal Evaluation Only-10 Marks)

Activity	Example Task
Using the tools learned on Module 1, design a variety of items, including:	Identify examples of translational and rotational motion from everyday engineering systems like connecting rod of IC engine etc. using MATLAB
Using the tools learned on Module 2, design a variety of items, including:	Develop free-body diagrams for rigid bodies undergoing plane motion.
Using the tools learned on Module 3, design a variety of items, including:	Develop a MATLAB code to compute instantaneous center of rotation for mechanisms such as rolling wheels and connecting rods.
Using the tools learned on Module 4, design a variety of items, including:	Develop MATLAB code to compute angular velocity and acceleration from Euler angles and compare numerical and analytical results.
Using the tools learned on Module 5, design a variety of items, including:	Demonstrate gyroscopic precession using a bicycle wheel.

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	1	1	0	1
CLO2	3	3	2	2	3	0	0	0	1	1	0	1

CLO3	3	3	3	2	3	1	1	0	1	1	1	1
CLO4	3	3	2	2	2	1	1	0	1	1	1	1
CLO5	3	3	3	3	3	1	1	0	1	1	0	2

S.No:	Text Books	Author	Publisher
	Engineering Mechanics: Dynamics	Anthony Bedford and Wallace Fowler	Pearson
2	Text book of Dynamics	F Chorlton	CBS Publishers
	References		
	Engineering Mechanics: Statics and Dynamics	R.C Hibbeler	Pearson
	Engineering Mechanics: Dynamics	J.L Meriam and L.G Kraige	Wiley
	Fundamentals of Dynamics & Analysis of Motion	R.M. Marcelo, Crespo Da Silva	Dover Publications Inc.

Course Code	**BMECCDR325**				
Category	**Professional Core courses**				
Course Title	**Dynamics of Rigid Bodies**				
Scheme and Credits	**L**	**T**	**P**	**Credits**	**Semester- 3 (*Three*)**
	2	**1**	**0**	**3**	
Pre requisites	**Engineering Mechanics**				

Course Learning Outcomes (CLOs)

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

i*) CLO1:** ***Understand the planar motion of rigid bodies by determining displacement, velocity, acceleration, relative motion, and instantaneous center of rotation for bodies undergoing translation, rotation, and general plane motion. ***(L2)***

ii)* CLO2:** ***Compare the principles of three-dimensional rigid body kinematics to determine orientation, angular velocity, and angular acceleration using translating and rotating reference frames and Euler angles. ***(L2)***

iii)* CLO3:** ***Interpret the motion of planar rigid bodies by applying Newton–Euler equations, D'Alembert's principle, and inertia properties to solve force and acceleration problems involving translation, rotation, and general plane motion . ***(L5)***

iv)* CLO4:** ***Draw work–energy and impulse–momentum principles to analyze planar rigid body motion and solve engineering problems involving conservation of energy and momentum. ***(L3)***

v)* CLO5:** ***Assemble the three-dimensional dynamic behavior of rigid bodies using angular momentum, inertia tensor, Euler's equations of motion, and gyroscopic principles for engineering applications. ***(L6)***

Theory Module (Internal and External Evaluation)

M.No:	Topic
Module 1.	kinematics of rigid bodies, translation and rotation about a fixed axis, Relative velocity and acceleration (rotating axes), Instantaneous center of rotation.
Module 2.	Translating and rotating reference frames, Euler angles, angular velocity, and acceleration.
Module 3.	Introduction to Kinetics of rigid bodies, force and acceleration, Moments and products of inertia, D'Alembert's principle, equations of motion, translation, fixed-axis rotation, and general plane motion.
Module 4.	Energy and Momentum Methods, Work and kinetic energy for a rigid body, Impulse and momentum for a rigid body, Conservation of momentum and energy.
Module 5.	Angular momentum, kinetic energy, and inertia tensor, Euler's equations of motion, Gyroscope motion and torque-free motion.

Activity Module (Internal Evaluation Only-10 Marks)

Activity	Example Task
Using the tools learned on Module 1, design a variety of items, including:	Identify examples of translational and rotational motion from everyday engineering systems like connecting rod of IC engine etc. using MATLAB
Using the tools learned on Module 2, design a variety of items, including:	Develop free-body diagrams for rigid bodies undergoing plane motion.
Using the tools learned on Module 3, design a variety of items, including:	Develop a MATLAB code to compute instantaneous center of rotation for mechanisms such as rolling wheels and connecting rods.
Using the tools learned on Module 4, design a variety of items, including:	Develop MATLAB code to compute angular velocity and acceleration from Euler angles and compare numerical and analytical results.
Using the tools learned on Module 5, design a variety of items, including:	Demonstrate gyroscopic precession using a bicycle wheel.

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

S.No:	Text Books	Author	Publisher
1.	Engineering Mechanics: Dynamics	Anthony Bedford and Wallace Fowler	Pearson
2.	Text book of Dynamics	F Chorlton	CBS Publishers
	References	**Author**	**Publisher**
3.	Engineering Mechanics: Statics and Dynamics	R.C Hibbeler	Pearson
4.	Engineering Mechanics: Dynamics	J.L Meriam and L.G Kraige	Wiley
5.	Fundamentals of Dynamics & Analysis of Motion	R.M. Marcelo, Crespo Da Silva	Dover Publications Inc.

Course Code	**BMECCCM325**				
Category	**Professional Core courses**				
Course Title	**Computer Aided Drawing and Modelling**				
Scheme and Credits	**L**	**T**	**P**	**Credits**	**Semester- 3 (*Three*)**
	0	**0**	**4**	**2**	
Pre requisites	**Engineering Drawing, Computer Aided Drawing**				

Course Learning Outcomes (CLOs)

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

i) **CLO1:** ***Understand*** the principles of parametric CAD modelling and apply basic sketching techniques, geometric and dimensional constraints, reference geometry, and elementary solid modelling features such as Extrude, Cut, Fillet, Chamfer, and Hole to create simple three-dimensional engineering components. ***(L2)***

ii) **CLO2:** ***Develop*** engineering models by applying advanced sketching techniques, including spline-based modelling and image-based sketching, and create complex part geometries using appropriate modelling strategies. ***(L3)***

iii) **CLO3:** ***Construct*** engineering components using reference geometry, revolve, mirror, and pattern features, and apply advanced modelling operations such as Loft, Sweep, Boundary, Shell, and Draft to develop complex parametric models. ***(L3)***

iv) **CLO4:** ***Evaluate*** different CAD modelling approaches and select the most appropriate feature-based modelling strategy for engineering components based on geometry, design intent, manufacturability, and modelling efficiency. *(L5)*

v) **CLO5:** ***Assemble*** a multi-part CAD model by defining mates and constraints between components, generating exploded views, and producing a detailed assembly drawing complete with a bill of materials, and part callouts. *(L5)*

Theory Module(Internal and External Evaluation)

M.No:	Topic
Module 1.	Introduction to the CAD environment, creating sketches using basic geometric entities, construction lines, geometric and dimensional constraints, reference planes, and sketch editing. Creation of basic solid models using extrude, cut, fillet, chamfer, and hole features, editing models, modifying features, and assigning material and appearance properties.
Module 2.	Creation of complex sketches using spline tools, importing and scaling reference images, tracing geometry, sketch repair, and preparing sketches for three-dimensional modeling.
Module 3.	Creation of reference planes, axes, and coordinate systems. Development of axisymmetric models using revolve features, application of mirror, linear pattern, circular pattern, and sketch pattern tools to create symmetric and repetitive features.
Module 4.	Creation of complex models using loft, sweep, boundary, and revolve features, use of guide curves, multiple profiles, shell, draft, thin features, and advanced reference geometry for developing engineering components.
Module 5.	Fundamentals of 3D scanning, point cloud acquisition, mesh generation (STL), mesh editing, noise filtering, hole filling, surface reconstruction, and importing scanned data as reference geometry for reverse engineering and model reconstruction.

Activity Module (Internal Evaluation only-10 Marks)

Activity	Example Task
Create parametric 3D models of basic mechanical components by applying the tools learned in Module 1.	Washer, spacer, bush, shaft, flange, L-bracket, base plate, pulley, and simple support bracket in SolidWorks/Fusion 360.
Develop engineering models by applying the advanced sketching and image-based modelling techniques learned in Module 2.	Cam profile, gasket, handwheel, airfoil profile, fan blade, and institute logo converted into a 3D model in SolidWorks/Fusion 360.
Develop engineering components by applying the reference geometry and pattern features learned in Module 3.	Bolt flange, chain sprocket, wheel hub, perforated plate, cooling fin, and simple gear blank in SolidWorks/Fusion 360.
Perform reverse engineering by applying the concepts learned in Module 5.	Pipe elbow, nozzle, hopper, bottle, funnel, impeller (basic), and screwdriver handle.
Using the tools learned on Module 5, design a variety of items, including:	Scan and reconstruct a spanner, machine knob, pipe fitting, valve handle, bearing housing, or simple bracket using a 3D scanner or photogrammetry.

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

S.No:	Text Books	Author	Publisher
1.	SolidWorks 2024: A Power Guide for Beginners and Intermediate Users	Sandeep Dogra	CADArtifex, 2024

2.	Autodesk Fusion 360: A Power Guide for Beginners and Intermediate Users	Sandeep Dogra & John Willis	CADArtifex, 2024
	References		
1.	Reverse Engineering: An Industrial Perspective	Vinesh Raja & Kiran J. Fernandes	Springer, 2008
2.	Engineering Design Graphics with SolidWorks 2022	James D. Bethune	Pearson, 2022
3.	3D Scanning and Printing for the Engineering Classroom (MIT OCW RES.16-002 Course Notes)	Andy G. Eskenazi	MIT OpenCourseWare, 2024

Course Code	**BMECCME325**				
Category	**Professional Core courses**				
Course Title	**Materials Engineering**				
Scheme and Credits	**L**	**T**	**P**	**Credits**	**Semester- 3 (Three)**
	2	1	2	4	
Pre-requisites	-				

Course Learning Outcomes (CLOs)

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

i)* CLO1:** Understand the classification, crystal structures, properties, imperfections, diffusion mechanisms, deformation behaviour, phase transformations, and heat treatment of engineering materials. ***(L2)

ii)* CLO2:** Compare the structure, properties, processing methods, and applications of metals, ceramics, polymers, composites, and advanced engineering materials. ***(L4)

iii)* CLO3:** Interpret crystallographic directions and planes, X-ray diffraction data, diffusion behaviour, stress–strain curves, phase diagrams, and microstructural evolution in engineering materials. ***(L4)

iv)* CLO4:** Draw unit cells, crystal structures, crystallographic planes and directions, stress–strain curves, phase diagrams, iron–carbon equilibrium diagram, and representative microstructures of engineering materials. ***(L3)

v)* CLO5:** Assemble the knowledge of crystal structure, defects, diffusion, deformation, strengthening mechanisms, phase transformations, and heat treatment to select suitable engineering materials for mechanical engineering applications. ***(L5)

Theory Module(Internal and External Evaluation)

M.No:	Topic
Module 1.	Historical perspective, classification of engineering materials, advanced engineering materials (smart materials, nanomaterials, biomaterials and shape memory alloys), atomic structure and bonding in solids, crystal structures of metals, unit cells, face-centered cubic (FCC), body-centered cubic (BCC) and hexagonal close-packed (HCP) crystal structures, density calculations for metals, ceramic crystal structures, density calculations for ceramics, polymorphism, allotropy, crystal systems, lattice parameters. .
Module 2.	Crystallographic directions, crystallographic planes, Miller indices, linear atomic density, planar atomic density, close-packed crystal structures, single crystals, polycrystalline materials, anisotropy, principles of X-ray diffraction, Bragg's law, determination of crystal structures, non-crystalline solids, amorphous materials, imperfections in solids, point defects, line defects, surface defects, volume defects, grain size, grain size determination, diffusion mechanisms, diffusion in solids, Fick's first and second laws, steady-state diffusion, non-steady-state diffusion, factors influencing diffusion.
Module 3.	Stress-strain behaviour, elastic deformation, plastic deformation, mechanical properties, hardness, deformation mechanisms, slip systems, plastic deformation of single and polycrystalline metals, deformation by twinning, strengthening mechanisms, grain size strengthening, solid solution strengthening, strain hardening, recovery, recrystallization, grain growth, fracture, ductile and brittle fracture, fatigue, creep and wear.
Module 4.	Phase concepts, solubility limits, phase equilibria, unary phase diagrams, binary phase diagrams, interpretation of phase diagrams, lever rule, iron-carbon phase diagram, microstructure of iron-carbon alloys, development of microstructure in iron-carbon alloys, heat treatment of steels, annealing, normalizing, hardening and tempering. .

Module 5.	Classification of polymers, thermoplastic polymers, thermosetting polymers, polymer crystallinity, polymer crystal structures, engineering ceramics, glasses, material selection for engineering applications, sustainability and recycling of engineering materials.

Activity Module (Internal Evaluation Only-10 Marks)

Activity	Example Task
Using the tools learned on Module 1, design a variety of items, including:	Construct BCC, FCC, and HCP crystal models using model kits or CAD software, identify unit cell parameters, and calculate the theoretical density of metallic and ceramic materials using MATLAB, Python, or Excel.
Using the tools learned on Module 2, design a variety of items, including:	Determine crystallographic directions and planes, calculate linear and planar atomic densities, simulate X-ray diffraction patterns using crystallographic software, and compare experimental and theoretical results.
Using the tools learned on Module 3, design a variety of items, including:	Solve steady-state and non-steady-state diffusion problems using MATLAB, Python, or Excel based on Fick's laws, and analyze the influence of temperature and time on diffusion behaviour
Using the tools learned on Module 4, design a variety of items, including:	Analyze experimental stress–strain data to determine elastic modulus, yield strength, and toughness, compare strengthening mechanisms, and evaluate the effect of heat treatment on mechanical properties using spreadsheet or computational tools.
Using the tools learned on Module 5, design a variety of items, including:	Use computational tools to interpret binary and iron–carbon phase diagrams, apply the lever rule to calculate phase fractions, predict microstructures under different cooling conditions, and correlate phase composition with mechanical properties.

Practical Module (Internal and External Evaluation)

M.No:	Experiments
Module 1.	To study 2D & 3D lattices.
Module 2.	To study crystal structures using appropriate models.
Module 3.	To study Bravais Lattices using appropriate models.
Module 4.	To study crystal imperfections using appropriate models.
Module 5.	To study three dimensional close packing using appropriate models.
Module 6.	Specimen preparation for micro structural examination.
Module 7.	To study microstructure of metals/alloys.
Module 8.	To study Heat Treatment Processes of steel.
Module 9.	To study creep behaviour of a given specimen(e.g. lead, zinc, solder wire).

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

S.No:	Text Books	Author	Publisher
1.	Fundamentals of Materials Science and Engineering	W.DJohn Wiley & Sons, 2011	John Wiley & Sons
	References	**Author**	**Publisher**
2.	Mechanical Metallurgy	George E. Dieter	McGraw Hill
3.	Physical Metallurgy	Cahn. R.W., Haasen. P	North-Holland

Course Code	BMECCET325				
Category	Professional Core courses				
Course Title	Engineering Thermodynamics				
Scheme and Credits	L	T	P	Credits	Semester- 3 (*Three*)
	2	1	0	3	
Pre requisites	Mathematics, Physics and Chemistry				

Course Learning Outcomes (CLOs)

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

i) **CLO1:** Explain the fundamental concepts of thermodynamics, thermodynamic properties, equations of state, and behaviour of pure substances and gas mixtures. *(L2)*

ii) **CLO2:** Apply the first law of thermodynamics to analyze energy interactions in closed and open systems *(L3)*

iii) **CLO3:** Analyze thermodynamic systems using the second law, entropy, and availability concepts. *(L4)*

iv) **CLO4:** Analyze entropy changes, exergy, and second-law efficiency using thermodynamic property diagrams. *(L4)*

v) **CLO5:**Apply thermodynamic property relations, Maxwell's relations, Clausius–Clapeyron equation, and Joule–Thomson coefficient to solve engineering thermodynamics *(L3)*

Theory Module(Internal and External Evaluation)

M.No:	Topic
Module 1.	Review of basic concepts of thermodynamics, thermodynamic systems and surroundings, properties and state of a system, thermodynamic equilibrium, Zeroth law of thermodynamics, concept of temperature and heat, thermometry and temperature scales, thermodynamic properties of pure substances, phase rule, P–V, P–T, T–V and PVT surfaces, ideal and real gases, equations of state, Avogadro's law, Van der Waals equation of state, compressibility factor, generalized compressibility charts.
Module 2.	Thermodynamic cycles, closed and open systems, first law of thermodynamics, internal energy, enthalpy, specific heats, energy balance for closed systems, control volume analysis, steady-flow energy equation, engineering applications.
Module 3.	Second law of thermodynamics, Kelvin–Planck and Clausius statements, heat engines, Carnot theorem, Carnot cycle, refrigerators and heat pumps, Clausius inequality, entropy, principle of increase of entropy, reversible and irreversible processes, entropy generation, second law analysis, availability, irreversibility, Gibbs free energy.
Module 4.	Entropy change of pure substances, entropy change of ideal gases, property diagrams, T–S diagram, h–s (Mollier) diagram, reversible steady-flow work, exergy, exergy balance for closed and open systems, exergy destruction, second law efficiency, engineering applications of exergy analysis.
Module 5.	Exact differentials, thermodynamic property relations, Maxwell's relations, Tds equations, Clausius–Clapeyron equation, Joule–Thomson coefficient, Joule–Thomson expansion.

