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MAHARAJA INSTITUTE OF TECHNOLOGY MYSORE

Autonomous Institution Affiliated to VTU

Competency Based Syllabus (CBS)

for

Mechanical Engineering

(Under Outcome Based Education (OBE) and Choice-Based Credit System (CBCS))

Offered from 1st to 2nd Semesters of Study

in

Partial Fulfillment for the Award of Master's Degree in

Thermal Power Engineering

2023 Scheme

Scheme Effective from the academic year 2023-24

General Contents of Competency Based Syllabus Document

APPROVED Dean Academics
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Principal MIT Mysore

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1st Semester	Basic Science Course (BS) APPLIED MATHEMATICS	M23MTP101

1. Prerequisites

S/L	Proficiency	Prerequisites
1	Calculus	Understanding of differential and integral calculus is essential. This includes knowledge of limits, derivatives, integration techniques, and their applications.
2	Linear Algebra	Knowledge of matrices, vectors, vector spaces, linear transformations, and eigenvalues/eigenvectors is crucial. Linear algebra forms the basis for many topics in applied mathematics.
3	Probability and Statistics:	Understanding probability theory, distributions (such as normal, binomial, and Poisson distributions), statistical methods (like hypothesis testing and regression analysis), and stochastic processes is important for modeling uncertainties and analyzing data.
4	Numerical Methods:	Basic knowledge of numerical techniques for solving equations, interpolation, differentiation, integration, and solving differential equations numerically.
5	Mathematical Modeling:	Ability to formulate mathematical models for real-world problems, interpret their results, and validate them against experimental or observational data.
6	Previous Coursework	Completion of introductory courses in Mathematics or a related field

2. Competencies

S/L	Competency	KSA Description
1	**Error definition, round off errors and truncation errors.**	**Knowledge:** Understanding errors in the context of numerical computation is crucial in applied mathematics and scientific computing. **Skills:** Ability to perform error analysis, including quantifying round-off and truncation errors in numerical computations. **Attitudes:** Appreciation of different numerical methods has varying susceptibilities to round-off and truncation errors.
2	**Roots of Equations**	**Knowledge:** Understanding roots of equations is essential for both theoretical understanding and practical application in solving mathematical problems across diverse fields **Skills:** Mastery of algebraic concepts such as polynomial equations, transcendental equations, and their properties. **Attitudes:** Solving equations, understanding that small errors can lead to significant discrepancies in results.
3	**Linear systems of algebraic equations**	**Knowledge:** Understanding linear systems of algebraic equations involves proficiency in both theoretical concepts and practical methods for solving and analyzing **Skills:** Solving equations where each equation is linear, meaning that each variable appears to the first power and there are no products of variables **Attitudes:** Solving linear systems can sometimes be complex, especially in larger or more intricate cases.
4	**Solving ODE's**	**Knowledge:** Understanding how to formulate ODEs from physical principles and solve them allows for predictive modeling and analysis in various scientific and engineering disciplines **Skills:** Recognizing whether the ODE is ordinary or partial, and determining its order **Attitudes:**

		Solving ODEs can sometimes be challenging, especially when dealing with complex systems or nonlinear equations.
5	**Probability distributions:**	**Knowledge:** Understanding of Poisson and Normal Distribution **Skills:** Apply probability for risk assessment in the design of structures such as bridges, dams and buildings **Attitudes:** Appreciation for the role of Anova in random block design

3. Syllabus

Applied Mathematics - SEMESTER-I			
Course Code	**M23MTP101**	CIE Marks	**50**
Number of Lecture Hours/Week(L: T: P: S)	**(3:0:0)**	SEE Marks	**50**
Total Number of Lecture Hours	**40 hours Theory**	Total Marks	**100**
Credits	**03**	Exam Hours	**03**

Course objectives: This course will enable students to:

1. The course is aimed to develop the basic Mathematical skills of engineering students that are imperative for effective understanding of Thermal engineering subjects.
2. The topics introduced will serve as basic tools for specialized studies in the fields of Thermal engineering and technology.
3. An understanding of Fourier Series and Laplace Transform to solve real world problems.
4. An understanding of Linear Algebra through matrices and understanding of statistical analysis using ANOVA.

Module -1	
Error definition, round off errors and truncation errors. Mathematical modeling and Engineering problem solving: Simple mathematical model, Conservation Laws of Engineering. Vector and Tensor Analysis in Cartesian system, effect of rotation of coordinate systems	L1, L2, L3
Module -2	
Roots of Equations: Graphical method, Bisection method, Newton- Raphson method, Secant Method. Simple fixed-point iteration. Roots of polynomial-Polynomials in Engineering and Science, Muller‘s method, Bairstow‘s Method Graeffe‘s Roots Squaring Method	L1, L2, L3
Module -3	
Linear systems of algebraic equations: Gauss elimination, LU decomposition, Triangularization method, Cholesky Method, Partition method. Eigen values and Eigen Vectors: Bounds on Eigen Values, Jacobi method for symmetric matrices, Givens method for symmetric matrices, Householder‘s method for symmetric matrices, Rutishauser method for arbitrary matrices, Power method, Inverse power method.	L1, L2, L3
Module -4	
Solving ODE's using: Picard's method, Runge-Kutta fourth order and Stiffness of ODE using shooting method. Solving PDE 's by numerical method: one dimensional wave equation and heat equation.	L1, L2, L3
Module -5	
Probability distributions: Binomial, Poisson. Normal. Sampling Theory: Testing of hypothesis for large and small samples, Goodness of fit. F-test, Analysis of Variance: One – way with/without interactions, problems related to ANOVA, Design of experiments	L1, L2, L3

Text Books

1. C. Ray Wylie and Louis C Barrett, ―Advanced Engineering Mathematics‖. 6th edition, McGraw-Hill, 1995.
2. K Shankar Rao, ―Introduction to Partial Differentia Equations‖ Prentice - Hall of India Pvt. Lt., 1995 Edition.
3. S. S. Sastry, Introductory Methods of Numerical Analysis, PHI, 2005.
4. Steven C Chapra and Raymond P Canale: Numerical Methods for Engineers, 7th Ed., McGraw-Hill Edition, 2015.

Reference Books

1. William W.H., Douglas C.M., David M.G. and Connie M.B., ―Probability and Statistics in. Engineering, 4th Edition, Willey Student edition, 2008.

2. B.S. Grewal: Higher Engineering Mathematics, Khanna Publishers, 44th Ed., 2017
3. M K Jain, S.R.K Iyengar, R K. Jain, Numerical methods for Scientific and engineering computation, New Age International, 2003.
4. Pervez Moin, Fundamentals of Engineering Numerical Analysis, Cambridge, 2010.

4. Syllabus Timeline

S/L	Syllabus Timeline	Description
1	Week 1-2: Errors	• **E**rror definition, round off errors and truncation errors, Mathematical modeling and Engineering. • Problem solving: Simple mathematical model Conservation Laws of Engineering. • Vector and Tensor Analysis in Cartesian system Worked Problems • Effect of rotation of coordinate systems Worked Problems
2	Week 3-4: Roots of Equations	• Graphical method, Bisection method, Newton- Raphson method and Secant Method. • Simple fixed-point iteration • Roots of Polynomial-Polynomials in Engineering and Science Muller 's method • **Bairstow's Method Graeffe's Roots Squaring Method**
3	Week 5-6: Linear systems of algebraic equations:	• Gauss elimination, LU decomposition • Triangularization method, Cholesky Method, Partition method. • Eigen values and Eigen Vectors: Bounds on Eigen • Values, Jacobi method for symmetric matrices, Givens method for symmetric matrices, Householder 's method for symmetric matrices • Rutishauser method for arbitrary matrices , Power method, Inverse power method.
4	Week 7-8: Solving ODE's	• Picard's method, Worked Problems • Runge-Kutta fourth order and Stiffness of ODE using Shooting method. • Worked problems, Solving PDE's by numerical method: one dimensional wave equation • Solving PDE's by numerical method: one dimensional heat equation.
5	Week 9-10 Probability distributions	• Binomial Distribution, Poisson Distribution and Normal Distribution • Worked Problems, Sampling Theory: Testing of hypothesis for large and small samples, Goodness of fit. F-test, Analysis of Variance: • One – way with/without interactions, problems related to ANOVA, Design of experiments
6	Week 11-12: Integration and Practical Applications	• Apply learned concepts and competencies to real-world scenarios. Hands-on practice

5. Teaching-Learning Process Strategies

S/L	TLP Strategies:	Description
1	Lecture Method	Utilize various teaching methods within the lecture format to reinforce competencies.
2	Video/Animation	Incorporate visual aids like videos/animations to enhance understanding of Verilog concepts.
3	Collaborative Learning	Encourage collaborative learning for improved competency application.
4	Higher Order Thinking (HOTS) Questions:	Pose HOTS questions to stimulate critical thinking related to each competency.

5	Problem-Based Learning (PBL)	Implement PBL to enhance analytical skills and practical application of competencies
6	Multiple Representations	Introduce topics in various representations to reinforce competencies
7	Real-World Application	Discuss practical applications to connect theoretical concepts with real-world competencies.
8	Flipped Class Technique	Utilize a flipped class approach, providing materials before class to facilitate deeper understanding of competencies
9	Programming Assignments	Assign programming tasks to reinforce practical skills associated with competencies.

6. Assessment Details (both CIE and SEE)

CIE

Components		Number	Weightage	Max. Marks	Min. Marks
(i)	Internal Assessment-Tests (A)	2	50%	25	10
(ii)	Assignments/Quiz/Activity (B)	2	50%	25	10
	Total Marks			**50**	**20**

Final CIE Marks = (A) + (B)

SEE

1. Question paper pattern will be ten questions. Each question is set for 20marks. The medium of the question paper shall be english unless otherwise it is mentioned.
2. There shall be 2 question from each module, each of the two questions under a module (with a maximum of 3 sub questions), may have mix of topics under that module if necessary.
3. The students have to answer 5 full questions selecting one full question from each module.
4. Marks scored will be proportionally scaled down to 50 marks

7. Learning Objectives

S/L	Learning Objectives	Description
1	Understanding Mathematical Foundations:	Students will Develop a solid understanding of fundamental mathematical concepts such as calculus, linear algebra, differential equations, probability, and statistics. This includes understanding the theoretical underpinnings and the ability to apply these concepts to diverse problems.
2	Modeling Real-World Phenomena:	Learn how to construct mathematical models that describe and simulate real-world phenomena. This involves identifying relevant variables, formulating assumptions, and selecting appropriate mathematical techniques for modeling.
3	Analytical and Numerical Techniques	Gain proficiency in both analytical techniques (using methods such as differential equations, optimization theory, and statistical analysis) and numerical techniques (employing algorithms for solving equations, numerical integration, and simulation methods).
4	Collaboration and Communication Skills	Students will work collaboratively in teams on design projects, enhancing their ability to communicate effectively, share ideas, and solve problems collectively.
5	Ethical and Professional Responsibility	Students will understand the ethical and professional responsibilities associated with digital design, including respecting intellectual property rights, ensuring design reliability and security, and adhering to industry standards and best practices.

8. Course Outcomes (COs) and Mapping with POs/ PSOs

Course Outcomes (COs)

COs	Description
M23MTP101.1	Demonstrate knowledge and understanding of the underlying concepts of probability theory and Numerical methods for finding roots.
M23MTP101.2	Demonstrate knowledge of the mathematical concepts and computational aspects of linear algebra and Ordinary differential equations (ODE)
M23MTP101.3	Analyze domain related engineering problems and develop analytical problem solving approach making use of the theoretical concepts

CO-PO-PSO Mapping

COs/POs	PO1	PO2	PO3
M23MTP101.1	3		
M23MTP101.2			3
M23MTP101.3			3

9. Assessment Plan

Continuous Internal Evaluation (CIE)

	CO1	CO2	CO3	CO4	CO5	Total
Module 1	**20**					**20**
Module 2		**20**				**20**
Module 3			**20**			**20**
Module 4				**20**		**20**
Module 5					**20**	**20**
Total	**20**	**20**	**20**	**20**	**20**	**100**

Semester End Examination (SEE)

	CO1	CO2	CO3	CO4	CO5	Total
Module 1	**20**					**20**
Module 2		**20**				**20**
Module 3			**20**			**20**
Module 4				**20**		**20**
Module 5					**20**	**20**
Total	**20**	**20**	**20**	**20**	**20**	**100**

10. Future with this Subject

Interdisciplinary Applications: Explore how mathematics applies to other disciplines such as physics, engineering, biology, finance, computer science, and social sciences. This can involve studying specialized mathematical techniques tailored to these fields.

Computational Mathematics: Focus on numerical methods, scientific computing, and computational techniques for solving complex mathematical problems. This field is crucial for simulations and solving real-world problems where analytical solutions are not feasible.

Mathematical Biology: Study mathematical models applied to biological systems, such as population dynamics, epidemiology, neuroscience, and ecological systems. This field combines mathematics with biology to understand biological phenomena quantitatively.

Mathematical Finance: Explore quantitative finance, where mathematical models are used to analyze financial markets, derivative pricing, risk management, and portfolio optimization.

Data Science and Machine Learning: Apply mathematical tools to analyze and interpret large datasets, develop predictive models, and understand statistical inference. This involves combining statistics, probability theory, and computational techniques.

Fluid Dynamics and Solid Mechanics: Study mathematical models and computational methods for fluid flow, turbulence, elasticity, and other aspects of mechanics. This area is important in engineering and physics.

1st Semester	Integrated Professional Core Course (IPC) THEORY AND DESIGN OF MODERN IC ENGINE	M23MTP102

1. **Prerequisites**

S/L	Proficiency	Prerequisites
1.	Fundamentals of Thermodynamics:	This is the foundation for understanding the energy transfer processes that occur within an IC engine. You'll need a grasp of concepts like work, heat, internal energy, enthalpy, entropy, and the first and second laws of thermodynamics.
2.	Basic Mechanics	A solid understanding of mechanics is crucial for comprehending the forces, motion, and stresses acting on various engine components. This includes knowledge of concepts like force, torque, power, linear and rotational motion, and basic mechanics of materials.
3.	Machine Design	Familiarity with machine design principles will be helpful when studying engine components like pistons, connecting rods, crankshafts, valves, and camshafts. This includes understanding stress analysis, bearing selection, and lubrication systems.
4.	Chemistry of Fuels	Knowing the properties and combustion characteristics of different fuels like gasoline, diesel, and alternative fuels is essential for understanding engine performance and emissions. Basic knowledge of chemical reactions and combustion processes would be beneficial.
5.	Mathematics	A strong foundation in mathematics, including algebra, trigonometry, calculus, and differential equations, is necessary for performing calculations related to engine performance parameters, thermodynamic cycles, and analyzing engine behavior.

2. **Competencies**

S/L	Competency	KSA Description
1.	Ability to identify the key components of an IC engine and their functions.	**Knowledge:** Understanding of common IC engine terms and nomenclature Knowledge of key parameters like power, torque, efficiency, specific emissions, and emission index. **Skills:** Ability to differentiate between ideal and actual engine cycles (Otto vs. Actual for SI engines, Diesel vs. Actual for CI engines). Skill to analyze the impact of operating variables (e.g., speed, load) on engine performance using basic calculations or charts. **Attitudes:** A desire to understand the fundamental working principles of internal combustion engines. An interest in exploring how engine design choices influence performance and efficiency.
2.	Ability to analyze the factors influencing normal and abnormal combustion phenomena in SI engines.	**Knowledge:** Understanding of the distinct stages of combustion in a spark ignition engine (ignition, flame propagation, burnout). Knowledge of detrimental combustion events like detonation (knocking) and misfire, and their causes. **Skills:** Skill to identify the effects of engine variables (e.g., spark timing, air-fuel ratio) on ignition lag and flame propagation. Ability to suggest potential strategies to minimize abnormal combustion events in SI engines. **Attitudes:** Appreciation for the significance of precise control over engine variables for achieving optimal combustion in SI engines.
3.	Ability to compare and contrast the combustion characteristics	**Knowledge:** Understanding of the key aspects of combustion in a compression ignition (CI) engine, including the concept of ignition delay and its dependence on engine variables. Knowledge of various alternative fuels (vegetable oils, alcohol, LPG, CNG,

	of conventional diesel fuel with alternative fuels in CI engines.	hydrogen) for CI engines and their potential impact on combustion and emissions. **Skills:** Skill to analyze cylinder pressure data to understand the progress of combustion in a CI engine. Ability to evaluate the suitability of different alternative fuels for CI engines based on their combustion properties and emission characteristics. **Attitudes:** A willingness to explore and learn about the potential of alternative fuels for sustainable engine operation. An appreciation for the role of clean combustion technologies in reducing the environmental impact of CI engines.
4.	Ability to select and justify the appropriate fuel delivery system (carburetion vs. injection) for a given SI engine application.	**Knowledge:** Understanding of the fundamental principles of carburetion and the factors influencing proper air-fuel mixture formation at different engine operating conditions. Knowledge of various electronic injection systems (e.g., MPFI, common rail) and their advantages over traditional carburetors in terms of performance, efficiency, and emissions. **Skills:** Skill to diagnose potential problems associated with carburetor malfunctions. Ability (for mechanically inclined individuals) to calibrate and adjust a carburetor for optimal engine performance. **Attitudes:** An understanding of the importance of precise air-fuel metering for efficient engine operation. A willingness to learn and adapt to the growing use of electronic injection systems in modern SI engines.
5.	Ability to recommend appropriate emission control strategies for mitigating various pollutants from IC engines.	**Knowledge:** Understanding of the different types of pollutants emitted by IC engines (HC, CO, NOx, particulate matter) and their impact on air quality. Knowledge of various emission control methods (catalytic converters, exhaust gas recirculation, particulate traps) and their working principles. **Skills:** Skill to identify potential causes of excessive engine emissions. Ability to interpret emission test data and evaluate the effectiveness of control strategies. **Attitudes:** An awareness of the environmental consequences of uncontrolled engine emissions. An appreciation for the importance of adhering to emission standards set by regulatory bodies (e.g., Euro norms).

3. Syllabus

Theory and Design of Modern IC Engine **SEMESTER – I**			
Course Code	M23MTP102	CIE Marks	**50**
Number of Lecture Hours/Week(L: T: P: S)	**(3:0:2:0)**	SEE Marks	**50**
Total Number of Lecture Hours	**40 T + 10-12 L**	Total Marks	**100**
Credits	**04**	Exam Hours	**03**

Course Objectives: This course will enable students to:

- To provide the sufficient knowledge of concept, applications, importance of IC engines.
- To understand the mechanism of combustion in SI and CI engine and its effect on engine Performance.
- To familiarize the students about the IC engines systems, processes, alternative fuels etc.
- Knowledge of different Injection Systems and Engine emissions and their control..

Module -1

Introduction to IC Engines: Basic engine components and nomenclature, Applications of IC Engines, Engine characteristics, geometrical properties of reciprocating engines, specific emissions and emission index, relationships between performance parameters, Engine design and performance	L L2 L3

data. Energy flow through IC engines, Various Auxiliary systems. Environment friendly engines. Fuel –Air and Actual Engines: Modeling of Fuel-Air cycle Effect of operating variables on the performance of Fuel –air Cycles, Detailed analysis of difference between Fuel-Air and Real Cycle, Combustion charts and Gas Tables.	
Module -2	
Combustion in SI engine: Introductions, Ignition limits, Stages of Combustion in SI Engine, Effect of Engine Variables on Ignition lag, Effect of Engine variable on flame propagation, Detonation on knocking, Abnormal combustion knock-surface ignition, Cyclic variations in combustion, partial burning, and misfire, SI Engine combustion chamber designs, Combustion chamber design principles	L1 L2 L3
Module -3	
Combustion in CI engine: Introduction, Combustion in the CI engine, Types of diesel Combustion Systems, Air-Fuel ration in CI Engines, Ignition Delay, Variables affecting delay period, Analysis of cylinder pressure Data, Fuel Spray Behaviour, The CI engine Combustion Chamber. Alternate fuels for IC engines: Vegetable oils, alcohol, LPG, CNG, and Hydrogen fuels, Biogas, Dual fuels, other possible fuels.	L1 L2 L3
Module -4	
Carburetion: Introduction, Factors affecting carburetion, mixture requirements at different load and speed, principles of carburetion, essential parts, and functions of a carburetor, compensating devices, Modern Carburetors, Altitude compensation devices, Injection in SI engine. **Injection Systems**: Introduction to Mechanical Injection System, Functional Requirements and classification, Fuel feed pump and Fuel Injector, Electronic injection systems: Types, Merits and Demerits, Multi point fuel injection system (MPFI), Electronic control system, Injection timings, Common –Rail Fuel Injection System.	L1 L2 L3
Module -5	
Engine emissions and their control: Air pollution due to IC engines, emission characteristics, Euro norms, engine emissions, Hydrocarbon emissions, CO emission, NOx- Photo chemical smog, Particulates, other emissions, Smoke, emission control methods – thermal converters, catalytic converters, particulate traps, Ammonia injection systems, exhaust gas recirculation, ELCD, Crank case blow by control. IC engine Noise characteristics, types, standards and control methods, **Air Quality emission standards Measurement:** Noise, Emission, Pressure, crank angle torque, valve timings, temperature, and flow measurements.	L1 L2 L3

PRACTICAL COMPONENT (May cover all / major modules)

1	Performance analysis of single cylinder, four stroke, Petrol engine connected to eddy current Dynamometer for loading**.**
2	Performance analysis of single cylinder, four stroke, Diesel engine connected to eddy Current dynamometer for loading**.**
3	Performance analysis of four cylinder, four stroke, Turbocharged Diesel engine connected to Eddy current dynamometer for engine loading
4	Performance analysis of a four cylinder, four stroke, Petrol (MPFI) engine connected to eddy current dynamometer for loading
5	Performance analysis of a single cylinder, four stroke, VCR (Variable Compression Ratio) Diesel engine connected to eddy current dynamometer for loading.
6	Performance analysis of a single cylinder, four stroke, VCR (Variable Compression Ratio) Diesel engine connected to eddy current dynamometer for loading for different biodiesel.
7	Performance analysis of a single cylinder, four stroke, VCR (Variable Compression Ratio) Diesel engine connected to eddy current dynamometer for loading for Dual Fuel Mode.
8	Performance analysis of a single cylinder, four stroke, CRDI VCR (Variable Compression Ratio) engine connected to eddy current dynamometer.
9	Set-up for Extraction of Vegetable Oil and its Transesterification
10	Exhaust Gas analyser for diesel and Biodiesel fuel

Text Books:

1. John B Heywood, ―IC Engines fundamentals‖, McGraw- Hill Publications, 2011.
2. V. Ganesan, ―Internal Combustion Engines‖, Tata McGraw-Hill Publications, 4th Edition.
3. Internal Combustion Engines, Mathur R.P. & Sharma M.L., Dhanpat Rai Publication, 2014.
4. Richard stone, "Introduction to IC Engines" Palgrave Publication 3rd edition.
5. The Internal Combustion Engines in Theory and practice, Taylor C.F., MIT Press, 1985

Web links and Video Lectures (e-Resources):

https://archive.nptel.ac.in/courses/112/103/112103262/

4. **Syllabus Timeline**

S/L	Syllabus Timeline	Description
1	Week 1-2	**Introduction to IC Engines:** Basic engine components and nomenclature, Applications of IC Engines, Engine characteristics, geometrical properties of reciprocating engines, specific emissions and emission index, relationships between performance parameters, Engine design and performance data. Energy flow through IC engines, Various Auxiliary systems. Environment friendly engines. Lab: Performance analysis of single cylinder, four stroke, Petrol engine connected to eddy current Dynamometer for loading. Fuel –Air and Actual Engines: Modeling of Fuel-Air cycle Effect of operating variables on the performance of Fuel –air Cycles, Detailed analysis of difference between Fuel-Air and Real Cycle, Combustion charts and Gas Tables. Lab: Performance analysis of single cylinder, four stroke, Diesel engine connected to eddy Current dynamometer for loading
2	Week 3-4	**Combustion in SI engine:** Introductions, Ignition limits, Stages of Combustion in SI Engine, Effect of Engine Variables on Ignition lag, Effect of Engine variable on flame propagation Lab: Performance analysis of four cylinder, four stroke, Turbocharged Diesel engine connected to Eddy current dynamometer for engine loading Detonation on knocking, Abnormal combustion knock-surface ignition, Cyclic variations in combustion, partial burning, and misfire, SI Engine combustion chamber designs, Combustion chamber design principles Lab: Performance analysis of a four cylinder, four stroke, Petrol (MPFI) engine connected to eddy current dynamometer for loading
3	Week 5-6:	**Combustion in CI engine**: Introduction, Combustion in the CI engine, Types of diesel Combustion Systems, Air-Fuel ration in CI Engines, Ignition Delay, Variables affecting delay period, Analysis of cylinder pressure Data, Fuel Spray Behaviour, The CI engine Combustion Chamber. Lab: Performance analysis of a single cylinder, four stroke, VCR (Variable Compression Ratio) Diesel engine connected to eddy current dynamometer for loading Alternate fuels for IC engines: Vegetable oils, alcohol, LPG, CNG, and Hydrogen fuels, Biogas, Dual fuels, other possible fuels. Lab: Performance analysis of a single cylinder, four stroke, VCR Diesel engine connected to eddy current dynamometer for loading for different biodiesel
4	Week 7-8	**Carburetion:** Introduction, Factors affecting carburetion, mixture requirements at different load and speed, principles of carburetion, essential parts, and functions of a carburettor, compensating devices, Modern Carburetors, Altitude compensation devices, Injection in SI engine. Lab: Performance analysis of a single cylinder, four stroke, VCR Diesel engine connected to eddy current dynamometer for loading for Dual Fuel Mode **Injection Systems**: Introduction to Mechanical Injection System, Functional Requirements and classification, Fuel feed pump and Fuel Injector, Electronic injection systems: Types, Merits and Demerits, Multi point fuel injection system (MPFI), Electronic control system, Injection timings, Common –Rail Fuel Injection System Lab: Performance analysis of a single cylinder, four stroke, CRDI VCR engine connected to eddy current dynamometer.
5	Week 9-10	**Engine emissions and their control:** Air pollution due to IC engines, emission characteristics, Euro norms, engine emissions, Hydrocarbon emissions, CO emission, NOx- Photo chemical smog, Particulates, other emissions, Smoke, emission control methods – thermal converters, catalytic converters, particulate traps, Ammonia injection systems, exhaust gas recirculation, ELCD, Crank case blow by control. IC engine Noise characteristics, types, standards and control methods, Lab: Set-up for Extraction of Vegetable Oil and its Transesterification **Air Quality emission standards Measurement:** Noise, Emission, Pressure, crank angle torque, valve timings, temperature, and flow measurements.

