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

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Course Code	**BMECCHT525**				
Category	**Professional Core courses**				
Course Title	**Heat Transfer**				
Scheme and	L	T	P	Credits	Semester- **5** (*Five*)
Credits	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

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

Course Code	**BMECCMV625**				
Category	**Professional Core courses**				
Course Title	**Mechanical Vibrations**				
Scheme and Credits	L 2	T 1	P 2	Credits 4	Semester- **6** (*Six*)
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** 0	**T** 2	**P** 2	**Credits** 3	Semester- **6** *(Six)*
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** 2 · **T** 0 · **P** 2 · **Credits** 3 · Semester- **6** (*Six*)
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** 2	**T** 1	**P** 2	**Credits** 4	**Semester- 6** (*Six*)
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

Course Code	BMECLCM725			
Category	Experiential Learning course			
Course Title	Computer Aided Manufacturing			
Scheme and Credits	L	T	P	Credits
	0	0	6	3

Semester- 7 (*Seven*)