Activity Module (Internal Evaluation Only-10 Marks)

Activity	Example Task
Using the tools learned on Module 1, design a variety of items, including:	Determine the properties of pure substances and gas mixtures, generate P–V and P–T plots, compare ideal and real gas behaviour using equations of state, and compute compressibility factors using Python, MATLAB, or Excel.
Using the tools learned on Module 2, design a variety of items, including:	Perform energy balance calculations for closed systems and steady-flow devices such as nozzles, turbines, compressors, pumps, and heat exchangers using analytical or computational methods, and compare the results.
Using the tools learned on Module 3, design a variety of items, including:	Evaluate the performance of heat engines, refrigerators, and heat pumps by calculating entropy generation, irreversibility, thermal efficiency, and second-law efficiency using Python, MATLAB, or Excel.
Using the tools learned on Module 4, design a variety of items, including:	Plot T–S and h–s diagrams, perform exergy analysis of engineering systems, determine exergy destruction and availability, and interpret the results using computational tools.
Using the tools learned on Module 5, design a variety of items, including:	Solve engineering problems involving Maxwell's relations, Clausius–Clapeyron equation, Joule–Thomson coefficient, and thermodynamic property relations using analytical methods or computational tools such as Python, MATLAB, or Excel. .

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	0	0	0	2
CLO2	2	3	3	0	3	0	0	0	0	0	0	2
CLO3	2	3	2	3	3	0	2	0	0	2	0	3
CLO4	3	2	3	0	3	2	0	2	0	3	0	0
CLO5	3	3	3	2	3	2	2	0	3	3	2	3

S.No:	Text Books	Author	Publisher
1.	Engineering Thermodynamics	Nag.P.K.	Tata McGraw-Hill
2.	Fundamentals of Thermodynamics	R. E. Sonntag, C. Borgnakke, & G. J. V Wylen.	John Wiley & Sons.
	References	**Author**	**Publisher**
1.	Thermodynamics, An Engineering Approach	Cengel,	Tata McGraw-Hill
2.	Fundamentals of Engineering Thermodynamics	Moran, J. Shapiro, H. N., Boe□ ner, D. D., & M. Bailey	John Wiley & Sons.

Course Code	**BMECCFM325**				
Category	**Professional Core courses**				
Course Title	**Fluid Mechanics**				
Scheme and Credits	**L**	**T**	**P**	**Credits**	Semester- **3** (*Three*)
	2	1	2	4	
Pre requisites	**Engineering Mechanics**				

Course Learning Outcomes (CLOs)

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

i) **CLO1:** ***Understand*** the fundamental concepts of fluid mechanics, including fluid properties, fluid statics, and fluid kinematics. *(L2)*

ii) **CLO2:** ***Compare*** different fluid flow phenomena, pressure measurement techniques, and methods of fluid flow analysis for engineering applications. *(L2)*

iii) **CLO3:** ***Interpret*** fluid flow behavior using conservation laws, Bernoulli's equation, momentum principles, and Navier–Stokes concepts to evaluate engineering systems *(L5)*.

iv) **CLO4:** ***Draw*** streamlines, flow nets, velocity profiles, and boundary layer representations for different fluid flow conditions. *(L3)*

v) **CLO5:** ***Assemble*** the principles of dimensional analysis, similarity, internal and external flows to develop solutions for practical fluid engineering problems. *(L6)*

Theory Module(Internal and External Evaluation)

M.No:	Topic
Module 1	Scope and applications of fluid mechanics, fluid as a continuum, fluid properties (density, specific gravity, specific weight, viscosity, compressibility, vapor pressure, surface tension), Newtonian and non-Newtonian fluids, methods of analysis (system and control volume), pressure measurement and manometry.
Module 2.	Pressure variation in static fluids, hydrostatic forces on plane and curved surfaces, buoyancy and stability of floating and submerged bodies, metacentric height, Eulerian and Lagrangian descriptions, velocity and acceleration fields, streamlines, pathlines, streaklines, continuity equation, rotation and vorticity, stream function and velocity potential, flow nets.

Module 3.	Reynolds Transport Theorem, conservation of mass, momentum and energy, Bernoulli equation and its applications, flow measurement devices, limitations of Bernoulli's equation.
Module 4.	Differential continuity equation, Euler's equation of motion, Navier–Stokes equations, exact solutions for Couette and Poiseuille flows, Darcy–Weisbach equation, major and minor losses in pipe flow, pipe systems in series and parallel.
Module 5.	Dimensional homogeneity, Buckingham π theorem, geometric, kinematic and dynamic similarity, model and prototype studies, boundary layer theory, laminar and turbulent boundary layers, flow over flat plates, cylinders and airfoils, lift and drag.

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 MATLAB/Python program to calculate hydrostatic pressure at different depths and plot pressure variation with depth for water, oil, and mercury.
Using the tools learned on Module 2, design a variety of items, including:	Use MATLAB/Python to generate streamlines and velocity vectors for a given 2D velocity field and interpret the flow pattern.
Using the tools learned on Module 3, design a variety of items, including:	Create a program in MATLAB/Python to determine flow rate through a Venturimeter using Bernoulli's equation and study the effect of pressure difference on discharge.
Using the tools learned on Module 4, design a variety of items, including:	Develop a MATLAB/Python program to calculate Reynolds number and classify the flow as laminar, transitional, or turbulent for different pipe diameters and flow rates.
Using the tools learned on Module 5, design a variety of items, including:	Develop a MATLAB/Python/Excel-based program to evaluate Reynolds, Froude, Weber, and Mach numbers for engineering applications such as pipe flow *etc.* determine the appropriate similarity criterion for model testing.

Practical Module (Internal and External Evaluation)

M.No:	Experiments
Module 1.	Measurement of viscosity
Module 2.	Study of pressure measuring devices
Module 3.	Determination of metacentric height
Module 4.	Hydrostatics force on flat surfaces/ curved surfaces
Module 5.	Verification of Bernoulli's theorem
Module 6.	Determination of friction factor as a function of Reynolds number in pipe flow
Module 7.	Determination of coefficient of discharge of Venturimeter/ Orifice meter
Module 8.	Studying laminar-turbulent transition for flow in a tube
Module 9.	Determination of friction factor as a function of Reynolds number in pipe flow
Module 10.	Flow Visualisation around a body/ over surface
Module 11	Boundary layer flow over a flat plate

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	0	0	0	2
CLO2	2	3	3	0	3	0	0	0	0	0	0	2
CLO3	2	3	2	3	3	0	2	0	0	2	0	3
CLO4	3	2	3	0	3	2	0	2	0	3	0	0
CLO5	3	3	3	2	3	2	2	0	3	3	2	3

S.No:	Text Books	Author	Publisher
1.	Introduction to Fluid Mechanics	Fox, R. W., McDonald, A. T., & Pritchard, P. J.	Wiley
2.	Introduction to Fluid Mechanics and Fluid Machines	S K Som, Gautam Biswas, S Chakraborty	McGraw Hill
	References		
3.	Fluid Mechanics	Munson | Okiishi | Huebsch | Roth Mayer	Wiley

4.	Fluid Mechanics	Dr. Bansal, R.K	Lakshmi Publications
5.	Fluid Mechanics and hydraulics	Dr. Jagadishlal	Metropolitan Book Co-Ltd., 1997
6.	Fluid Mechanics: Fundamentals and Applications.	Yunus A. Cingel John M.Oimbala.	McGraw Hill
7.	Fluid Mechanics	John F. Douglas, Janul and M.Gasiosek and john A.Swaffield	Pearson Education Asia,

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Course Code	**BMECCMP325**				
Category	**Professional Core courses**				
Course Title	**Metal Cutting and Machining Processes**				
Scheme and Credits	**L**	**T**	**P**	**Credits**	**Semester- 3 (*Three*)**
	2	1	2	4	
Pre requisites	**Engineering Workshop, Materials Engineering**				

Course Learning Outcomes (CLOs)

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

i*) CLO1: *Understand machining processes, chip formation, tool materials, grinding, etc. ***(L2)***

ii)* CLO2: *Compare orthogonal *vs.* oblique cutting, EDM vs. ECM, honing vs. lapping, polishing vs. buffing, conventional vs. non-conventional machining. ***(L2)***

iii)* CLO3: Interpret** Merchant Force Circle, tool life equations, grinding forces, machining economics, and process performance. ***(L5)

iv)* CLO4: Draw** single-point cutting tool geometry, Merchant Force Circle, chip formation, grinding wheel, EDM, ECM, LBM, honing, lapping, etc. ***(L3)

v)* CLO5: Assemble** machining operations by selecting suitable tools, machining processes, cutting parameters, and finishing methods for a given component. ***(L6)

Theory Module(Internal and External Evaluation)

M.No:	Topic
Module 1.	Machining Processes: Mechanics of Cutting; Geometry of Single-point Cutting Tool, Mechanism in Chip Formation, Types of Chips, Orthogonal and Oblique Cutting, Cutting Forces and Merchant Force Circle Diagram, Shear and Friction angle, Shear and Chip Velocity, Energy in Shear and Friction Plane,
Module 2.	Materials and Life of Cutting Tool; Composition and Properties of Tool Materials, Tool Life; Various Failures in Cutting Tool, Calculation of Tool life (Taylor's Tool Life Equation), Description of Practical Machining Processes; Process Geometry, Process Parameters for Turning and related machining operations, Economics of Cutting.
Module 3.	Abrasive Machining Processes: Need and Classifications; Abrasive Grinding: Wheel Specification, Wheel Life, Balancing, Truing and Dressing of Wheels, Classifications of Abrasive Grinding Processes, Chipping action in grinding, Calculation of Material Removal Rate, Forces and Power, Heat and Temperature in Abrasive Grinding, Working Principle and Applications of Grinding Processes for Prismatic and Rotational Parts.
Module 4.	Abrasive Finishing Processes: Conventional Abrasive Finishing: Honing, Lapping, Polishing and Buffing, Modern Abrasive Finishing: Abrasive Flow Finishing, Magnetic Abrasive Finishing and Magnetic Float Finishing.
Module 5.	Non-conventional Machining Processes: Need and Classification of Mechanical Machining Processes,, Electrochemical Processes, Electro-Thermal & Optical Processes, Process Principle, Equipments and Applications

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 Orthogonal Cutting to Determine Cutting Forces and Merchant Circle Parameters (Using MATLAB/Excel)
Using the tools learned on Module 2, design a variety of items, including:	Simulation of Tool Life Prediction Using Taylor's Tool Life Equation *(Using MATLAB/Excel)*
Using the tools learned on Module 3, design a variety of items, including:	Computational Analysis of Grinding Wheel Speed and Depth of Cut on Surface Finish (Using MATLAB/Excel)
Using the tools learned on Module 4, design a variety of items, including:	Simulation of Material Removal during Honing and Lapping Processes (Using MATLAB/Excel)
Using the tools learned on Module 5, design a variety of items, including:	Computational Analysis of Electrochemical Machining (ECM) Material Removal Rate Using Faraday's Law (Using MATLAB/Excel)

Practical Module (Internal and External Evaluation)

M.No:	Experiments
Module 1.	To study the geometry of a single-point cutting tool.
Module 2.	To investigate the effect of machining process parameters on the surface roughness of machined components.
Module 3.	To compare the theoretical and experimental machining time in the turning operation.
Module 4.	To make a job as per drawing using a surface grinding machine. Write the process sheet and draw the sketches of the machine tool and tools used.
Module 5.	To study the Abrasive Flow Finishing process and evaluate material removal
Module 6.	To produce a cavity on a conductive workpiece using EDM.
Module 7.	To study the effect of discharge current on MRR during EDM.
Module 8.	To determine electrode wear during EDM.
Module 9.	To compare machining performance using copper and graphite electrodes using EDM.
Module 10.	To identify machining parameters for maximum MRR and minimum tool wear.

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

S.No:	Text Books	Author	Publisher
1.	Fundamentals of Modern Manufacturing: Materials Processes and Systems	M. P. Groover	John Wiley and Sons
2.	Manufacturing Technology: Volume 2	P N Rao	Tata McGraw Hill
3.	Manufacturing Science	Ghosh and Mallik	East West Press.
	References		
1.	Introduction to Machining Science	G. K. Lal	New Age International
2.	Fundamentals of Machining Processes	Hassan El-Hofy	Taylor and Francis.
3.	Rapid Prototyping: Principles and Applications	Rafiq Noorani	Wiley International.

Course Code	BMECBPD425				
Category	Basic Science Course				
Course Title	Partial Differential Equations, Laplace and Z-transform.				
Scheme and Credits	L	T	P	Credits	Semester- 4 (*Four*)
	2	1	0	3	
Pre requisites	-				

Course Learning Outcomes (CLOs)

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

i) **CLO1:** ***Classify*** and distinguish between linear and non-linear partial differential equations. *(L2)*

ii) **CLO2**: ***Explain*** the fundamental concepts of Laplace transforms, vector spaces, and multivariate calculus structures. *(L2)*

iii) **CLO3**: ***Evaluate*** the consistency of systems of linear equations and analyze the physical and geometric meaning of mathematical models, such as wave equations, periodic functions, and optimization boundaries. *(L4)*

iv) **CLO4**: ***Synthesize*** concepts from linear algebra, integral calculus, and differential equations to model, solve, and analyze complex engineering systems. *(L6)*

v) **CLO5:** ***Construct, formulate,*** and ***sketch*** geometric transformations, coordinate changes (Jacobians), and change of limits in multiple integrals to solve engineering boundary-value problems. *(L6)*

Theory Module (Internal and External Evaluation)

M.No:	Topic
Module 1.	Formation of partial differential equations, first-order partial differential equations, linear and non-linear first-order PDEs, Lagrange's linear equations, standard forms, Charpit's method.
Module 2.	Homogeneous and non-homogeneous linear partial differential equations with constant coefficients, complementary function (CF), particular integral (PI), methods for solving higher-order linear PDEs and applications.
Module 3.	Laplace transform, condition for the existence of Laplace transform, Laplace transform of some elementary functions, differentiation and integration of laplace transform, laplace transform of periodic functions, shifting theorem, Laplace transforms of different functions. Heavisides unit function, dirac delta function, its Laplace transform, Heaviside's expansion theorem.
Module 4.	Initial and final value theorems, convolution theorem and its applications, inverse Laplace transforms, solution of ordinary differential equations using Laplace transforms, applications to engineering problems.
Module 5.	Finite Fourier transform, Fourier integral formula, properties of Fourier transform, Fourier sine and cosine transforms, convolution theorem, Parseval's identity, applications of Fourier transforms to the solution of boundary value problems.

Activity Module (Internal Evaluation Only-10 Marks)

Activity	Example Task
Using the tools learned on Module 1, design a variety of items, including:	Solve first-order partial differential equations using MATLAB/Python and compare analytical and numerical solutions.
Using the tools learned on Module 2, design a variety of items, including:	Simulate one-dimensional heat conduction, wave propagation, and string vibration using MATLAB.
Using the tools learned on Module 3, design a variety of items, including:	Develop MATLAB/Python programs to compute Laplace transforms and inverse Laplace transforms of engineering functions.
Using the tools learned on Module 4, design a variety of items, including:	Laplace transforms using MATLAB Symbolic Toolbox/Python (SymPy) to solve linear differential equations arising in engineering systems.
Using the tools learned on Module 5, design a variety of items, including:	Implement MATLAB/Python codes to compute Fourier transforms and solve boundary value problems through graphical visualization and interpretation.

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	3	3	2	2	2	0	0	0	0	1	0	1

CLO3	2	3	2	3	3	0	0	0	0	1	0	2
CLO4	3	3	2	3	2	0	0	0	0	1	0	2
CLO5	2	2	2	2	3	0	0	0	1	2	1	3

S.No:	Text Books	Author	Publisher
1.	Advanced Engineering Mathematics	Erwin Kreyszig	Wiley India
2.	Advanced Engineering Mathematics,	H. K. Dass,	S. Chand Publishing.
3.	Higher Engineering Mathematics	B. S. Grewal,	Khanna Publishers.
	References		
1.	Laplace Transforms (Schaum's Outline Series)	Murray R. Spiegel,	McGraw-Hill Education.
2.	Advanced Engineering Mathematics,	Michael D. Greenberg	Pearson Education.
3.	Elements of Partial Differential Equations	Ian N. Sneddon	McGraw-Hill Education.