		Lab: Exhaust Gas analyser for diesel and Biodiesel fuel
6	Week 11-12:	Course Review and Summary of Key Concepts Applications of IC Engines in Different Engineering Fields

5. Teaching-Learning Process Strategies

S/L	TLP Strategies:	Description
1	Chalk and Talk	This method is very useful in solving problems based on fluid flow thereby strengthening the competencies
2	Lecture Method	Utilize various teaching methods within the lecture format to reinforce competencies
3	Video/Simulation	Incorporate visual aids like videos/simulations/animations to enhance understanding of types of fluid flow concepts
4	Laboratory Demonstrations	Taking students to laboratory to reinforce practical skills associated with competencies
5	Collaborative Learning	Encourage collaborative learning for improved competency application
6	Problem-Based Learning (PBL)	Implement PBL to enhance analytical skills and practical application of competencies
7	Real-World Application	Discuss practical applications to connect theoretical concepts with real-world competencies

6. Assessment Details (both CIE and SEE)

Continuous Internal Evaluation:

Components		Number	Weightage	Max. Marks	Min. Marks
(i)	Internal Assessment-Tests (A)	2	50%	25	10
(ii)	Assignments/Quiz/Activity (B)	2	50%	25	10
	Total Marks			**50**	**20**

Final CIE Marks = (A) + (B)

SEE for IPCC

Theory SEE will be conducted by University as per the scheduled timetable, with common question papers for the course (duration 03 hours)

1. The question paper will be set for 100 marks and marks scored will be scaled down Proportionately to 50 marks.
2. The question paper will have ten questions. Each question is set for 20 marks.
3. There will be 2 questions from each module. Each of the two questions under a module (with a maximum of 3 sub-questions), **should have a mix of topics** under that module.
4. The students must answer 5 full questions, selecting one full question from each module.

The theory portion of the IPCC shall be for both CIE and SEE, whereas the practical portion will have a CIE component only. Questions mentioned in the SEE paper shall include questions from the practical component).

The minimum marks to be secured in CIE to appear for SEE shall be the 15 (50% of maximum marks-30) in the theory component and 10 (50% of maximum marks -20) in the practical component. The laboratory component of the IPCC shall be for CIE only. However, in SEE, the questions from the laboratory component shall be included**.** The maximum of 04/05 questions to be set from the practical component of IPCC, the total marks of all questions should not be more than the 20 marks. SEE will be conducted for 100 marks and students shall secure 40% of the maximum marks to qualify in the SEE. Marks secured will be scaled down to 50. (Student must secure an aggregate of 50% of maximum marks of the course (CIE+SEE)

5. **Learning Objectives**

S/L	Learning Objectives	Description
1	Understand the fundamentals of internal combustion (IC) engines	Understand the fundamental components, operation, and performance characteristics of internal combustion (IC) engines, including their environmental impact and auxiliary systems. Additionally, students will analyze fuel-air cycles and combustion processes in SI engines, evaluating the effects of engine variables on performance and combustion phenomena.
2	understand the principles and stages of combustion in SI (Spark Ignition) engines	Understand the fundamental principles and stages of combustion in SI (Spark Ignition) engines, including the effects of various engine variables on ignition lag, flame propagation, and detonation. Additionally, students will explore abnormal combustion phenomena such as knock and surface ignition, as well as the design principles and variations of combustion chambers in SI engines.
3	understand the principles and stages of combustion in CI engines	understand the principles and processes of combustion in CI engines, including the various types of diesel combustion systems and the factors influencing ignition delay and fuel spray behavior. Additionally, students will explore the use of alternate fuels for IC engines, such as vegetable oils, alcohol, LPG, CNG, hydrogen, biogas, and dual fuels, to evaluate their potential benefits and challenges.
4	analyze modern carburetion techniques	Understand the principles, essential parts, and functions of carburetion and injection systems in SI engines. They will also be able to analyze modern carburetion techniques and electronic injection systems, including their merits, demerits, and applications in various operational conditions.
5	analyze noise characteristics	Understand the impact of internal combustion (IC) engine emissions on air pollution and to explore various control methods and standards for mitigating these emissions. Students will learn to identify and measure different types of emissions, analyze noise characteristics

6. **Course Outcomes (COs) and Mapping with POs/ PSOs**

Course Outcomes (COs)

COs	Description
M23MTP102.1	To explore the knowledge of performance parameters and its characteristics, variables effect the performance of engine and methods of improving engine performance of internal combustion engine.
M23MTP102.2	Analyze combustion and apply remedial measures to avoid abnormal Combustion in SI and CI Engine..
M23MTP102.3	Specify and interpret data of alternative fuels and its emission which effect the Environment.
M23MTP102.4	Analyze different electronic fuel injection system, supercharging and its effect on performance of SI and CI engine.
M23MTP102.5	Apply various emission control system and modification to take corrective Actions to reduce pollution.

CO-PO-PSO Mapping

COs/POs	PO1	PO2	PO3
M23MTP102.1	3		
M23MTP102.2			3
M23MTP102.3			3
M23MTP102.4			3
M23MTP102.5			3

7. **Assessment Plan**

Continuous Internal Evaluation (CIE)

	CO1	CO2	CO3	CO4	CO5	**Total**
Module 1	**20**					**20**
Module 2		**20**				**20**
Module 3			**20**			**20**
Module 4				**20**		**20**
Module 5					**20**	**20**
Total	**20**	**20**	**20**	**20**	**20**	**100**

Semester End Examination (SEE)

	CO1	CO2	CO3	CO4	CO5	Total
Module 1	**20**					**20**
Module 2		**20**				**20**
Module 3			**20**			**20**
Module 4				**20**		**20**
Module 5					**20**	**20**
Total	**20**	**20**	**20**	**20**	**20**	**100**

8. **Future with this Subject**

The "Theory and Design of Modern IC Engines " course in the first semester of the Thermal Power Engineering program lays a strong foundation for several future courses in the post graduate program. The contributions of this subject extend across various areas, enhancing the students' understanding and skills in the field of digital systems. Here are some notable contributions:

1. **Advanced Thermodynamics and Heat Transfer**: In-depth study of thermodynamic principles and heat transfer mechanisms, focusing on applications in engine design and performance.
2. **Combustion and Emissions**: Detailed exploration of combustion processes, emission formation, and strategies for emission reduction in IC engines.
3. **Engine Control Systems**: Examination of electronic control systems used in modern engines for optimizing performance and emissions.
4. **Alternative Fuels and Energy Systems**: Investigation of alternative fuel sources such as biofuels, hydrogen, and electric propulsion systems, and their integration into engine design.
5. **Computational Fluid Dynamics (CFD) and Finite Element Analysis (FEA) for Engines**: Application of CFD and FEA tools to simulate and analyze engine performance, fluid flow, and structural integrity.

1st Semester	Professional Course (PC) ADVANCED FLUID MECHANICS	M23MTP103

1. Prerequisites

S/L	Proficiency	Prerequisites
1.	Physics (Mechanics)	Understanding concepts like force, pressure, work, and energy. These principles form the foundation for analyzing fluid forces, pressure distributions, and energy transfer within fluids
2.	Calculus (Differential and Integral)	Proficiency in differentiation (finding rates of change) and integration (finding total quantities) to understand concepts like fluid motion, pressure variations, and flow rates
3.	Units and its conversions	Familiarity with converting between different units of measurement (e.g., meters to centimeters, kilograms to grams) as fluid properties and calculations involve various units
4.	Problem-solving skills	Fluid mechanics involves applying concepts and equations to solve real-world problems. Strong problem-solving skills will be essential for analyzing scenarios and manipulating equations to find solutions
5.	Basic Programming (Optional)	Having some basic programming experience in languages like Python can be advantageous. Computational Fluid Dynamics (CFD) software that utilizes programming concepts

2. Competencies

S/L	Competency	KSA Description
1.	Review of undergraduate Fluid Mechanics	**Knowledge:** Understand fluid properties, pressure, forces, buoyancy Derive continuity equation (all coordinates), explain Navier-Stokes & energy equations (3D) **Skills:** Apply equations to analyze fluid behavior (forces, pressures, velocities) Use equations confidently in different coordinate systems (Cartesian, Cylindrical, Spherical) **Attitudes:** Be curious, actively seek understanding and explore applications Evaluate assumptions, analyze solutions, assess real-world applicability
2.	Mechanics of Laminar and Turbulent Flow	**Knowledge:** Flow Regimes: Laminar (smooth, layered) vs. Turbulent (chaotic, mixing) flows. Reynolds Number & Transition: Its role in flow transition (Re) and analytical solutions (Poiseuille, Stokes) for laminar cases. **Skills:** Flow Characterization: Identify laminar vs. turbulent based on problem data. Pipe Network Analysis: Solve for flow rates and pressure drops using the Hardy Cross method. **Attitudes:** Critical Thinking: Evaluate applicability of flow models (laminar vs. turbulent). Problem-Solving Strategy: Select appropriate methods based on the problem.
3.	Exact and Approximate solutions of N-S Equations and Boundary layer over a flat plate	**Knowledge:** Understand limitations of solving Navier-Stokes equations exactly. Explore approximate methods (e.g., Oseen's approximation). Grasp boundary layer thickness, displacement thickness, momentum thickness, and their significance. **Skills:** Apply relevant approximate methods (e.g., Oseen's approximation) to solve specific problems Utilize Prandtl's equation to analyze boundary layer behavior (thickness, separation). **Attitudes:** Recognize when exact solutions are impractical and choose appropriate approximations. Interpret results from boundary layer analysis (forces, separation) to understand flow behavior.

4.	Energy equation and Isentropic Flow with variable Area	**Knowledge:** Understand energy forms (internal, kinetic, and potential) in flow and non-flow processes. Grasp the concept of adiabatic flow, stagnation enthalpy, temperature, pressure, and velocity of sound. Differentiate between isentropic and adiabatic processes. Understand the relationship between Mach number variation, stagnation and critical states, area ratio, impulse function, mass flow rate, and flow through nozzles and diffusers. **Skills:** Apply the energy equation to analyze fluid flow problems considering various energy forms. Utilize relationships between Mach number, area ratio, and other flow properties for isentropic flow problems. **Attitudes:** Identify the relevant energy forms involved in specific fluid flow scenarios. Understand the limitations of the isentropic assumption and its applicability to real flows.
5.	Flow across Normal Shock and Oblique Shock	**Knowledge:** Understand the concept of shock waves and differentiate them from rarefaction waves. Grasp the governing equations describing the changes in flow properties Learn about Prandtl-Meyer relation and its role in oblique shocks. Understand how Mach number, pressure, temperature, and density vary across an oblique shock using Rankine-Hugoniot equations. **Skills:** Apply governing equations to analyze changes in flow properties across a normal shock. Utilize Prandtl-Meyer relation and Rankine-Hugoniot equations to solve for flow parameters in oblique shocks. **Attitudes:** Recognize the significance of shock waves in compressible fluid flow. Understand the limitations of normal and oblique shock models and choose the appropriate one for specific problems.

3. **Syllabus**

ADVANCED FLUID MECHANICS SEMESTER – I			
Course Code	M23MTP103	CIE Marks	**50**
Number of Lecture Hours/Week(L: T: P: S)	**(3:0:2:0)**	SEE Marks	**50**
Total Number of Lecture Hours	**40 hours**	Total Marks	**100**
Credits	**04**	Exam Hours	**03**

Course Objectives: This course will enable students to:

- To understand the kinematics of fluids, their governing equations, Mechanics of laminar and turbulent f
- Advanced knowledge of boundary layer equation, as well as a fundamental understanding ofthe drag an
- Understanding of the fundamental of the Flow across Normal Shock and Oblique Shock and Comparis adiabatic processes.
- Knowledge of several practical applications of the theory covered.

Module -1	
Review of undergraduate Fluid Mechanics: Introduction: Fluid Statics, Relative Motion of Liquids. Kinematics of Fluids- Review of basics-Velocity potential, Stream function and Vorticity. Fundamental Equations, Applications of Fundamental Equations, Differential Flow analysis- Continuity equation (3D Cartesian, Cylindrical and spherical Coordinates) Navier Stokes equations (3D- Cartesian, coordinates), Energy Equations (3D- Cartesian, coordinates), Elementary in viscid flows; superposition (2D).	L1 , L2 , L3
Module -2	
Mechanics of Laminar and Turbulent Flow: Introduction; Laminar and turbulent flows; viscous flow at different Reynolds number - wake frequency; laminar plane Poiseuille flow; stokes flow; flow through a concentric annulus. structure and origin of turbulent flow - Reynolds, average concept, Reynolds equation of motion; zero equation model for fully turbulent flows and other turbulence	L1 , L2 ,

models; turbulent flow through pipes; losses in bends, valves etc; analysis of pipe network - Hard cross method.	L3
Module -3	
Exact and Approximate solutions of N-S Equations: Introduction; Parallel flow past a sphere; Oseen's approximation; hydrodynamic theory of lubrication; Hele-Shaw Flow. **Boundary layer over a flat plate:** Thickness of boundary layer, displacement and momentum thickness, Prandtl's boundary layer equation, Vonkarmann momentum equation – shear stress and drag force, laminar boundary layer, turbulent boundary layer, pressure distribution in the boundary layer, boundary layer separation, drag and lift force – lift on an airfoil.	L1, L2, L3
Module -4	
Energy equation: Energy equation for non-flow and flow processes, adiabatic energy equation, stagnation enthalpy, stagnation temperature, stagnation pressure, stagnation velocity of sound, reference velocities, Bernoulli's equation, effect of Mach number on compressibility. **Isentropic Flow with variable Area:** Comparison of isentropic and adiabatic processes, Mach Number variation, Stagnation and critical states, Area ratio as a function of Mach number, impulse function, Mass flow rate, Flow through nozzles and diffusers	L1, L2, L3
Module -5	
Flow across Normal Shock and Oblique Shock: Development of a shock wave, rarefaction wave, governing equations, Prandtl-Meyer relation, Mach number downstream of the shock wave, static pressure ratio, temperature ratio, density ratio, and stagnation pressure ratio across the shock. Oblique shock waves fundamental relations, Prandtl's Equation, Rankine – Hugoniot Equation, Variation of flow parameters, Relations and Tables, Numerical Problems.	L1, L2, L3

Text Books:

- *Foundations of fluid mechanics* - S.W. Yuan, *Foundations of Fluid Mechanics*, Prentice Hall of India, 2000.
- White F.M., *Viscous Fluid Flow*, 3rd edition, Tata McGraw Hill Book Company, 2011.
- S.M. Yahya, *Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion (SIUNITs)*, Fifth Edition, New Age International Publishers, New Delhi, 2020.

Reference Books:

- Yunus A. Cengel and John M. Cimbala, Introduction to Fluid Mechanics, Second Edition, TataMcGraw-Hill, 2010.
- *Introduction to fluid dynamics - Principles of analysis & design* - Stanley Middleman, Wiley,1997.
- D. S. Kumar, *Fluid Mechanics and Fluid power engineering*, S. K. Kataria & sons, 2010.

4. Syllabus Timeline

S/L	Syllabus Timeline	Description
1	Week 1-2:Review of Undergraduate Fluid Mechanics	**Week 1:** Introduction: Fluid Statics, Relative Motion of Liquids. Kinematics of Fluids: Velocity Potential, Stream Function, and Vorticity. **Week 2:** Fundamental Equations: Continuity Equation (all coordinates). Fundamental Equations: Navier-Stokes Equations (3D Cartesian) and Energy Equations (3D Cartesian).
2	Week 3-4:Mechanics of Laminar and Turbulent Flow	**Week 3:** Introduction: Laminar and Turbulent Flows. Viscous Flow at Different Reynolds Numbers: Poiseuille Flow and Stokes Flow. **Week 4:** Structure and Origin of Turbulent Flow. Reynolds Averaged Navier-Stokes (RANS) Equations and Zero-Equation Model for Turbulent Flows.
3	Week 5-6:Exact and Approximate Solutions & Boundary Layers	**Week 5:** Introduction and Challenges of Solving Navier-Stokes Equations Exactly. Approximate Solutions: Oseen's Approximation. **Week 6:** Boundary Layer Concepts: Thickness, Displacement, and Momentum Thickness Governing Equations for Boundary Layers: Prandtl's Boundary Layer Equation

4	Week 7-8:Energy Equation & Isentropic Flow	**Week 7:** Energy Equation for Flow and Non-Flow Processes Adiabatic Energy Equation, Stagnation Properties **Week 8:** Isentropic vs. Adiabatic Processes Mach Number Variation, Stagnation & Critical States in Isentropic Flow
5	Week 9-10:Flow Across Normal and Oblique Shocks	**Week 9:** Development of Shock Waves and Governing Equations. Normal Shock Wave Properties: Pressure, Temperature, Density, Mach Number Changes. **Week 10:** Oblique Shocks: Fundamental Relations and Prandtl-Meyer Relation. Rankine-Hugoniot Equation and Variation of Flow Parameters in Oblique Shocks.
6	Week 11-12:Review, Applications, and Projects	**Week 11 & 12** Course Review and Summary of Key Concepts Applications of Fluid Mechanics in Different Engineering Fields

5. Teaching-Learning Process Strategies

S/L	TLP Strategies:	Description
1	Chalk and Talk	This method is very useful in solving problems based on fluid flow thereby strengthening the competencies
2	Lecture Method	Utilize various teaching methods within the lecture format to reinforce competencies
3	Video/Simulation	Incorporate visual aids like videos/simulations/animations to enhance understanding of types of fluid flow concepts
4	Laboratory Demonstrations	Taking students to Fluid Mechanics and Machinery laboratory to reinforce practical skills associated with competencies
5	Collaborative Learning	Encourage collaborative learning for improved competency application
6	Problem-Based Learning (PBL)	Implement PBL to enhance analytical skills and practical application of competencies
7	Real-World Application	Discuss practical applications to connect theoretical concepts with real-world competencies
8	Flipped Class Technique	Utilize a flipped class approach, providing materials before class to facilitate deeper understanding of competencies

6. Assessment Details (both CIE and SEE)

CIE

Components		Number	Weightage	Max. Marks	Min. Marks
(i)	Internal Assessment-Tests (A)	2	50%	25	10
(ii)	Assignments/Quiz/Activity (B)	2	50%	25	10
	Total Marks			**50**	**50**

Final CIE Marks = (A) + (B)

SEE

1. Question paper pattern will be ten questions. Each question is set for 20marks. The medium of the question paper shall be English unless otherwise it is mentioned.
2. There shall be 2 question from each module, each of the two questions under a module (with a maximum of 3 sub questions), may have mix of topics under that module if necessary.
3. The students have to answer 5 full questions selecting one full question from each module.
4. Marks scored will be proportionally scaled down to 50 marks

7. Learning Objectives

S/L	Learning Objectives	Description
1	Refresh core concepts & solve basic problems	Fluid properties, relative motion, kinematics, fundamental equations
2	Understand flow regimes &	Laminar vs. turbulent, viscous flow (Re), laminar flow solutions

	solve for laminar flows	(Poiseuille, Stokes), turbulence basics, pipe networks.
3	Analyze limitations & solve boundary layer problems	Limitations of exact solutions, approximate methods, boundary layers, Prandtl's equation.
4	Apply energy principles & analyze isentropic flow	Energy forms, energy equation, adiabatic flow, isentropic flow (Mach number, area ratio).
5	Understand shock waves & analyze flow across them	Shock waves vs. rarefaction, normal shock analysis, oblique shock relations (Prandtl-Meyer), flow parameters (Rankine-Hugoniot).

8. Course Outcomes (COs) and Mapping with POs/ PSOs

Course Outcomes (COs)

COs	Description
M23MTP103.1	Illustrate the basic concepts fluid flow and their governing equations
M23MTP103.2	Analyse the laminar and turbulent flow problems.
M23MTP103.3	Demonstrate the concept of boundary layer equations and drag and lift force
M23MTP103.4	Distinguish normal and oblique shocks and their governing Equations.
M23MTP103.5	Explain the propagation of sound waves and Comparison of isentropic and adiabatic processes in fluid mechanics.

CO-PO-PSO Mapping

COs/POs	PO1	PO2	PO3
M23MTP103.1	3		
M23MTP103.2			3
M23MTP103.3			3
M23MTP103.4			3
M23MTP103.5			3

9. Assessment Plan

Continuous Internal Evaluation (CIE)

	CO1	CO2	CO3	CO4	CO5	**Total**
Module 1	**20**					**20**
Module 2		**20**				**20**
Module 3			**20**			**20**
Module 4				**20**		**20**
Module 5					**20**	**20**
Total	**20**	**20**	**20**	**20**	**20**	**100**

Semester End Examination (SEE)

	CO1	CO2	CO3	CO4	CO5	Total
Module 1	**20**					**20**
Module 2		**20**				**20**
Module 3			**20**			**20**
Module 4				**20**		**20**
Module 5					**20**	**20**
Total	**20**	**20**	**20**	**20**	**20**	**100**

10. Future with this Subject

The "Advanced Fluid Mechanics" course in the first semester of the Thermal Power Engineering program lays a strong foundation for several future courses in the post graduate program. The contributions of this subject extend across various areas, enhancing the students' understanding and skills in the field of digital systems. Here are some notable contributions:

1. **Renewable Energy:** As the world transitions to clean energy sources, fluid mechanics will be instrumental in optimizing wind turbine designs for improved efficiency and capturing energy from ocean currents and waves.
2. **Microfluidics and Bioengineering:** Understanding fluid flow at the microscopic level is crucial for developing microfluidic devices for medical diagnostics, drug delivery, and lab-on-a-chip technologies.
3. **Computational Fluid Dynamics (CFD):** Advancements in CFD software and hardware will enable more accurate simulations of complex fluid flows. This will be critical for designing efficient aircraft, optimizing combustion engines, and improving building ventilation systems.
4. **Nano-fluidics:** Exploring the behavior of fluids at the nanoscale opens doors for developing new materials with unique properties for heat transfer, lubrication, and energy storage.
5. **Hypersonic Flow and Space Exploration:** Understanding hypersonic flow, where speeds exceed five times the speed of sound, is vital for designing future hypersonic vehicles for space travel and high-speed transportation.

1st Semester	Professional Course (PC) ADVANCED THERMODYNAMICS & COMBUSTION ADVANCED	M23MTP104

1. Prerequisites

S/L	Proficiency	Prerequisites
1.	Basic Calculus	A solid understanding of differentiation and integration is essential for performing calculations involving thermodynamic properties, energy changes, and work done in various processes.
2.	General Physics	Familiarity with concepts like pressure, volume, temperature, work, heat, and ideal gas laws will be crucial for comprehending the fundamental principles of thermodynamics.
3.	Chemistry Fundamentals	Basic knowledge of chemical reactions, elements, compounds, stoichiometry, and enthalpy changes will be necessary for studying combustion processes and fuel properties
4.	Introduction to Fluid Mechanics	Understanding the behavior of fluids (liquids and gases) at rest and in motion will be beneficial when analyzing transport phenomena in combustion systems.
5.	Linear Algebra (Optional)	While not always mandatory, familiarity with matrices and basic linear algebra can be helpful for advanced topics involving property relations and thermodynamic calculations.

2. Competencies

S/L	Competency	KSA Description
1.	Ability to apply the first and second laws of thermodynamics to analyze energy transfer and entropy changes in various systems (closed and open)	**Knowledge:** Understanding of the first law (conservation of energy) and the second law (entropy) and their implications for energy transfer and system behavior. Knowledge of entropy as a measure of disorder and its role in irreversible processes and entropy generation. **Skills:** Skill to solve problems involving energy transfer, work done, and heat exchange in closed and open systems using the first law. Ability to calculate entropy changes for different processes using appropriate relationships and tables. **Attitude:** An inclination to analyze problems from a thermodynamic perspective, considering energy transfer and entropy changes. A desire to apply the first and second laws to solve practical engineering problems involving energy conversion and utilization.
2.	Ability to utilize thermodynamic property relations (Maxwell relations, relations involving enthalpy, internal energy, and entropy) to analyze and predict the behavior of gas mixtures.	**Knowledge:** Understanding of the relationships between thermodynamic properties (pressure, volume, temperature, entropy) like Maxwell relations and their applications. Knowledge of how to describe the behavior of ideal and real gas mixtures using equations of state, property relations, and concepts like mole and mass fractions. **Skills:** Skill to derive or utilize existing relationships between thermodynamic properties for specific applications. Ability to solve problems involving property changes in gas mixtures using relevant equations and property tables. **Attitude:** An inclination to analyze problems by identifying the relevant thermodynamic properties and applying appropriate relationships. A focus on obtaining accurate results by considering the limitations of ideal gas behavior and using real gas properties when necessary.
3.	Ability to analyze combustion processes	**Knowledge:** Understanding of the differences between theoretical and actual combustion

	using both the first and second laws of thermodynamics.	processes, including factors like enthalpy changes and irreversibilities. Knowledge of how to apply the first law (energy conservation) and the second law (entropy) to analyze energy transfer and entropy changes in reacting systems during combustion. **Skills:** Skill to calculate enthalpy of formation, enthalpy of combustion, and adiabatic flame temperature for various fuels. Ability to interpret the results of first and second law analysis to understand the efficiency and limitations of combustion processes. **Attitude:** A desire to apply thermodynamic principles to solve problems related to fuel selection, combustion efficiency, and emission control. An appreciation for the importance of analyzing combustion processes from an energy and entropy perspective for optimizing efficiency and minimizing environmental impact.
4.	Ability to predict the extent of a chemical reaction at equilibrium in combustion processes.	**Knowledge:** Understanding of the concept of chemical equilibrium, the role of Gibbs free energy and equilibrium constant, and how they influence reaction progress. Knowledge of combustion kinetics (reaction rates) and transport phenomena (heat and mass transfer) and their significance in combustion processes. **Skills:** Knowledge of combustion kinetics (reaction rates) and transport phenomena (heat and mass transfer) and their significance in combustion processes. Knowledge of combustion kinetics (reaction rates) and transport phenomena (heat and mass transfer) and their significance in combustion processes. **Attitude:** An inclination to critically evaluate the limitations of equilibrium assumptions when analyzing real-world combustion processes. An appreciation for the importance of considering both chemical and physical aspects (kinetics and transport) for a comprehensive understanding of combustion.
5.	Ability to classify different types of flames (premixed, diffusion, laminar, turbulent) and analyze the factors influencing their behavior.	**Knowledge:** Understanding of the key features of various flame types (premixed vs. diffusion, laminar vs. turbulent) and their dependence on factors like fuel properties, mixing, and flow conditions. Knowledge of the fundamental processes involved in combustion, including burning velocity, flame propagation, and the role of liquid and solid fuel atomization and spray characteristics. **Skills:** Skill to identify different flame types based on their visual characteristics and operating conditions. Ability to predict how changes in fuel properties, mixing, and flow will influence burning velocity, stability, and overall combustion efficiency. **Attitude:** Ability to predict how changes in fuel properties, mixing, and flow will influence burning velocity, stability, and overall combustion efficiency. A desire to apply the understanding of flame behavior to solve practical problems related to combustion system design and optimization.

