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** 2	**T** 1	**P** 2	**Credits** 4	**Semester- 4** *(Four)*
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 1	T 0	P 2	Credits 2	Semester- 4 *(Four)*
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** 2	**T** 1	**P** 2	**Credits** 4	**Semester- 4 (*Four*)**
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

Course Code	**BMECCMC425**				
Category	**Professional Core Courses**				
Course Title	**Metal Casting and Forming Processes**				
Scheme and Credits	L 2	T 1	P 2	Credits 4	Semester- 4 (*Four*)
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** 2	**T** 1	**P** 0	**Credits** 3	Semester- **5** (*Five*)
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** 2	**T** 0	**P** 2	**Credits** 3	**Semester- 5 (*Five*)**
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

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 2	T 1	P 2	Credits 4	Semester- 5 (*Five*)
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

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