Course Code	**BMECCMS425**				
Category	**Professional Core courses**				
Course Title	**Mechanics of Solids**				
Scheme and Credits	**L**	**T**	**P**	**Credits**	**Semester- 4 (*Four*)**
	2	1	2	4	
Pre-requisites	**Statics and Dynamics**				

Course Learning Outcomes (CLOs)

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

i) **CLO1:** ***Analyze*** stress, strain, deformation, and thermal effects in axially loaded members by applying elasticity principles, generalized Hooke's law, compatibility conditions, and equilibrium equations to solve determinate and indeterminate problems. ***(L2)***

ii) **CLO2:** ***Analyze*** two-dimensional stress and strain states using stress transformation equations, Mohr's circle, and strain rosette techniques to determine principal stresses, principal strains, and maximum shear stresses. ***(L2)***

iii) **CLO3:** ***Apply*** torsion theory to determine shear stresses, angle of twist, torsional deformation, and spring deflection in circular shafts and helical springs under various loading conditions. ***(L5)***

iv) **CLO4:** ***Analyze*** the structural behavior of beams by determining shear forces, bending moments, bending stresses, shear stresses, beam deflection, and shear center for beams subjected to different loading conditions. ***(L3)***

v) **CLO5:** ***Analyze*** stress distributions in thin- and thick-walled pressure vessels using pressure vessel theory, Lamé's equations, and shrink-fit principles to evaluate the structural integrity of cylindrical and spherical vessels. ***(L6)***

Theory Module(Internal and External Evaluation)

M.No:	Topic
Module 1.	Introduction to stress and strain, stress-strain diagram, Poisson's ratio, multiaxial loading- generalized Hooke's law, dilatation and bulk modulus, shearing strain, deformations under axial loading, stress concentrations, plastic deformations, residual stresses, elastic constants and their relations, statically indeterminate problems, problems involving temperature change.
Module 2.	State of stress at a point, Stress tensor, general state of stress, introduction to three dimensional analysis of stress, Plane Stress, complimentary property of shear stress, transformation of plane stress, transformation equations, principal stresses and maximum shearing stress, Mohr's Circle for plane stress, transformation of plane strain, transformation equations, Mohr's circle for plane strain, , measurement of strain and strain rosette.
Module 3.	Torsion, stresses and deformation in circular and hollow shafts, stepped shafts, Power transmission for solid and hollow circular shafts.

Module 4.	Theory of bending of beams, bending stress distribution and neutral axis, shear stress distribution, shear stresses in beams of rectangular and circular cross section, shear stresses in the webs of beams with flanges, shear centre concept and its determination for thin walled members.
Module 5.	Thin walled pressure vessels, stresses in thin cylindrical and spherical pressure vessels subjected to internal pressure, deformation of and thin cylinders, deformation in spherical shells subjected to internal pressure. Introduction to Hertz contact stresses.

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 MATLAB/Python program to compute normal stress, strain, elongation, and thermal stresses in prismatic and non-prismatic bars under axial loading.
Using the tools learned on Module 2, design a variety of items, including:	Develop MATLAB/ Python program to calculate and plot Mohr's Circle for plane stress and plane strain.
Using the tools learned on Module 3, design a variety of items, including:	Develop MATLAB/ Python code to generate Shear Force Diagrams (SFD) and Bending Moment Diagrams (BMD) for various loading conditions.
Using the tools learned on Module 4, design a variety of items, including:	Develop a MATLAB/ Python program to analyze the torsional behavior of solid, hollow, and stepped circular shafts,
Using the tools learned on Module 5, design a variety of items, including:	Plot radial and hoop stress distributions using Lamé's equations for thick cylinders.

Practical Module (Internal and External Evaluation)

M.No:	Experiments
Module 1.	Tensile test of mild steel and Aluminum Bars
Module 2.	Shear test on specimens of two different materials.
Module 3.	Charpy and Izod Impact test on a metallic specimen.
Module 4.	Brinnell and Rockwell hardness tests on metallic specimens.
Module 5.	Bending deflect on test on beams.
Module 6.	Strain measurement using rosette strain gauge.
Module 7.	Torsion test on specimens of different metals for determining the angle of twist for a given torque.
Module 8.	Compressive test of a specimen.
Module 9.	Shear test on specimens of two different metals.

CLO-PLO Mapping Matrix

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

Recommended Books

S.No:	Text Books	Author	Publisher
1.	Mechanics of Materials	R. C. Hibbeler	Pearson
2.	Mechanics of Materials	Barry J Goodno, James M. Gere	Cengage Learning
	References		
1.	Mechanics of Materials	J.M. Gere and S.P. Timoshenko	Cengage Learning, 1997
2.	Introduction to Solid Mechanics	I.H. Shames and J.M. Pitarresi	Pren ce Hall of India,1999
3.	Mechanics of Materials	Andrew Pytel & JAAN Kiulaas	Cengage Learning

Course Code	BMECDPE425				
Category	Professional Elective Course				
Course Title	Programming for Engineers				
Scheme and Credits	L	T	P	Credits	Semester- 4 (*Four*)
	1	0	2	2	
Pre-requisites	Basic Mathematics				

Course Learning Outcomes (CLOs)

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

i) **CLO1:** ***Understand*** the fundamentals of algorithms, flowcharts, pseudocode, computing software, and object-oriented programming concepts. ***(L2)***

ii) **CLO2:** ***Compare*** programming constructs, software types, functions, and object-oriented programming features for solving computational problems. ***(L2)***

iii) **CLO3:** ***Interpret*** computational results obtained from vector and matrix operations, numerical methods, program execution, and graphical visualizations. ***(L5)***

iv) **CLO4:** ***Develop*** algorithms, flowcharts, and 2D/3D graphical representations using programming constructs, functions, and visualization tools. ***(L3)***

v) **CLO5:** ***Design*** and implement modular object-oriented programs by integrating data structures, functions, file handling, numerical techniques, and visualization to solve engineering problems. ***(L6)***

Theory Module(Internal and External Evaluation)

M.No:	Topic
Module 1.	Role of computation in engineering analysis, engineering problem-solving methodology, algorithms, flowcharts, pseudocode, introduction to computational platforms (MATLAB, Python, GNU Octave, or equivalent), variables, constants, data types, operators, expressions, basic input/output operations.
Module 2.	Scalars, vectors, and matrices, mathematical operations on vectors and matrices, matrix manipulation, solution of linear algebraic equations, engineering data representation, file input/output operations.
Module 3.	Decision-making statements, logical operators, loops and iterations, implementation of engineering algorithms, debugging techniques, program testing and verification, computational problem-solving using iterative methods.
Module 4.	User-defined functions, built-in libraries, script and function files, modular programming concepts, two-dimensional plotting, graph customization, annotations, engineering data visualization and interpretation.
Module 5.	Numerical solution of engineering problems, introduction to root-finding methods, numerical differentiation, numerical integration, simple finite difference formulation for one-dimensional heat conduction, engineering case studies using computational platforms.

Activity Module (Internal Evaluation Only-10 Marks)

Activity	Example Task
Using the tools learned on Module 1, design a variety of items, including:	Design an algorithm and flowchart to calculate stress, strain, and factor of safety for a mechanical component.
Using the tools learned on Module 2, design a variety of items, including:	Solve the stiffness matrix of a simple spring system or truss using matrix operations using MATLAB, Python, GNU Octave, or any other equivalent computational platform.
Using the tools learned on Module 3, design a variety of items, including:	Develop a program to determine the root of a heat transfer or fluid flow equation using the Bisection or Newton–Raphson method using MATLAB, Python, GNU Octave, or any equivalent computational platform.
Using the tools learned on Module 4, design a variety of items, including:	Create a reusable function to calculate Reynolds number, Nusselt number, pressure drop, or beam deflection for different operating conditions using MATLAB, Python (Matplotlib), GNU Octave, or any equivalent computational platform.
Using the tools learned on Module 4, design a variety of items, including:	Simulate one-dimensional steady-state heat conduction using the Finite Difference Method and visualize the temperature distribution using 2D and

	surface plots using MATLAB, Python (Matplotlib), GNU Octave, or any equivalent computational platform.

Practical Module (Internal and External Evaluation)

M.No:	Experiments
Module 1.	Write the algorithm, draw the flowchart, and prepare pseudocode for simple problems such as finding the largest number, factorial, and checking whether a number is prime.
Module 2.	Create vectors and matrices, and perform addition, subtraction, multiplication, transpose, determinant, and inverse operations.
Module 3.	Write programs to accept scalar, string, vector, and matrix inputs from the user and display formatted outputs. Save and load data using MAT-files.
Module 4.	Implement programs using if, if-else, and switch statements to solve problems such as grading systems, leap year checking, and maximum of three numbers.
Module 5.	Develop programs using for and while loops to generate multiplication tables, Fibonacci series, factorial, and prime numbers.
Module 6.	Solve nonlinear equations using numerical methods such as the Bisection Method, Newton-Raphson Method, and MATLAB's fzero() function.
Module 7.	Create user-defined functions, anonymous functions, subfunctions, and function files. Pass arrays as function arguments and use built-in mathematical functions.
Module 8.	Create user-defined functions, anonymous functions, subfunctions, and function files. Pass arrays as function arguments and use built-in mathematical functions.
Module 9.	Create a simple class with properties and methods. Demonstrate OOP concepts such as encapsulation, inheritance, and polymorphism through basic examples.
Module 10.	Plot mathematical functions (e.g., sine, cosine, exponential), add titles, labels, legends, grids, annotations, and create simple animations using draw now.
Module 11	Generate 3D line plots, mesh plots, surface plots, contour plots, and customize their appearance using MATLAB plotting commands.
Module 12	Create mesh, surf, contour 3, and waterfall plots for mathematical functions and engineering data.

CLO-PLO Mapping Matrix

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

Recommended Books

S.No:	Text Books	Author	Publisher
1.	Programming for Engineers	Aaron. R. Bradley	Springer
2.	Introduction to Programming with C++ for Engineers	Boguslaw Cyganek	Wiley
	References	**Author**	**Publisher**
1.	How to Solve It by Computer	R. G. Dromey (algorithms and programming logic)	Prentice Hall
2.	MATLAB: A Practical Introduction to Programming and Problem Solving	Stormy Attaway (primary textbook)	Butterworth-Heinemann

Course Code	**BMECDRE425**

Category	**Professional Elective**				
Course Title	**Renewable Energy Systems**				
Scheme and Credits	**L**	**T**	**P**	**Credits**	**Semester- 4 (*Four*)**
	2	**0**	**0**	**2**	
Pre-requisites	**Engineering Thermodynamics and Environmental Studies**				

Course Learning Outcomes (CLOs)

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

i) **CLO1:** The student will understand the fundamental concepts, principles, and significance of renewable energy systems, including solar, wind, biomass, geothermal, and small hydro energy technologies. ***(L1)***

ii) **CLO2:** The student will compare different renewable energy technologies based on their working principles, efficiency, environmental impact, economic feasibility, and applications.***(L2)***

iii) **CLO3:** The student will interpret the performance characteristics, resource availability, and operational data of renewable energy systems for various engineering applications. ***(L3)***

iv) **CLO4:** The student will draw schematic layouts and design basic renewable energy systems, including solar photovoltaic, solar thermal, wind energy, and hybrid energy systems for specific application. ***(L4)***

v) **CLO5:** The student will apply engineering principles and analytical methods to evaluate, size, and select appropriate renewable energy systems for domestic, commercial, and industrial applications. ***(L5)***

Theory Module(Internal and External Evaluation)

M.No:	Topic
Module 1.	Global and Indian energy scenario, energy demand and supply, conventional and non-conventional energy resources, classification of renewable energy sources, energy utilization, environmental impacts of energy systems, energy conservation, energy and climate change.
Module 2.	Biomass resources, classification and properties of biomass, proximate and ultimate analysis, calorific value, density and moisture content, biomass pre-treatment, thermochemical and biochemical conversion processes, stoichiometry of biomass combustion, heat and power generation from biomass, biomass-based power generation using internal combustion engines, gas turbines and fuel cells.
Module 3.	Wind characteristics, wind data analysis, energy available in the wind, wind energy extraction principles, Betz limit and its derivation, classification and components of wind turbines, blade profiles, performance analysis of wind turbines, wind resource assessment and wind energy potential in India.
Module 4.	Solar radiation and its measurement, fundamentals of solar thermal energy conversion, photovoltaic effect, semiconductor materials and doping, solar photovoltaic systems, solar energy potential in India. Small hydropower: power equation, classification of small hydropower plants, hydraulic turbines, major components of small hydropower projects. Geothermal energy: geothermal resources, geothermal power generation, global status, advantages and limitations.
Module 5.	Fundamentals of thermal radiation, blackbody radiation, emissive power and surface properties. Hydrogen energy systems: hydrogen production methods, storage technologies, safety considerations, renewable hydrogen applications. Fuel cells: operating principles, types, components, performance characteristics and applications. Hybrid energy systems: need and configuration of hybrid systems, integration of renewable energy sources, integrated gasification combined cycle (IGCC), combined cycle power plants, electric vehicles, hybrid electric vehicles and hydrogen fuel-cell electric vehicles.

Activity Module (Internal Evaluation Only-10 Marks)

Activity	Example Task
Using the tools learned on Module 1, design a variety of items, including:	Conduct a comparative study of conventional and renewable energy resources in India. Prepare an energy scenario report highlighting India's energy mix, renewable energy potential, environmental impacts, and climate change mitigation strategies. Present the findings through a seminar or poster.
Using the tools learned on Module 2, design a variety of items, including:	Determine the moisture content and calorific value of locally available biomass samples (or analyze provided data). Develop a flowchart illustrating biomass conversion technologies and perform simple stoichiometric calculations for biomass combustion. Prepare a case study on a biomass-based power plant.
Using the tools learned on Module 3, design a variety of items, including:	Collect wind speed data from a selected location (or use publicly available data) and estimate the wind power potential. Plot the power curve of a wind turbine and calculate turbine efficiency using Betz limit concepts.
Using the tools learned on Module 4, design a variety of items, including:	Design a basic stand-alone solar PV system for a residential load using given specifications. Draw the layout of a small hydropower plant and identify its

	major components. Prepare a presentation comparing solar PV, small hydropower, and geothermal power generation technologies in terms of efficiency, cost, environmental impact, and applications.

CLO-PLO Mapping Matrix

CLO \ PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO10	PLO11	PLO12
CLO1	3	3	0	0	0	2	3	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	3	2	3	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.	Solar Energy: Fundamental and Application	H. P. Garg and S. Prakash	McGraw Hill
2.	Non-Conventional Energy Resources	B H Khan	McGraw Hill
	References	**Author**	**Publisher**
1.	Solar Photovoltaics: Fundamentals, Technologies and Applications	Solanki C. S.	Prentice Hall India
2.	Applied Energy: An Introduction	Mohammad Omar Abdullah	CRC Press

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Course Code	**BMECDMC425**				
Category	**Professional Elective Course**				
Course Title	**Material Characterization Methods**				
Scheme and Credits	**L**	**T**	**P**	**Credits**	**Semester- 4 (*Four*)**
	1	0	2	2	
Pre-requisites	**Material Engineering**				

Course Learning Outcomes (CLOs)

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

i) **CLO1:** ***Understand*** the principles, concepts, and applications of X-ray diffraction techniques for structural characterization of ceramic and crystalline materials. ***(L2)***

ii) **CLO2:** ***Compare*** different microscopy techniques such as optical microscopy, SEM, and TEM based on their principles, capabilities, and applications in material characterization. ***(L2)***

iii) **CLO3:** ***Interpret*** surface morphology, elemental composition, chemical bonding, and structural information obtained from AFM, SEM, EDAX, WDS, and XPS analysis. ***(L5)***

iv) **CLO4:** ***Draw*** and represent the working principles, instrumentation setup, and analysis procedures of spectroscopic techniques such as UV-Visible and FTIR spectroscopy. ***(L3)***

v) **CLO5:** ***Assemble*** suitable characterization techniques including fluorescence, XRF, ESR, NMR, and thermal analysis methods for evaluating glass and ceramic materials. ***(L6)***

Theory Module(Internal and External Evaluation)

M.No:	Topic
Module 1.	X-ray Diffraction, diffraction under non-ideal conditions, atomic scattering and geometrical structure factors, factors influencing the intensities of diffracted beams, powder X-ray diffractometer, EXAFS and XANES, applications of XRD in ceramic materials.

Module 2.	Microscopy, study of the morphology, aggregation, size and microstructure of ceramic materials using. optical microscope, quantitative phase analysis, principle of electron microscopy. Construction and operation of transmission electron microscope and scanning electron microscope, electron diffraction by crystalline solids; selected area diffraction.
Module 3.	AFM, SEM and XPS, atomic force microscope, mechanism of image formation in SEM and its processing. electron microprobe analysis (EDAX and WDS), preparation of samples for electron microscopic studies, electron spectroscopy for chemical analysis (ESCA/XPS).
Module 4.	Spectrophotometric analysis of materials, basic laws of spectrophotometry and its application in micro analysis in UV/ visible range, effect of reflectance factor on optical analysis, construction and working principle of spectrophotometer, importance of additive absorbance in multiple analysis of materials. Infrared spectrophotometry, general aspects of IR spectroscopy and its application in structural analysis of systems, sources of IR radiations, optical systems and operation of Fourier transformed infrared (FTIR) spectrophotometer, samples preparation, IR analysis and structural co-relations.
Module 5.	Fluorescence and phosphorescence spectroscopy, basic principle, geometrical optics, construction, working principle and use of fluorescence spectrometry in materials analysis. X-ray fluorescence, electron spin resonance spectroscopy, nuclear magnetic resonance, thermal characterization, differential thermal analysis, thermogravimetric analysis and differential scanning calorimetry with suitable examples of glass and ceramic materials.