3. Syllabus

Advanced Thermodynamics and Combustion SEMESTER – I			
Course Code	**M23MTP104**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	2:0:2	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	03	Exam Hours	3 Hrs.
Course Learning objectives:			

- To enhance the understanding of thermodynamics principles and their relevance to the problems of humankind.
- Provide the student with experience in applying thermodynamic principles to predict physical phenomena and to solve engineering problems.
- To clarify availability concept and analyze availability cycles.
- Understanding the fundamental of properties of gas mixtures, chemical reactions, and Chemistry of combustion

Module -1	
Review of Basic Thermodynamics: First &Second Law Analysis, Review of entropy, Concept of entropy and entropy generation, Entropy balance for closed & open systems; Concept of energy & irreversibility, Energy analyses of open and closed system.	L1 L2 L3
Module -2	
Thermodynamic Property Relations: Maxwell relations; Relations involving enthalpy, internal energy, and entropy; Mayer relation, Clausius-Clapeyron equation, Joule-Thompson experiment. **Properties of Gas Mixtures**: Composition of Gas mixtures: Mass and Mole fractions: P-V-T behavior of Gas mixtures Ideal and Real gases. Equations of states and properties of ideal and real gas mixtures, Property relations for mixtures and Psychrometry, Change in entropy in mixing.	L1 L2 L3
Module -3	
Chemical Reactions: Fuels and combustion, Theoretical and actual combustion processes, Enthalpy of formation and enthalpy of combustion, first law analysis of reacting systems, Adiabatic flame temperature, Entropy change of Reacting systems, second law analysis of reacting systems.	L1 L2 L3
Module -4	
Concept of Chemical Equilibrium: Criterion for Chemical equilibrium, Gibbs free energy and the equilibrium constant of a chemical reaction (Vant-Hofts equation). Calculation of equilibrium, Composition of a chemical reaction. **Chemistry of Combustion**: Combustion Kinetics, Detailed combustion Kinetics, simplified combustion kinetics. Physics of Combustion: Fundamental laws of transport phenomena, Conservations Equations, Transport in Turbulent Flow.	L1 L2 L3
Module -5	
Combustion and Flames: Premixed Flame, laminar premixed flames, burning velocity measurement methods, Effects of chemical and physical variables on Burning velocity, Turbulent Premixed Flames, Laminar Diffusion Flames, Turbulent Diffusion Flames, Turbulent Mixing, Liquid fuel combustion, Atomization, Spray Combustion, Solid fuel combustion. **Teaching-Learning Process** Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.	L1 L2 L3

Text Books:

1. M. J. Moran, H. N. Shapiro, D. D. Boettner and M. B. Bailey, Principles of Engineering Thermodynamics, Eighth Edition, Wiley, New Delhi, 2015
2. Y. U. Cengel and M. A. Boles, Thermodynamics: An Engineering Approach, Fourth Edition, Tata McGraw-Hill, New Delhi, 2003
3. R. H. Dittman and M. W. Zemansky, Heat and Thermodynamics, Seventh Edition, Tata McGraw-Hill, New Delhi, 2007
4. S. R. Turns, An Introduction to Combustion: Concepts and Applications, McGraw Hill International Edition, Singapore, 200
5. K. K. Kuo, Principles of Combustion, Second Edition, Wiley India Pvt. Ltd., New Delhi, 2012
6. Modern Engineering Thermodynamics, Robert Balmer, Elsevier. Advanced Thermodynamics for Engineers, Kenneth Wark, and McGraw Hill.

Web links and Video Lectures

https://archive.nptel.ac.in/courses/112/103/112103307/
https://archive.nptel.ac.in/courses/112/103/112103313/
https://archive.nptel.ac.in/courses/112/106/112106310/
https://archive.nptel.ac.in/courses/103/103/103103162/
https://archive.nptel.ac.in/courses/103/104/103104151/

4. Syllabus Timeline

S/L	Syllabus Timeline	Description
1	Week 1-2: Review of Basic Thermodynamics	**Week 1:** First &Second Law Analysis, Review of entropy, Concept of entropy and entropy generation. **Week 2:** Entropy balance for closed & open systems; Concept of energy & irreversibility, Energy analyses of open and closed system
2	Week 3-4: Thermodynamic Property Relations	**Week 3:** Maxwell relations; Relations involving enthalpy, internal energy, and entropy; Mayer relation, Clausius-Clapeyron equation, Joule-Thompson experiment. **Week 4:** Composition of Gas mixtures: Mass and Mole fractions: P-V-T behaviour of Gas mixtures Ideal and Real gases
3	Week 5-6: Chemical Reactions	**Week 5:** Equations of states and properties of ideal and real gas mixtures, Property relations for mixtures and Psychrometry, Change in entropy in mixing. **Week 6:** Fuels and combustion, Theoretical and actual combustion processes, Enthalpy of formation and enthalpy of combustion
4	Week 7-8: Concept of Chemical Equilibrium	**Week 7:** First law analysis of reacting systems, Adiabatic flame temperature, Entropy change of Reacting systems, second law analysis of reacting systems. **Week 8:** Criterion for Chemical equilibrium, Gibbs free energy and the equilibrium constant of a chemical reaction (Vant-Hofts equation). Calculation of equilibrium, Composition of a chemical reaction.
5	Week 9-10: Combustion and Flames:	**Week 9:** Combustion Kinetics, Detailed combustion Kinetics, simplified combustion kinetics. Physics of Combustion:Fundamental laws of transport phenomena, Conservations Equations, Transport in Turbulent Flow **Week 10:** Premixed Flame, laminar premixed flames, burning velocity measurement methods, Effects of chemical and physical variables on Burning velocity,
6	Week 11-12: Laminar Diffusion	**Week 11** Turbulent Premixed Flames, Laminar Diffusion Flames, Turbulent Diffusion Flames, Turbulent Mixing, Liquid fuel combustion, Atomization, Spray Combustion, Solid fuel combustion. **Week 12** Course Review and Summary of Key Concepts

5. Teaching-Learning Process Strategies

S/L	TLP Strategies:	Description
1	Chalk and Talk	This method is very useful in solving problems based on fluid flow thereby strengthening the competencies
2	Lecture Method	Utilize various teaching methods within the lecture format to reinforce competencies
3	Video/Simulation	Incorporate visual aids like videos/simulations/animations to enhance understanding of types of fluid flow concepts
4	Laboratory Demonstrations	Taking students to Fluid Mechanics and Machinery laboratory to reinforce practical skills associated with competencies
5	Collaborative Learning	Encourage collaborative learning for improved competency application
6	Problem-Based Learning (PBL)	Implement PBL to enhance analytical skills and practical application of competencies

7	Real-World Application	Discuss practical applications to connect theoretical concepts with real-world competencies
8	Flipped Class Technique	Utilize a flipped class approach, providing materials before class to facilitate deeper understanding of competencies

Assessment Details (both CIE and SEE)

CIE

Components		Number	Weightage	Max. Marks	Min. Marks
(i)	Internal Assessment-Tests (A)	3	50%	20	10
(ii)	Assignments/Quiz/Activity (B)	2	50%	20	10
	Total Marks			**100**	**50**

Final CIE Marks = (A) + (B)

SEE

1. Question paper pattern will be ten questions. Each question is set for 20marks. The medium of the question paper shall be English unless otherwise it is mentioned.
2. There shall be 2 question from each module, each of the two questions under a module (with a maximum of 3 sub questions), may have mix of topics under that module if necessary.
3. The students have to answer 5 full questions selecting one full question from each module.
4. Marks scored will be proportionally scaled down to 50 marks

6. Learning Objectives

S/L	Learning Objectives	Description
1	Refresh core concepts & solve basic problems	Fluid properties, relative motion, kinematics, fundamental equations
2	Understand flow regimes & solve for laminar flows	Laminar vs. turbulent, viscous flow (Re), laminar flow solutions (Poiseuille, Stokes), turbulence basics, pipe networks.
3	Analyze limitations & solve boundary layer problems	Limitations of exact solutions, approximate methods, boundary layers, Prandtl's equation.
4	Apply energy principles & analyze isentropic flow	Energy forms, energy equation, adiabatic flow, isentropic flow (Mach number, area ratio).
5	Understand shock waves & analyze flow across them	Shock waves vs. rarefaction, normal shock analysis, oblique shock relations (Prandtl-Meyer), flow parameters (Rankine-Hugoniot).

7. Course Outcomes (COs) and Mapping with POs/ PSOs

Course Outcomes (COs)

COs	Description
M23MTP104.1	Illustrate the basic concepts on First & Second Law Analysis, entropy, and energy analysis in thermodynamic systems.
M23MTP104.2	Analyse the Thermodynamic property relations and its application to gas mixtures, phase change processes.
M23MTP104.3	Demonstrate the Combustion fundamentals involving premixed and non- Pre-mixed flames for laminar and turbulent combustion.
M23MTP104.4	Explain the fundamental of properties of gas mixtures, chemical reactions, and chemistry of combustion.
M23MTP104.5	Applications of combustion phenomena in practical occurring applications such IC and GT engines.

CO-PO-PSO Mapping

COs/POs	PO1	PO2	PO3
M23MTP104.1	3		
M23MTP104.2			3
M23MTP104.3			3
M23MTP104.4			3
M23MTP104.5			3

8. Assessment Plan

Continuous Internal Evaluation (CIE)

	CO1	CO2	CO3	CO4	CO5	Total
Module 1	20					20
Module 2		20				20
Module 3			20			20
Module 4				20		20
Module 5					20	20
Total	20	20	20	20	20	100

Semester End Examination (SEE)

	CO1	CO2	CO3	CO4	CO5	Total
Module 1	20					20
Module 2		20				20
Module 3			20			20
Module 4				20		20
Module 5					20	20
Total	20	20	20	20	20	100

9. Future with this Subject

1. Energy Systems and Power Generation
- **Thermodynamic Cycles:** Advanced understanding of cycles (e.g., Carnot, Rankine, Brayton) improves the efficiency of thermal power plants.
- **Renewable Energy:** Thermodynamics principles are applied to enhance solar thermal, geothermal, and biomass energy systems.
- **Combustion Processes:** Optimization of combustion in engines and power plants to increase efficiency and reduce emissions.

2. Aerospace Engineering
- **Propulsion Systems:** Study of combustion and thermodynamics is crucial for designing efficient jet engines, rockets, and scramjets.
- **Thermal Management:** Advanced thermodynamics aids in managing thermal loads and improving heat dissipation in aerospace vehicles.
- **Materials:** Understanding high-temperature behavior of materials used in aerospace components.

3. Automotive Engineering
- **Engine Design:** Improving internal combustion engines (ICEs) for higher efficiency and lower emissions using advanced combustion theories.
- **Alternative Fuels:** Researching and optimizing the use of alternative fuels (e.g., hydrogen, biofuels) in automotive engines.
- **Hybrid Systems:** Thermodynamics helps in optimizing energy management in hybrid and electric vehicles.

4. Environmental Engineering
- **Pollution Control:** Combustion and thermodynamic analysis help in developing technologies to reduce pollutants from industrial processes.
- **Climate Change Mitigation:** Thermodynamic principles are used to enhance carbon capture and storage (CCS) technologies.
- **Waste Management:** Optimizing incineration processes for energy recovery and minimal environmental impact.

5. Chemical Engineering

- **Reaction Engineering:** Understanding exothermic and endothermic reactions to optimize chemical manufacturing processes.
- **Process Design:** Thermodynamics is crucial for designing efficient chemical processes and equipment (e.g., reactors, distillation columns).
- **Safety:** Managing thermal runaway reactions and ensuring safe operation of chemical plants.

6. Materials Science and Engineering

- **Phase Transitions:** Thermodynamics helps in understanding and controlling phase changes in materials.
- **High-Temperature Materials:** Studying the behavior of materials under extreme temperatures for applications in engines and turbines.

7. Nuclear Engineering

- **Reactor Design:** Thermodynamics is essential for the design and operation of nuclear reactors, including thermal management and safety analysis.
- **Fusion Research:** Understanding the thermodynamics of plasma and confinement systems in nuclear fusion reactors.

1st Semester	Professional Course (PC) FINITE ELEMENT METHOD IN HEAT TRANSFER	M23MTP105

1. Prerequisites

S/L	Proficiency	Prerequisites
1	**Solid Mechanics**	A basic understanding of solid mechanics is helpful, especially concepts of stress, strain, and constitutive relationships. This will help you understand how heat transfer can be coupled with other engineering problems.
2	**Heat Transfer Fundamentals**	A strong foundation in heat transfer fundamentals is essential. This includes understanding the governing equations for conduction, convection, and radiation heat transfer, as well as boundary conditions.
3	**Calculus**	A solid understanding of calculus, including differential equations, is necessary. FEM relies heavily on calculus for manipulating and solving the governing equations of heat transfer.
4	**Linear Algebra**	Familiarity with linear algebra concepts like matrices and vectors is beneficial. FEM uses these concepts extensively to represent the system of equations arising from the discretization process.
5	**Numerical Methods**	A basic understanding of numerical methods, such as matrix inversion and equation solving techniques, is helpful. FEM utilizes various numerical methods to solve the discretized equations.

2. Competencies

S/L	Competency	KSA Description
1	**Finite Element Formulations**	**Knowledge:** Theoretical understanding of the finite element method (FEM) including its mathematical foundation and governing equations. **Skills:** Skills in pre-processing (e.g., geometry creation, mesh generation, applying boundary conditions), solving finite element problems and interpreting the results (e.g., stress analysis, strain analysis, heat transfer analysis). **Attitude:** Ability to think critically and solve complex engineering problems, learn new software and techniques related to finite element analysis.
2	**Formulation of Heat Conduction Equations**	**Knowledge (K)** Understanding the concepts of thermal conductivity, convection, and radiation, as well as the laws governing them, such as Fourier's law of heat conduction. **Skills (S)** The ability to identify the relevant heat transfer mechanisms in a given situation, apply appropriate physical laws and mathematical techniques to formulate the governing equations, and interpret the obtained solutions. **Attitude:** The ability to break down complex heat transfer problems into smaller, more manageable components and analyze them systematically. **Attention to detail:** Heat transfer equations often involve several variables and parameters. Careful attention to detail is crucial to ensure the accuracy of the formulation.
3	**Application to Heat Transfer Problems**	**Knowledge (K)** Understanding the three modes of heat transfer (conduction, convection, and radiation), as well as the factors that influence each mode (e.g., thermal conductivity, convection coefficient, emissivity). **Skills (S)** The ability to identify the relevant heat transfer mechanisms, formulate a mathematical model, solve the model using appropriate techniques, and interpret the results in the context of the problem. The ability to collect, analyze, and interpret experimental data related to heat transfer is essential. **Attitude:** The ability to analyze a problem, identify assumptions, and evaluate the validity

		of solutions. The ability to effectively communicate heat transfer concepts and solutions, both verbally and in writing, is important.
4	**Applications to Fluid Mechanics Problems**	**Knowledge (K)** Fundamental principles of fluid mechanics: This includes understanding concepts such as fluid statics, fluid dynamics, Bernoulli's equation, continuity equation, Navier-Stokes equations, and Reynolds number. **Skills (S)** Problem-solving skills: This includes the ability to identify and define fluid mechanics problems, develop solution strategies, apply relevant equations and concepts, and interpret results. Analytical skills: This includes the ability to analyze data, identify trends, and draw conclusions. **Attitude:** Critical thinking skills: This includes the ability to evaluate the validity of assumptions, identify potential errors, and make sound engineering judgments. Communication skills: This includes the ability to clearly and concisely communicate fluid mechanics concepts and solutions to both technical and non-technical audiences.

3. Syllabus

Finite Element Method in Heat Transfer (M23MTP105) **SEMESTER – I**			
Course Code	**M23MTP105**	CIE Marks	**50**
Number of Lecture Hours/Week (L: T: SDA)	2:0:2	SEE Marks	**50**
Total Number of Lecture Hours	40	Total Marks	**100**
Credits	3	Exam Hours	**03**

Course objectives

- The basic concepts of finite element methods and its applications to thermal engineering problems.
- The Formulation of heat conduction equations and its application to heat transfer problems.
- The application of the FEM technique to nonlinear heat conduction analysis, convective heat transfer and fluid mechanics problems.

Module -1		
Introduction: Historical Perspective of FEM and applicability to Thermal Engineering problems, Types of Governing Equations for Heat Conduction, Initial, boundary and interface conditions, Approximate methods, Rayleigh – Ritz Methods and Galerkin's methods, Different Approaches in FEM, Some Basic Discrete Systems (Heat Conduction and Fluid flow network), Numerical Problems.		L1, L2, L3
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.	
Module -2		
Finite Element Formulations: Formulation of one dimensional linear and quadratic element characteristic matrices and vectors. Assembly considerations and boundary conditions, quadratic elements and their advantages and disadvantages, Two dimensional elements; triangular and quadrilateral elements with parametric representation, Higher order elements, Sub parametric, super parametric and Iso-parametric elements, Problems with one and two dimensional linear and Quadratic elements.		L1, L2, L3
Module -3		
Formulation of Heat Conduction Equations: The Variational method and method of weighted residuals of finite element equation for 3-D heat conduction, Requirements for Interpolation Functions. **Steady State Heat Conduction in One Dimension:** Heat conduction in Plain walls, Radial Heat Flow in a Cylinder, Conduction–Convection Systems, Two-dimensional Plane Problems, Axisymmetric Problems, Three-dimensional Heat Transfer Problems.		L1, L2, L3
Module -4		
Application to Heat Transfer Problems: Straight uniform fin analysis with convection heat loss, Tapered Fin, Fin analysis with quadratic elements. **Nonlinear Heat conduction Analysis:** Lumped Heat Capacity System, Galerkin's method to nonlinear transient heat conduction; Governing equation with initial and boundary conditions, One dimensional nonlinear steady-state problems.		L1, L2, L3
Module -5		

Convective Heat Transfer: Basic equations, steady convection diffusion problems and transient convection-diffusion problems, Characteristic-based Split (CBS) Scheme. **Applications to Fluid Mechanics Problems:** Inviscid and Incompressible flows, Viscous and Non-Newtonian Flows, Stream Function Formulation (using Variational method), Velocity-pressure formulation (using Galerkin's method). Examples of heat transfer in a fluid flowing between parallel planes.	L1, L2, L3

Suggested Learning Resources:

Books

1. Fundamentals of the Finite Element Method for Heat and Fluid Flow: Roland W. Lewis, Perumal Nithiarasu, Kankanhalli N. Seetharamu: John Wiley & Sons Ltd,2004, ISBN:9780470847886
2. Finite element Method in Engineering: Singiresu S. Rao: 5th Edition, Elsevier, 2012.
3. The Finite Element Method in Heat Transfer and Fluid dynamics: Reddy J.N., Gartling. D.K.: 3rd Edition, CRC Press Taylor & Francis Group, 2010.

Reference Books

1. The Finite Element Method: Zeincowicz: 4 Vol set. 4th Edition, Elsevier 2007.
2. The finite element method in heat transfer analysis - R.W. Lewis, K Morgan, H.R. Thomas, K.N. Seetharamu, John Wiley and Sons,1996.

Web links and Video Lectures (e-Resources):

1. http://nptel.ac.in/courses/112104116/
2. https://archive.nptel.ac.in/courses/112/105/112105308/
3. https://archive.nptel.ac.in/courses/112/103/112103295/
4. https://archive.nptel.ac.in/courses/112/104/112104116/
5. https://archive.nptel.ac.in/courses/112/104/112104115/#

4 Syllabus Timeline

S/L	Syllabus Timeline	Description
1	Week 1-2	**Finite Element Formulations:** Formulation of one dimensional linear and quadratic element characteristic matrices and vectors. Assembly considerations and boundary conditions, quadratic elements and their advantages and disadvantages, Two dimensional elements; triangular and quadrilateral elements with parametric representation, Higher order elements, Sub parametric, super parametric and Iso-parametric elements, Problems with one and two dimensional linear and Quadratic elements. **Module 2: Finite Element Formulations:** Formulation of one dimensional linear and quadratic element characteristic matrices and vectors.
2	Week 3-4	Assembly considerations and boundary conditions, quadratic elements and their advantages and disadvantages, Two dimensional elements; triangular and quadrilateral elements with parametric representation, Higher order elements, Sub parametric, super parametric and Iso-parametric elements, Problems with one and two dimensional linear and Quadratic elements. **Module 3: Formulation of Heat Conduction Equations:** The Variational method and method of weighted residuals of finite element equation for 3-D heat conduction, Requirements for Interpolation Functions.
3	Week 5-6	**Steady State Heat Conduction in One Dimension:** Heat conduction in Plain walls, Radial Heat Flow in a Cylinder, Conduction–Convection Systems, Two-dimensional Plane Problems, Axisymmetric Problems, Three-dimensional Heat Transfer Problems. **Module 4: Application to Heat Transfer Problems:** Straight uniform fin analysis with convection heat loss, Tapered Fin, Fin analysis with quadratic elements.
4	Week 7-8	**Nonlinear Heat conduction Analysis:** Lumped Heat Capacity System, Galerkin's method to nonlinear transient heat conduction; Governing equation with initial and boundary conditions, One dimensional nonlinear steady-state problems.
5	Week 9-10	**Module 5: Convective Heat Transfer:** Basic equations, steady convection diffusion problems and transient convection-diffusion problems, Characteristic-based Split (CBS) Scheme.
6	Week 11-12	**Applications to Fluid Mechanics Problems:** Inviscid and Incompressible flows, Viscous and Non-Newtonian Flows, Stream Function Formulation (using Variational method), Velocity-pressure formulation (using Galerkin's method). Examples of heat transfer in a fluid flowing between parallel planes.

5 Teaching-Learning Process Strategies

S/L	TLP Strategies:	Description
1	Lecture Method	Utilize various teaching methods within the lecture format to reinforce competencies.
2	Video/Animation	Incorporate visual aids like videos/animations to enhance understanding of nano materials concepts.
3	Collaborative Learning	Encourage collaborative learning for improved competency application.
4	Higher Order Thinking (HOTS) Questions:	Pose HOTS questions to stimulate critical thinking related to each competency.
5	Problem-Based Learning (PBL)	Implement PBL to enhance analytical skills and practical application of competencies
6	Multiple Representations	Introduce topics in various representations to reinforce competencies
7	Real-World Application	Discuss practical applications to connect theoretical concepts with real-world competencies.

6 Assessment Details (both CIE and SEE)

CIE

Components		Number	Weightage	Max. Marks	Min. Marks
(i)	Internal Assessment-Tests (A)	2	50%	25	10
(ii)	Assignments/Quiz/Activity (B)	2	50%	25	10
	Total Marks			50	20

Final CIE Marks = (A) + (B)

SEE

1. Question paper pattern will be ten questions. Each question is set for 20marks. The medium of the question paper shall be English unless otherwise it is mentioned.
2. There shall be 2 question from each module, each of the two questions under a module (with a maximum of 3 sub questions), may have mix of topics under that module if necessary.
3. The students have to answer 5 full questions selecting one full question from each module.
4. Marks scored will be proportionally scaled down to 50 marks

7 Learning Objectives

S/L	Learning Objectives	Description
1	**Foundational Knowledge**	• Understand the fundamental concepts of heat transfer, including conduction, convection, and radiation. [Heat Transfer Modes] • Apply governing equations for heat transfer in one-dimensional steady-state conditions.
2	**Finite Element Application**	• Grasp the philosophy behind the finite element method (FEM) for solving engineering problems. • Explain the process of discretizing a continuous domain into finite elements. • Formulate element stiffness matrices and load vectors for heat transfer problems. • Implement techniques to handle different boundary conditions in FEM heat transfer analysis.
3	**Solution and Analysis**	• Solve one, two, and potentially three-dimensional steady-state and transient heat transfer problems using FEM. • Evaluate the convergence of FEM solutions and assess the accuracy of results. • Interpret the results of FEM analysis in the context of heat transfer phenomena.
4	**Additional Skills**	• Gain proficiency in using commercial finite element software for heat transfer problems. • Develop an understanding of advanced FEM concepts like higher-order elements and error estimation.

8 Course Outcomes (COs) and Mapping with POs/ PSOs

Course Outcomes (COs): Students will be able to

COs	Description
M23MTP105.1	Recall Governing Equations for Heat Conduction for solving 1-D thermal problems using Approximate methods, Rayleigh – Ritz Methods and Galerkin's methods.
M23MTP105.2	Formulate the element characteristic for linear and Quadratic matrices and vectors for1-D and 2-D problems.
M23MTP105.3	Explain the Formulation of Heat Conduction Equations for 1D, 3-D, Fin, and Nonlinear Heat conduction for developing mathematical models.
M23MTP105.4	Demonstrate the Application of numerical methods on heat transfer problems, Convective Heat Transfer and Fluid Mechanics Problems.

CO-PO-PSO Mapping

COs/POs	PO1	PO2	PO3
M23MTP105.1	**3**		
M23MTP105.2	**3**		
M23MTP105.3	**3**		
M23MTP105.4			**3**

9 Assessment Plan

Continuous Internal Evaluation (CIE)

	CO1	CO2	CO3	CO4	Total
Module 1	**20**				**20**
Module 2		**20**			**20**
Module 3			**20**		**20**
Module 4				**20**	**20**
Module 5					**20**
Total	**20**	**20**	**20**	**20**	**100**

Semester End Examination (SEE)

	CO1	CO2	CO3	CO4	Total
Module 1	**20**				**20**
Module 2		**20**			**20**
Module 3			**20**		**20**
Module 4				**20**	**20**
Module 5					**20**
Total	**20**	**20**	**20**	**20**	**100**

10 Future with this Subject

Studying Finite Element Method (FEM) for Heat Transfer opens up a bright future for students in a variety of fields. Here's why:

Valuable Skillset:

- FEM is a powerful computational tool used extensively in engineering for simulating heat transfer in various situations. Understanding FEM equips students with a sought-after skill that can be applied across many industries.
- Heat Transfer is a fundamental principle in many engineering disciplines. Proficiency in this area makes students strong candidates for jobs in: Mechanical Engineering, Aerospace Engineering, Chemical Engineering, Civil Engineering, Materials Science

Applications:

- FEM is used in designing heat exchangers, optimizing thermal management systems in electronics, analyzing building insulation performance, and many more applications. Students with this knowledge will be well-positioned for careers focused on: Thermal Design, Energy Efficiency, Product Development

Future Trends:

- The engineering field is constantly evolving, and FEM is no exception. Students who grasp the core concepts will be prepared to adapt to advancements in:
  - ✓ Coupled Field Analysis (combining heat transfer with other disciplines)
  - ✓ Multiscale Modeling (analyzing heat transfer at different size scales)
  - ✓ Integration with Artificial Intelligence (using AI to improve FEM simulations)

By studying FEM for Heat Transfer, students gain a valuable skillset applicable to a wide range of engineering fields. This knowledge positions them well for successful careers in various industries and prepares them to adapt to future advancements in computational engineering.

1st Semester	Professional Course (PC) RESEARCH METHODOLOGY AND IPR	M23MTP106

1. Prerequisites

S/L	Proficiency	Description
1	**Research Problems**	Able to identify and clearly define relevant research problems in mechanical engineering. This includes understanding the significance, feasibility, and potential impact of the chosen problem
2	**Literature Review**	Proficient in conducting comprehensive literature reviews using various resources like academic databases, journals, and conferences.
3	**Research Methodology**	Skills in data collection, analysis, interpretation, and presentation. They will be able to select and apply appropriate methods based on their research objectives.
4	**Scientific Writing**	Able to write clear, concise, and well-structured research proposals, reports, and technical papers. This includes proper referencing, technical language usage, and adherence to ethical guidelines
5	**Research Ethics**	Adhere to ethical principles in research, including data privacy, authorship, and responsible conduct.

2. Competencies

S/L	Competency	KSA Description
1	**Research Problem Identification**	**Knowledge** • Understands the research process and its key stages. • Identifies potential research areas within Mechanical Engineering. • Recognizes gaps in existing knowledge. • Grasps the concept of Intellectual Property Rights (IPR) and its relevance to research findings. **Skill** • Critically analyzes current literature and identifies areas needing further investigation. • Formulates clear and focused research questions or problems. • Conducts effective research using appropriate search strategies. • Applies IPR principles to assess the potential for patenting or copyrighting research outcomes. **Attitude** • Understands the research process and its key stages. • Identifies potential research areas within Mechanical Engineering. • Recognizes gaps in existing knowledge. * Grasps the concept of Intellectual Property Rights (IPR) and its relevance to research findings. • Critically analyzes current literature and identifies areas needing further investigation.
2	**Data collection & Analysis**	**Knowledge** • Understands different data collection methods (surveys, experiments, simulations) and their strengths and weaknesses. • Possesses knowledge of basic statistical concepts (descriptive statistics, hypothesis testing) and common data analysis techniques. • Has a foundational understanding of Intellectual Property Rights (IPR) concepts relevant to research data. **Skills** • Can design a data collection plan aligned with the research objectives, considering ethical considerations. • Can apply appropriate data analysis techniques to extract meaningful insights from collected data. • Can interpret and communicate research findings effectively, considering potential limitations. **Attitude** • Demonstrates a critical and curious approach to data collection and analysis.

		• Values accuracy, objectivity, and ethical principles in research data handling. • Maintains a lifelong learning mindset and seeks to stay updated on evolving data analysis techniques.
3	**Report Writing**	**Knowledge** • Understands the structure and purpose of different research reports (e.g., technical reports, progress reports, final reports). • Knows how to effectively present research findings, data analysis, and conclusions. • Familiarity with proper referencing styles and ethical considerations in research reporting. **Skills** • Can critically analyze research data and identify key findings for reporting. • Can write clear, concise, and well-organized technical reports using appropriate language and formatting. • Can effectively use tables, figures, and graphs to present data visually. **Attitude** • Demonstrates a commitment to accuracy, clarity, and objectivity in research reporting. • Values ethical practices in research and acknowledges the work of others through proper citations. • Strives for continuous improvement in writing and presentation skills.
4	**Research Ethics**	**Knowledge** • Understand fundamental principles of research ethics, such as honesty, integrity, objectivity, and respect for participants. • Identify different types of ethical concerns in engineering research (e.g., data falsification, plagiarism, conflicts of interest). • Recognize the legal and regulatory frameworks governing research ethics (e.g., data privacy laws). **Skills** • Apply ethical principles to design and conduct research projects in mechanical engineering. • Identify and mitigate potential ethical risks in research (e.g., by obtaining informed consent, ensuring data security). • Critically evaluate the ethical implications of research findings and engineering practices. **Attitude** • Demonstrate a commitment to responsible research conduct. • Value honesty, transparency, and accountability in research. • Be open to discussing and addressing ethical dilemmas that may arise during research.

3. Syllabus

SEMESTER – I Research Methodology and IPR			
Course Code	**M23MTP106**	CIE Marks	**50**
Number of Lecture Hours/Week(L: T: P: S)	**(3:0:0)**	SEE Marks	**50**
Total Number of Lecture Hours	**40 hours Theory**	Total Marks	**100**
Credits	**03**	Exam Hours	**03**

Module -1	
Research Methodology: Introduction, Meaning of Research, Objectives of Research, Motivation in Research, Types of Research, Research Approaches, Significance of Research, Research Methods versus Methodology, Research and Scientific Method, Importance of Knowing How Research is Done, Research Process, Criteria of Good Research, and Problems Encountered by Researchers in India. Defining the Research Problem: Research Problem, Selecting the Problem, Necessity of Defining the Problem, Technique Involved in Defining a Problem, An Illustration.	L1,L2

Module -2	
Reviewing the literature: Place of the literature review in research, Bringing clarity and focus to your research problem, Improving research methodology, Broadening knowledge base in research area, Enabling contextual findings, How to review the literature, searching the existing literature, reviewing the selected literature, Developing a theoretical framework, Developing a conceptual framework, Writing about the literature reviewed. Research Design: Meaning of Research Design, Need for Research Design, Features of a Good Design, Important Concepts Relating to Research Design, Different Research Designs, Basic Principles of Experimental Designs, Important Experimental Designs.	L1, L2
Module -3	
Design of Sampling: Introduction, Sample Design, Sampling and Non-sampling Errors, Sample Survey versus Census Survey, Types of Sampling Designs. Measurement and Scaling: Qualitative and Quantitative Data, Classifications of Measurement Scales, Goodness of Measurement Scales, Sources of Error in Measurement Tools, Scaling, Scale Classification Bases, Scaling Technics, Multidimensional Scaling, Deciding the Scale. **Data Collection:** Experimental and Surveys, Collection of Primary Data, Collection of Secondary Data, Selection of Appropriate Method for Data Collection, Case Study Method.	L1, L2
Module -4	
Testing of Hypotheses: Hypothesis, Basic Concepts Concerning Testing of Hypotheses, Testing of Hypothesis, Test Statistics and Critical Region, Critical Value and Decision Rule, Procedure for Hypothesis Testing, Hypothesis Testing for Mean, Proportion, Variance, for Difference of Two Mean, for Difference of Two Proportions, for Difference of Two Variances, P-Value approach, Power of Test, Limitations of the Tests of Hypothesis. Chi-square Test: Test of Difference of more than Two Proportions, Test of Independence of Attributes, Test of Goodness of Fit, Cautions in Using Chi Square Tests	L1, L2
Module -5	
Interpretation and Report Writing: Meaning of Interpretation, Technique of Interpretation, Precaution in Interpretation, Significance of Report Writing, Different Steps in Writing Report, Layout of the Research Report, Types of Reports, Oral Presentation, Mechanics of Writing a Research Report, Precautions for Writing Research Reports. Intellectual Property: The Concept, Intellectual Property System in India, Development of TRIPS Complied Regime in India, Patents Act, 1970, Trade Mark Act, 1999,The Designs Act, 2000, The Geographical Indications of Goods (Registration and Protection) Act1999, Copyright Act,1957,The Protection of Plant Varieties and Farmers‘ Rights Act, 2001,The Semi-Conductor Integrated Circuits Layout Design Act, 2000, Trade Secrets, Utility Models, IPR and Biodiversity, The Convention on Biological Diversity (CBD) 1992, Competing Rationales for Protection of IPRs, Leading International Instruments Concerning IPR, World Intellectual Property Organization (WIPO),WIPO and WTO, Paris Convention for the Protection of Industrial Property, National Treatment, Right of Priority, Common Rules, Patents, Marks, Industrial Designs, Trade Names, Indications of Source, Unfair Competition, Patent Cooperation Treaty (PCT), Advantages of PCT Filing, Berne Convention for the Protection of Literary and Artistic Works, Basic Principles, Duration of Protection, Trade Related Aspects of Intellectual Property Rights(TRIPS) Agreement, Covered under TRIPS Agreement, Features of the Agreement, Protection of Intellectual Property under TRIPS, Copyright and Related Rights, Trademarks, Geographical indications, Industrial Designs, Patents, Patentable Subject Matter, Rights Conferred, Exceptions, Term of protection, Conditions on Patent Applicants, Process Patents, Other Use without Authorization of the Right Holder, Layout-Designs of Integrated Circuits, Protection of Undisclosed Information, Enforcement of Intellectual Property Rights, UNSECO.	L1, L2

4. Syllabus Timeline

S/L	Syllabus Timeline	Description
1	Week 1-2:	• **Research Methodology:** Introduction, Meaning of Research, Objectives of Research, Motivation in Research, Types of Research, Research Approaches, Significance of Research, Research Methods versus Methodology. • Research and Scientific Method, Importance of Knowing How Research is Done, Research Process, Criteria of Good Research, and Problems Encountered by Researchers in India. • Defining the Research Problem: Research Problem, Selecting the Problem, Necessity of Defining the Problem, Technique Involved in Defining a

		Problem, An Illustration.
2	Week 3-4:	• Reviewing the literature: Place of the literature review in research, Bringing clarity and focus to your research problem, Improving research methodology. • Broadening knowledge base in research area, Enabling contextual findings, How to review the literature, searching the existing literature, reviewing the selected literature. • Developing a theoretical framework, Developing a conceptual framework, Writing about the literature reviewed. • Research Design: Meaning of Research Design, Need for Research Design, Features of a Good Design, Important Concepts Relating to Research Design, • Different Research Designs, Basic Principles of Experimental Designs, Important Experimental Designs.
3	Week 5-6:	• **Design of Sampling**: Introduction, Sample Design, Sampling and Non-sampling Errors, Sample Survey versus Census Survey, Types of Sampling Designs. Measurement and Scaling: • Qualitative and Quantitative Data, Classifications of Measurement Scales, Goodness of Measurement Scales, Sources of Error in Measurement Tools, Scaling, Scale Classification Bases, Scaling Technics, Multidimensional Scaling, Deciding the Scale. • Data Collection: Experimental and Surveys, Collection of Primary Data, Collection of Secondary Data. • Selection of Appropriate Method for Data Collection, Case Study Method.
4	Week 7-8:	• **Testing of Hypotheses:** Hypothesis, Basic Concepts Concerning Testing of Hypotheses, Testing of Hypothesis, Test Statistics and Critical Region, Critical Value and Decision Rule, Procedure for Hypothesis Testing, • Hypothesis Testing for Mean, Proportion, Variance, for Difference of Two Mean, for Difference of Two Proportions, for Difference of Two Variances, • P-Value approach, Power of Test, Limitations of the Tests of Hypothesis. • Chi-square Test: Test of Difference of more than Two Proportions, Test of Independence of Attributes, Test of Goodness of Fit, Cautions in Using Chi Square Tests
5	Week 9-10:	• Interpretation and Report Writing: Meaning of Interpretation, Technique of Interpretation, Precaution in Interpretation, Significance of Report Writing, Different Steps in Writing Report, Layout of the Research Report, • Types of Reports, Oral Presentation, Mechanics of Writing a Research Report, Precautions for Writing Research Reports. • Intellectual Property: The Concept, Intellectual Property System in India, Development of TRIPS Complied Regime in India, Patents Act, 1970, Trade Mark Act, 1999,The Designs Act, 2000, The Geographical Indications of Goods (Registration and Protection) Act1999, Copyright Act,1957, • The Protection of Plant Varieties and Farmers‘ Rights Act, 2001,The Semi-Conductor Integrated Circuits Layout Design Act, 2000, Trade Secrets, Utility Models, IPR and Biodiversity, The Convention on Biological Diversity (CBD) 1992,
6	Week 11-12:	• Competing Rationales for Protection of IPRs, Leading International Instruments Concerning IPR, World Intellectual Property Organization (WIPO),WIPO and WTO, Paris Convention for the Protection of Industrial Property, • National Treatment, Right of Priority, Common Rules, Patents, Marks, Industrial Designs, Trade Names, Indications of Source, Unfair Competition, Patent Cooperation Treaty (PCT), • Advantages of PCT Filing, Berne Convention for the Protection of Literary and Artistic Works, • Basic Principles, Duration of Protection, Trade Related Aspects of Intellectual Property Rights(TRIPS) Agreement, Covered under TRIPS Agreement, Features of the Agreement, Protection of Intellectual Property under TRIPS, Copyright and Related Rights, Trademarks, Geographical indications, Industrial Designs, Patents, Patentable Subject Matter, Rights Conferred, Exceptions, Term of protection, Conditions on Patent Applicants,

		• Process Patents, Other Use without Authorization of the Right Holder, Layout-Designs of Integrated Circuits, Protection of Undisclosed Information, Enforcement of Intellectual Property Rights, UNSECO.

5. Teaching-Learning Process Strategies

S/L	TLP Strategies:	Description
1	Lecture Method	Utilize various teaching methods within the lecture format to reinforce competencies.
2	Video/Animation	Incorporate visual aids like videos/animations to enhance understanding
3	Collaborative Learning	Encourage collaborative learning for improved competency application.
4	Higher Order Thinking (HOTS) Questions:	Pose HOTS questions to stimulate critical thinking related to each competency.
5	Real-World Application	Discuss practical applications to connect theoretical concepts with real-world competencies.
6	Flipped Class Technique	Utilize a flipped class approach, providing materials before class to facilitate deeper understanding of competencies

6. Assessment Details (both CIE and SEE)

CIE

	Components	Number	Weightage	Max. Marks	Min. Marks
(i)	Internal Assessment-Tests (A)	2	50%	25	10
(ii)	Assignments/Quiz/Activity (B)	2	50%	25	10
	Total Marks			**50**	**20**

Final CIE Marks = (A) + (B)

SEE

1. Question paper pattern will be ten questions. Each question is set for 20marks. The medium of the question paper shall be English unless otherwise it is mentioned.
2. There shall be 2 question from each module, each of the two questions under a module (with a maximum of 3 sub questions), may have mix of topics under that module if necessary.
3. The students have to answer 5 full questions selecting one full question from each module.
4. Marks scored will be proportionally scaled down to 50 marks

7. Learning Objectives

S/L	Learning Objectives	Description
1	Identify an appropriate research problem in their interesting domain.	Students will grasp the fundamental concepts of research, Necessity of Defining the Problem, Technique Involved in Defining a research Problem
2	Understand ethical issues Understand the Preparation of a research project thesis report	Students will grasp the fundamental concepts ethical issues which includes Improving research methodology, Broadening knowledge base in research area, Enabling contextual findings, How to review the literature, searching the existing literature, reviewing the selected literature
3	Understand the Preparation of a research project thesis report	Students will become proficient in Interpretation and Report Writing: Meaning of Interpretation, Technique of Interpretation, Precaution in Interpretation, Significance of Report Writing, Different Steps in Writing Report, Layout of the Research Report, Types of Reports, Oral Presentation, Mechanics of Writing a Research Report,
4	Understand the law of patent and copyrights.	Students will become proficient in understanding of Competing Rationales for Protection of IPRs, Leading International Instruments Concerning IPR, World Intellectual Property Organization (WIPO),WIPO and WTO, Paris Convention for the Protection of Industrial Property, National Treatment, Right of Priority, Common

		Rules, Patents, Marks, Industrial Designs, Trade Names, Indications of Source, Unfair Competition, Patent Cooperation Treaty (PCT),
5	Understand the Adequate knowledge on IPR	Students will grasp the fundamental of Trade Related Aspects of Intellectual Property Rights(TRIPS) Agreement, Covered under TRIPS Agreement, Features of the Agreement, Protection of Intellectual Property under TRIPS, Copyright and Related Rights, Trademarks, Geographical indications, Industrial Designs, Patents, Patentable Subject Matter, Rights Conferred, Exceptions, Term of protection, Conditions on Patent Applicants, Process Patents

8. Course Outcomes (COs) and Mapping with POs/ PSOs

Course Outcomes (COs)

COs	Description
M23MTP106.1	Infer research methodology and the technique of defining a research problem
M23MTP106.2	Illustrate the functions of the literature review in research, carrying out a literature search, developing theoretical and conceptual frameworks and writing a review.
M23MTP106.3	Illustrate various research designs, sampling designs, measurement and scaling techniques and different methods of data collections.
M23MTP106.4	Illustrate several parametric tests of hypotheses, Chi-square test, art of interpretation and writing research reports
M23MTP106.5	Infer various forms of the intellectual property, its relevance and business impact in the changing global business environment and leading International Instruments concerning IPR

CO-PO-PSO Mapping

COs/POs	PO1	PO2	PO3
M23MTP106.1	3		
M23MTP106.2	3		
M23MTP106.3	3		
M23MTP106.4	3		
M23MTP106.5	3		

9. Assessment Plan

Continuous Internal Evaluation (CIE)

	CO1	CO2	CO3	CO4	CO5	Total
Module 1	**20**					**20**
Module 2		**20**				**20**
Module 3			**20**			**20**
Module 4				**20**		**20**
Module 5					**20**	**20**
Total	**20**	**20**	**20**	**20**	**20**	**100**

Semester End Examination (SEE)

	CO1	CO2	CO3	CO4	CO5	Total
Module 1	**20**					**20**
Module 2		**20**				**20**
Module 3			**20**			**20**
Module 4				**20**		**20**
Module 5					**20**	**20**
Total	**20**	**20**	**20**	**20**	**20**	**100**

10. Future with this Subject

The “Research Methodology and IPR” course in the fourth semester of the P.G program lays a strong foundation for several future courses in the P.G program. The contributions of this subject extend across various areas, enhancing the students' understanding and skills in the field of Thermal Power Engineering.

Project Work and Research: The learning attributes gained through conceptualization, Research methodology, problem-solving, using this course prepares students for more extensive projects in their later years. It equips them with the skills needed for research in the field of thermal engineering.

In summary, the "Research Methodology and IPR " course serves as a stepping stone, equipping students with foundational knowledge and skills on research that are essential for the subsequent courses in their P.G program and for their future careers in various technology-related fields.

1st Semester	Professional Course (PC) FINITE ELEMENT METHODS AND SIMULATION LAB	M23MTPL107

1. Prerequisites

S/L	Proficiency	Prerequisites
1	Mathematics	Linear Algebra: This is essential for understanding the concepts of matrices, vectors, and eigenvalues, which are fundamental to FEM. Calculus: Calculus is used to derive the governing equations that describe the behavior of physical systems. This includes differential calculus for understanding rates of change and integral calculus for solving for total quantities. Differential Equations: Ordinary and partial differential equations are used to model the behavior of physical systems in FEM simulations.
2	Engineering Fundamentals	Mechanics of Materials: This course provides a foundation for understanding the behavior of materials under stress and strain, which is essential for setting up and interpreting FEM simulations. Strength of Materials: This course builds on mechanics of materials by providing methods for analyzing the strength and deformation of structures. Heat Transfer: This course covers the principles of heat transfer, which is important for thermal simulations using FEM.
3	Software Skills	CAD (Computer-Aided Design): Familiarity with CAD software is helpful for creating the geometry of models that will be analyzed in FEM simulations. FEM Software: There are many different FEM software packages available. Some popular options include ANSYS, ABAQUS, and NASTRAN. Learning the basics of how to use one of these software packages will be helpful for the lab portion of the course.
4	Problem-solving skills	FEM simulations can be complex, and strong problem-solving skills are essential for setting up, running, and interpreting the results of simulations. Critical thinking skills: It is important to be able to critically evaluate the results of FEM simulations and to understand the limitations of this technique.
5	Communication skills	Being able to communicate the results of FEM simulations effectively, both orally and in writing, is an important skill for engineers.