Activity Module (Internal Evaluation Only-10 Marks)

Activity	Example Task
Using the tools learned on Module 1, design a variety of items, including:	Students are shown simple XRD diffraction patterns and asked to identify peak positions, intensity variations, and relate peaks to crystal structure/material identification through group discussion.
Using the tools learned on Module 2, design a variety of items, including:	Image processing and grain size Measurement from SEM/optical microscope Images.
Using the tools learned on Module 3, design a variety of items, including:	Simulation of atomic force microscopy Surface Topography Analysis (using Gwyddion)
Using the tools learned on Module 4, design a variety of items, including:	Simulation of FTIR spectrum acquisition and functional group identification (using spectragryph /Excel)
Using the tools learned on Module 5, design a variety of items, including:	Students participate in a rapid quiz or create a classroom concept map linking characterization techniques (XRF, fluorescence, DSC, TGA, DTA) with their principles and applications.

Practical Module (Internal and External Evaluation)

M.No:	Experiments
Module 1.	Identification of crystalline phases and determination of crystal structure using X-ray Diffraction (XRD) analysis.
Module 2.	Determination of crystallite size and lattice parameters from XRD diffraction patterns.
Module 3.	Study of morphology and microstructure of ceramic materials using Optical Microscope and SEM images.
Module 4.	Analysis of TEM images and Selected Area Electron Diffraction (SAED) patterns for crystalline material characterization.
Module 5.	Surface topography and roughness analysis of materials using Atomic Force Microscopy (AFM).
Module 6.	Elemental and chemical composition analysis of materials using EDAX and XPS techniques.
Module 7.	Determination of optical properties of materials using UV-Visible spectrophotometry.
Module 8.	Identification of functional groups and structural analysis of materials using FTIR spectroscopy.
Module 9.	Elemental composition analysis of ceramic/glass materials using X-ray Fluorescence (XRF) spectroscopy.
Module 10.	Thermal characterization of materials using TGA/DSC/DTA analysis and interpretation of thermal behavior.

CLO-PLO Mapping Matrix

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

CLO4	2	2	0	2	2	0	0	0	1	2	0	1
CLO5	3	3	2	3	3	1	1	0	2	2	1	3

Recommended Books

S.No:	Text Books	Author	Publisher
1.	Materials Characterization Techniques	Sam Zhang, Lin Li and Ashok Kumar	CRC Press
2.	Materials Characterization: Introduction to Microscopic and Spectroscopic Methods	Yang Leng,	Wiley & Sons.
	References	**Author**	**Publisher**
1.	Characterization of Materials	Elton N. Kaufmann	Wiley & Sons.
2.	Springer Handbook of Crystal Growth	G. Dhanaraj, K. Byrappa, V. Prasad and M. Dudley	Springer-Verlag
3.	Physical Methods of Materials Characterization	Peter E.J. Flewitt and R.K. Wild	Taylor & Francis.

Course Code	**BMECCTM425**				
Category	**Professional Core courses**				
Course Title	**Theory of Machines**				
Scheme and Credits	**L**	**T**	**P**	**Credits**	**Semester- 4 (*Four*)**
	2	1	2	4	
Pre-requisites	**Engineering Mechanics**				

Course Learning Outcomes (CLOs)

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

i*) CLO1:** ***Understand the kinematic behavior of planar mechanisms by determining mobility, velocity, acceleration, instantaneous centers, and Coriolis acceleration for common mechanisms such as four-bar and slider-crank chains. ***(L2)***

ii) **CLO2:** ***Compare*** and analyze cam-follower mechanisms by selecting appropriate follower motion laws and evaluating displacement, velocity, acceleration, and pressure angle characteristics for engineering applications. ***(L2)***

iii) **CLO3:** ***Interpret*** the principles of friction to analyze screw threads, screw jacks, and belt drive systems, and determine belt tensions, velocity ratio, slip, efficiency, and power transmission characteristics. ***(L5)***

iv) CLO4: Draw gear geometry and gear train configurations by applying the law of gearing to determine velocity ratios, contact ratio, interference, and power transmission in simple, compound, reverted, and epicyclic gear trains.***(L3)***

v) **CLO5:** ***Assemble and*** analyze the performance of governors, flywheels, and gyroscopic systems by evaluating speed regulation, stability, controlling force, and gyroscopic effects in engineering applications, ***(L6)***

Theory Module(Internal and External Evaluation)

M.No:	Topic
Module 1.	Mechanism and machine, elements or links, kinematic Joint, kinematic pair, degree of freedom (DOF), Mobility of Mechanism, Gruebler Criterion, four bar chain, inversions of four bar mechanism, Grashoff's law, transmission angle, single slider crank chain and double slider crank chain, velocity and acceleration analysis, Instantaneous centre of velocity, special cases of instantaneous centre of rotation, Coriolis acceleration.
Module 2.	Classification of cams and followers, terminology for cams, types of motion curves and their analytical expressions, graphical construction of cam profile for different types of followers, pressure angle.
Module 3.	Types of friction, laws of friction, force analysis of a single body, screw threads friction, screw jack, types of belt drive, velocity ratio, effect of slip, belt tensions, power transmission of belt drive, conditions for max power transmission.
Module 4.	Gear introduction, classification of gears, gear terminology, law of gearing, velocity of sliding , conjugate teeth, meshing of involute teeth, comparison of cyclodial and involute tooth, length of contact, contact ratio, interference, simple gear train, compound gear train, reverted gear train and epicyclic gear train.
Module 5.	Governors, Watt governor, Porter governor, Proell governor, Hartnell governor, controlling force, sensitivity, stability, hunting, isochronism, effort and power of a governor, working and analysis of flywheel,

	gyroscope, gyroscopic torque, gyroscopic effects on an airplane and ships, gyroscopic stabilization, stability analysis of a two wheel vehicle, four-wheel drive on a curved path.

Activity Module (Internal Evaluation Only-10 Marks)

Activity	Example Task
Using the tools learned on Module 1, design a variety of items, including:	Build a wooden four-bar linkage using four wooden bars joined with pivot pins.
Using the tools learned on Module 2, design a variety of items, including:	Profile synthesis and simulation of high speed cam follower systems to evaluate SVAJ curves and contact forcelift off thresholds using MATLAB
Using the tools learned on Module 3, design a variety of items, including:	Model an open belt drive and investigate the effects of pulley diameter and slip on velocity ratio.
Using the tools learned on Module 4, design a variety of items, including:	Modeling, simulation and kinematic analysis of simple, compound and epicyclic gear trains using MATLAB Multibody.
Using the tools learned on Module 5, design a variety of items, including:	Simulation-based dynamic analysis of slider-crank and flywheel systems for turning moment diagrams, fluctuation of energy and flywheel sizing.
Using the tools learned on Module 6 design a variety of items, including	MATLAB-based simulation of gyroscopic torque effects and directional stability of two-wheel and four-wheel vehicles during curved path maneuvers.

Practical Module (Internal and External Evaluation)

M.No:	Experiments
Module 1.	Study of kinematic pairs.
Module 2.	Study slider crank motion and reciprocating engine mechanism.
Module 3.	Study characteristics of various types of cams and followers.
Module 4.	To plot follower displacement vs cam rotation for various Cam Follower systems
Module 5.	To find coefficient of friction between belt and pulley
Module 6.	To study simple and compound screw jack and determine the mechanical advantage, velocity ratio and efficiency
Module 7.	Study the characteristics of a Watt Governor, Proell Governor and Porter Governor
Module 8.	Performance characteristics of a spring loaded governor
Module 9.	To study various types of gears- Spur, Helical, Worm and Bevel Gears
Module 10.	Determine the velocity of precession of a given motorized gyroscope.

CLO-PLO Mapping Matrix

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

S.No:	Text Books	Author	Publisher
1.	Theory of Mechanisms and Machines	Amitabha Ghosh and Ashok Kumar Mallik	EWP, 2007
2.	Theory of Machines	SS Ratan	Mc Graw Hill
	References	**Author**	**Publisher**
1.	Theory of Machines	Shigley	McGraw Hill, 1995
2.	Theory of Machines	Bevan	C.B.S Publica on, 1997
3.	Theory of Machines	Sadhu Singh	Pearson

Course Code	**BMECDFM425**				
Category	**Experiential Learning Course**				
Course Title	**Fluid Machinery**				
Scheme and Credits	**L**	**T**	**P**	**Credits**	**Semester- 4 (*Four*)**
	0	**2**	**2**	**3**	
Pre-requisites	**Fluid Mechanics**				

Course Learning Outcomes (CLOs)

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

i) **CLO1:** ***Explain*** the classification, operating principles, energy transfer mechanisms, and performance parameters of fluid machines using the fundamental concepts of turbomachinery. ***(L2)***

ii) **CLO2:** ***Analyze*** the performance of hydraulic turbines by constructing velocity triangles, applying Euler's turbomachinery equation, determining efficiencies, and selecting suitable turbines for specified operating conditions. ***(L4)***

iii) **CLO3:** ***Evaluate*** the performance of rotodynamic pumps by analyzing pump characteristics, system characteristics, pumps in series and parallel, NPSH, cavitation, and pump selection for engineering applications. ***(L4)***

iv) **CLO4:** ***Apply*** the principles of positive displacement pumps to determine discharge, slip, acceleration head, power requirements, and select appropriate pumps for industrial applications. ***(L3)***

v) **CLO5:** ***Analyze*** hydraulic transients, cavitation, and fluid power devices, and recommend suitable engineering measures for improving the reliability and efficiency of fluid systems. ***(L4)***

Theory Module(Internal and External Evaluation)

M.No:	Topic
Module 1.	Introduction to fluid machinery and its engineering applications, classification of fluid machines, positive displacement and rotodynamic machines, energy transfer in turbomachines, Euler's turbomachinery equation, velocity triangles, hydraulic, mechanical, volumetric and overall efficiencies, application of dimensional analysis and model testing for turbomachines, dimensionless groups, specific speed and unit quantities.
Module 2.	Classification and selection of hydraulic turbines, Impulse turbines: Pelton wheel-construction, working principle, velocity triangles, work done, efficiencies and governing, Reaction turbines: Francis, Propeller and Kaplan turbines-construction, inlet and outlet elements of turbine, draft tubes and their performance, characteristic curves of turbines, cavitation in hydraulic turbines.
Module 3.	Classification of pumps, centrifugal pumps, Euler and manometric head, hydraulic, manometric, mechanical, volumetric and overall efficiencies, Hydraulic Grade Line (HGL) and Energy Grade Line (EGL) in pumping systems, pump and system characteristic curves, pumps in series and parallel, axial-flow and mixed-flow pumps, Net Positive Suction Head (NPSH), cavitation in pumps.
Module 4.	Classification of positive displacement pumps, reciprocating pumps, slip and coefficient of discharge, acceleration head, air vessels, double-acting and multicylinder pumps, rotary positive displacement pumps: gear, vane, screw and lobe pumps, performance characteristics and engineering applications.
Module 5.	Head losses in pump and turbine systems, water hammer in pipelines, surge tanks and surge phenomena, cavitation and its prevention, hydraulic accumulator, hydraulic ram, hydraulic lift and hydraulic press, fluid coupling and torque converter.

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 MATLAB/Python/Excel program to construct velocity triangles and calculate work output using Euler's turbomachinery equation. apply dimensional analysis and similarity laws to predict the performance of a prototype from model test data.
Using the tools learned on Module 2, design a variety of items, including:	Analyze the performance of Pelton, Francis and Kaplan turbines using manufacturer or experimental data, develop a computational model to estimate turbine efficiency under varying head and discharge conditions, and prepare a case study on the hydraulic turbine employed in an existing hydroelectric power station. Conduct a field visit to a hydroelectric power station and prepare a performance evaluation report. Design a micro-hydropower system for a given site.
Using the tools learned on Module 3, design a variety of items, including:	Develop a MATLAB/Python/Excel program to generate pump characteristic curves and determine the operating point using system curves, evaluate the performance of pumps connected in series and parallel, design a pumping

	system for water supply, irrigation, or industrial applications using manufacturer's performance data.
Using the tools learned on Module 4, design a variety of items, including:	Develop a computational model to calculate discharge, slip, acceleration head, and power requirements of reciprocating pumps, compare reciprocating, gear, vane, screw, and lobe pumps for different industrial services and justify the selection based on operating conditions.
Using the tools learned on Module 5, design a variety of items, including:	Prepare a case study on the design and operation of hydraulic accumulators, hydraulic presses, hydraulic lifts, hydraulic rams, fluid couplings, or torque converters.

Practical Module (Internal and External Evaluation)

M.No:	Experiments
Module 1.	Impact of jet of water on vane (To find the coefficient of impact of jet on flat circular and hemispherical vanes).
Module 2.	Study of Pelton turbine (To conduct performance test on the Pelton turbine).
Module 3.	Study of Francis turbine (To conduct performance test on the Francis turbine).
Module 4.	Study of Kaplan turbine (To conduct performance test on the Kaplan turbine).
Module 5.	Study of centrifugal Pump (To analyse the pump and system characteristics).

CLO-PLO Mapping Matrix

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

Recommended Books

S.No:	Text Books	Author	Publisher
1.	Turbomachinery	Maneesh Dubey, BVSSS Prasad, Archana Nema	Mc Graw Hill Education
2.	Hydraulic Machines	Jagdish Lal	Metropolitan Book Company Pvt. Ltd., New Delhi
	References	**Author**	**Publisher**
1.	Fluid Machinery: Performance, Analysis, and Design	Terry Wright	New Age
2.	Principles of Turbomachinery	R.K Turton	Chapman and Hall
3.	Turbomachinery Design and Theory	Rama S. R. Gorla, Aijaz A. Khan	Marcel Dekkerinc

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Course Code	**BMECCMC425**				
Category	**Professional Core Courses**				
Course Title	**Metal Casting and Forming Processes**				
Scheme and Credits	**L**	**T**	**P**	**Credits**	**Semester- 4 (*Four*)**
	2	1	2	4	
Pre-requisites	**Basic knowledge of Material Science, Fluid Mechanics and Engineering Thermodynamics**				

Course Learning Outcomes (CLOs)

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

i) **CLO1:** ***Understand*** the principles of metal casting processes, moulding materials, gating and risering systems, casting defects, and special casting techniques used in manufacturing. ***(L2)***

ii) **CLO2:** ***Compare*** various metal forming processes such as rolling, forging, extrusion, wire drawing, and tube drawing based on their working principles, applications, and product characteristics. ***(L2)***

iii) **CLO3:** ***Interpret*** the sequence of operations, tooling requirements, and process parameters involved in sheet metal manufacturing processes and die design. ***(L5)***

iv) **CLO4:** ***Draw*** process flow diagrams, mould layouts, die designs, and schematic representations of advanced plastic moulding processes used in product manufacturing. ***(L3)***

v) **CLO5:** ***Assemble*** the knowledge of powder metallurgy processing, powder production methods, compaction techniques, and sintering operations to develop suitable manufacturing solutions for engineering components. ***(L6)***

Theory Module(Internal and External Evaluation)

M.No:	Topic
Module 1.	Fundamentals of metal casting, pattern design and allowances, moulding materials and mould preparation, gating and risering systems, melting practice, solidification, casting cleaning and inspection, casting defects and remedies, product design considerations for castings. Special casting processes: shell moulding, investment casting, permanent mould casting, pressure die casting, vacuum die casting, low-pressure die casting, centrifugal casting, continuous casting and squeeze casting.
Module 2.	Fundamentals of plastic deformation, stress–strain relationships in metal forming, hot and cold working, rolling, forging, extrusion, wire drawing, rod drawing and tube drawing, process parameters, defects, applications and product design considerations.
Module 3.	Sheet metal characteristics, shearing mechanism, press working operations, blanking, punching, piercing, drawing, drawability, draw die design, bending, stretch forming, spinning, embossing, coining, sheet metal die design, defects and applications.
Module 4.	Classification and properties of engineering polymers, injection moulding, blow moulding, rotational moulding, thermoforming, compression moulding, mould design considerations, process parameters, defects and industrial applications.
Module 5.	Introduction to powder metallurgy, production and characterization of metallic powders, powder blending and compaction, sintering, secondary processing operations, alternative compaction techniques, defects and applications of powder metallurgy.

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 Casting Solidification and Shrinkage Defect Prediction (Using ANSYS Student)
Using the tools learned on Module 2, design a variety of items, including:	Computational Analysis of Rolling Load and Power Requirement (Using Excel/MATLAB)
Using the tools learned on Module 3, design a variety of items, including:	Simulation of Deep Drawing Process and Springback Analysis (Using SolidWorks Simulation/ ANSYS Student)
Using the tools learned on Module 4, design a variety of items, including:	Computational Analysis of Blow Moulding Parameters and Wall Thickness Distribution (Using Excel/MATLAB)
Using the tools learned on Module 5, design a variety of items, including:	Computational Analysis of Powder Compaction Pressure and Green Density (Using Excel/MATLAB)

Practical Module (Internal and External Evaluation)

M.No:	Experiments
Module 1.	To prepare a green sand mould and study the properties and constituents of moulding sand used in casting.
Module 2.	To design a pattern and gating system for a given casting component and understand metal flow during casting.
Module 3.	To produce a casting using the sand casting process and examine the quality of the cast product.
Module 4.	To identify common casting defects and analyze their causes and remedial measures.
Module 5.	To perform a forging operation and study the effect of plastic deformation on the shape and dimensions of a workpiece.
Module 6.	To fabricate a simple sheet metal component using marking, cutting, bending, and joining operations.
Module 7.	To perform blanking and piercing operations using a press tool and study the working of sheet metal dies.
Module 8.	To produce a cup-shaped component by deep drawing and study the influence of drawing parameters.