2. Competencies

S/L	Competency	KSA Description
1	Determination of the interface temperatures	**Knowledge:** Understanding the fundamental principles of heat transfer, including conduction, convection, and radiation. Ability to apply analytical techniques to calculate interface temperatures in various geometries and boundary conditions. **Skills:** Ability to collect temperature data using appropriate instruments and analyze it to determine interface temperatures. Skills in using computer software to model heat transfer phenomena and predict interface temperatures. Ability to design and set up experiments to measure interface temperatures accurately. **Attitude:** Ability to analyze complex thermal problems and develop solutions to ensure optimal interface temperatures. Skills in critically evaluating data and making sound judgments about interface temperature requirements. Ability to pay close attention to detail when collecting and analyzing temperature data.
2	Heat flow through the wall	**Knowledge:** Understanding the fundamental concepts of heat transfer, including conduction, convection. Knowing the thermal conductivity, specific heat capacity, and density of different building materials. Being able to distinguish between steady-state (constant heat flow) and transient (changing heat flow) conditions. **Skills:** Ability to gather necessary data such as wall dimensions, material properties, indoor and outdoor temperatures, and any relevant environmental conditions. Applying relevant formulas and equations to calculate heat transfer rate through the wall. This may involve using thermal conductivity, 3thickness, and temperature

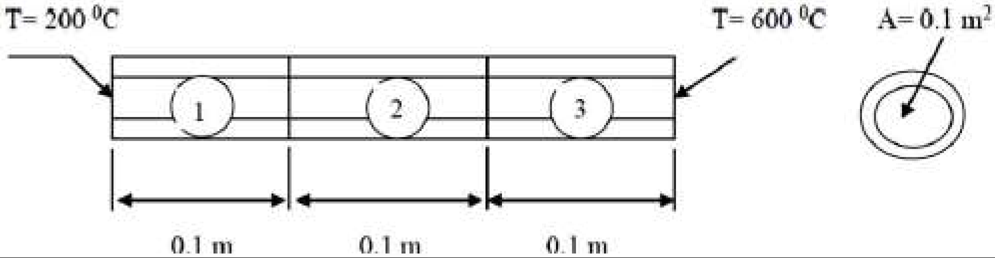
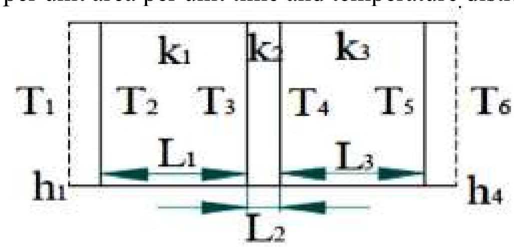
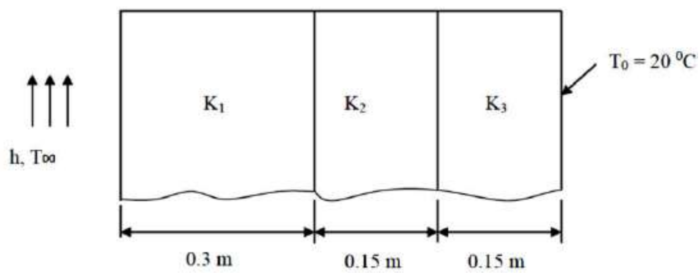
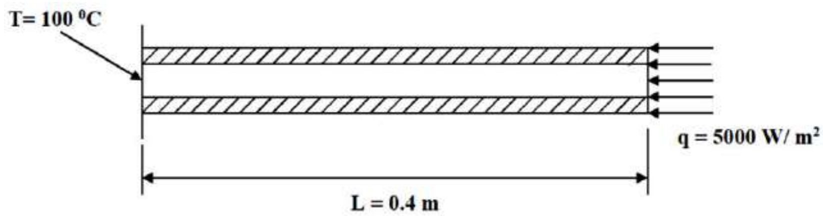
		difference to determine heat flux using Fourier's Law of Conduction. **A4ttitude:** Critically analyzing the problem, identifying key factors, and making assumptions when necessary. Applying knowledge and skills to solve the problem of determining heat flow through the wall. Selecting the most appropriate method for calculating heat flow based on the specific situation. Paying close attention to details such as units, material properties, and environmental conditions to ensure accurate calculations.
3	Heat transfer through the fin	**Knowledge:** Understanding the three modes of heat transfer (conduction, convection, and radiation). understanding the concept of fins, their purpose, and the different types of fins (e.g., pin fins, plate fins). Understanding the thermal conductivity, specific heat, and density of the fin material and the surrounding air. **Skills:** The ability to apply relevant heat transfer equations, such as Fourier's law of conduction and the convection heat transfer coefficient equation, to analyze fin problems. The ability to develop a mathematical model of the fin, considering its geometry, material properties, and boundary conditions. Using spreadsheets or specialized thermal analysis software to solve fin problems. **Attitude:** The ability to analyze a fin problem, identify the relevant parameters, and solve for the temperature distribution and heat transfer rate. The ability to troubleshoot and identify potential issues that may affect the heat transfer from the fin. The ability to communicate the results of the analysis in a clear and concise manner, both verbally and in writing.
4	Convection heat transfer	**Knowledge (K):** Fundamentals of heat transfer, including the three primary modes (conduction, convection, radiation), Principles of convection heat transfer, including natural convection and forced convection, Factors affecting convection heat transfer, such as fluid properties (density, viscosity), temperature difference, surface geometry, and flow conditions, Convection heat transfer coefficients and their determination through empirical correlations or physical measurements. **Skills:** Ability to analyze a heat transfer situation and identify convection as the dominant mode. Ability to apply relevant equations and correlations to calculate convection heat transfer rates. Skill in interpreting property data for fluids (e.g., thermal conductivity, viscosity). Proficiency in using appropriate engineering software or tools for convection heat transfer analysis (optional, but beneficial) **Attitude:** Ability to critically evaluate the results of convection heat transfer calculations and assess their accuracy. Ability to troubleshoot issues related to convection heat transfer in a system. Ability to communicate heat transfer problems and solutions effectively (written and oral)

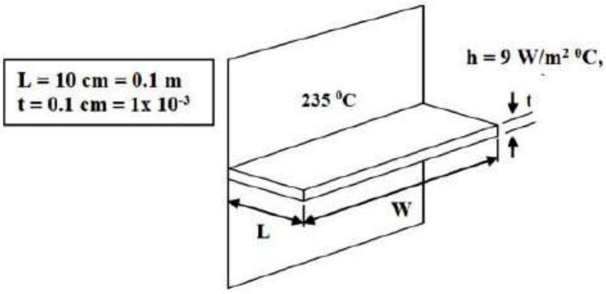
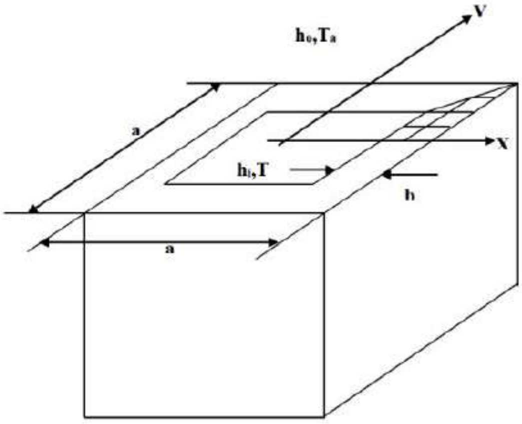
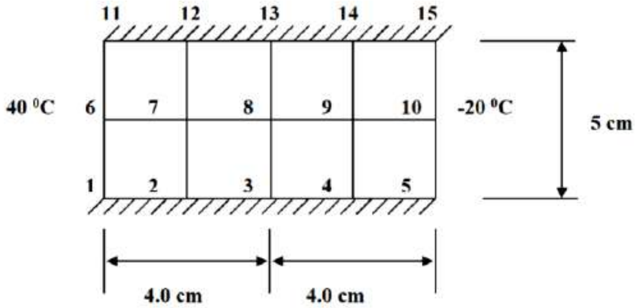
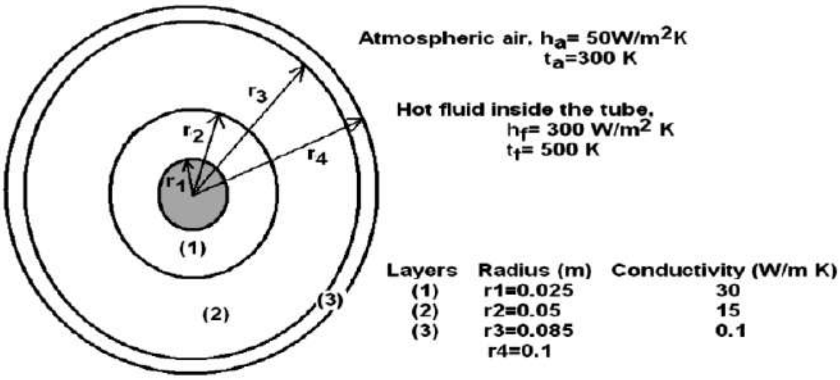
3. Syllabus

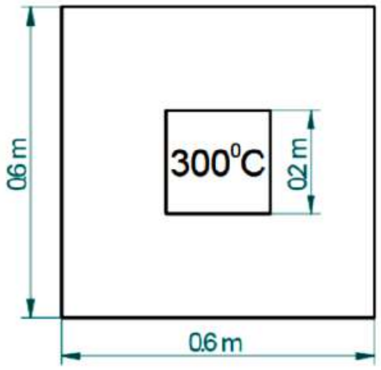
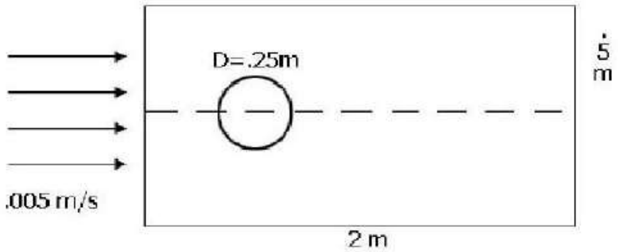
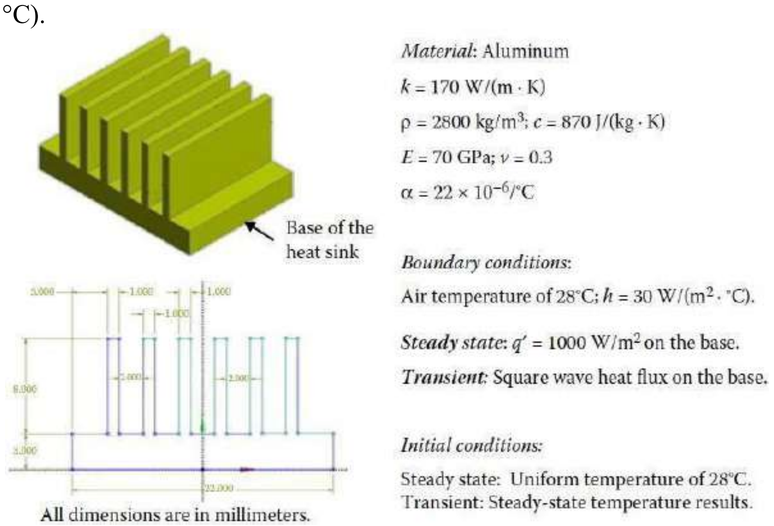
Finite Element Methods and Simulation LAB SEMESTER – I			
Course Code	**M23MTPL107**	**CIE Marks**	**50**
Number of Lecture Hours/Week (L: T: P: S)	**(0:1:2:0)**	**SEE Marks**	**50**
Total Number of Lecture Hours	**15 Sessions**	**Total Marks**	**100**
Credits	**02**	**Exam Hours**	**03**
Examination nature (SEE)	**Practical**		

Course objectives:
- The basic concepts of Finite Element methods and its applications to thermal engineering problems using ANSYS.
- The Formulation of Heat Conduction Equations and its Application to Heat Transfer Problems solve using ANSYS.
- The application of the FEM technique to Nonlinear Heat conduction Analysis, Convective Heat Transfer and Fluid Mechanics Problems solves using ANSYS.

Sl.	**Experiments**

No		
1	For the composite wall idealized by the 1-D model shown in figure below, determine the interface temperatures. For element 1, let K_1 = 5 W / m °C, for element 2, K_2 = 10 W / m °C and for element 3, K_3 = 15 W / m °C. The left end has a constant temperature of 200 °C and the right end has a constant temperature of 600 °C 	L2 L3
2	A furnace wall is made of inside silica brick (K=1.5 W /mK) and outside magnesia brick (k=4.9W/mK), each 10 cm thick. The inner and outer surfaces are exposed to fluids at temperatures of 820°C and 110°C respectively. The contact resistance is 0.001m^2 K/W the heat transfer co-efficient for inner and outer surfaces is equal to 35W/m^2 K. Find the heat flow through the wall per unit area per unit time and temperature distribution across the wall. 	L2 L3
3	A composite wall consists of three materials as shown. The outer temperature is T0 = 20 °C. Convection heat transfer takes place on the inner surface of the wall with T_{∞} = 800°C and h =25 W/m^2°C. Determine the temperature distribution in the wall. K_1 = 20 W/m°C, K_2 = 30 W/m°C, K_3 = 50 W/m°C, h = 25 W/m^2°C, T_∞ = 800°C. 	L2 L3
4	The fin shown in figure is insulated on the perimeter. The left end has a constant temperature of 100°C. A positive heat flux q*= 5000 W / m^2 acts on the right end. Let Kxx = 6 W/m°C and cross-sectional area A = 0.1 m^2. Determine the temperatures at and $L/4$, $L/2$, $3L/4$, $and\ L$ Where L = 0.4 m. 	L2 L3
5	A metallic fin, with thermal conductivity Kxx = 360 W/m°C, 0.1 cm thick, and 10 cm long, extends from a plane wall whose temperature is 235°C. Determine the temperature distribution and amount of heat transferred from the fin to the air at 20°C with h = 9 W/m^2°C. Take the width of fin to be 1 m.	L2 L3

		
6	Determine the temperature distribution and the rate of heat flow "q" per metre of the height for a tall chimney whose cross section is shown below. Assume that the inside gas temp is Tg = 311 K, the inside convection coefficient is hi, the surrounding air temp is Ta = 255 K and the outside convection coefficient is ho. 	L2 L3
7	For the body shown in figure, determine the temperature distribution. The body is insulated along the top and bottom edges, Kxx = Kyy = 1.7307 W/m°C. No internal heat generation is present. 	L2 L3
8	Obtain the temperature distribution for the composite cylinder inside which a hot fluid is flowing, and the outer surface is exposed to surrounding atmospheric conditions as shown. Assume perfect continuity between the layers. Capture the temperature values at the interface of materials (Use an element size of 0.002m or less). 	L2 L3
9	The cross section of a 20 cm x 20 cm duct made of concrete walls 20 cm thick is shown in figure. The inside surface of the duct is maintained at a temperature of 300°C due to hot gases flowing from a furnace. On the outside the duct is exposed to air with an ambient temperature	L2 L3

	of 20°C. The heat conduction coefficient of concrete is 1.4 W/m°C. The average convection heat transfer coefficient on the outside of the duct is 27 W/m°C. 	
10	Atmospheric air at 20°C flows with a velocity of 5 mm/s over a long horizontal cylinder of diameter 25 cm. Compute and plot the velocity distribution of air over the cylinder. 	L2 L3
	Demonstration Experiments (For CIE) if any	
11	Model Fully developed laminar flow and turbulent flow through a circular pipe using ANSYS Workbench	L2 L3
12	Build a generic IC engine (petrol /diesel) Model in MATLAB Simulink and draw the performance curves (a) torque v/s speed, (b) power v/s speed, (c) overall efficiency v/s brake power (d) specific fuel consumption v/s brake power and analyse the curves for varied Air: Fuel ratio.	L2 L3
13	Use a comprehensive model for combustion of fuel at atmospheric pressure and develop a computer program to estimate the heat released assuming a single step reaction using MATLAB Simulink.	L2 L3
14	Heat sinks are commonly used to enhance heat dissipation from electronic devices. In the case study, we conduct thermal analysis of a heat sink made of aluminum with thermal conductivity k = 170 W/(m K), density ρ = 2800 kg/m3 , specific heat c = 870 J/(kg K), Young's modulus E = 70 GPa, Poisson's ratio ν = 0.3, and thermal expansion coefficient α =22 × 10−6/°C. A fan forces air over all surfaces of the heat sink except for the base, where a heat flux q′ is prescribed. The surrounding air is 28°C with a heat transfer coefficient of h = 30 W/(m2 °C). 	
Text Books:		

1. Mechanical Measurements Beckwith Marangoni and Lienhard Pearson Education 6th Ed., 2006
2. Engineering Metrology R.K. Jain Khanna Publishers 2009
3. Engineering Metrology and Measurements Bentley Pearson Education
4. Engineering Metrology Gupta I.C Dhanpat Rai Publications

Reference Books:

1. Engineering Metrology and Measurements N.V.Raghavendra and L. Krishnamurthy Oxford University Press.
2. Instrumentation, Measurement and Analysis B C Nakra, K K Chaudhry McGraw–Hill 4th Edition

4. Syllabus Timeline

S/L	Syllabus Timeline	Description
1	Week 1-2	Experiments 1 & 2
2	Week 3-4	Experiments 3 & 4
3	Week 5-6	Experiments 5 & 6
4	Week 7-8	Experiments 7 & 8
5	Week 9-10	Experiments 9 & 10
6	Week 11-12	Demonstration Experiments

5. Teaching-Learning Process Strategies

S/L	TLP Strategies:	Description
1	Active Learning	Move beyond passive lectures. Encourage active learning through guided exercises, case studies, and open-ended problem-solving tasks.
2	Visualization and Interpretation	Help students visualize results effectively. Use animations, plots, and color coding to understand stress distribution, deformation, or other simulation outputs.
3	Peer Learning and Collaboration	Promote teamwork by having students work in pairs or small groups on simulations. This fosters communication and problem-solving skills.
4	Post-Lab Analysis	Assign post-lab reports that require students to analyze their simulation results, interpret them in the context of engineering principles, and draw conclusions.
5	Solid Foundation	Ensure students have a strong understanding of fundamental engineering mechanics and mathematics concepts relevant to FEM.

6. Assessment Details (both CIE and SEE)

CIE

Sl. No.	Description	% of Marks	In Marks
1	Write-up, Conduction, result and Procedure	60%	60
2	Viva-Voce	40%	40
	Total	**100%**	**100**

SEE

Sl. No.	Description	% of Marks	In Marks
1	Scaled Down marks of record/journal	60% of the maximum	30
2	Scaled Down marks of test	40% of the maximum	20
	Total	**100%**	**50**

7. Learning Objectives

S/L	Learning Objectives	Description
1	Valuable Skillset	FEM is a powerful computational tool used extensively in engineering for simulating heat transfer in various situations. Understanding FEM equips students with a sought-after skill that can be applied across many industries. Heat Transfer is a fundamental principle in many engineering disciplines. Proficiency in this area makes students strong candidates for jobs in: • Mechanical Engineering • Aerospace Engineering • Chemical Engineering • Civil Engineering

		• Materials Science
2	Applications	FEM is used in designing heat exchangers, optimizing thermal management systems in electronics, analyzing building insulation performance, and many more applications. Students with this knowledge will be well-positioned for careers focused on: • Thermal Design • Energy Efficiency • Product Development
3	Future Trends	The engineering field is constantly evolving, and FEM is no exception. Students who grasp the core concepts will be prepared to adapt to advancements in: • Coupled Field Analysis (combining heat transfer with other disciplines) • Multiscale Modeling (analyzing heat transfer at different size scales) • Integration with Artificial Intelligence (using AI to improve FEM simulations) By studying FEM for Heat Transfer, students gain a valuable skillset applicable to a wide range of engineering fields. This knowledge positions them well for successful careers in various industries and prepares them to adapt to future advancements in computational engineering.

8. Course Outcomes (COs) and Mapping with POs/ PSOs

Course Outcomes (COs)

COs	Description
M23MTPL107.1	Develop skills in making geometry and meshing for various configurations using ANSYS Workbench.
M23MTPL107.2	Develop knowledge in CFD simulation of Convective heat transfer and phase change problems using ANSYS Workbench.
M23MTPL107.3	Develop knowledge in simulation of lamina and turbulent flow using ANSYS Workbench.
M23MTPL107.4	Develop MATLAB programme for simulation of IC engine performances.

CO-PO-PSO Mapping

COs/POs	PO1	PO2	PO3
M23MTPL107.1	**3**		
M23MTPL107.2	**3**		
M23MTPL107.3	**3**		
M23MTPL107.4	**3**		

9. Assessment Plan

Continuous Internal Evaluation (CIE)

	CO1	CO2	CO3	CO4	Total
Total	**25**	**25**	**25**	**25**	**100**

Semester End Examination (SEE)

	CO1	CO2	CO3	CO4	Total
Total	**25**	**25**	**25**	**25**	**100**

10. Future with this Subject

A student who studies Finite Element Method (FEM) and simulation labs has a bright future with many exciting possibilities! Here's a breakdown of their potential career paths:

Strong foundation in various fields:

- **Engineering:** FEM is a cornerstone of various engineering disciplines like mechanical, civil, aerospace, and automotive. A strong understanding positions them well for careers in structural analysis, product design, material science, and more.
- **Science:** FEM is used in fields like physics and chemistry to model complex phenomena. This knowledge can be valuable in research and development roles.

Specialization and emerging areas:

- **Multiphysics Simulation:** FEM is increasingly coupled with other simulation techniques to analyze coupled problems (fluid-structure interaction, heat transfer with stress). Expertise in this area is highly sought-after.
- **Machine Learning and AI:** Machine learning is being integrated with FEM to create smarter simulations. This field is ripe for those with both skillsets.
- **Additive Manufacturing:** FEM plays a crucial role in designing and simulating 3D printed objects. As additive manufacturing gains traction, this expertise will be valuable.

Overall, a FEM and simulation student will develop valuable skills including:

- **Analytical thinking:** Ability to break down complex problems into smaller, solvable components.
- **Problem-solving:** Identifying and solving engineering challenges through simulations.
- **Software proficiency:** Expertise in FEM software like ANSYS, Abaqus, and others.
- **Technical communication:** Communicating complex engineering concepts effectively.

These skills are highly transferable and can be applied across various industries. Here are some potential career paths:

- **CAE (Computer-Aided Engineering) Engineer**
- **Simulation Analyst**
- **Design Engineer**
- **Research Scientist**
- **Product Development Specialist**

The future of FEM and simulation is bright, and students with this expertise will be well-positioned for success in various fields.

2nd Semester	Professional Course (PC) ADVANCED POWER PLANT CYCLES	M23MTP201

1. **Prerequisites**

S/L	Proficiency	Prerequisites
1.	**Basic Physics**	A foundation in physics concepts like mechanics, heat transfer, and fluid mechanics.
2.	**Calculus**	Ability to perform basic calculus operations for solving thermodynamical and engineering problems.
3.	**Chemistry**	An understanding of basic chemical concepts relevant to nuclear reactions and nuclear power plants
4.	**Engineering Mechanics**	Knowledge of fundamental engineering mechanics principles related to hydropower plant structures and water flow.
5.	**Environmental Science**	A background in environmental science to understand the ecological impact of power generation and pollution.

2. **Competencies**

S/L	Competency	KSA Description
1.	**Analysis of Steam cycles**	**Knowledge:** Understanding different steam types (wet/dry/superheated) and their behavior in Rankine & Carnot cycles. Knowledge of techniques like reheating, regeneration, and supercritical cycles to enhance steam plant efficiency. **Skills:** Ability to analyze Rankine cycle for efficiency and identify approaches to improve it. Solving numerical problems related to steam cycle analysis and calculations. **Attitudes:** Emphasis on improving efficiency and reducing environmental impact of steam power plants. A commitment to staying updated on the latest advancements in steam cycle technology.
2.	**Steam Generators**	**Knowledge:** Understanding the fundamental differences between fire-tube and water-tube boilers Knowledge of the purpose and function of key components like economizers, super heaters, air preheaters, and feed water treatment systems. **Skills:** Ability to operate and control steam generators safely and efficiently. Solving numerical problems related to steam generator performance and water treatment calculations. **Attitudes:** Prioritizing safety considerations in all aspects of steam generator operation and maintenance. Striving to optimize steam generator performance for efficient fuel utilization and minimal environmental impact.
3.	**Safe and Efficient Operation of Nuclear Power Plants**	**Knowledge:** Understanding the principles of nuclear fission, chain reactions, neutron behavior, and reactor types (PWR, BWR, etc.). Knowledge of safety measures employed in nuclear power plants to prevent accidents and mitigate their impact **Skills:** Ability to operate nuclear reactors safely and efficiently within design parameters. Diagnosing and resolving operational issues in nuclear power plants while ensuring safety. **Attitudes:** Upholding a strong safety culture that prioritizes the prevention of nuclear accidents. Maintaining a commitment to staying updated on advancements in nuclear

		technology and safety protocols.
4.	**Hydroelectric Power Plant Assessment and Optimization**	**Knowledge:** Understanding the benefits and drawbacks of hydropower, including its role in a hydro-thermal power mix. Knowledge of key economic factors influencing hydropower plant location, equipment selection, and overall project feasibility. **Skills:** Ability to assess the economic and technical viability of potential hydropower projects. Optimizing the operation of hydropower plants in conjunction with thermal power plants for a reliable and cost-effective electricity grid. **Attitudes:** Emphasis on responsible development of hydropower resources with minimal environmental impact. Balancing the environmental benefits of hydropower with the need for economically viable power generation solutions.
5.	**Environmental Awareness and Pollution Mitigation Strategies**	**Knowledge:** Understanding the different types of pollution (air, water, soil, etc.), their causes, and their environmental and human health impacts. Knowledge of various strategies for preventing and controlling pollution, including waste management, cleaner technologies, and environmental legislation. **Skills:** Identifying and evaluating potential solutions to address specific pollution problems in a community or organization. Critically analyzing environmental information and policies to advocate for sustainable practices. **Attitudes:** A strong sense of responsibility for protecting the environment and promoting sustainable living. A willingness to participate in efforts to address environmental challenges and promote environmental legislation.

3. Syllabus

Course Code	**M23MTP201**	**CIE Marks**	50
Teaching Hours/Week (L:P:SDA)	2:0:2	**SEE Marks**	50
Total Hours of Pedagogy	40	**Total Marks**	100
Credits	03	**Exam Hours**	3 Hr

Module 1: Analysis of Steam Cycles
Rankine Cycle: Basics, Carnot cycle comparison, thermal efficiency variations with steam conditions, Reheating and Regeneration: Impact on cycle efficiency, feed-water heating, Supercritical Pressure Cycle: Characteristics and advantages, Combined Heat and Power (CHP) Systems: Principles and benefits, Numerical Problems: Applications of cycle analysis to real-world scenarios.
Module 2: Steam Generators and Auxiliary Systems
Types of Steam Generators: Fire tube and water tube boilers, Components: Economizers, super-heaters, re-heaters, and their functions, Boiler Operation and Control: Efficiency improvements through air preheating and fluidized bed combustion, Pollution Control: Electrostatic precipitators, fabric filters, and ash handling systems, Feed-water Treatment: De-aeration, evaporation, and internal treatment, Numerical Problems: Calculations involving boiler efficiency and heat transfer.
Module 3: Nuclear Power Plants
Nuclear Reactions: Fission processes, chain reactions, and energy release, Reactor Types: PWR, BWR, gas-cooled reactors, and their operational characteristics, Safety Measures: Control systems, containment structures, and emergency procedures, Nuclear Fusion: Basics and potential future applications.
Module 4: Hydroelectric Power Plants
Hydroelectric Power Generation: Advantages, challenges, and optimization strategies; **Components:** Turbines, penstocks, and reservoir management; **Economic Analysis:** Cost-benefit analysis, project

feasibility, and site selection.
Module 5: Environmental Impact and Management
Pollution Types and Effects: Air, water, soil, marine, noise, thermal, and nuclear pollution; **Control Measures:** Regulations, technologies, and public policies; Case Studies: Real-world examples of environmental challenges and solutions; **Social Issues:** Climate change, global warming, acid rain, ozone depletion, and their impacts; **Environmental Legislation:** Overview of key laws and their enforcement issues.

Suggested Learning Resources:

Textbooks

1. *Power Plant Engineering* - P.K. Nag, Tata McGraw-Hill Publications. 2nd edition.
2. *Power Plant Engineering* - M.M. EI-Wakil, McGraw- Hill Publications. 1st edition.
3. *Power plant engineering* –R. K. Rajput, Laxmi Publications 3rd edition.
4. Gill, A.B., *"Power Plant Performance"*, Butterworths, 1984.
5. Lamarsh, J.R., *"Introduction to Nuclear"*, Engg.2nd edition, Addison Wesley, 1983.