Module 9.	To study and differentiate products manufactured by injection moulding, blow moulding, rotational moulding, thermoforming, and compression moulding processes.
Module 10.	To prepare a powder metallurgy compact using a die and press and evaluate the green density of the compact.

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

Recommended Books

S.No:	Text Books	Author	Publisher
1.	Manufacturing Science	A Ghosh and A K Mallik	Wiley Eastern
2.	Manufacturing Technology: Foundry, Forming And Welding	P N. Rao	Tata McGraw Hill
3.	Introduction to manufacturing technologies Principles and technologies	Prashant P Date	Jaico publications
	References	**Author**	**Publisher**
1.	Manufacturing Processes for Engineering Materials	S Kalpakjian and S R Schmid	Pearson education
2.	Principles Of Manufacturing Materials And Processes	J S Campbell	Tata McGraw Hill 3.
3.	Production Engineering Sciences	P C Pandey and C K Singh	Standard Publishers Ltd.

Course Code	BMECBCA525				
Category	Basic Science Course				
Course Title	Complex Analysis and Special Functions				
Scheme and Credits	L	T	P	Credits	Semester- 5 (*Five*)
	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 concepts of complex variables, analytic functions, and harmonic functions. ***(L2)***

ii) **CLO2:** ***Apply*** Cauchy's theorems, integral formulae, and series expansions to solve complex variable problems. ***(L3)***

iii) **CLO3:** ***Analyze*** contour integrals, residues, poles, and conformal mappings in engineering applications. ***(L4)***

iv) **CLO4:** ***Solve*** differential equations using power series and Frobenius methods. ***(L3)***

v) **CLO5:** ***Evaluate*** engineering problems using Bessel and Legendre functions and their recurrence relations. ***(L5)***

Theory Module (Internal and External Evaluation)

M.No:	Topic
Module 1.	Review of complex numbers, Cartesian and polar form of a complex number, Functions of a complex variable, Limits, continuity and Differentiability of complex functions, Analytic functions, The necessary condition for the function to be analytic functions, Harmonic functions.
Module 2.	Cauchy's fundamental theorem, Cauchy's integral formula, Cauchy's integral formula for derivatives Cauchy's inequality and Liouville's theorem, Taylor's and Laurent's expansions,
Module 3.	Zeros and poles of analytic functions, Residues, Cauchy's residue theorem, Evaluation of integrals with the help of residue and Contour integration. Conformal Mappings,
Module 4.	Power series solutions of differential equations, ordinary point, solution about singular point, Frobenius Method.
Module 5.	Bassel's functions, Recurrence formulae and Bessel's functions of integral order Legendre's functions, Rodrigues's formula, generations functions for Legendre's polynomials and recurrence formulae.

Activity Module (Internal Evaluation Only-10 Marks)

Activity	Example Task
Using the tools learned on Module 1, design a variety of items, including:	Plot complex numbers and visualize analytic functions using MATLAB/Octave to study mappings in the complex plane.
Using the tools learned on Module 2, design a variety of items, including:	Use MATLAB/Python to verify Cauchy's integral theorem and visualize contour integration for simple analytic functions.
Using the tools learned on Module 3, design a variety of items, including:	Compute residues and generate conformal mapping plots using MATLAB, Mathematica, or Python for selected complex functions.
Using the tools learned on Module 4, design a variety of items, including:	Implement MATLAB programs to obtain power series and Frobenius solutions of ordinary differential equations and compare with analytical solutions.
Using the tools learned on Module 5, design a variety of items, including:	Generate and analyze Bessel and Legendre functions using MATLAB/Python, and study their engineering applications through graphical visualization.

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	3	3	2	2	2	0	0	0	0	1	0	1
CLO3	2	3	2	3	2	0	0	0	0	1	0	1
CLO4	3	3	2	3	2	0	0	0	0	1	0	2
CLO5	2	2	2	2	2	0	0	0	0	1	0	2

CLO5	2	2	2	2	2	0	0	0	0	1	0	2

Recommended Books

S.No:	Text Books	Author	Publisher
2	Advance Engineering Mathematics	R.k.Jain and S.R.K Iyengar	Narosa Publishing House
	Advance Engineering Mechanics	Erwin Kreyszig	John wiley and sons
	A Textbook of Engineering Mathematics	N. P. Bali and Manish Goyal	Laxmi Publications
	References	**Author**	**Publisher**
	Complex Variables and Applications Transfer	J.W. Brown and R.V. Churchill	McGraw- Hill
	Laplace transform	Murray R Spiegel	McGraw-Hill

Course Code	**BMECCAC525**				
Category	**Professional Core course**				
Course Title	**Automatic Control**				
Scheme and Credits	**L**	**T**	**P**	**Credits**	**Semester- 5 (*Five*)**
	2	**0**	**2**	**3**	
Pre-requisites	**Laplace Transforms**				

Course Learning Outcomes (CLOs)

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

i) **CLO1:** ***Formulate*** mathematical transfer functions of mechanical, electrical, and electromechanical systems from physical principles, and simplify complex configurations using block diagram reduction and signal flow graphs. ***(L5)***

ii) **CLO2:**. ***Analyze*** the transient and steady-state time responses of first and second-order systems to calculate performance specifications and track steady-state errors under standard test inputs. ***(L4)***

iii) **CLO3:** ***Evaluate*** absolute system stability using the Routh-Hurwitz criterion and determine optimal industrial controller configurations (P, PI, PD, PID) to satisfy performance metrics in mechanical applications. ***(L5)***

iv) **CLO4:** ***Design*** and assess relative stability parameters using graphical root locus and frequency response methods (Bode, Polar, and Nyquist plots) including introductory lead-lag compensation networks..***(L6)***

v) **CLO5:** ***Develop*** state-space vector-matrix representations for multi-variable mechanical systems, examine controllability and observability criteria, and validate system loops using MATLAB/Simulink tools. ***(L5)***

Theory Module(Internal and External Evaluation)

M.No:	Topic
Module 1.	Introduction to automatic control systems, open-loop and closed-loop control systems, applications in mechanical engineering, feedback control systems, mathematical modelling of mechanical, electrical and electromechanical systems, differential equations and Laplace transform review, transfer functions, block diagram reduction techniques, Signal Flow Graphs and Mason's gain Formula.
Module 2.	Standard test signals, time response of first-order and second-order systems, performance specifications, rise time, peak time, settling time, maximum overshoot, steady-state error, system type, static error constants, steady-state error analysis.
Module 3.	Concept of stability, BIBO stability, Routh–Hurwitz stability criterion, root locations and stability, control actions, ON–OFF control, proportional (P), integral (I), derivative (D), PI, PD and PID controllers, effect of controllers on system performance.
Module 4.	Root locus technique, construction rules, effect of pole-zero locations, frequency response, polar plot, Bode plot, gain margin, phase margin, Nyquist stability criterion.
Module 5.	Introduction to state-space representation, state variables, state equations, elementary concepts of controllability and observability, MATLAB/Simulink for control system analysis, applications in cruise control, DC motor speed control, servo mechanisms, hydraulic and pneumatic control systems, mechatronic systems.

Activity Module (Internal Evaluation only-10 Marks)

Activity	Example Task
Using the tools learned on Module 1, design a variety of items, including:	Model a mechanical or electromechanical control system, develop its transfer function using mathematical modelling techniques, represent the system using block diagrams and signal flow graphs, and validate the model using MATLAB/Simulink.
Using the tools learned on Module 2, design a variety of items, including:	Analyse the transient and steady-state response of first-order and second-order systems, determine performance specifications including rise time, peak time, settling time and overshoot, and evaluate the effect of system parameters using MATLAB/Simulink.
Using the tools learned on Module 3, design a variety of items, including:	Analyse the stability of a control system using the Routh–Hurwitz criterion, design and tune P, PI, PD and PID controllers for a mechanical engineering application such as DC motor speed control, temperature control or servo position control, and compare their performance through simulation.
Using the tools learned on Module 4, design a variety of items, including:	Construct root locus, Bode and Nyquist plots for a control system, analyse gain margin and phase margin, design a lead, lag or lead–lag compensator to improve system performance, and validate the design using MATLAB/Simulink.
Using the tools learned on Module 5, design a variety of items, including:	Develop a state-space model of a dynamic system, analyse controllability and observability, simulate the system using MATLAB/Simulink, and investigate engineering applications such as cruise control, DC motor speed control, servo mechanisms, hydraulic and pneumatic systems, or mechatronic systems.

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	0
CLO2	3	3	0	0	0	0	0	0	0	0	0	0
CLO3	3	3	3	0	0	0	0	0	0	0	0	0
CLO4	3	3	3	2	0	0	0	0	0	0	0	0
CLO5	3	2	0	0	3	0	0	0	0	0	0	2

Recommended Books

S.No:	Text Books	Author	Publisher
	Modern control Engineering	Ogata. K	Prentce Hall
2	**Automatic Control Systems**	Benjamin C. Kuo & Farid Golnaraghi	Wiley
	References	**Author**	**Publisher**
	Automatic Control	Raven.H	McGraw Hill
	Feedback Control of Dynamic Systems	Gene F. Franklin, J. David Powell, & Abbas Emami-Naein	Pearson

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Course Code	**BMECCHT525**					
Category	**Professional Core courses**					
Course Title	**Heat Transfer**					
Scheme and Credits	**L**	**T**	**P**	**Credits**	**Semester- 5 (*Five*)**	
	2	1	2	4		
Pre-requisites	**Basic Engineering Thermodynamics**					

Course Learning Outcomes (CLOs)

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

i) **CLO1:** ***Understand*** the fundamental modes and mechanisms of heat and mass transfer, including conduction, convection, radiation, and diffusion. ***(L2)***

ii) **CLO2:** ***Compare*** various heat transfer modes, heat exchangers, boiling, condensation, and mass transfer processes under different operating conditions. ***(L2)***

iii) **CLO3:** ***Interpret*** heat and mass transfer phenomena using governing equations, empirical correlations, and dimensionless parameters for engineering applications. ***(L5)***

iv) **CLO4:** ***Draw*** and interpret thermal resistance networks, heat exchanger configurations, boundary layer profiles, and radiation exchange diagrams. ***(L3)***

v) **CLO5:** ***Assemble*** and ***apply*** appropriate heat and mass transfer principles to analyze and solve engineering thermal system problems. ***(L6)***

Theory Module(Internal and External Evaluation)

M.No:	Topic
Module 1.	Modes of heat transfer; Fourier's law; thermal conductivity and thermal resistance; one-dimensional steady and transient conduction; composite walls, cylinders, and spheres; critical insulation thickness; extended surfaces (fins); two-dimensional heat conduction.
Module 2.	Transient heat conduction; lumped system analysis; transient conduction in plane walls, cylinders, spheres, and semi-infinite solids; analytical and graphical solutions; multidimensional transient conduction;
Module 3.	Free and forced convection; hydrodynamic and thermal boundary layers; external and internal flows; empirical heat transfer correlations; natural convection; condensation and boiling heat transfer; pool boiling regimes and phase-change applications.
Module 4.	Types of heat exchangers; overall heat transfer coefficient; LMTD and effectiveness–NTU methods; analysis of parallel-flow, counter-flow, cross-flow, and multi-pass heat exchangers; selection of heat exchangers.
Module 5.	Fundamentals of thermal radiation; blackbody radiation; surface properties; Planck's, Kirchhoff's, Wien's, and Stefan–Boltzmann laws; view factor; and radiation heat exchange between surfaces.

Activity Module (Internal Evaluation Only-10 Marks)

Activity	Example Task
Using the analytical/numerical tools learned on Module 1	Numerical solution of heat conduction problems using the Finite Difference Method (FDM).
Using the analytical/numerical tools learned on Module 2.	Simulation of Cooling of Microprocessors and Electronic Chips Using ANSYS
Using the analytical/numerical tools learned on Module 3.	Simulation of natural convection from a vertical heated plate. Simulation of flow and heat transfer over a circular cylinder.
Using the analytical/numerical tools learned on Module 4.	Apply AI tools for thermal modelling, heat transfer prediction, and optimization of heat exchangers and thermal systems.
Using the tools learned on Module 5, design a variety of items, including:	Simulation of radiative heat exchange between two parallel plates

Practical Module (Internal and External Evaluation)

M.No:	Experiments
Module 1.	Determination of thermal conductivity of a metallic rod using Searle's Conductivity Apparatus
Module 2.	Determination of thermal conductivity of an insulating material using Lee's Disc Apparatus
Module 3.	To determine the thermal conductivity of the given composite wall.
Module 4.	Heat pipe demonstration (superconductivity of material).
Module 5.	Verification of Stefan-Boltzmann Law using Stefan-Boltzmann Apparatus
Module 6.	To determine heat transfer coefficient by forced convection
Module 7.	To determine heat transfer coefficient by natural convection
Module 8.	To determine the overall heat transfer coefficient of shell and tube type heat exchangers
Module 9.	To determine the emissivity of a gray body.
Module 10.	To study drop & film wise condensation & determine the film coefficient.
Module 11	To measure convective heat transfer co-efficient and effectiveness of the fin under forced convection.
Module 12	To measure convective heat transfer co-efficient and effectiveness of the fin under natural convection.

CLO-PLO Mapping Matrix

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

Recommended Books

S.No:	Text Books	Author	Publisher
	Heat and Mass Transfer: Fundamentals and Applications	Yunus Cengel,	McGraw Hill
2	Heat Transfer	J P Holman	McGraw Hill
	References	**Author**	**Publisher**
	Fundamental of Heat and Mass Transfer	Incropera and Dewit	Wiley Publication
	Heat Transfer	Mills and Ganesan	Pearson Education

Course Code	**BMECCAT525**				
Category	**Professional Core courses**				
Course Title	**Applied Thermodynamics**				
Scheme and Credits	**L**	**T**	**P**	**Credits**	**Semester- 5 (*Five*)**
	2	1	2	4	
Pre-requisites	**Engineering Thermodynamics**				

Course Learning Outcomes (CLOs)

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

i) **CLO1:** ***Understand*** the principles of combustion, fuel analysis, air–fuel ratio, calorific value, emissions, boiler systems, and steam power cycles. *(L2)*

ii) **CLO2:** ***Compare*** different combustion methods, fuels, boilers, steam cycles, turbines, nozzles, condensers, and cooling systems based on their performance, efficiency, and applications. *(L2)*

iii) **CLO3:** ***Interpret*** the performance characteristics of combustion systems, boilers, nozzles, steam turbines, condensers, and thermal power plant components using thermodynamic principles and performance parameters. *(L5)*

iv) **CLO4:** ***Draw*** and explain the construction, working principles, and schematic diagrams of boilers, steam power plants, nozzles, turbines, condensers, cooling towers, and associated systems. *(L3)*

v) **CLO5:** ***Assemble*** thermodynamic concepts to evaluate, design, and integrate efficient and sustainable steam power plant systems incorporating modern technologies such as biomass boilers, IoT-based monitoring, carbon capture, and low-carbon combustion techniques. *(L6)*

Theory Module(Internal and External Evaluation)

M.No:	Topic
Module 1.	Combustion Analysis, Air requirement, air-fuel ratio, Combustion analysis of solid, liquid, gaseous, and alternative fuels, Stoichiometric air-fuel ratio, Calorific value of fuels, Standard heat of reaction, heat of formation. Emission formation (NOx, SOx, CO, particulate matter) and emission control techniques, Introduction to carbon capture and low-carbon combustion technologies

Module 2.	Steam generators-classification, working of fire tube and water tube boilers, boiler mountings and accessories, Boiler performance, efficiency and heat balance, Fluidized Bed Combustion (FBC) boilers Biomass-fired and hybrid boilers, Boiler automation, smart monitoring, IoT-based boiler health monitoring Boiler safety and modern standards
Module 3.	Carnot vapour power cycle, Rankine cycle, modified rankine cycle, Steam power plant working, binary vapour cycle, regenerative cycle.
Module 4.	Nozzle, variation of velocity, area and specific volume, choked flow, nozzle efficiency, off design operation of nozzle, super saturated flow. Applications in steam turbines and power plants Steam turbines, compounding of impulse turbine, velocity diagrams, reaction turbine, degree of reaction, work output, governing of turbine.
Module 5.	Condensers- type of condensers, air leakage, condenser performance parameters, Cooling towers and cooling water systems, Air-cooled condensers, Water conservation techniques in thermal power plants Environmental considerations and sustainable cooling technologies

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 MATLAB/Python/Excel program to calculate the stoichiometric air requirement, air-fuel ratio, excess air, flue gas composition, and calorific value for different fuels (e.g., coal, diesel, natural gas, hydrogen). Compare the combustion characteristics and emissions of the selected fuels graphically. .
Using the tools learned on Module 2, design a variety of items, including:	Develop a computational model using MATLAB/Python/Excel to calculate boiler efficiency (direct and indirect methods), equivalent evaporation, factor of evaporation, steam generation rate, and fuel consumption. Analyze the effect of varying boiler pressure, steam temperature, and excess air on boiler efficiency. Conduct a boiler performance test and prepare a heat balance sheet using laboratory or industrial data, prepare a case study on boiler safety standards and smart boiler monitoring in modern power plants.
Using the tools learned on Module 3, design a variety of items, including:	.Model the Rankine cycle using MATLAB or Python. Compare the efficiencies of the simple Rankine, reheat, regenerative, and Organic Rankine Cycle (ORC) using T-s diagrams.
Using the tools learned on Module 4, design a variety of items, including:	Develop a one-dimensional computational model using MATLAB/Python to calculate the throat area, exit area, exit velocity, mass flow rate, and nozzle efficiency under isentropic flow conditions. Investigate the effect of pressure ratio on nozzle performance and determine the choked flow condition.
Using the tools learned on Module 5, design a variety of items, including:	Develop a MATLAB/Python program to generate velocity triangles and compute blade velocity coefficient, work output, blade efficiency, stage efficiency, degree of reaction, and steam consumption for impulse and reaction turbines.Prepare a case study on water conservation techniques, cooling tower optimization, and sustainable cooling technologies in thermal power plants.

Practical Module (Internal and External Evaluation)

M.No:	Experiments
Module 1.	Study the working of different Boilers.
Module 2.	Calculation of heat balance sheet of a boiler.
Module 3.	Calculation of dryness fraction of steam.
Module 4.	To study the working of impulse and reaction steam turbines.
Module 5.	To study various types of steam condenser.

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	1	0	0	0	0	1
CLO2	2	3	2	1	0	0	1	0	0	0	0	1
CLO3	2	3	2	3	2	0	1	0	0	1	0	1
CLO4	3	2	2	0	2	0	0	0	0	2	0	0

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

Recommended Books

S.No:	Text Books	Author	Publisher
1.	Applied Thermodynamics	T.D. Eastop, A.McConkey	Pearson Education
2.	Basic and Applied Thermodynamics	P.K.Nag	McGraw-Hill Education
	References	**Author**	**Publisher**
1.	Engineering Thermodynamics	P K Nag	Mc Graw Hill
2.	Fundamentals of Engineering Thermodynamics	Moran M J and H N Shapiro	Wiley

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Course Code	**BMECCSM525**				
Category	**Professional Core courses**				
Course Title	**Structural Mechanics**				
Scheme and Credits	**L**	**T**	**P**	**Credits**	**Semester- 5 (*Five*)**
	2	**1**	**0**	**3**	
Pre-requisites	**Engineering Mechanics**				

Course Learning Outcomes (CLOs)

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

i) **CLO1:** ***Analyze*** the deflection and slope of statically determinate beams using Euler–Bernoulli beam theory, double integration, Macaulay's method, singularity functions, moment-area method, superposition, Castigliano's theorem, and the principle of virtual work. ***(L2)***

ii) **CLO2:** ***Evaluate*** the behavior of statically determinate and indeterminate beams under transverse, axial, and combined loading by applying energy methods, superposition, and shear deformation concepts, including Timoshenko beam theory, shear flow, and shear center. ***(L2)***

iii) **CLO3:** ***Analyze*** the stress distribution and deformation in curved bars, circular rings, and chain links using the theory of curved beams. ***(L5)***

iv) **CLO4:** ***Evaluate*** the stability and buckling behavior of columns under various end conditions and loading configurations using Euler's theory, beam-column equations, Rankine's formula, the secant formula, and elastic and inelastic buckling concepts. ***(L3)***

v) **CLO5:** ***Apply*** appropriate theories of failure to predict the failure of ductile and brittle materials subjected to complex states of stress and recommend suitable design criteria for engineering components. ***(L6)***

Theory Module(Internal and External Evaluation)

M.No:	Topic
Module 1.	Euler–Bernoulli beam theory, assumptions, differential equation of the elastic curve, deflection of statically determinate beams, double integration method, Macaulay's method, singularity functions, moment-area method, superposition principle, Castigliano's first theorem, principle of virtual work.
Module 2.	Deflection of statically indeterminate beams, beam-columns under combined axial and transverse loading, Timoshenko beam theory, shear flow, shear centre, unsymmetrical bending, principal axes of bending.
Module 3.	Curved beams with small and large initial curvatures, stresses in curved beams, circular rings, chain links and crane hooks.
Module 4.	Columns and stability: Euler's critical load, effective length, slenderness ratio, end conditions, Rankine formula, eccentrically loaded columns, secant formula, elastic and inelastic buckling.
Module 5.	Theories of Failure: maximum principal stress theory, maximum principal strain theory, maximum shear stress theory, total strain energy theory, distortion energy (Von Mises) theory, Mohr's theory of failure, application of failure theories in machine component design.

Activity Module (Internal Evaluation Only-10 Marks)

Activity	Example Task
Using the tools learned on Module 1, design a variety of items, including:	Compare Euler–Bernoulli assumptions with real beam behavior through classroom discussion.
Using the tools learned on Module 2, design a variety of items, including:	Write a MATLAB/ Python function to calculate beam deflection for simply supported and cantilever beams under various loads
Using the tools learned on Module 3, design a variety of items, including:	Debate the suitability of various failure theories for engineering applications.
Using the tools learned on Module 4, design a variety of items, including:	Develop MATLAB/ Python code to compute shear flow distribution in I-, T-, and channel sections and visualize results.
Using the tools learned on Module 5, design a variety of items, including:	Write MATLAB/ Python code to calculate stress distribution in curved beams and plot radial stress variation.

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

Recommended Books

S.No:	Text Books	Author	Publisher
1.	Mechanics of Materials	Beer and Johnston	McGraw Hill, 2015
2.	Mechanics of Materials	Barry J Goodno, James M. Gere	Cengage Learning
	References	**Author**	**Publisher**
1.	Mechanics of Materials	J.M. Gere and S.P. Timoshenko	Cengage Learning, 1997
2.	Engineering Mechanics of Solids	Popov. E.P	Prentice Hall of India, 2004
3.	Mechanics of Materials	Hibbeler R.C	Pearson Education, 2007

Course Code	**BMECLMI525**				
Category	**Experiential Learning course**				
Course Title	**Metrology & Instrumentation**				
Scheme and Credits	**L**	**T**	**P**	**Credits**	**Semester - 5 (*Five*)**
	0	**2**	**2**	**3**	
Pre-requisites	**Engineering Physics, Basic Electrical/ Mechanical Engineering**				

Course Learning Outcomes (CLOs)

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

i) **CLO1:** ***Understand*** the fundamentals of Mechanical, Electrical and Electronic measurements of physical quantities with fundamentals of Sensors and Transducers. *(L2)*

ii) **CLO2:** ***Compare*** different types of measuring instruments, sensors, transducers, and their performance characteristics for various applications. *(L2)*

iii) **CLO3:** ***Interpret*** measurement data, instrument specifications, and error analysis to evaluate the accuracy and reliability of measurement systems. *(L5)*

iv) **CLO4:** ***Draw*** block diagrams, circuit configurations, and instrumentation system layouts for measurement applications. *(L3)*

v) **CLO5:** ***Assemble*** and **demonstrate** basic measurement systems using sensors, transducers, and measuring instruments for practical applications. ***(L6)***

Theory Module(Internal and External Evaluation)

M.No:	Topic
Module 1.	Definitions, significance of measurement, fundamental methods of measurement, generalized measurement system, types of input quantities, calibration, errors and methods of correction, static and dynamic characteristics of measuring instruments, classification of instruments, zero and first-order instruments, time constants, transient response characteristics, transducers, signal conditioning, digital measurement systems, data acquisition systems, smart sensors, and an introduction to IoT-enabled measurement systems.
Module 2.	Basic concepts of metrology, standards of measurement, accuracy, precision, sensitivity, resolution, limits, fits and tolerances, hole basis and shaft basis systems, limit gauges, Taylor's principles of gauge design, coordinate measuring machine (CMM) (overview).
Module 3.	Motion and vibration measurements, force measurement, hydraulic and pneumatic load cells, elastic force measuring devices, strain gauge load cells, torque and power measurement using dynamometers, condition monitoring using smart sensors, wireless sensor networks, and IoT-based monitoring of mechanical systems (overview).
Module 4.	Instruments for high, medium and low pressure measurements, dead-weight tester, elastic element pressure gauges, null-type instruments, differential pressure measurement, pressure transmitters, high-pressure and low-pressure measurements, Pirani gauge, McLeod pressure gauge, smart pressure transmitters, and remote pressure monitoring using Industrial IoT (overview).
Module 5.	Flow measurement using rotameter, positive displacement flow meter, turbine flow meter, electromagnetic flow meter, ultrasonic flow meter, temperature measurement using contact and non-contact sensors, thermocouples, RTDs, thermistors, pyrometers, IoT-enabled flow and temperature monitoring, cloud-based data logging, and real-time process monitoring (overview).

Activity Module (Internal Evaluation Only-10 Marks)

Activity	Example Task
Using the tools learned on Module 1, design a variety of items, including:	Interface a displacement, force, or pressure sensor (e.g., LVDT, strain gauge, potentiometer, or load cell) with a microcontroller to acquire, display, and record measurement data in real time. Visualize the sensor output using Arduino IDE, MATLAB.
Using the tools learned on Module 2, design a variety of items, including:	Develop a CAD model incorporating limits, fits, and tolerances. Verify critical dimensions using metrology instruments or CMM (where available) and demonstrate hole-basis and shaft-basis systems using SolidWorks/AutoCAD/Fusion 360.
Using the tools learned on Module 3, design a variety of items, including:	Measure force, vibration, torque, or speed using suitable sensors. Acquire the data using a DAQ or microcontroller and analyse the results. Demonstrate a basic IoT-based condition monitoring dashboard using Arduino IDE with ThingSpeak or Node-RED.
Using the tools learned on Module 4, design a variety of items, including:	Measure pressure using a Bourdon pressure gauge, manometer, or digital pressure sensor (where available). Compare the readings under different operating conditions and plot the pressure variation using Excel, MATLAB, or Arduino IDE.
Using the tools learned on Module 5, design a variety of items, including:	Measure flow rate or temperature using suitable flow meters, thermocouples, RTDs, or thermistors. Record and analyse the data, and develop a simple IoT-enabled real-time monitoring system for flow or temperature using Arduino IDE with ThingSpeak/Blynk IoT or MATLAB.

Practical Module (Internal and External Evaluation)

M.No:	Experiments
Module 1.	To measure displacement using slip gauges.
Module 2.	To study the working of Bourdon pressure gauge and to check the calibration of the gauge in a deadweight pressure gauge calibration set up.
Module 3.	To measure flow rate using different flow measurement devices.
Module 4.	Measurement of strain using strain gauge.
Module 5.	To study characteristics cs of various temperature measuring instruments like thermocouple, thermistor and RTD.

CLO-PLO Mapping Matrix

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

Recommended Books:

S.No:	Text Books	Author	Publisher
1.	Instrumentation, Measurements & Analysis	Nakra B.C.	Tata McGrawHill, N.Delhi.
2.	Mechanical Measurements and Instrumentation and control	A.K. Sawhney, Puneet Sawhney	Dhanpat Rai & Co.
	References	**Author**	**Publisher**
1.	Mechanical Measurements	Beckwith, B	Pearson Education Int.
2.	Measurement systems	Doeblin, E.O	McGraw Hill.
3.	Engineering Metrology and Measurements	N.V Raghavendra, L. Krishnamurthy	Oxford Higher Education

Course Code	BMECHIE625				
Category	Professional Core courses				
Course Title	Industrial Engineering				
Scheme and Credits	L	T	P	Credits	Semester- 6 (*Six*)
	2	0	2	4	
Pre-requisites	-				

Course Learning Outcomes (CLOs)

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

i) **CLO1:** Explain the fundamental concepts of Industrial Engineering and apply facility location principles and systematic layout planning techniques to design efficient plant layouts. *(L2)*

ii) **CLO2:** Analyze work methods and measure work using process charts, work measurement techniques, and ergonomic principles to improve productivity and workplace efficiency. *(L2)*

iii) **CLO3:** Apply inventory management techniques, including EOQ, inventory control systems, inventory classification methods, and Material Requirements Planning (MRP), to optimize inventory decisions and minimize costs. *(L5)*

iv) **CLO4:** Evaluate product and process quality using inspection methods, statistical quality control techniques, sampling inspection, and control charts to support effective quality management.*(L3)*

v) **CLO5:.** Analyze production planning and control systems, manufacturing system characteristics, and break-even analysis to support effective production and operational decision-making. *(L6)*

Theory Module(Internal and External Evaluation)

M.No:	Topic
Module 1.	Introduction to industrial engineering and its various techniques, Facilities location, Introduction and Importance, plant layout: Types of production, types of layouts, advantages and disadvantages of layout, factor affecting layout, systematic layout planning.
Module 2.	Introduction to work study and its basic procedures, definitions and concept of work study with examples, Method study, recording techniques (process charts and diagrams), outline PC , flow process charts, two hand process charts etc, Work measurement, basic procedure of work measurement, techniques of work measurement, standard time, normal time, rating factor etc. ergonomics, scope and objectives of ergonomics.
Module 3.	Inventory Management: Introduction, Inventory related costs, EOQ model, Inventory models allowing shortages, Inventory models allowing price discounts, Inventory control systems: continuous review, periodic review, optional replenishment etc., Inventory classification systems: ABC, FMS, VED etc, MRP
Module 4.	Inspection and quality control, concept and definition of quality, concepts of inspection and quality control, objectives of inspection, function of inspection and their types, concept of statistical quality control, process variation, sampling inspection, concepts and types of control charts, acceptance sampling, application of control charts.
Module 5.	Production planning and control: Introduction, system approach, type of manufacturing systems, Factors affecting manufacturing systems. Break even analysis.

Activity Module (Internal Evaluation Only-10 Marks)

Activity	Example Task
Using the tools learned on Module 1, design a variety of items, including:	Group discussion on the role of Industrial Engineering in modern industries.
Using the tools learned on Module 2, design a variety of items, including:	Conduct a time study for a simple nut bolt assembly using a stopwatch.
Using the tools learned on Module 3, design a variety of items, including:	Develop a simple Material Requirements Planning (MRP) table using any suitable software.
Using the tools learned on Module 4, design a variety of items, including:	Prepare a production planning and control flowchart for a simple manufacturing process.

Practical Module (Internal and External Evaluation)

M.No:	Experiments
Module 1.	Ergonomic design study (present/proposed/new) of a product, equipment or work environment (human-machine interface).

Module 2.	To assemble a product (electrical holder, etc.), record the cycle and draw the learning curve of the operator performing the assembly.
Module 3.	Draw out line process chart and two hand flow process charts for the assembly performed in experiment no. 2, and analyse the present method and also suggest improved method/s.
Module 4.	To calculate the standard me of a suitable job, using predetermined standard techniques.
Module 5.	Study the layout in an organization and draw existing and proposed layouts in WITNESS software.
Module 6.	Develop a simulation on a model in WITNESS software and get results in Gantt chart format.
Module 7.	To measure the variable characteristics (diameter of pins, with micrometer) and prepare a frequency histogram. Calculate values of and sigma.
Module 8.	To draw a control chart for percent defectives and Inspecting a sample and sorting out the defective units.

CLO-PLO Mapping Matrix

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

Recommended Books

S.No:	Text Books	Author	Publisher
1.	Motion and Time Study, Design & Measurement of Work	Barnes. R. L.	John Wiley & Sons, 1990
2.	Production and Operations Management	Evere , E.A., Ronald J.E	Pren ce Hall of India
	References	**Author**	**Publisher**
1.	Plant Layout & Material Handling.	Apple, J.M,	John Wiley & Sons, New York.
2.	Industrial Engineering & Management	Dr. Ravi Shankar	Galgotia Publication

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Course Code	**BMECCMV625**				
Category	**Professional Core courses**				
Course Title	**Mechanical Vibrations**				
Scheme and Credits	**L**	**T**	**P**	**Credits**	**Semester- 6 (*Six*)**
	2	1	2	4	
Pre-requisites	**Engineering Mechanics**				

Course Learning Outcomes (CLOs)

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

i*) CLO1:** ***Understand the fundamental characteristics of mechanical vibration systems by classifying vibration types and applying energy, Rayleigh, and equilibrium methods to determine the dynamic response of vibrating systems. ***(L2)***

ii)* CLO2:** ***Analyze the free vibration behavior of single-degree-of-freedom systems by formulating equations of motion and determining natural frequency for translational, torsional, pendulum, and beam vibration systems. ***(L2)***

iii)* CLO3:** ***Analyze the response of damped single-degree-of-freedom systems by evaluating damping characteristics, logarithmic decrement, damping ratio, and damped natural frequency under different damping conditions. ***(L5)***

iv) **CLO4:** ***Analyze*** forced vibration response, vibration isolation, transmissibility, and the dynamic behavior of single- and two-degree-of-freedom systems using equations of motion and frequency response characteristics. ***(L3)***

v) **CLO5:** ***Analyze*** dynamic forces and balancing requirements of rotating and reciprocating machinery by applying the principles of static and dynamic balancing to improve machine performance and reduce vibration. ***(L6)***

Theory Module (Internal and External Evaluation)

M.No:	Topic
Module 1.	Fundamentals of Mechanical Vibrations: Introduction to mechanical vibrations, definitions and terminology, elements of a vibrating system, mathematical modelling of vibrating systems, degrees of freedom, lumped and continuous parameter systems, simple harmonic motion, amplitude, time period, frequency, natural frequency, phase angle, classification of vibrations, free and forced vibrations, linear and nonlinear vibrations, damped and undamped vibrations, longitudinal, transverse and torsional vibrations.
Module 2.	Undamped Free Vibrations of Single Degree of Freedom Systems : Undamped free vibrations of single degree of freedom systems, derivation of equations of motion using Newton's second law, D'Alembert's principle, energy method and Rayleigh's method, natural frequency of longitudinal and torsional vibration systems, equivalent stiffness of spring combinations, compound pendulum, transverse vibrations of beams, beams carrying several concentrated masses.
Module 3.	Damped Free Vibrations of Single Degree of Freedom Systems: Introduction to damping, different types of damping, equations of motion for damped free vibrations, free vibrations with viscous damping, underdamped, critically damped and overdamped systems, logarithmic decrement, Coulomb damping, viscous dampers, frequency of damped oscillations.
Module 4.	Forced Vibrations and Vibration Control: Forced vibrations of single degree of freedom systems, sources of excitation, equations of motion under harmonic excitation, rotating unbalance excitation, base excitation, total response, resonance, frequency response curves, vibration isolation, transmissibility, dynamic vibration absorber, vibration measuring instruments, vibrometer, accelerometer.
Module 5.	Multi-Degree of Freedom Systems and Balancing: Introduction to two-degree-of-freedom systems, equations of motion of undamped two-degree-of-freedom systems, natural frequencies, mode shapes, balancing of rotating and reciprocating masses, static and dynamic balancing, primary and secondary balancing of reciprocating engines, balancing of in-line engines, whirling of shafts, critical speed of shafts, Rayleigh's method and Dunkerley's method for critical speed estimation.