Web links and Video Lectures (e-Resources):

1. https://archive.nptel.ac.in/courses/112/107/112107291/
2. https://archive.nptel.ac.in/courses/112/101/112101007/

4. Syllabus Timeline

S/L	Syllabus Timeline	Description
	Week 1-2: Analysis of Steam Cycles	Rankine Cycle: Basics, comparison with Carnot cycle, thermal efficiency variations with steam conditions; Reheating and Regeneration: Impact on cycle efficiency, feed-water heating; Supercritical Pressure Cycle: Characteristics and advantages; Combined Heat and Power (CHP) Systems: Principles and benefits; Numerical Problems: Applications of cycle analysis to real-world scenarios
2	Week 3-4: Steam Generators and Auxiliary Systems	Types of Steam Generators: Fire tube and water tube boilers; Components: Economizers, super heaters, re-heaters, and their functions; Boiler Operation and Control: Efficiency improvements through air preheating, fluidized bed combustion; Pollution Control: Electrostatic precipitators, fabric filters, ash handling systems; Feed-water Treatment: De-aeration, evaporation, internal treatment; Numerical Problems: Calculations involving boiler efficiency and heat transfer
3	Week 5-6: Nuclear Power Plants	Nuclear Reactions: Fission processes, chain reactions, energy release; Reactor Types: PWR (Pressurized Water Reactor), BWR (Boiling Water Reactor), gas-cooled reactors; Operational Characteristics: Safety measures, control systems, containment structures, emergency procedures; Nuclear Fusion: Basics and potential future applications
4	Week 7-8: Hydroelectric Power Plants	Hydroelectric Power Generation: Advantages, challenges, optimization strategies; Components: Turbines, penstocks, reservoir management; Economic Analysis: Cost-benefit analysis, project feasibility, site selection
5	Week 9-10: Environmental Impact and Management	Pollution Types and Effects: Air, water, soil, marine, noise, thermal, nuclear pollution; Control Measures: Regulations, technologies, public policies; Case Studies: Real-world examples of environmental challenges and solutions; Social Issues: Climate change, global warming, acid rain, ozone depletion, impacts; Environmental Legislation: Overview of key laws, enforcement issues
6	Week 11-12: Advanced Topics and Review	Review of Key Concepts from all Modules; Discussion of Advanced Topics and Recent Developments in Power Plant Engineering
7	Week 13-14: Final Project and Exam Preparation	Integration of Course Content into Final Projects; Preparation for Final Exams: Discussion of Potential Exam Questions and Problem-Solving Techniques

5. Teaching-Learning Process Strategies

S/L	TLP Strategies:	Description
1	Lecture Method	Deliver detailed lectures covering fundamental principles and theoretical concepts related to steam cycles, steam generators, nuclear power plants,

		hydroelectric power plants, and environmental impact and Use various teaching aids such as slides, diagrams, and charts to illustrate complex processes and concepts effectively.
2	Video/Animation	Incorporate visual aids such as animations, videos, and simulations to enhance understanding of dynamic processes like steam cycle operations, nuclear reactions, and environmental pollution control measures and Utilize videos to demonstrate the functioning of steam generators, components of nuclear reactors, and practical applications of hydroelectric power.
3	Collaborative Learning	Foster collaborative learning through group activities, discussions, and projects and Organize group tasks to solve problems related to steam cycle efficiency, nuclear reactor safety measures, and environmental pollution management strategies.
4	Higher Order Thinking (HOTS) Questions	Pose challenging questions to stimulate critical thinking and deeper understanding of the subject matter and Engage students with complex scenarios that require analysis, synthesis, and evaluation of information, such as optimizing steam cycle performance or evaluating nuclear reactor designs.
5	Problem-Based Learning (PBL)	Implement case studies and real-world problems to enhance analytical skills and practical application of theoretical knowledge and Assign projects that require students to apply concepts learned to solve engineering problems, such as designing efficient steam generators or analyzing environmental impacts of power plants.
6	Multiple Representations	Introduce topics using various representations such as graphs, equations, physical models, and computational simulations and Reinforce learning by explaining concepts through different perspectives and methods, aiding in comprehensive understanding of power plant engineering principles.
7	Real-World Application	Discuss practical applications to connect theoretical concepts with real-world scenarios and Provide examples from industry, current power generation practices, and environmental case studies to illustrate the relevance of power plant engineering principles in practice.
8	Flipped Class Technique	Utilize a flipped classroom approach by assigning readings, videos, or simulations before class to prepare students for in-depth discussions and problem-solving activities during class and Engage students in active learning by focusing on application-oriented tasks and discussions during face-to-face sessions.
9	Programming Assignments	Assign programming tasks or use software simulations to model and analyze various aspects of power plant operations and Develop students' computational skills by coding solutions for problems related to steam cycle efficiency, nuclear reactor simulations, or environmental impact assessments.

6. Assessment Details (both CIE and SEE)
Continuous Internal Evaluation:

Components		Number	Weightage	Max. Marks	Min. Marks
(i)	Internal Assessment-Tests (A)	2	50%	25	10
(ii)	Assignments/Quiz/Activity (B)	2	50%	25	10
	Total Marks			**50**	**20**

Final CIE Marks = (A) + (B)

Semester End Examination:

1. The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
2. The question paper will have ten full questions carrying equal marks.
3. Each full question is for 20 marks. There will be two full questions (with a maximum of four sub-questions) from each module.
4. Each full question will have a sub-question covering all the topics under a module.
5. The students will have to answer five full questions, selecting one full question from each module.

7. Learning Objectives

S/L	Learning Objectives	Description
1	Fundamental Understanding	Develop a deep understanding of the fundamental principles and mechanisms underlying steam cycles, steam generators, nuclear power, hydroelectric power generation, and environmental impact management.
2	Analytical Skills	Enhance analytical abilities to solve complex problems related to steam cycles, reactor types, power plant operations, and pollution control measures using mathematical and computational methods.
3	Practical Application	Apply theoretical knowledge to real-world scenarios in designing efficient power generation systems, analyzing safety measures in nuclear plants, optimizing hydroelectric power plants, and implementing pollution control strategies.
4	Research Skills	Foster research capabilities to explore advanced topics such as supercritical pressure cycles, Combined Heat and Power (CHP) systems, nuclear fusion, and environmental legislation, contributing to advancements in the field.
5	Core Principles	Gain a thorough understanding of the core principles governing steam cycles, steam generators, reactor types, hydroelectric power generation, and environmental pollution types and effects.
6	Mathematical Modeling	Understand and apply mathematical models to analyze and optimize steam cycles, power plant components, reactor operations, economic feasibility, and environmental impact assessments.
7	Problem Solving	Develop proficiency in solving numerical problems, evaluating efficiency metrics, conducting economic analyses, and proposing sustainable solutions for energy generation and environmental management challenges.

8. Course Outcomes (COs) and Mapping with POs

COs	Description
M23MTP201.1	Develop a deep understanding of heat transfer mechanisms (conduction, convection, and radiation) and their mathematical descriptions and Apply these principles to solve complex engineering problems involving heat transfer in various systems.
M23MTP201.2	Enhance analytical skills to predict heat transfer phenomena using advanced mathematical and computational methods and Apply these skills to solve both steady-state and transient heat transfer problems effectively.
M23MTP201.3	Conduct experiments to measure and analyze heat transfer coefficients, thermal conductivity, and related parameters and Utilize theoretical knowledge to optimize the design of heat transfer systems such as heat exchangers, fins, and insulation materials.
M23MTP201.4	Design efficient heat transfer systems, considering factors like heat transfer efficiency, cost-effectiveness, and environmental impact and Use computational tools and theoretical models to optimize the performance of heat transfer equipment and systems.
M23MTP201.5	Communicate effectively through technical reports and presentations on heat transfer topics, ensuring clarity and coherence and Produce comprehensive technical documents that include theoretical analysis, experimental findings, and practical recommendations for heat transfer applications.

CO-PO Mapping

COs/POs	PO1	PO2	PO3
M23MTP201.1	3		
M23MTP201.2			3
M23MTP201.3			3
M23MTP201.4			3
M23MTP201.5			3

9. Assessment Plan

Continuous Internal Evaluation (CIE)

	CO1	CO2	CO3	CO4	CO5	**Total**
Module 1	5%	5%	5%	4%	3%	**22%**
Module 2	5%	5%	5%	4%	3%	**22%**
Module 3	4%	4%	4%	4%	2%	**18%**
Module 4	4%	4%	4%	4%	3%	**19%**

Module 5	4%	4%	4%	5%	2%	**19%**
Total	**22%**	**22%**	**22%**	**21%**	**13%**	**100%**

Semester End Examination (SEE)

	CO1	CO2	CO3	CO4	CO5	**Total**
Module 1	5%	5%	5%	4%	3%	**22%**
Module 2	5%	5%	5%	4%	3%	**22%**
Module 3	4%	4%	4%	4%	2%	**18%**
Module 4	4%	4%	4%	4%	3%	**19%**
Module 5	4%	4%	4%	5%	2%	**19%**
Total	**22%**	**22%**	**22%**	**21%**	**13%**	**100%**

Conditions for SEE Paper Setting:

- **Coverage of All Modules**: Ensure that each module is adequately covered in the exam paper, reflecting the weightage assigned in the assessment plan.
- **Variety of Questions:** Include a mix of question types (e.g., multiple choice, short answer, long answer, numerical problems, and case studies) to assess different cognitive levels.
- **Bloom's Taxonomy:** Ensure questions cover various cognitive levels such as knowledge, comprehension, application, analysis, synthesis, and evaluation.
- **Integration of COs and POs:** Design questions to specifically address the course outcomes (COs) and program outcomes (POs) to ensure comprehensive evaluation.
- **Balanced Difficulty Level:** Ensure a balance of easy, moderate, and difficult questions to fairly assess all students.
- **Practical Relevance:** Incorporate real-world problems and case studies to test practical understanding and application of concepts.
- **Time Management:** Design the paper to be completed within the allocated time, ensuring that the questions are clearly stated and unambiguous.
- **Clarity and Precision:** Ensure questions are clear, precise, and free from any ambiguity or errors.
- **Consistency:** Maintain consistency in the pattern and structure of questions across different sets of the paper, if applicable.

10. Future with this Subject

The subject of Advanced Heat Transfer holds significant potential for driving innovations across various sectors. By focusing on emerging research areas, technological advancements, industrial applications, environmental sustainability, interdisciplinary collaborations, and educational development, the field can address critical challenges and contribute to global advancements in energy efficiency, medical technology, and sustainable development.

1) **Emerging Research Areas:**
   Nano-Scale Heat Transfer: Understanding heat transfer at the nano-scale, which is crucial for the development of new materials and technologies such as nanoelectronics and nanocomposites.
   Bioheat Transfer: Applications in medical treatments, such as hyperthermia for cancer treatment, cryosurgery, and the design of biomedical devices.
   Phase Change Materials (PCMs): Research on PCMs for efficient thermal energy storage systems, improving the performance of renewable energy systems.
2) **Technological Innovations:**
   Micro and Nano-Fluidics: Developing efficient cooling systems for electronic devices and microprocessors using micro and nano-fluidic channels.
   Advanced Thermal Management Systems: Innovations in thermal management for electric vehicles, aerospace applications, and wearable technology.
   Thermoelectric Materials: Enhancing the efficiency of thermoelectric materials for power generation and refrigeration applications.
3) **Industrial Applications:**
   Renewable Energy Systems: Improving the efficiency of solar thermal collectors, wind turbines, and geothermal systems through advanced heat transfer techniques.
   Energy Efficiency in Buildings: Developing advanced HVAC systems and building materials that enhance energy efficiency and reduce environmental impact.
   Process Industries: Optimization of heat exchangers, boilers, and condensers in industries such as petrochemical, pharmaceutical, and food processing.
4) **Environmental and Sustainability Focus:**
   Waste Heat Recovery: Techniques to capture and reuse waste heat from industrial processes, reducing energy consumption and greenhouse gas emissions.

Sustainable Cooling Technologies: Development of eco-friendly refrigerants and cooling systems to minimize the environmental impact of air conditioning and refrigeration.
Climate Change Mitigation: Applying advanced heat transfer solutions to improve the performance of carbon capture and storage (CCS) technologies.

5) **Interdisciplinary Collaborations:**
Material Science and Engineering: Collaborations to develop new materials with enhanced thermal properties for various applications.
Biomedical Engineering: Joint efforts to design medical devices and treatments that rely on precise thermal management.
Computational Fluid Dynamics (CFD): Advancements in CFD tools to model complex heat transfer scenarios, leading to better predictions and optimizations.

6) **Educational and Skill Development:**
Advanced Coursework and Training: Offering specialized courses and training programs in advanced heat transfer topics to prepare students for cutting-edge research and industry roles.
Hands-on Research Opportunities: Providing students with opportunities to engage in hands-on research projects, internships, and collaborations with industry partners.

7) **Policy and Regulation Influence:**
Energy Policies: Shaping energy policies and regulations that promote the adoption of advanced heat transfer technologies for energy efficiency and sustainability.
Standards Development: Contributing to the development of industry standards and best practices for the design and implementation of heat transfer systems.

2nd Semester	Professional Course (IPC) ADVANCED HEAT TRANSFER	M23MTP202

1. Prerequisites

S/L	Proficiency	Prerequisites
1.	Basic Thermodynamics	Understanding of fundamental thermodynamic concepts like energy, enthalpy, entropy, and first and second laws of thermodynamics
2.	Fluid Mechanics	Familiarity with fluid properties, fluid flow regimes (laminar, turbulent), and basic conservation laws (mass, momentum, energy) applied to fluids.
3.	Differential Equations:	Ability to solve basic ordinary differential equations (ODEs) encountered in heat transfer analysis (e.g., steady-state conduction).
4.	Calculus	Knowledge of calculus concepts like differentiation, integration, and applying them to analyze heat transfer processes
5.	Physics (Basic Heat Transfer)	A solid foundation in physics, particularly heat transfer mechanisms (conduction, convection, radiation) and basic heat transfer laws.

2. Competencies

S/L	Competency	KSA Description
1.	Ability to analyze and solve 1D steady-state and transient heat conduction problems	**Knowledge:** Understand the concept of heat transfer and its three main mechanisms: conduction, convection, and radiation. Be familiar with the 3D differential equation for heat conduction in Cartesian, cylindrical, and spherical coordinates. **Skills:** Apply 1D steady-state heat conduction principles to analyze problems involving conduction through a single layer or a composite wall. Utilize relevant mathematical tools to solve for temperature distribution, heat flux, and critical thickness of insulation in 1D steady-state problems **Attitudes:** Approach heat transfer problems with a logical and systematic approach, breaking them down into manageable steps. Pay close attention to units, signs, and assumptions made while solving problems
2.	Apply fundamental concepts and analytical tools to analyze and predict heat transfer by convection in various scenarios	**Knowledge:** Understand the concept of hydrodynamic and thermal boundary layers and their role in convection. Utilize dimensionless parameters like Reynolds number and Nusselt number to analyze forced and free convection. **Skills:** Apply analytical techniques, such as Blasius solution or integral methods, to estimate convection heat transfer coefficients for simple geometries. Utilize Reynolds analogy to relate heat transfer to momentum transfer in turbulent boundary layers. **Attitudes:** Develop a critical approach to identify relevant parameters and select appropriate methods for convection analysis. Recognize the limitations of simplified methods and develop an understanding of the accuracy of different approaches.
3.	Distinguish between natural and forced convection mechanisms and apply appropriate analysis methods to	**Knowledge:** Understand the driving forces (buoyancy for natural, external forces for forced) and their influence on heat transfer. Recognize the importance of dimensionless parameters like Rayleigh number in natural convection and Reynolds number in forced convection. **Skills:** Apply analytical methods (approximate analysis) or empirical correlations to predict heat transfer rates in natural convection scenarios. Utilize appropriate empirical correlations to estimate heat transfer coefficients for various forced convection geometries (tubes, cylinders) **Attitudes:** Develop the ability to critically evaluate and choose the most suitable

	solve heat transfer problems in each regime.	analysis method (analytical or empirical) for natural or forced convection. Critically interpret the results obtained from analytical methods or correlations, considering their limitations and applicability.
4.	Apply fundamental principles of thermal radiation and phase change phenomena to analyze heat transfer processes involving radiation and boiling/condensation	**Knowledge:** Understand the basic concepts & laws governing thermal radiation heat transfer (e.g., blackbody radiation, emissivity, absorptivity). Grasp the fundamentals of boiling and condensation heat transfer mechanisms and their governing relationships **Skills:** Apply knowledge of emissivity, absorptivity, and shape factors to analyze radiative heat exchange between surfaces. Utilize appropriate correlations or analytical methods to estimate heat transfer rates during boiling or condensation processes **Attitudes:** Develop the ability to identify the dominant heat transfer mode (radiation, convection, conduction) in a given scenario. Recognize the assumptions and limitations associated with different radiation models and phase change correlations.
5.	Analyze and select appropriate heat exchangers to achieve desired heat transfer rates between fluids in various industrial applications	**Knowledge:** Understand the basic principles of heat transfer between fluids in different types of heat exchangers (e.g., shell and tube, plate type). Grasp the concepts of Log Mean Temperature Difference (LMTD) and effectiveness (NTU) for analyzing heat exchanger performance in parallel and counter-flow configurations. **Skills:** Apply LMTD & NTU methods to calculate heat transfer rates & outlet fluid temperatures for parallel & counter-flow arrangements. Utilize technical and economic factors (heat transfer rate, cost, pressure drop, size/weight) to select the most suitable heat exchanger for a specific application **Attitudes:** Develop an approach to optimize heat exchanger selection based on a balance between performance, cost, and practical constraints. Recognize the ongoing development of heat exchanger technologies and stay updated on advancements in compact designs and multi-phase flow applications.

3. Syllabus

Course Code	M23MTP202	**CIE Marks**	50
Teaching Hours/Week (L:P:SDA)	3:2:0	**SEE Marks**	50
Total Hours of Pedagogy	40	**Total Marks**	100
Credits	04	**Exam Hours**	3 Hr.

Module-1: Introduction and One-Dimensional Heat Transfer

3-D Differential Equation of Heat Conduction: Cartesian, cylindrical, and spherical coordinates; **Steady-State Heat Conduction:** One-dimensional, with heat generation, critical thickness of insulation; **Two-Dimensional Steady-State Heat Conduction:** Basic problems; **Unsteady-State Conduction:** Lumped heat capacity, transient heat flow; **Extended Surfaces (Fins):** Uniform and non-uniform cross sections, thermal resistance networks

Module-2: Convection Heat Transfer Analysis

Boundary Layer Fundamentals: Evaluation of convection heat transfer coefficient Hydrodynamic and Thermal Boundary Layers; **Dimensional Analysis:** Forced and free convection; **Laminar Boundary Layer Flow:** Blasius solution, approximate integral boundary layer analysis; **Turbulent Boundary Layer:** Integral energy equation, analogy between momentum and heat transfer, Reynolds analogy.

Module-3: Natural and Forced Convection Heat Transfer

Natural Convection: Similarity parameters, approximate analysis on vertical plates, empirical correlations for various shapes, rotating cylinders, disks, spheres, finned surfaces; **Forced Convection:** Turbulent tube flow, empirical correlations in laminar and turbulent flow, flow across bluff objects, packed beds, bank of tubes, combined natural and forced convection

Module-4: Thermal Radiation
Basic Concepts and Laws of Thermal Radiation; Shape Factor and Heat Exchange: Non-black bodies, enclosures with black and grey surfaces, radiation shields; **Radiation Properties:** Participating medium, emissivity, absorptivity of gases and gas mixtures; **Boiling and Condensation:** Boiling heat transfer, pool boiling correlations, laminar and turbulent film condensation, condensation in horizontal tubes.
Module-5: Heat Exchangers
Basic Concepts and Types; Analysis Methods: LMTD and NTU for parallel and counter-flow heat exchangers, multi-pass and cross-flow heat exchangers, correction factor use; **Selection Criteria:** Heat transfer rate, cost, pumping power, size and weight, type, materials, other considerations; **Compact Heat Exchangers:** Heat exchangers for multi-phase flow

PRACTICAL COMPONENT OF IPCC

S/L	Experiments
1.	**Composite Wall Thermal Conductance:** Determine overall thermal conductance and temperature distribution.
2.	**Heat Exchanger Efficiency:** Measure overall heat transfer coefficient for parallel and counter flow configurations.
3.	**Natural Convection Heat Transfer**: Measure heat transfer coefficient of a vertical cylinder in natural convection.
4.	**Pin Fin Temperature Distribution:** Analyze temperature distribution along a pin fin in free and forced convection.
5.	**Thermal Conductivity Measurement:** Determine thermal conductivity of insulating materials and liquids.
6.	**Condensation Heat Transfer:** Compare heat transfer coefficients for drop-wise and film-wise condensation.
7.	**Free Convection on Vertical Tube:** Measure heat transfer coefficient for free convection on a vertical tube.
8.	**Forced Convection in a Pipe:** Determine heat transfer coefficient for forced convection through a pipe.
9.	**Critical Heat Flux Determination:** Measure critical heat flux in boiling heat transfer.
10.	**Surface Emissivity:** Determine the emissivity of a given surface.
11.	**Stefan-Boltzmann Constant:** Measure the Stefan-Boltzmann constant.
12.	**Vapour Compression Refrigeration Performance:** Conduct a performance test on a vapour compression refrigeration system.

Suggested Learning Resources:

Books

1. *Heat Transfer- A practical Approach*: Yunus A Cengel: McGraw-Hill Publications 2nd edition
2. *Heat Transfer – A Basic Approach* - Ozisik M.N., McGraw-Hill Publications, 1st edition.
3. *Heat Transfer* - Holmon J.P., McGraw-Hill Publications, 6th Edition.
4. *Principles of Heat Transfer* - Frank Kreith, Thomson Publications, 7th Edition.
5. *Fundamentals of Heat and Mass Transfer*: Theodore L. Bergman, Adrienne S. Lavine, Frank
6. P. Incropera, David P. Dewitt seventh edition John Wiley & Sons, Inc
7. *Heat and mass Transfer*: Er. R.K. Rajput, S. Chand & Company Ltd., 5th Edition.

Web links and Video Lectures (e-Resources):

1. https://archive.nptel.ac.in/courses/103/105/103105052/
2. https://archive.nptel.ac.in/courses/103/105/103105140/
3. https://archive.nptel.ac.in/courses/112/107/112107256/
4. https://archive.nptel.ac.in/courses/112/103/112103297/
5. https://archive.nptel.ac.in/courses/103/101/103101137/
6. https://archive.nptel.ac.in/courses/112/108/112108246/

4. Syllabus Timeline

S/L	Syllabus Timeline	Description
1	Week 1-2: Introduction and One-	**Lecture Topics:** 3-D differential equation of heat conduction in Cartesian, cylindrical, and spherical coordinates, Steady-state heat conduction (one-

	Dimensional Heat Transfer	dimensional, with heat generation), Critical thickness of insulation, Two-dimensional steady-state heat conduction, Unsteady-state conduction (lumped heat capacity, transient heat flow), Extended surfaces (fins of uniform and non-uniform cross sections) **Experiments:** Composite Wall Thermal Conductance
2	Week 3-4: Convection Heat Transfer Analysis	**Lecture Topics:** Boundary layer fundamentals, Hydrodynamic and thermal boundary layers, Dimensional analysis for forced and free convection, Blasius solution for laminar boundary layer flow over a flat plate, Approximate integral boundary layer analysis, Turbulent boundary layer, Analogy between momentum and heat transfer (Reynolds analogy) **Experiments:** Heat Exchanger Efficiency; Natural Convection Heat Transfer (Vertical Cylinder)
3	Week 5-6: Natural and Forced Convection Heat Transfer	**Lecture Topics:** Natural convection: similarity parameters, approximate analysis on vertical plates, Empirical correlations for various shapes, rotating cylinders, disks, spheres, finned surfaces, Forced convection: turbulent tube flow, empirical correlations in laminar and turbulent flow, Flow across bluff objects, packed beds, bank of tubes, Combined natural and forced convection **Experiments:** Pin Fin Temperature Distribution; Thermal Conductivity Measurement
4	Week 7-8: Thermal Radiation	**Lecture Topics:** Basic concepts and laws of thermal radiation, Shape factor and heat exchange between non-black bodies, Enclosures with black and grey surfaces, Radiation shields, Radiation properties of participating medium (emissivity and absorptivity of gases and gas mixtures), Boiling and condensation (boiling heat transfer, pool boiling correlations), Laminar and turbulent film condensation, condensation in horizontal tubes **Experiments:** Condensation Heat Transfer; Free Convection on Vertical Tube
5	Week 9-10: Heat Exchangers	**Lecture Topics:** Basic concepts and types of heat exchangers, Analysis methods: LMTD and NTU for parallel and counterflow heat exchangers, Multi-pass and cross-flow heat exchangers, Correction factor use Selection criteria: heat transfer rate, cost, pumping power, size and weight, type, materials, other considerations, Compact heat exchangers, heat exchangers for multi-phase flow **Experiments:** Forced Convection in a Pipe; Critical Heat Flux Determination
6	Week 11-12: Advanced Topics and Review	**Lecture Topics:** Review of key concepts from all modules, Discussion of advanced topics and recent developments in heat transfer **Experiments:** Surface Emissivity; Stefan-Boltzmann Constant; Vapour Compression Refrigeration Performance

5. Teaching-Learning Process Strategies

S/L	TLP Strategies:	Description
1	Lecture Method	Deliver detailed lectures on core principles and theoretical concepts, and Use a variety of teaching methods within lectures to reinforce competencies.
2	Video/Animation	Incorporate visual aids like videos and animations to enhance understanding of complex concepts, and Use animations to demonstrate dynamic processes such as fluid flow and heat transfer.
3	Collaborative Learning	Encourage group activities and discussions to solve problems and apply concepts and Facilitate peer learning through team exercises and projects.

4	Higher Order Thinking (HOTS) Questions	Pose challenging questions to stimulate critical thinking and deepen understanding and Engage students with complex scenarios that require analysis and synthesis of information.
5	Problem-Based Learning (PBL)	Implement case studies and real-world problems to enhance analytical skills and Assign projects that require practical application of theoretical knowledge.
6	Multiple Representations	Introduce topics using various representations such as graphs, equations, physical models, and simulations and reinforce competencies by explaining concepts through different perspectives and methods.
7	Real-World Application	Discuss practical applications to connect theoretical concepts with real-world situations and provide examples from industry and everyday life to illustrate the relevance of heat transfer principles.
8	Flipped Class Technique	Utilize a flipped classroom approach by providing materials (readings, videos) before class and facilitate deeper understanding during class through discussions and problem-solving activities.
9	Programming Assignments	Assign programming tasks to simulate heat transfer processes and analyze data and develop computational skills by coding solutions for various heat transfer problems.