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 chart comparing different types of vibrations (free, forced, damped, undamped, linear, non-linear).
Using the tools learned on Module 2, design a variety of items, including:	Construct a simple spring–mass system using readily available materials.
Using the tools learned on Module 3, design a variety of items, including:	Conduct simulation exercise in matlab to study the effect of damping on system response.
Using the tools learned on Module 4, design a variety of items, including:	Simulate forced vibration responses using Matlab.
Using the tools learned on Module 5, design a variety of items, including:	Analyze balancing techniques used in automotive engines and present the findings

Practical Module (Internal and External Evaluation)

M.No:	Experiments
Module 1.	Study the time period of different pendulums.
Module 2.	Compare the me periods of rod and thread pendulum.
Module 3.	Verify the radius of gyration of a given pendulum.
Module 4.	Study free undamped vibrations of equivalent spring mass systems.
Module 5.	Study forced undamped vibrations of equivalent spring mass system.
Module 6.	Study undamped torsional vibrations of a single rotor shaft system.
Module 7.	Study damped torsional vibrations and determine damping coefficient of single rotor shaft system.
Module 8.	Study forced (damped & undamped) vibration of a simply supported beam with damping.
Module 9.	Study and observe the effect of unbalanced reciprocating masses in an engine
Module 10.	To study the balancing of reciprocating masses in an internal combustion engine and determine the effect of balancing on vibration reduction.

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

Recommended Books

S.No:	Text Books	Author	Publisher
1.	Mechanical Vibrations Theory and Applications	S. Graham Kelly	Cengage Learning
2.	Mechanical Vibrations	Singiresu S. Rao	Pearson
	References	**Author**	**Publisher**
1.	Theory of Vibrations with applications	Thomson. W.T	Pearson Education, 2010
2.	Elements of vibration analysis	Meirovitch	McGraw Hill, 2011

Course Code	**BMECLIC625**				
Category	**Experiential Learning course**				
Course Title	**Internal Combustion Engines**				
Scheme and Credits	**L**	**T**	**P**	**Credits**	**Semester- 6 (*Six*)**
	0	**2**	**2**	**3**	
Pre-requisites					

Course Learning Outcomes (CLOs)

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

i) **CLO1:** ***Understand*** the classification, working principles, thermodynamic cycles, fuel systems, and combustion processes of internal combustion engines. ***(L2)***

ii) **CLO2:** ***Compare*** the construction, operation, performance, fuel supply, ignition, and combustion characteristics of SI and CI engines. ***(L2)***

iii) **CLO3:** ***Interpret*** engine performance characteristics, combustion behaviour, cooling and lubrication systems, and test results. ***(L5)***

iv) **CLO4:** ***Analyze*** the effects of engine operating parameters, supercharging, cooling, lubrication, and combustion on engine performance and efficiency. ***(L3)***

v) **CLO5:** ***Select*** suitable engine systems, fuels, and performance improvement techniques for different automotive and industrial applications. ***(L6)***

Theory Module(Internal and External Evaluation)

M.No:	Topic
Module 1.	Classification of I.C. engines based on fuel, operating cycle, and number of strokes; review of air-standard cycles; comparison of ideal and actual engine cycles; factors influencing engine performance.
Module 2.	Properties of I.C. engine fuels; fuel quality; octane and cetane numbers; ignition quality; knock rating; variable compression ratio (VCR) engines.
Module 3.	Air–fuel ratios and mixture requirements of SI engines; stoichiometric air–fuel ratio; carburetion principles; types of carburetors; venturi and fuel metering; charge stratification and mixture distribution.
Module 4.	Fuel–air requirements of CI engines; fuel injection systems; combustion in SI and CI engines; flame propagation; detonation and knocking; comparison of SI and CI combustion; ignition systems for SI and CI engines.

Module 5.	Engine friction and lubrication; factors affecting engine friction; lubricants and their properties; lubrication systems and their requirements. Engine cooling systems; heat transfer and heat rejection; air and water cooling methods; scavenging in two-stroke engines; supercharging and turbocharging; engine testing and performance evaluation.

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 study the construction, working, and functions of major components of SI and CI engines through cut-section models or dismantled engines.
Using the tools learned on Module 2, design a variety of items, including:	Conduct performance tests on a petrol or diesel engine to determine brake power, fuel consumption, thermal efficiency, and prepare performance characteristic curves.
Using the tools learned on Module 3, design a variety of items, including:	Study carburetion, fuel injection, and ignition systems of SI and CI engines, and compare their operation and performance.
Using the tools learned on Module 4, design a variety of items, including:	Visit an automobile workshop, engine testing laboratory, or manufacturing industry to observe engine assembly, diagnostics, emission testing, and maintenance practices, followed by submission of a technical report.
Using the tools learned on Module 5, design a variety of items, including:	Prepare a comparative study of SI and CI engines by analyzing their fuel systems, combustion characteristics, cooling and lubrication systems, performance parameters, and emission characteristics. Present the findings through a technical report and seminar.

Practical Module (Internal and External Evaluation)

M.No:	Experiments
Module 1.	To study the constructional details and working principles of SI and CI engines
Module 2.	To determine the performance characteristics of a four-stroke diesel engine under varying load conditions.
Module 3.	To determine the performance characteristics of a four-stroke petrol engine under varying load conditions.
Module 4.	To conduct a Morse test for determining the indicated power and mechanical efficiency of a multi-cylinder SI engine.
Module 5.	To conduct a heat balance test on an I.C. engine and evaluate the energy distribution.
Module 6.	To determine the friction power of an I.C. engine using the Willan's line method.
Module 7.	To study and evaluate the performance of a carburettor in a spark ignition engine.
Module 8.	To study the fuel injection system and injection timing in a compression ignition engine.
Module 9.	To determine the volumetric efficiency and brake thermal efficiency of an I.C. engine.
Module 10.	To study the effect of supercharging/turbocharging on engine performance and efficiency.

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

Recommended Books

S.No:	Text Books	Author	Publisher
1.	Internal Combustion Engines	V. Ganesan	McGraw Hill
2.	A Textbook of Internal Combustion Engines	Rajput, R. K.	Laxmi Publications
	References	**Author**	**Publisher**
1.	Internal Combustion Engine Fundamentals	Heywood J. B.	McGraw-Hill.

2.	Introduction to Internal Combustion Engines	Stone, R	Palgrave Macmillan.

Course Code	**BMECOAM625**				
Category	**Open Elective Course**				
Course Title	**Additive Manufacturing**				
Scheme and Credits	**L**	**T**	**P**	**Credits**	**Semester- 6 (*Six*)**
	2	0	2	3	
Pre-requisites	**Engineering Materials, CAD**				

Course Learning Outcomes (CLOs)

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

i) **CLO1:** ***Understand*** the fundamental principles, classifications, process chain, digital workflow, and applications of additive manufacturing technologies. ***(L1)***

ii) **CLO2:** ***Explain*** various additive manufacturing processes, materials, and process parameters, and compare their advantages, limitations, and industrial applications. ***(L2)***

iii) **CLO3:** ***Apply*** design for Additive Manufacturing (DfAM) principles, CAD modelling, slicing techniques, and process planning for the fabrication of engineering components. ***(L3)***

iv) **CLO4:** ***Analyze*** the quality, post-processing techniques, process economics, sustainability, and emerging technologies such as Industry 4.0, Artificial Intelligence (AI), and Digital Twin in additive manufacturing for engineering applications. ***(L4)***

v) **CLO5:** ***Evaluate*** and optimize additive manufacturing processes for engineering applications by considering material selection, design requirements, quality, cost, sustainability, and industrial standards. ***(L5)***

Theory Module (Internal and External Evaluation)

M.No:	Topic
Module 1.	Introduction to additive manufacturing (AM), evolution of manufacturing: conventional versus additive manufacturing, advantages, limitations and applications of AM, ASTM classification of additive manufacturing processes, additive manufacturing process chain, CAD modeling for AM, file formats (STL, AMF and 3MF), mesh generation and repair, build orientation, support structures, slicing techniques, toolpath generation, reverse engineering and 3D scanning.
Module 2.	Polymer-based additive manufacturing: fused deposition modeling, stereolithography (SLA), digital light processing, material jetting and binder jetting. Metal-based additive manufacturing: powder bed fusion, electron beam melting (EBM), directed energy deposition and wire arc additive manufacturing. Materials for additive manufacturing: polymers, metals and alloys, ceramics, composites and biomaterials, powder characteristics, material selection and comparison of additive manufacturing processes.
Module 3.	Design principles and guidelines for additive manufacturing, design optimization, topology optimization, generative design, lattice and cellular structures, lightweight design, part consolidation, support minimization, design validation, manufacturability analysis and engineering case studies.
Module 4.	Support removal, heat treatment, hot isostatic pressing, machining and surface finishing, dimensional accuracy, surface roughness, mechanical testing, non-destructive evaluation, defect analysis, process qualification, quality assurance, standards and certification, cost estimation and economic analysis.
Module 5.	Industry 4.0 in additive manufacturing, Internet of Things (IoT), cyber-physical systems, digital twin and digital thread, artificial intelligence and machine learning applications, sensor integration, in-situ process monitoring, data analytics, predictive maintenance, sustainability and circular manufacturing, industrial applications in aerospace, automotive, biomedical and energy sectors, future trends and emerging technologies.

Activity Module (Internal Evaluation Only-10 Marks)

Activity	Example Task

Using the concepts learned in Module 1, design and prepare a digital model of an engineering component.	Create a 3D CAD model (e.g., keychain, gear, bracket, phone stand, or wrench) using CAD software. export the model in STL format, inspect for errors, repair the mesh if required, and compare STL with AMF/3MF file formats.
Using the concepts learned in Module 2, investigate different additive manufacturing processes and materials.	Print or simulate the same component using different process parameters (layer height, infill density, print speed, orientation). Compare surface finish, dimensional accuracy, build time, and material consumption, and prepare a technical report.
Using the concepts learned in Module 3, apply design for additive manufacturing principles.	Redesign a conventionally manufactured component using topology optimization or lattice structures to reduce weight while maintaining strength. Compare the original and redesigned models based on material usage, build time, and manufacturability. .
Using the concepts learned in Module 4, study industrial applications and emerging trends in Additive Manufacturing.	Prepare a case study on the application of Additive Manufacturing in Aerospace, Biomedical, Automotive, or Defence sectors. Highlight the role of Industry 4.0, AI, Digital Twin, sustainability, and future trends in product development.

Practical Module (Internal and External Evaluation)

M.No:	Experiments
Module 1.	Introduction to Additive Manufacturing systems and safety procedures.
Module 2.	Creation of a 3D CAD model and conversion to STL/3MF format.
Module 3.	STL file repair, build orientation, support generation, and slicing using slicing software (Cura/PrusaSlicer/Bambu Studio).
Module 4.	Calibration and operation of an FDM 3D printer.
Module 5.	Fabrication of a simple engineering component using FDM technology.
Module 6.	Study of the effect of layer height, infill density, and print speed on print quality and build time.
Module 7.	Measurement of dimensional accuracy, surface finish, and visual inspection of printed components.
Module 8.	Mechanical testing (tensile/compression/flexural-demonstration if facilities are available) of printed specimens.
Module 9.	Reverse engineering using a 3D scanner (or photogrammetry software) and preparation of a printable model.
Module 10.	Mini Project: design, optimize, fabricate, and present an innovative engineering component using design for additive manufacturing principles.

CLO-PLO Mapping Matrix

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

Recommended Books

S.No:	Text Books	Author	Publisher
1.	Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing	Ian Gibson, David W. Rosen & Brent Stucker	Springer
2.	Fundamentals of Additive Manufacturing and 3D Printing	William E. Frazier	ASM International
	References	**Author**	**Publisher**
1.	3D Printing Handbook: Technologies, Design and Applications	Ben Redwood, Filemon Schöffer & Brian Garret	3D Hubs B.V.

2.	Design for Additive Manufacturing	Martin Leary	Elsevier

Course Code	**BMECODE625**				
Category	**Open Elective Course**				
Course Title	**Design of Experiment**				
Scheme and Credits	**L**	**T**	**P**	**Credits**	**Semester- 6 (*Six*)**
	2	**0**	**2**	**3**	
Pre-requisites	**Basic Statistics**				

Course Learning Outcomes (CLOs)

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

i) **CLO1:** ***Understand*** the fundamentals of optimization techniques, Design of Experiments (DOE), statistical concepts, regression, and Taguchi methods. ***(L2)***

ii) **CLO2:** ***Compare*** statistical methods, experimental designs, regression models, factorial designs, and Taguchi techniques for engineering applications. ***(L2)***

iii) **CLO3:** ***Interpret*** experimental data and statistical results using hypothesis testing, regression analysis, ANOVA, and model diagnostics to support engineering decisions. ***(L5)***

iv) **CLO4:** ***Construct*** design matrices, regression models, orthogonal arrays, and graphical representations for experimental design and data analysis. ***(L3)***

v) **CLO5:** ***Design*** and conduct optimization experiments by integrating DOE, factorial designs, Taguchi methods, regression analysis, and ANOVA to improve engineering processes. ***(L6)***

Theory Module (Internal and External Evaluation)

M.No:	Topic
Module 1.	Brief introduction to optimization techniques, strategy of experimentation, basic principles of design, terminology used in design of experiments, guidelines for designing experiments, basic statistical concepts, types of data, graphical representation of data, measures of central tendency and dispersion, skewness.
Module 2.	Sampling and sampling distribution, test of significance for a single mean and for the difference of means of two samples, inferences about the differences in means using randomized designs, inferences about the differences in means using paired comparison designs, inferences about the variances of normal distributions, tests of significance based on t, F, and chi-square distributions.
Module 3.	Introduction to linear regression models, estimation of parameters in linear regression models, method of least squares, hypothesis testing, null hypothesis, alternative hypothesis, prediction of new response observations, testing for lack of fit.
Module 4.	Basic definitions and principles of factorial design, advantages of factorial designs, types of factorial designs, full factorial design, fractional factorial design, design matrix, development of mathematical models, regression model diagnostics.
Module 5.	Introduction to Taguchi methods, concept design, parameter design, tolerance design, orthogonal array experiments, Taguchi quality loss function, signal-to-noise ratio, quality characteristics, parameter optimization experiments, one-way ANOVA, two-way ANOVA, degrees of freedom, case studies on factorial design, Taguchi method, and ANOVA.

Activity Module (Internal Evaluation Only-10 Marks)

Activity	Example Task
Using the tools learned on Module 1, design a variety of items, including:	Using SYSTAT, Microsoft Excel, Minitab, R, or Python, design and perform statistical analysis of a simple experiment using descriptive statistics and graphical data analysis.
Using the tools learned on Module 2, design a variety of items, including:	Using SYSTAT, Minitab, IBM SPSS Statistics, R, or Python, perform hypothesis testing and statistical inference using real-life sample data.
Using the tools learned on Module 3, design a variety of items, including:	Using SYSTAT, Minitab, MATLAB, R, or Python, develop a linear regression model, estimate model parameters, and analyze experimental data.

Using the tools learned on Module 4, design a variety of items, including:	Using SYSTAT, Minitab, JMP, R, or Python, design and analyze full or fractional factorial experiments, develop regression models, and optimize process parameters.
Using the tools learned on Module 5, design a variety of items, including:	Using SYSTAT, Minitab, JMP, R, or Python, perform parameter optimization using the Taguchi method and validate the results through one-way or two-way ANOVA.