6. Assessment Details (both CIE and SEE)

CIE

Components		**Number**	**Weightage**	**Max. Marks**	**Min. Marks**
Theory (A)	Internal Assessment-Tests (A)	2	**60%**	**15**	**06**
	Assignments/Quiz/Activity (B)	2	**40%**	**10**	**04**
	Total Marks		**100%**	**25**	**10**
Components		**Number**	**Weightage**	**Max. Marks**	**Min. Marks**
Laboratory(B)	Record Writing	Continuous	**60%**	15	06
	Test at the end of the semester	1	**40%**	10	04
	Total Marks		**100%**	**25**	**10**

SEE for IPCC

1. The question paper will be set for 100 marks and marks scored will be scaled down Proportionately to 50 marks.
2. The question paper will have ten questions. Each question is set for 20 marks.
3. There will be 2 questions from each module. Each of the two questions under a module (with a maximum of 3 sub-questions), **should have a mix of topics** under that module.
4. The students must answer 5 full questions, selecting one full question from each module.

The theory portion of the IPCC shall be for both CIE and SEE, whereas the practical portion will have a CIE component only. Questions mentioned in the SEE paper shall include questions from the practical component).

The minimum marks to be secured in CIE to appear for SEE shall be the 15 (50% of maximum marks-30) in the theory component and 10 (50% of maximum marks -20) in the practical component. The laboratory component of the IPCC shall be for CIE only. However, in SEE, the questions from the laboratory component shall be included**.** The maximum of 04/05 questions to be set from the practical component of IPCC, the total marks of all questions should not be more than the 20 marks. SEE will be conducted for 100 marks and students shall secure 40% of the maximum marks to qualify in the SEE. Marks secured will be scaled down to 50. (Student must secure an aggregate of 50% of maximum marks of the course (CIE+SEE)

7. Learning Objectives

S/L	**Learning Objectives**	**Description**
1	Fundamental Understanding	Develop a deep understanding of heat transfer mechanisms including conduction, convection, and radiation.
2	Analytical Skills	Enhance analytical skills to solve complex heat transfer problems using

		mathematical and computational methods.
3	Practical Application	Apply theoretical knowledge to real-world engineering problems and design efficient heat transfer systems.
4	Research Skills	Foster research skills to explore advanced topics and contribute to the field of heat transfer.
5	Core Principles	Develop a thorough understanding of the fundamental mechanisms of heat transfer, including conduction, convection, and radiation.
6	Mathematical Modeling	Understand and derive the mathematical models governing heat transfer in different coordinate systems (Cartesian, cylindrical, and spherical).

8. Course Outcomes (COs) and Mapping with POs

COs	Description
M23MTP202.1	Develop a deep understanding of the fundamental mechanisms of heat transfer (conduction, convection, and radiation) and their governing equations.
M23MTP202.2	Analyze and solve complex heat transfer problems, including steady-state and transient scenarios, using advanced mathematical and computational methods.
M23MTP202.3	Conduct experiments to measure thermal conductance, thermal conductivity, and heat transfer coefficients, and compare theoretical predictions with experimental data.
M23MTP202.4	Design efficient heat transfer systems such as heat exchangers, extended surfaces (fins), and insulation, considering factors like heat transfer rate, cost, and material properties.
M23MTP202.5	Write and present substantial technical reports and documents on heat transfer topics, effectively communicating complex concepts and findings.

CO-PO Mapping

COs/POs	PO1	PO2	PO3
M23MTP202.1	3		
M23MTP202.2			3
M23MTP202.3			3
M23MTP202.4			3
M23MTP202.5			3

9. Assessment Plan

Continuous Internal Evaluation (CIE)

	CO1	CO2	CO3	CO4	CO5	**Total**
Module 1	5%	5%	5%	4%	3%	**22%**
Module 2	5%	5%	5%	4%	3%	**22%**
Module 3	4%	4%	4%	4%	2%	**18%**
Module 4	4%	4%	4%	4%	3%	**19%**
Module 5	4%	4%	4%	5%	2%	**19%**
Total	**22%**	**22%**	**22%**	**21%**	**13%**	**100%**

Semester End Examination (SEE)

	CO1	CO2	CO3	CO4	CO5	**Total**
Module 1	5%	5%	5%	4%	3%	**22%**
Module 2	5%	5%	5%	4%	3%	**22%**
Module 3	4%	4%	4%	4%	2%	**18%**
Module 4	4%	4%	4%	4%	3%	**19%**
Module 5	4%	4%	4%	5%	2%	**19%**
Total	**22%**	**22%**	**22%**	**21%**	**13%**	**100%**

Conditions for SEE Paper Setting:

- **Coverage of All Modules**: Ensure that each module is adequately covered in the exam paper, reflecting the weightage assigned in the assessment plan.
- **Variety of Questions:** Include a mix of question types (e.g., multiple choice, short answer, long answer, numerical problems, and case studies) to assess different cognitive levels.
- **Bloom's Taxonomy:** Ensure questions cover various cognitive levels such as knowledge, comprehension, application, analysis, synthesis, and evaluation.
- **Integration of COs and POs:** Design questions to specifically address the course outcomes (COs) and program outcomes (POs) to ensure comprehensive evaluation.

- **Balanced Difficulty Level:** Ensure a balance of easy, moderate, and difficult questions to fairly assess all students.
- **Practical Relevance:** Incorporate real-world problems and case studies to test practical understanding and application of concepts.
- **Time Management:** Design the paper to be completed within the allocated time, ensuring that the questions are clearly stated and unambiguous.
- **Clarity and Precision:** Ensure questions are clear, precise, and free from any ambiguity or errors.
- **Consistency:** Maintain consistency in the pattern and structure of questions across different sets of the paper, if applicable.

10. Future with this Subject

Studying Advanced Heat Transfer offers students a solid foundation and specialized knowledge in the field of thermal sciences, which can lead to several promising career opportunities and future prospects:

a) **Career Opportunities:** Graduates can pursue careers as thermal engineers, HVAC (Heating, Ventilation, and Air Conditioning) specialists, thermal system designers, energy analysts, or researchers in industries such as aerospace, automotive, energy production, electronics cooling, and environmental engineering.

b) **Research and Development:** Advanced knowledge in heat transfer opens doors to research and development roles, where students can innovate new thermal management solutions, improve energy efficiency, develop new materials for insulation and heat exchange, and contribute to cutting-edge technologies.

c) **Specialization:** This subject allows students to specialize in specific areas of heat transfer such as conduction, convection, radiation, and phase change phenomena (boiling and condensation). Such specialization enhances their expertise and makes them valuable assets in industries requiring thermal management solutions.

d) **Industry Demand:** With increasing global emphasis on energy efficiency and sustainability, there is a growing demand for professionals who can optimize thermal processes, reduce energy consumption, and improve thermal performance in various applicatio

2nd Semester	Professional Elective Course (PE) STEAM AND GAS TURBINES	M23MTP231

1. Prerequisites

S/L	Proficiency	Prerequisites
1.	Engineering Thermodynamics	Solid foundation in engineering thermodynamics, including first and second laws, property relations, and cycle analysis.
2.	Fluid Mechanics	Familiarity with fundamental fluid mechanics principles (fluid properties, fluid flow regimes, conservation laws) applied to compressible and incompressible fluids.
3.	Turbo machinery Fundamentals	Basic understanding of turbo machinery concepts like energy transfer, staging, and performance characteristics of turbines and compressors.
4.	Engineering Mathematics	Ability to apply calculus (differential and integral) and differential equations for solving problems related to fluid flow, thermodynamics, and turbine/compressor performance.
5.	Strength of Materials	Knowledge of basic material properties and strength of materials concepts relevant to turbine and compressor blade design considerations

2. Competencies

S/L	Competency	KSA Description
1.	Analyze and design nozzles and diffusers for fluid flow applications	**Knowledge:** Understand the operating principles of nozzles and diffusers and their role in accelerating/decelerating fluids. Recognize the concept of critical pressure ratio and its impact on nozzle performance and efficiency. **Skills:** Apply governing equations to design nozzles for desired flow rates and pressure changes, considering factors like friction and compressibility. Analyze the performance of nozzles and diffusers using parameters like velocity coefficient and experimental data. **Attitudes:** Develop an approach to optimize nozzle and diffuser design for specific applications, balancing performance with efficiency considerations. Utilize a systematic approach to solve problems involving fluid flow through nozzles and diffusers.
2.	Analyze and design steam turbines considering performance parameters, compounding, and flow characteristics.	**Knowledge:** Understand the fundamental differences between steam engines and turbines, and classify various steam turbine types (impulse, reaction). Apply concepts of velocity diagrams to analyze steam flow through impulse and impulse-reaction blades and assess turbine performance parameters. **Skills:** Select appropriate steam turbine types (impulse, reaction) based on application requirements and design basic turbine stages using velocity diagrams and compounding techniques. Analyze factors affecting steam turbine efficiency, including blade speed ratio and degree of reaction, to optimize performance. **Attitudes:** Develop an approach to balance various design considerations in steam turbines, such as efficiency, cost, and operational requirements. Recognize advancements in steam turbine technology and stay updated on new design concepts and efficiency improvements.
3.	Evaluate performance and design considerations for steam turbines, considering state	**Knowledge:** Understand concepts like state point locus and reheat factor to analyze the thermodynamic performance of steam turbines. Recognize different sources of energy losses in steam turbines (e.g., valves, blades, leakage) and their impact on efficiency. **Skills:** Apply knowledge of energy losses to optimize steam turbine design for

	point locus, reheat factor, and various energy loss mechanisms.	improved efficiency, considering factors like stage layout and blade geometry. Utilize state point locus and reheat factor concepts to predict the performance of steam turbine designs under different operating conditions. **Attitudes:** Develop a mindset focused on minimizing energy losses in steam turbine design for better overall plant efficiency. Maintain a balanced approach that considers both efficiency gains and practical design constraints when optimizing steam turbines.
4.	Analyze and select between centrifugal and axial flow compressors based on their operating principles, performance parameters, and suitability for specific applications.	**Knowledge:** Understand the fundamental operating principles of centrifugal and axial flow compressors. Recognize key performance parameters (surging, choking, and efficiency) for both compressor types. **Skills:** Apply knowledge of compressor types and their performance characteristics to select the most suitable option for a given application based on pressure requirements, flow rate, and efficiency considerations. Analyze performance characteristics of centrifugal and axial compressors using concepts like velocity triangles and performance coefficients. **Attitudes:** Develop a problem-solving approach that focuses on selecting the appropriate compressor technology based on specific application requirements. Recognize ongoing advancements in compressor technology and stay updated on the latest developments in both centrifugal and axial flow designs.
5.	Analyze and design gas turbine cycles for power generation and jet propulsion applications, considering ideal and real cycle performance, component losses, and various engine configurations.	**Knowledge:** Understand the principles of various gas turbine cycles (Brayton cycle, intercooled, reheated, regenerated) for power generation and jet propulsion (turbojet, turbofan, etc.). Recognize the impact of component losses (incomplete combustion, polytropic efficiency) on real cycle performance compared to ideal cycles. **Skills:** Apply knowledge of different gas turbine cycles and component losses to design and optimize cycles for specific applications, considering factors like efficiency, power output, and thrust. Perform calculations to predict the performance of gas turbine cycles at design points, accounting for component losses and real-world operating conditions. **Attitudes:** Develop a critical approach that balances maximizing performance (power output, thrust) with achieving high efficiency in gas turbine design. Embrace advancements in gas turbine technology, exploring opportunities for improved efficiency and reduced environmental impact.

3. Syllabus

Steam and Gas Turbines SEMESTER – II			
Course Code	**M23MTP231**	CIE Marks	**50**
Teaching Hours/Week (L:P:SDA)	**(2:0:2)**	SEE Marks	**50**
Total Number of Lecture Hours	**40 hours**	Total Marks	**100**
Credits	**03**	Exam Hours	**03**

Course Learning objectives:

- To develop the ability to use the concepts of Nozzles and Diffusers for various applications in gas and steam turbines.
- To understand the working principle, operations and analysis of impulse and reaction steam turbines and its applications in steam power plant.
- To develop an intuitive understanding of state point locus of an impulse turbine and its various losses in turbines.
- To present a comprehensive and rigorous treatment of Axial and Centrifugal compressor and its applications in gas and jet propulsion cycles.

Module -1

Nozzles and diffusers: Introduction types of nozzles, types of Diffusers, Equation of Continuity Sonic Velocity and Mach Numbers, The Steady Flow Energy Equation in Nozzles, Gas Nozzles The Momentum Equation for the flow Through Steam Nozzles, Entropy Changes with friction, Nozzle Efficiency, The Effect of Friction on the Velocity of steam Leaving the Nozzles, Diffusion Efficiency, shape of Nozzle for Uniform Pressure Drop, Mass of Discharge of Critical Pressure in Nozzle Flow or Chocked Flow, Physical Explanation of Critical Pressure, Maximum Discharge of Saturated Steam, Maximum Discharge of Steam initially Superheated, Critical Pressure Ratio for Adiabatic and Frictionless Expansion of Steam from Ratio for Adiabatic and Frictionless Expansion of Steam from a given initial Velocity, Idea of Total or Stagnation Enthalpy and Pressure, General Relationship Between or Area Velocity and pressure in Nozzle Flow ,Effect of Friction on Critical Pressure Ratio Critical Pressure Ratio in a Frictionally Resisted Expansion from a Given Initial Velocity, Su per saturated Flow in Nozzles, Effect of Variation of Back Pressure, Parameters Affecting the Performance of Nozzles, Experimental Methods to Determine Velocity Coefficient, Experimental Results.	L1, L2, L3
Module -2	
Steam Turbines Types and Flow of Steam through Impulse Blades: Basic concepts, Principal of operation of turbine, Comparison of Steam Engines and Turbines, Classifications of Steam Turbine, compounding, Velocity Diagram for Impulse Turbines, Performance parameters of Impulse Turbine, Influence of ratio of blade speed to steam speed on blade efficiency in single stage impulse turbine, Efficiency of multistage impulse turbine with single row wheel, Velocity diagram for three row velocity compound wheel, Most economical ratio of blade speed for a two row velocity compounded impulse wheel. **Flow of Steam Through Impulse-Reaction Turbine Blades:** Velocity diagram, degree of reaction, impulse- reaction turbine with similar blade section and half degree reaction turbine, height of reaction turbine blading, effect of working steam on the stage efficiency of Parson's turbine,operation of impulse blading with varying heat drop or variable speed, impulse- reaction turbine section.	L1, L2, L3
Module -3	
State Point Locus Reheat Factor and Design Procedure: Introduction, stage efficiency of impulse turbines, state point locus of an impulse turbine, reheat factor, internal and other efficiencies, increase in isentropic heat drop in a stage due to friction in proceeding stage, correction for terminal velocity, reheat factor for an expansion with the uniform adiabatic index and a constant stage efficiency, correction of reheat factor for finite number of stages, design procedure of impulse turbine, design procedure for impulse- reaction turbines. **Energy losses in turbines:** List of Energy Losses, Valve, nozzle, blade, Trailing edge wake, Impingement, leakage losses. Blade friction, turning of steam jet, blade wind age losses, losses due to shrouding, Disc friction, radiation and conduction, mechanical losses, leakage through the end seals.	L1, L2, L3
Module -4	
Centrifugal Compressors: Components of Centrifugal compressor, Principle of operation, Blade shapes and velocity triangles, Ideal and actual energy transfer, Slip Factor, Diffuser, Volute casing, Performance parameters, Surging and choking. **Axial Flow Compressors:** Description and principle of operation, Stage velocity triangle, work done factor, blading efficiency, performance coefficients, and flow through blade rows, flow losses, performance characteristics, comparison of axial and centrifugal compressor.	L1, L2, L3
Module -5	
Shaft power Cycles and Gas turbine cycles: Ideal cycles, the simple gas turbine cycles, closed cycle gas turbines, open cycle gas turbine with intercooler, reheater and regeneration, methods of accounting for component losses, design point performance calculations, Loss due to incomplete combustion, polytropic efficiency, and performance of actual cycle, combined cycles and cogeneration schemes. **Jet Propulsion Cycles:** The simple turbojet cycle, turbo fan engine, turbo prop engine, Ramjet engines, the pulse jet engines, thrust equations, efficiencies, parameters affecting flight performance, thrust augmentation.	L1, L2, L3

Text Books:

1. *Steam and Gas Turbines* - R. Yadav, Central Publishing House, Allahabad, 7th edition.
2. *Gas Turbines* - V. Ganesan, Tata McGraw-Hill Publications, 3rd edition.
3. *Gas Turbine and Propulsive Systems* – P.R. Khajuria, S. P. Dubey, Dhanpat rai publications, 5th edition 2012.
4. *Gas Turbine Theory* – H.I.H. Saravanamuttoo, G.F.C. Rogers & H Cohen, Pearson Education, 8th edition.
5. *Elements of Gas Turbine Propulsion*- Jack D Mattingley, McGraw-Hill Publications 1st edition.
6. *Turbines compressors and fans* – S. M. Yahya, Tata McGraw-Hill Publications, 4th edition.

Links:

- https://archive.nptel.ac.in/courses/112/107/112107216/
- https://archive.nptel.ac.in/courses/112/103/112103262/
- https://archive.nptel.ac.in/courses/112/103/112103277/

4. Syllabus Timeline

S/L	Syllabus Timeline	Description
1	Week 1-2: Nozzles and diffusers	Introduction types of nozzles, types of Diffusers, Equation of Continuity Sonic Velocity and Mach Numbers, The Steady Flow Energy Equation in Nozzles, Gas Nozzles The Momentum Equation for the flow Through Steam Nozzles, Entropy Changes with friction, Nozzle Efficiency, The Effect of Friction on the Velocity of steam Leaving the Nozzles, Diffusion Efficiency, shape of Nozzle for Uniform Pressure Drop, Mass of Discharge of Critical Pressure in Nozzle Flow or Chocked Flow, Physical Explanation of Critical Pressure, Maximum Discharge of Saturated Steam, Maximum Discharge of Steam initially Superheated, Critical Pressure Ratio for Adiabatic and Frictionless Expansion of Steam from Ratio for Adiabatic and Frictionless Expansion of Steam from a given initial Velocity, Idea of Total or Stagnation Enthalpy and Pressure, General Relationship Between or Area Velocity and pressure in Nozzle Flow ,Effect of Friction on Critical Pressure Ratio Critical Pressure Ratio in a Frictionally Resisted Expansion from a Given Initial Velocity, Su per saturated Flow in Nozzles, Effect of Variation of Back Pressure, Parameters Affecting the Performance of Nozzles, Experimental Methods to Determine Velocity Coefficient, Experimental Results.
2	Week 3-4: Steam Turbines Types and Flow of Steam through Impulse Blades. Flow of Steam Through Impulse-Reaction Turbine Blades:	Basic concepts, Principal of operation of turbine, Comparison of Steam Engines and Turbines, Classifications of Steam Turbine, compounding, Velocity Diagram for Impulse Turbines, Performance parameters of Impulse Turbine, Influence of ratio of blade speed to steam speed on blade efficiency in single stage impulse turbine, Efficiency of multistage impulse turbine with single row wheel, Velocity diagram for three row velocity compound wheel, Most economical ratio of blade speed for a two row velocity compounded impulse wheel. Velocity diagram, degree of reaction, impulse- reaction turbine with similar blade section and half degree reaction turbine, height of reaction turbine blading, effect of working steam on the stage efficiency of Parson's turbine, operation of impulse blading with varying heat drop or variable speed, impulse-reaction turbine section.
3	Week 5-6: State Point Locus Reheat Factor and Design Procedure. Energy losses in turbines	Introduction, stage efficiency of impulse turbines, state point locus of an impulse turbine, reheat factor, internal and other efficiencies, increase in isentropic heat drop in a stage due to friction in proceeding stage, correction for terminal velocity, reheat factor for an expansion with the uniform adiabatic index and a constant stage efficiency, correction of reheat factor for finite number of stages, design procedure of impulse turbine, design procedure for impulse- reaction turbines. List of Energy Losses, Valve, nozzle, blade, Trailing edge wake, impingement, leakage losses. Blade friction, turning of steam jet, blade wind age losses, losses due to shrouding, Disc friction, radiation and conduction, mechanical losses, leakage through the end seals.
4	Week 7-8: Centrifugal Compressors & Axial Flow Compressors	Components of Centrifugal compressor, Principle of operation, Blade shapes and velocity triangles, Ideal and actual energy transfer, Slip Factor, Diffuser, Volute casing, Performance parameters, Surging and choking. Description and principle of operation, Stage velocity triangle, work done factor, blading efficiency, performance coefficients, flow through blade rows, flow losses, performance characteristics, comparison of axial and centrifugal compressor
5	Week 9-10: Shaft power Cycles and Gas turbine cycles	Ideal cycles, the simple gas turbine cycles, closed cycle gas turbines, open cycle gas turbine with intercooler, reheater and regeneration, methods of accounting for component losses, design point performance calculations, Loss due to incomplete combustion, polytropic efficiency, and performance of actual cycle, combined cycles and cogeneration schemes.
6	Week 11-12: Jet Propulsion Cycles	The simple turbojet cycle, turbo fan engine, turbo prop engine, Ramjet engines, the pulse jet engines, thrust equations, efficiencies, parameters affecting flight performance, thrust augmentation.

5. Teaching-Learning Process Strategies

S/L	TLP Strategies:	Description
1.	Lecture Method	Utilize various teaching methods within the lecture format to reinforce competencies.
2.	Video/Animation	Incorporate visual aids like videos/animations to enhance understanding the concepts.
3.	Collaborative Learning	Encourage collaborative learning for improved competency application.
4.	Real-World Application	Discuss practical applications to connect theoretical concepts with real-world competencies.
5.	Flipped Class Technique	Utilize a flipped class approach, providing materials before class to facilitate deeper understanding of competencies.

6. Assessment Details (both CIE and SEE)
Continuous Internal Evaluation:

Components		Number	Weightage	Max. Marks	Min. Marks
(i)	Internal Assessment-Tests (A)	2	50%	25	10
(ii)	Assignments/Quiz/Activity (B)	2	50%	25	10
	Total Marks			**50**	**20**

Final CIE Marks = (A) + (B)

Semester End Examination:

1. The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
2. The question paper will have ten full questions carrying equal marks.
3. Each full question is for 20 marks. There will be two full questions (with a maximum of four sub questions) from each module.
4. Each full question will have a sub-question covering all the topics under a module.
5. The students will have to answer five full questions, selecting one full question from each module

7. Learning Objectives

S/L	Learning Objectives	Description
1	Fundamental Principles	Grasp the basic thermodynamic principles and cycles (Rankine and Brayton) that govern steam and gas turbines. Understand the energy conversion process in both steam and gas turbines.
2	Component Identification and Function	Identify and describe the main components of steam and gas turbines, such as compressors, combustors, turbines, boilers, condensers, and pumps. Explain the function and importance of each component within the turbine system.
3	Performance Analysis	Analyze the performance characteristics and efficiency of steam and gas turbines. Calculate key performance metrics such as thermal efficiency, work output, and power generation. Compare the efficiency and performance of different turbine configurations, including combined cycle power plants.
4	Application Knowledge	Recognize the various applications of steam and gas turbines in power generation, transportation, and industrial processes. Understand the specific advantages and limitations of steam and gas turbines in different applications.
5	Technological Advancements	Stay informed about the latest technological advancements and innovations in turbine technology. Explore future trends and potential developments in steam and gas turbines, including advancements in materials, efficiency improvements, and emerging applications.

8. Course Outcomes (COs) and Mapping with POs/ PSOs
Course Outcomes (COs)

COs	Description
M23MTP231.1	Interpret the working principles of Gas and steam turbine nozzles and diffusers.

M23MTP231.2	Apply the working principles of impulse and reaction turbines using velocity triangles.
M23MTP231.3	Solve the concepts of State Point Locus Reheat Factor and Identify the various losses associated with the turbines.
M23MTP231.4	Illustrate the concepts of axial flow and centrifugal compressors and its application in gas turbine.
M23MTP231.5	Apply the concepts of open and closed cycle gas turbine and its application in jet propulsion.

CO-PO-PSO Mapping

COs/POs	PO1	PO2	PO3
M23MTP231.1	3		
M23MTP231.2			3
M23MTP231.3			3
M23MTP231.4			3
M23MTP231.5			3

9. Assessment Plan

Continuous Internal Evaluation (CIE)

	CO1	CO2	CO3	CO4	CO5	**Total**
Module 1	20					20
Module 2		20				20
Module 3			20			20
Module 4				20		20
Module 5					20	20
Total	20	20	20	20	20	100

Semester End Examination (SEE)

	CO1	CO2	CO3	CO4	CO5	Total
Module 1	20					20
Module 2		20				20
Module 3			20			20
Module 4				20		20
Module 5					20	20
Total	20	20	20	20	20	100

10. Future with this Subject

The future scope of studying steam and gas turbines is vast and promising due to the increasing demand for efficient and sustainable energy solutions, advancements in technology, and the need for innovative applications in various industries. Here are some key areas where the study of steam and gas turbines will continue to be significant.

Advancements in Efficiency and Performance

- **Improved Materials:** Development of advanced materials that can withstand higher temperatures and pressures, leading to more efficient turbines.
- **Enhanced Designs:** Innovations in turbine blade design, cooling techniques, and aerodynamics to improve efficiency and reduce losses.
- **Digital Twin Technology:** Use of digital twins for real-time monitoring and optimization of turbine performance.

Renewable Energy Integration

- **Hybrid Systems:** Integration of steam and gas turbines with renewable energy sources like solar thermal and biomass to create hybrid power plants.
- **Energy Storage:** Development of combined cycle power plants with integrated energy storage systems to balance supply and demand.

Industrial and Commercial Applications:

- **Industrial Cogeneration**: Increased use of combined heat and power (CHP) systems in industrial processes to improve energy efficiency.
- **Aviation and Marine Applications**: Continued advancements in gas turbine technology for more efficient and environmentally friendly aircraft and marine vessels.