Practical Module (Internal and External Evaluation)

M.No:	Experiments
Module 1.	Study of basic statistical concepts using a given dataset (Mean, Median, Mode, Standard Deviation, Variance, Skewness, Graphical Representation)
Module 2.	Study of sampling techniques and sampling distributions using random samples
Module 3.	Test of significance for a single mean using the Student's t-test
Module 4.	Test of significance for the difference between two sample means (Independent Samples t-test and Paired t-test)
Module 5.	Test of significance for variances using F-test and Chi-square test
Module 6.	Estimation of parameters in a simple linear regression model using the least squares method and prediction of new response values
Module 7.	Development of a Design Matrix for a Full Factorial Design and analysis of main and interaction effects
Module 8.	Development and analysis of a Fractional Factorial Design
Module 9.	Parameter optimization using the Taguchi Method with Orthogonal Arrays (L4/L8/L9) and Signal-to-Noise Ratio analysis
Module 10.	Quality analysis using the Taguchi Quality Loss Function and Parameter Design
Module 11	One-Way ANOVA to compare the means of three or more groups
Module 12	Two-Way ANOVA for studying the effect of two factors and their interaction, including a case study on Factorial Design or Taguchi Method

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	2	0	0	0	0	1	0	2
CLO3	3	3	2	3	3	0	0	0	0	2	0	2
CLO4	3	3	3	2	3	0	0	0	1	2	1	2
CLO5	3	3	3	3	3	1	1	1	2	2	2	3

Recommended Books

S.No:	Text Books	Author	Publisher
1.	Design and Analysis of Experiments	Douglas C Montgomery,	John Wiley
2.	Statistical Design and Analysis of Experiments	John P.W.M	Macmillan
	References	**Author**	**Publisher**
1.	Design of Experiments	Mark J. Anderson, Martin A. Bezener	Wiley
2.	Introduction to Design of Experiments	Dr. Genichi Taguchi engineering, Dr. Subir Chowdhury	Wiley

Course Code	**BMECONM625**				
Category	**Open Elective Courses**				
Course Title	**Numerical Methods for Engineers**				
Scheme and Credits	**L**	**T**	**P**	**Credits**	**Semester - 6 (*Six*)**
	2	**0**	**2**	**3**	
Pre-requisites	**Calculus and linear algebra.**				

Course Learning Outcomes (CLOs)

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

i) **CLO1:** ***Analyze*** errors in numerical computations and apply appropriate numerical methods to solve nonlinear equations arising in engineering applications. ***(L4)***

ii) **CLO2:** ***Apply*** direct and iterative numerical techniques to solve systems of linear algebraic equations in scientific and engineering computations. ***(L3)***

iii) **CLO3:** ***Construct*** interpolation models and finite difference approximations for engineering data analysis and function approximation. ***(L3)***

iv) **CLO4:** ***Compute*** numerical differentiation and integration using appropriate methods for engineering and scientific problems. ***(L3)***

v) **CLO5:** ***Apply*** numerical methods to solve ordinary differential equations for modelling and simulation of engineering systems. ***(L3)***

Theory Module(Internal and External Evaluation)

M.No:	Topic
Module 1.	Numerical solutions of nonlinear equations, solutions of non-linear equations in single variables using Bisection, Regula-Falsi and Newton-Raphson methods, convergence criteria, Newton-Raphson method for solution of system of non-linear equations.
Module 2.	Errors and Numerical solutions of nonlinear equations, error analysis, Exact and approximate numbers, rounding off numbers, types of errors encountered in computations, propagation of errors. Solution of a system of linear equations using direct methods, Gauss elimination and LU decomposition methods, Gauss-Jacobi, Gauss-Seidel to solve linear systems of equations.
Module 3.	Interpolation techniques: Finite difference operator and their relationships, difference tables, interpolation formulae, divided differences, Lagrange and Hermite interpolations.
Module 4.	Numerical Differentiation and integration: Differentiation using interpolation formulas. Numerical integration: Trapezoidal and Simpson's rules with errors and their combinations.
Module 5.	Numerical solutions of differential equations: Solution of first and second order ordinary differential equations: Picard's method, Taylor's series method, Euler, modified Euler, Runge-Kutta methods, 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:	Students solve assigned nonlinear equations using the Bisection, Regula-Falsi, and Newton-Raphson methods, compare convergence rate, iterations, and accuracy, and validate the results using MATLAB/Python/Excel.
Using the tools learned on Module 2, design a variety of items, including:	Students investigate rounding and truncation errors and solve systems of equations using Gauss Elimination, LU Decomposition, Gauss-Jacobi, and Gauss-Seidel methods. Results are compared using MATLAB, Python (NumPy), or Excel.
Using the tools learned on Module 3, design a variety of items, including:	Students construct interpolation models using Newton, Lagrange, and Hermite interpolation techniques for experimental datasets and visualize the results using MATLAB, Python, or Excel.
Using the tools learned on Module 4, design a variety of items, including:	Students perform numerical differentiation and integration using Trapezoidal and Simpson's rules, compare with analytical solutions, estimate errors, and implement the methods using MATLAB, Python, or Excel.
Using the tools learned on Module 5, design a variety of items, including:	Students solve engineering initial value problems using Euler, Modified Euler, Taylor series, Picard, and Runge-Kutta methods, compare solution accuracy, and simulate the results using MATLAB, Python, or GNU Octave.

Practical Module (Internal and External Evaluation)

M.No:	Experiments
Module 1.	Develop programs to solve nonlinear equations using Bisection, Regula-Falsi, and Newton-Raphson methods. Compare convergence rate, number of iterations, and accuracy.
Module 2.	Implement Gauss Elimination, LU Decomposition, Gauss-Jacobi, and Gauss-Seidel methods. Compare computational efficiency and convergence for different systems.
Module 3.	Construct interpolation polynomials using Newton's Divided Difference and Lagrange interpolation techniques. Estimate unknown function values and compare interpolation errors.
Module 4.	Compute numerical derivatives using interpolation formulas and evaluate definite integrals using Trapezoidal and Simpson's rules. Analyze approximation errors against exact solutions.
Module 5.	Solve first-order ordinary differential equations using Euler, Modified Euler, Taylor Series, and Fourth-Order Runge-Kutta methods. Compare numerical solutions with exact solutions and analyze error behavior.

CLO-PLO Mapping Matrix

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

Recommended Books

S.No:	Text Books	Author	Publisher
	Numerical Methods for Engineers	Steven C. Chapra and Raymond P. Canale	McGraw Hill Education India Private Limited
2	Applied Numerical Analysis	C. F. Gerald and P. O. Whitely	Pearson Education India
	References	**Author**	**Publisher**
	Numerical Methods for Scientific and Engineering Computation	by M. K. Jain, S. R. K. Iyengar and R. K. Jain	New Age Pvt. Pub, New Delhi
	Introduction to Applied Linear Algebra: Vectors, Matrices, and Least Squares	S. Boyd and L. Vandenberghe	Cambridge University Press

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Course Code	**BMECCDM625**				
Category	**Professional Core course**				
Course Title	**Design of Machine Elements**				
Scheme and Credits	**L**	**T**	**P**	**Credits**	**Semester- 6 (*six*)**
	2	1	0	3	
Pre-requisites	**Engineering Mechanics**				

Course Learning Outcomes (CLOs)

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

i) **CLO1:** Understand the fundamentals of machine design, theories of failure, fatigue behaviour, stress concentration, and the design principles of mechanical joints and machine elements. ***(L2)***

ii) **CLO2:** Compare static and fatigue failure theories, joint types (riveted, welded, threaded), spring types, and shaft design criteria for mechanical engineering applications. ***(L2)***

iii) **CLO3:** Interpret the performance and failure behaviour of machine elements under static, dynamic, and fluctuating loads using appropriate design criteria and fatigue theories. ***(L5)***

iv) **CLO4:** Develop engineering designs and detailed design calculations for shafts, joints, springs, fasteners, and power screws based on specified loading conditions. ***(L3)***

v) **CLO5:** Design and integrate machine elements, including shafts, joints, springs, threaded fasteners, and power screws, to develop safe and reliable mechanical systems. ***(L6)***

Theory Module (Internal and External Evaluation)

M.No:	Topic
Module 1.	Introduction to Design, need of design, Design process, problem formulation and calculation, factor of safety, design codes, materials and process, loading determination, static loading, dynamic loading, impact loading.
Module 2.	Failure theories, failure theories of ductile and brittle materials under static loading, fatigue failure theories: mechanism, models, notches and stress concentration.
Module 3.	Rotating beam test and S-N curve, endurance strength and its modifying factors, design for finite and infinite life, failure criteria for fluctuating stresses (Goodman, Soderberg and Gerber).
Module 4.	Design of shafts, keys and couplings, static loads, combined torsion-bending and axial loads, critical speed of the shaft, design of keys and keyways, failure of keys, couplings, rigid and flexible types.
Module 5.	Lubrications and Bearings: Lubricants, properties, types, Bearings, sliding contact, rolling contact bearings – hydrodynamic bearing.

Activity Module (Internal Evaluation Only-10 Marks)

Activity	Example Task
Using the tools learned on Module 1, design a variety of items, including:	Analyze a machine component (e.g., bicycle crank, spanner, fan blade, or bracket) to identify functional requirements, loading conditions, material selection, design constraints, and applicable factor of safety using SolidWorks, Autodesk Fusion 360.
Using the tools learned on Module 2, design a variety of items, including:	Develop a computational model to determine stresses and factors of safety using Maximum Principal Stress, Maximum Shear Stress (Tresca), von Mises, Goodman, Soderberg, and Gerber criteria for static and fluctuating loads using MATLAB, Python or Microsoft Excel.
Using the tools learned on Module 3, design a variety of items, including:	Design riveted, welded, and bolted joints for specified loading conditions and validate joint strength, efficiency, and failure modes using SolidWorks Simulation or MATLAB/Python.
Using the tools learned on Module 4, design a variety of items, including:	Design a transmission shaft considering strength, rigidity, fatigue, and critical speed for a given power and speed. Verify stresses and deflection using SolidWorks Simulation, MATLAB, or Python.
Using the tools learned on Module 5, design a variety of items, including	Design a power screw, threaded fastener, keys, and couplings for a given application. Determine bolt preload, tightening torque, stresses, efficiency, and self-locking conditions using MATLAB, Python or Microsoft Excel.

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	2	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
	Design of Machine Elements	V.B. Bhandari	Tata McGraw Hill, New Delhi
	References		
	Machine Elements in Mechanical Design	Robert L. Mo	Pearson Education

	Mechanical Engineering Design	Shigley, Budynas, Nisbett	McGraw Hill, New York

Course Code	**BMECCCF625**				
Category	**Professional Core course**				
Course Title	**Compressible Fluid Flow**				
Scheme and Credits	**L**	**T**	**P**	**Credits**	**Semester- 6 (*Six*)**
	2	1	2	4	
Pre-requisites					

Course Learning Outcomes (CLOs)

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

i*) CLO1:** ***Explain the fundamental principles of compressible flow, including the speed of sound, Mach number, compressibility effects, and wave propagation. ***(L2)***

ii) **CLO2:** ***Apply*** the governing equations of compressible flow to analyze isentropic, Fanno, Rayleigh, and isothermal flow processes in ducts and nozzles. ***(L3)***

iii) **CLO3:** ***Analyze*** normal and oblique shock waves, expansion waves, and their influence on flow properties in compressible flow systems. ***(L4)***

iv) **CLO4:** ***Evaluate*** the performance of convergent-divergent nozzles, diffusers, supersonic wind tunnels, and jet propulsion systems under different operating conditions. ***(L5)***

v) **CLO5:** ***Interpret*** three-dimensional scan data in the form of point clouds and mesh models, perform reverse engineering of mechanical components, and evaluate the accuracy of reconstructed CAD models by comparing them with the scanned geometry. ***(L6)***

Theory Module(Internal and External Evaluation)

M.No:	Topic
Module 1.	Basics of compressible flow, velocity of sound, compressibility effects in fluids and mach number, isentropic flow, stagnation conditions.
Module 2.	One dimensional flow for constant area duct, one dimensional flow with heat addition (rayleigh flow), one dimensional flow with friction (fanno flows), normal shock waves, oblique shock and Prandtl–Meyer expansion waves.
Module 3.	Quasi one dimensional flow, isentropic flow through variable area duct, Convergent and convergent-divergent nozzles, diffusers, Choked flow, Nozzle performance.
Module 4.	Gas turbine, Brayton cycle and modification, Jet propulsion, thrust power and propulsive efficiency, ramjet, turbojet, turbofan and turboprop engines, rocket engines.
Module 5.	Measurement of pressure, temperature, and velocity in compressible flows, shock tubes and wind tunnels, compressible flow in propulsion systems, Industrial and aerospace applications of compressible flow. Introduction to computational analysis of compressible flows.

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 MATLAB/Python code to calculate the speed of sound, Mach number, and stagnation properties for different gases and operating conditions.
Using the tools learned on Module 2, design a variety of items, including:	Develop a MATLAB/Python code to analyze Rayleigh flow, Fanno flow, and normal shock relations, and generate plots of pressure, temperature, density, and Mach number variations.
Using the tools learned on Module 3, design a variety of items, including:	Develop a MATLAB/Python code or perform a CFD simulation to analyze flow through convergent-divergent nozzles and diffusers, predicting choking conditions, exit Mach number, and pressure distribution.
Using the tools learned on Module 4, design a variety of items, including:	Develop a MATLAB/Python code to analyze Brayton cycle performance and compare the thrust, thermal efficiency, and propulsive efficiency of turbojet, turbofan, turboprop, ramjet, and rocket engines.

Using the tools learned on Module 5, design a variety of items, including:	Develop a MATLAB/Python program to solve a selected compressible flow problem involving nozzles, shock waves, or compressible duct flows, and visualize the variation of flow properties using appropriate plots.

Practical Module (Internal and External Evaluation)

M.No:	Experiments
Module 1.	To determine the velocity of sound in different solids and fluids.
Module 2.	To study wave propagation at different Mach numbers using Schlieren flow visualization.
Module 3.	To investigate isentropic flow through a variable-area duct and visualize density gradients using the Schlieren technique.
Module 4.	To study flow through a constant-area duct with friction (Fanno flow) and analyze compressibility effects.
Module 5.	To study flow through a constant-area duct with heat addition (Rayleigh flow) and investigate the effect of heat transfer on compressible flow.
Module 6.	To investigate isothermal flow through a constant-area duct and compare its characteristics with adiabatic flow.
Module 7.	To study the formation, propagation, and interaction of normal and oblique shock waves using Schlieren flow visualization.
Module 8.	To study supersonic flow through a convergent-divergent nozzle and a supersonic wind tunnel using Schlieren flow visualization.
Module 9.	To determine the thrust generated by a jet engine under different operating conditions and correlate thrust with nozzle exit conditions.
Module 10.	To visualize expansion fans, compression waves, and shock structures in supersonic flow using a Schlieren imaging system.

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	3	3	2	0	2	0	2	0	0	0	0	1
CLO3	3	3	2	2	2	0	0	0	0	0	0	1
CLO4	3	3	3	2	2	1	1	0	0	0	1	2
CLO5	2	3	3	2	2	1	2	1	1	2	2	2

Recommended Books

S.No:	Text Books	Author	Publisher
1.	Modern Compressible Flow with Historical Perspective	Anderson, J. D.	McGraw Hill
2.	Fundamentals of Compressible Flow	Yahya, S. M.	New Age International Publishers, New Delhi.
	References	**Author**	**Publisher**
1.	Compressible Fluid Flow.	Saad, M. A.	Prentice Hall.
2.	Gas Dynamics, Volumes I & II.	Zucrow, M. J., and Hoffman, J. D.	Wiley India.
3.	Elements of Gas Turbine Propulsion.	Mattingly, J. D.	McGraw-Hill International Editions

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Course Code	**BMECLCM725**					
Category	**Experiential Learning course**					
Course Title	**Computer Aided Manufacturing**					
Scheme and Credits	**L**	**T**	**P**	**Credits**	**Semester- 7 (*Seven*)**	
	0	0	6	3		

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

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Course Code	**BMECLWT725**				
Category	**Lab Course**				
Course Title	**Welding Technology**				
Scheme and Credits	**L**	**T**	**P**	**Credits**	**Semester- 7 (*Seven*)**
	0	**0**	**4**	**2**	
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*)**
	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, I²C 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

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Course Code	**BMECDRF725**					
Category	**Professional Elective Course**					
Course Title	**Refrigeration**					
Scheme and Credits	**L**	**T**	**P**	**Credits**	**Semester- 7 (*Seven*)**	
	2	0	2	3		
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

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Course Code	**BMECLOD725**				
Category	**Experiential Learning courses**				
Course Title	**Operations and Diagnostics of Rotary Machines**				
Scheme and Credits	**L**	**T**	**P**	**Credits**	**Semester- 7 (*Seven*)**
	0	**2**	**2**	**3**	
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**	**T**	**P**	**Credits**	**Semester- 7 (*Seven*)**	
	2	**1**	**0**	**3**		
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

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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	T	P	Credits	Semester- 8 (*Eight*)
	2	1	0	3	
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

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Course Code	**BMECONT825**				
Category	**Open Elective Course**				
Course Title	**Non-Destructive Testing**				
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 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

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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

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Course Code	BMECORB825				
Category	Open Elective Course				
Course Title	Robotics				
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 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

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

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Course Code	**BMECDPP825**				
Category	**Professional Elective Courses**				
Course Title	**Power Plant Engineering**				
Scheme and Credits	**L**	**T**	**P**	**Credits**	**Semester- 8 (*Eight*)**
	2	**1**	**0**	**3**	
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**	**T**	**P**	**Credits**	**Semester- 8 (*Eight*)**
	2	0	2	2	
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	T	P	Credits	Semester- 8 *(Eight)*
	2	1	0	3	
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**	**T**	**P**	**Credits**	**Semester- 8 (*Eight*)**	
	0	**0**	**14**	**7**		
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	T	P	Credits	Semester - 8 *(Eight)*
	0	0	0	1	
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
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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.