2nd Semester	Professional Elective Course (PE) RENEWABLE ENERGY TECHNOLOGY	M23MTP232

1. Prerequisites

S/L	Proficiency	Prerequisites
1.	Fundamentals of Energy	Basic understanding of energy forms (kinetic, potential, thermal), energy transfer mechanisms, and units of energy measurement.
2.	Physics	Familiarity with basic physics concepts like mechanics, thermodynamics, electricity, and electromagnetism, relevant to renewable energy technologies.
3.	Environmental Science	Awareness of environmental issues related to energy consumption and the potential benefits of renewable energy sources.
4.	Basic Mathematics	Ability to perform calculations involving algebra, trigonometry, and basic calculus, essential for analyzing renewable energy systems.
5.	Introduction to Engineering	A general understanding of engineering principles and problem-solving approaches applicable to renewable energy projects.

2. Competencies

S/L	Competency	KSA Description
1.	Gain a foundational understanding of energy sources, consumption patterns, and the role of renewable energy in a sustainable future.	**Knowledge:** Recognize different forms of energy (kinetic, potential, thermal, etc.) and their transformations. Understand the link between per capita energy consumption and a nation's prosperity. **Skills:** Classify energy resources as conventional (fossil fuels) or non-conventional (renewable) based on their source and renewability. Analyze basic trends in global and Indian energy consumption patterns. **Attitudes:** Appreciate the need for sustainable energy sources like renewables to address environmental concerns and resource depletion. Develop a sense of responsibility for promoting efficient energy use in everyday life.
2.	Master solar capture and conversion principles to assess application suitability and identify government incentives for promoting the technology.	**Knowledge:** Grasp the concepts of sun path diagrams, sun-earth angles, and solar radiation measurement on horizontal and tilted surfaces. Recognize the principle of converting solar radiation into heat (collectors) and electricity (Photovoltaic). **Skills:** Identify suitable solar energy applications based on factors like technology (heating, electricity), purpose (water heating, cooking, etc.), and user needs. Maintain basic understanding of government schemes and policies promoting solar energy adoption. **Attitudes:** Foster an appreciation for solar energy as a clean and sustainable alternative to conventional energy sources. Recognize the rapid advancements in solar technology and be open to learning about new developments in the field.
3.	Analyze the fundamentals of wind energy conversion, assess its potential and applications, and identify key factors for	**Knowledge:** Understand the basic principles of how wind energy is captured and converted into electricity by Wind Energy Conversion Systems (WECS). Recognize different wind energy applications (standalone, grid-connected, hybrid) and their economic considerations. **Skills:** Apply knowledge of wind resource assessment and site selection criteria to evaluate the suitability of locations for wind farms. Analyze wind farm characteristics like power output, capacity factor, and wind

	successful wind farm development.	rose diagrams. **Attitudes:** Appreciate wind energy as a clean and renewable alternative energy source with environmental benefits. Develop a balanced approach that considers both technical feasibility and economic viability when evaluating wind energy projects.
4.	Evaluate the potential of biomass as a renewable energy source, analyze conversion technologies and applications	**Knowledge:** Recognize different biomass conversion technologies (gasification, ethanol production, biogas generation) for energy production. Understand the environmental benefits (reduced reliance on fossil fuels) and potential drawbacks (sustainability of feedstock) of biomass energy. **Skills:** Analyze the suitability of various biomass conversion technologies based on feedstock type, desired output (heat, electricity, fuel), and environmental considerations. Identify factors affecting biogas generation and select appropriate biogas plant types for specific waste streams. **Attitudes:** Promote responsible practices for biomass utilization to ensure long-term sustainability and resource management. Approach biomass energy with a critical eye, considering both its potential and limitations in a sustainable energy future.
5.	Analyze the potential and applications of various ocean and geothermal energy sources, considering their environmental and social impacts.	**Knowledge:** Understand the principles and potential of tidal and ocean thermal energy conversion (OTEC). Recognize different resources of geothermal energy and their utilization methods. **Skills:** Evaluate the potential environmental and social impacts of ocean and geothermal energy projects. Analyze the suitability of different ocean and geothermal energy technologies for specific locations and applications. **Attitudes:** Embrace exploration of renewable ocean and geothermal energy sources for a sustainable energy future. Develop a balanced approach that considers both the benefits and potential drawbacks of ocean and geothermal energy technologies.

3. Syllabus

RENEWABLE ENERGY TECHNOLOGY SEMESTER – II			
Course Code	**M23MTP232**	CIE Marks	**50**
Teaching Hours/Week (L:P:SDA)	**(2:0:2)**	SEE Marks	**50**
Total Number of Lecture Hours	**40 hours**	Total Marks	**100**
Credits	**03**	Exam Hours	**03**
Course Learning objectives: • To provide the sufficient knowledge of concept, applications, importance of solar energy • To familiarize the students about the solar energy and its applications in real life situations • To carry out a case study on the existed solar energy system			
Module -1			
Introduction, Energy science and Technology, Forms of Energy, Importance of Energy Consumption as Measure of Prosperity, Per Capita Energy Consumption, Roles, and responsibility of Ministry of New and Renewable Energy Sources, Needs of renewable energy, Classification of Energy Resources, Conventional Energy Resources, Non-Conventional Energy Resources, World Energy Scenario, Indian Energy Scenario.			L1, L2
Module -2			
Introduction, Solar Radiation, Sun path diagram, Basic Sun-Earth Angles, Solar Radiation Geometry and its relation, Measurement of Solar Radiation on horizontal and tilted surfaces, Principle of Conversion of Solar Radiation into Heat, Collectors, Collector efficiency, Selective surfaces, Solar Water Heating system, Solar Cookers, Solar driers, Solar Still, Solar Furnaces,			L1, L2

Solar Green Houses. Solar Photovoltaic, Solar Cell fundamentals, Characteristics, Classification, Construction of module, panel, and array. Solar PV Systems (stand-alone and grid connected), Solar PV Applications. Government schemes and policies.	
Module -3	
Introduction, History of Wind Energy, Wind Energy Scenario of World, and India. Basic principles of Wind Energy Conversion Systems (WECS), Types and Classification of WECS, Parts of WECS, Power, torque and speed characteristics, Electrical Power Output and Capacity Factor of WECS, stand alone, grid connected and hybrid applications of WECS, Economics of wind energy utilization, Site selection criteria, Wind farm, Wind rose diagram.	L1, L2
Module -4	
Introduction, Biomass energy, Photosynthesis process, Biomass fuels, Biomass energy conversion technologies and applications, Urban waste to Energy Conversion, Biomass Gasification, Types and application of gasifiers, Biomass to Ethanol Production, Biogas production from waste biomass, Types of biogas plants, Factors affecting biogas generation, Energy plantation, Environmental impacts and benefits, Future role of biomass, Biomass programs in India.	L1, L2
Module -5	
Hydropower: Introduction, Capacity and Potential, Small hydro, Environmental and social impacts. Tidal Energy: Introduction, Capacity and Potential, Principle of Tidal Power, Components of Tidal Power Plant, Classification of Tidal Power Plants. Ocean Thermal Energy: Introduction, Ocean Thermal Energy Conversion (OTEC), Principle of OTEC system, Methods of OTEC power generation. Geothermal Energy: Introduction, Capacity and Potential, Resources of geothermal energy.	L1, L2

Text Books:

1. D. Y. Goswami, F. Kreith and J. F. Kreider, *Principles of Solar Engineering*, Taylor and Francis, 2000.
2. *Non-Conventional Energy Resources*, B. H. Khan, The McGraw Hill, 2017.
3. *Renewable Energy Sources*, Twidell, J.W. & Weir, A., EFN Spon Ltd., UK, 2006.
4. *Solar Energy – Principles of Thermal Collection and Storage*, S. P. Sukhatme and J.K. Nayak, Tata McGraw-Hill, New Delhi, 2008.
5. *Solar Energy, Fundamentals and Applications*, Garg, Prakash, TMH, 2017.

Reference Books:

1. *Solar Energy*, Sukhatme. S.P., Tata McGraw Hill Publishing Company Ltd., 1997.
2. *Renewable Energy, Power for a Sustainable Future*, Godfrey Boyle, Oxford University Press, U.K., 1996.
3. *Biogas Technology – A Practical Handbook*, Khandelwal, K.C., Mahdi, S.S., Tata McGraw- Hill, 1986.
4. *Solar Energy – Fundamentals Design, Modelling & Applications*, Tiwari. G.N., Narosa Publishing House, New Delhi, 2002.
5. *Wind Energy Conversion Systems*, Freris. L.L., Prentice Hall, 1990.
6. *Principles of Solar Energy*, Frank Krieth & John F Kreider, John Wiley, New York, 1987.

Links

- https://archive.nptel.ac.in/courses/103/103/103103206/
- https://archive.nptel.ac.in/courses/121/106/121106014/
- https://drive.google.com/file/d/1TezxsWvbHDda45wGLHt7vDS5zFv7kd56/view

4. Syllabus Timeline

S/L	Syllabus Timeline	Description
1	Week 1-2: Introduction, Types and Availability of Energy Sources	Introduction, Energy science and Technology, Forms of Energy, Importance of Energy Consumption as Measure of Prosperity, Per Capita Energy Consumption, Roles, and responsibility of Ministry of New and Renewable Energy Sources, Needs of renewable energy, Classification of Energy Resources, Conventional Energy Resources, Non-Conventional Energy Resources, World Energy Scenario, Indian Energy Scenario.
2	Week 3-4: Solar Radiation Geometry, Thermal Energy Conversion & Storage	Introduction, Solar Radiation, Sun path diagram, Basic Sun-Earth Angles, Solar Radiation Geometry and its relation, Measurement of Solar Radiation on horizontal and tilted surfaces, Principle of Conversion of Solar Radiation into Heat, Collectors, Collector efficiency, Selective surfaces, Solar Water Heating system, Solar

	Systems, Solar Photovoltaic system.	Cookers, Solar driers, Solar Still, Solar Furnaces, Solar Green Houses. Solar Photovoltaic, Solar Cell fundamentals, Characteristics, Classification, Construction of module, panel, and array. Solar PV Systems (stand-alone and grid connected), Solar PV Applications. Government schemes and policies.
3	Week 5-6: Wind Energy, its types, working principles & its parameters.	Introduction, History of Wind Energy, Wind Energy Scenario of World, and India. Basic principles of Wind Energy Conversion Systems (WECS), Types and Classification of WECS, Parts of WECS, Power, torque and speed characteristics, Electrical Power Output and Capacity Factor of WECS, stand alone, grid connected and hybrid applications of WECS, Economics of wind energy utilization, Site selection criteria, Wind farm, Wind rose diagram.
4	Week 7-8: Biomass Energy, Types, Methods, Working Mechanisms.	Introduction, Biomass energy, Photosynthesis process, Biomass fuels, Biomass energy conversion technologies and applications, Urban waste to Energy Conversion, Biomass Gasification, Types and application of gasifiers, Biomass to Ethanol Production, Biogas production from waste biomass, Types of biogas plants, Factors affecting biogas generation, Energy plantation, Environmental impacts and benefits, Future role of biomass, Biomass programs in India.
5	Week 9-10: Hydropower& Working principles, problem	Hydropower: Introduction, Capacity and Potential, Small hydro, Environmental and social impacts.
6	Week 11-12: Ocean Energy	Tidal Energy: Introduction, Capacity and Potential, Principle of Tidal Power, Components of Tidal Power Plant, Classification of Tidal Power Plants. Ocean Thermal Energy: Introduction, Ocean Thermal Energy Conversion (OTEC), Principle of OTEC system, Methods of OTEC power generation. Geothermal Energy: Introduction, Capacity and Potential, Resources of geothermal energy.

5. Teaching-Learning Process Strategies

S/L	TLP Strategies:	Description
1.	Lecture Method	Utilize various teaching methods within the lecture format to reinforce competencies.
2.	Video/Animation	Incorporate visual aids like videos/animations to enhance understanding of RET concepts.
3.	Collaborative Learning	Encourage collaborative learning for improved competency application.
4.	Real-World Application	Discuss practical applications to connect theoretical concepts with real-world competencies.
5.	Flipped Class Technique	Utilize a flipped class approach, providing materials before class to facilitate deeper understanding of competencies.

6. Assessment Details (both CIE and SEE)

Continuous Internal Evaluation:

	Components	Number	Weightage	Max. Marks	Min. Marks
(i)	Internal Assessment-Tests (A)	2	50%	25	10
(ii)	Assignments/Quiz/Activity (B)	2	50%	25	10
	Total Marks			**50**	**20**

Final CIE Marks = (A) + (B)

Semester End Examination (SEE):

1. The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
2. The question paper will have ten full questions carrying equal marks.
3. Each full question is for 20 marks. There will be two full questions (with a maximum of four sub questions) from each module.
4. Each full question will have a sub-question covering all the topics under a module.
5. The students will have to answer five full questions, selecting one full question from each module.

7. Learning Objectives

S/L	Learning Objectives	Description
1	Basics of Renewable Energy	Students will learn to define renewable energy and distinguish it from non-renewable sources & identify various renewable energy sources, including solar, wind, hydroelectric, biomass, geothermal, and tidal energy.
2	Analyzing Resource Availability	Students will learn to assess the global distribution and availability of renewable energy resources & identify factors influencing the spatial and temporal variability of renewable energy sources, such as sunlight intensity, wind speed, water flow, biomass productivity, geothermal gradients, and tidal patterns.
3	Working Principles of RES	Students will learn the construction & working of solar, wind, Tidal, OTEC, Geothermal & hydrogen energy.
4	Project-Based Learning	Through mini projects & seminar, students will learn about the team work, ppt presentation, and writing report and communication skills also.
5	Ethical and Professional Responsibility	Students will understand the ethical and professional responsibilities associated Renewable Energy Sources and their importance.

8. Course Outcomes (COs) and Mapping with POs/ PSOs
Course Outcomes (COs)

COs	Description
M23MTP232.1	Apply the basic physics of energy conversion to identify the environmental aspects of renewable energy resources in comparison with various conventional energy systems, their prospects and limitations.
M23MTP232.2	Interpret the measurement of solar radiations falling on horizontal, inclined & titled surfaces, thermal energy storage systems & Analyze the performance of flat plate collector, air heater and concentrating type collector.
M23MTP232.3	Explore the concepts involved in wind energy conversion system by studying its components, types and performance.
M23MTP232.4	Interpret the sources, types and methods of Biomass energy conversion.
M23MTP232.5	Interpret the different energy generation technologies by identifying the key operating principles of ocean energy and hydro power.

CO-PO-PSO Mapping

COs/POs	PO1	PO2	PO3
M23MTP232.1	3		
M23MTP232.2	3		
M23MTP232.3	3		
M23MTP232.4	3		
M23MTP232.5	3		

9. Assessment Plan

Continuous Internal Evaluation (CIE)

	CO1	CO2	CO3	CO4	CO5	**Total**
Module 1	20					20
Module 2		20				20
Module 3			20			20
Module 4				20		20
Module 5					20	20
Total	20	20	20	20	20	100

Semester End Examination (SEE)

	CO1	CO2	CO3	CO4	CO5	Total
Module 1	20					20
Module 2		20				20

Module 3			20			20
Module 4				20		20
Module 5					20	20
Total	20	20	20	20	20	100

10. Future with this Subject

The trend in renewable energy technology is characterized by significant growth and increasing adoption worldwide. Renewable energy capacity, particularly solar and wind, has been experiencing rapid growth globally. This expansion is driven by falling costs, technological advancements, supportive policies, and increasing environmental concerns.

- **Identifying Technology Advancements:**

Investigate emerging technologies and innovations in renewable energy generation, storage, and distribution. Assess the potential impact of technological advancements on the cost-effectiveness and efficiency of renewable energy systems.

- **Addressing Challenges and Barriers**

Identify technological barriers and limitations hindering the widespread adoption of renewable energy. Explore research and development efforts aimed at overcoming technical challenges and improving renewable energy technologies.

- **Assessing Environmental Benefits:**

Investigate the environmental benefits of renewable energy, including reductions in air and water pollution, land use impacts, and ecosystem preservation.
Analyze the potential for renewable energy to contribute to biodiversity conservation and ecological sustainability.

- **Encouraging Research and Development:**

Identify areas for further research and innovation in renewable energy technology, policy, and market design. Explore interdisciplinary approaches and collaborations to address complex challenges in the renewable energy sector.

2nd Semester	Professional Elective Course (PE) DESIGN & OPTIMIZATION Of THERMAL ENERGY SYSTEMS	M23MTP233

1. **Prerequisites**

S/L	Proficiency	Prerequisites
1	Thermodynamics	A strong foundation in concepts like energy, enthalpy, entropy, exergy, and the laws of thermodynamics. Familiarity with thermodynamic cycles (e.g., Rankine cycle) used in power plants is also beneficial.
2	Heat Transfer	Knowledge of heat transfer mechanisms (conduction, convection, radiation) and governing equations is necessary for modeling thermal systems and components (heat exchangers, evaporators, condensers).
3	Fluid Mechanics	Understanding fluid mechanics principles like fluid properties, pressure drop calculations, and pipe flow behavior is crucial for designing piping networks and analyzing pump performance.
4	Engineering Mathematics	A solid foundation in calculus, linear algebra, and differential equations is necessary for applying mathematical models and optimization techniques.
5	Basics of Computer Programming (Optional)	While not essential, familiarity with basic computer programming can be helpful for utilizing software tools used for thermal system modeling and optimization.

2. **Competencies**

S/L	Competency	KSA Description
1	Apply thermal system fundamentals and modeling techniques to design and analyze heat transfer processes.	**Knowledge:** Understand the characteristics of thermal systems and the steps involved in the design process. Identify different types of thermal system models (mathematical, empirical) and their importance in design analysis. **Skills:** Formulate design problems for thermal systems based on performance requirements. Apply mathematical models (e.g., exponential functions) and curve fitting techniques (e.g., least squares) to analyze heat transfer in systems like counter-flow heat exchangers, evaporators, and condensers. **Attitudes:** Appreciate the value of modeling and analysis in optimizing thermal system performance. Maintain a problem-solving approach to identify and address design challenges in thermal systems.
2	Design and analyze piping networks for efficient fluid flow, considering head loss and pump performance.	**Knowledge:** Understand methods for representing head loss in piping systems (e.g., Darcy-Weisbach equation). Identify different techniques for analyzing piping networks, including the Hardy-Cross method. **Skills:** Apply methods to calculate head loss and pressure drops in piping systems. Utilize the Hardy-Cross method or similar techniques to analyze flow rates and pressure distribution in complex piping networks. **Attitudes:** Recognize the importance of minimizing head loss for efficient pump operation. Emphasize the need for considering cavitation limitations during pump selection and system design.
3	Apply appropriate optimization techniques to solve engineering design problems with or without	**Knowledge:** Understand the difference between unconstrained and constrained optimization problems. Identify various optimization techniques, including univariate methods (e.g., conjugate gradient method) and methods for constrained problems (e.g., feasible directions method).

	constraints.	**Skills:** Select the appropriate optimization technique (univariate, conjugate gradient, feasible directions) based on the problem characteristics (with or without constraints). Apply the chosen technique to solve engineering design problems involving objective functions and potentially present constraints. **Attitudes:** Recognize the importance of selecting the most suitable optimization method for efficient problem-solving. Maintain a critical thinking approach to evaluate the optimality and validity of solutions obtained through optimization techniques.
4	Perform thermo-economic analysis to evaluate the economic viability and efficiency of energy systems.	**Knowledge:** Understand the core principles of thermo-economics and the concept of exergy (available energy) as a key variable. Identify relevant thermo-economic variables used for component and overall system evaluation. **Skills:** Apply thermo-economic analysis techniques to assess the combined effects of energy use and economic costs in energy systems. Utilize cost data and exergy analysis to evaluate the economic viability and efficiency of different design options for a system component or the entire system. **Attitudes:** Recognize the importance of considering both economic and thermodynamic factors for optimal design and operation of energy systems. Emphasize the value of thermo-economic analysis in making informed decisions for energy systems.
5	Apply thermo-economic optimization techniques to improve the overall performance and cost-effectiveness of energy systems.	**Knowledge:** Understand the concept of thermo-economic optimization and its role in energy system design. Identify different optimization techniques used for thermo-economic analysis, including analytical and numerical methods. **Skills:** Apply thermo-economic optimization techniques to optimize heat exchanger networks for improved efficiency and reduced costs. Utilize optimization methods to design cogeneration systems (combined heat and power) that achieve optimal economic performance, as exemplified through case studies. **Attitudes:** Appreciate the value of thermo-economic optimization in achieving a balance between energy efficiency and economic feasibility. Maintain a continuous improvement mindset by seeking opportunities to optimize the design and operation of energy systems.

3. Syllabus

Design and Optimization of Thermal Energy Systems **SEMESTER – II**			
Course Code	**M23MTP233**	CIE Marks	**50**
Number of Lecture Hours/Week(L: T: P: S)	**(2:0:2)**	SEE Marks	**50**
Total Number of Lecture Hours	**40 hours Theory**	Total Marks	**100**
Credits	**03**	Exam Hours	**03**

Course objectives:

- To Understand the concept of optimization and its importance in the background of real life engineering systems
- To familiarize the students about the optimization techniques and their implementations
- To carry out the case study using optimization technique.

Module -1

Thermal Systems: Characteristics- formulation of design problem - Steps in the design process - Modeling of thermal systems – importance - Types of models – Mathematical Modeling, Exponential forms- Method of least squares - Counter flow heat exchanger, Evaporators and Condensers, Effectiveness, NTU, Pressure drop and pumping power.	L1, L2,L3
Module -2	
Design of piping and pump systems: - Head loss representation; Piping networks; Hardy – Cross method Generalized Hardy – Cross analysis; Pump testing methods; Cavitation considerations; Dimensional analysis of pumps; piping system design practice.	L1, L2,L3
Module -3	
Unconstrained Optimization Techniques: Univariate, Conjugate Gradient Method and Variable Metric Method. **Constrained Optimization Techniques:** Characteristics of a constrained problem; Direct Method of feasible directions; Indirect Method of interior and exterior penalty functions.	L1, L2, L3
Module -4	
Thermo-economic analysis and evaluation: Fundamentals of thermo-economics, Thermo-economic variables for component evaluation; thermo-economic evaluation; additional costing considerations.	L1, L2, L3
Module -5	
Thermo-economic optimization: Introduction; optimization of heat exchanger networks; analytical and numerical optimization techniques; design optimization for the co-generation system- a case study; thermo-economic optimization of complex systems.	L1, L2, L3

Text Books:
1. Essentials of Thermal System Design and Optimization, Prof. C. Balaji, Aue Books, New Delhi in India, and CRC Press in the rest of the world.
2. Design and optimization of thermal systems, Y. Jaluria, Mc Graw Hill, 1998.
3. Elements of thermal fluid system design, L. C. Burmeister, Prentice Hall, 1998.

Reference Books:
1. Design of thermal systems, W. F. Stoecker, Mc Graw Hill, 1989.
2. Introduction to optimum design, J. S. Arora, Mc Graw Hill, 1989.
3. Optimization for engineering design - algorithms and examples, K. Deb, Prentice Hall, 1995.

4. **Syllabus Timeline**

S/L	Syllabus Timeline	Description
1	Week 1-2: Thermal Systems	Characteristics- formulation of design problem. Steps in the design process - Modeling of thermal systems. Types of models. Evaporators and Condensers, Effectiveness, NTU. Pressure drop and pumping power.
2	Week 3-4: Design of piping and pumping systems	Head loss representation Piping networks Hardy – Cross method Generalized Hardy – Cross analysis Pump testing methods Dimensional analysis of pumps; piping system design practice.
3	Week 5-6: Unconstrained Optimization Techniques: Constrained Optimization Techniques:	Conjugate Gradient Method and Variable Metric Method. Characteristics of a constrained problem Direct Method of feasible directions Indirect Method of interior and exterior penalty functions.
4	Week 7-8: Thermo-economic analysis and evaluation:	Fundamentals of thermo-economics Thermo-economic variables for component evaluation Thermo-economic evaluation Additional costing considerations.
5	Week 9-10: Thermo-economic optimization:	Optimization of heat exchanger networks Analytical and numerical optimization techniques Design optimization for the co-generation system- a case study Thermo-economic optimization of complex systems.

6	Week 11-12:	Apply learned concepts and competencies to real-world scenarios.

5. Teaching-Learning Process Strategies

S/L	TLP Strategies:	Description
1	Lecture Method	Utilize various teaching methods within the lecture format to reinforce competencies.
2	Video/Animation	Incorporate visual aids like videos/animations to enhance understanding of Verilog concepts.
3	Collaborative Learning	Encourage collaborative learning for improved competency application.
4	Higher Order Thinking (HOTS) Questions:	Pose HOTS questions to stimulate critical thinking related to each competency.
5	Problem-Based Learning (PBL)	Implement PBL to enhance analytical skills and practical application of competencies
6	Multiple Representations	Introduce topics in various representations to reinforce competencies
7	Real-World Application	Discuss practical applications to connect theoretical concepts with real-world competencies.
8	Flipped Class Technique	Utilize a flipped class approach, providing materials before class to facilitate deeper understanding of competencies

6. Assessment Details (both CIE and SEE)

CIE

Components		Number	Weightage	Max. Marks	Min. Marks
(i)	Internal Assessment-Tests (A)	2	50%	25	10
(ii)	Assignments/Quiz/Activity (B)	2	50%	25	10
	Total Marks			**50**	**20**

Final CIE Marks = (A) + (B)

SEE

1. Question paper pattern will be ten questions. Each question is set for 20marks. The medium of the question paper shall be English unless otherwise it is mentioned.
2. There shall be 2 question from each module, each of the two questions under a module (with a maximum of 3 sub questions), may have mix of topics under that module if necessary.
3. The students have to answer 5 full questions selecting one full question from each module.
4. Marks scored will be proportionally scaled down to 50 marks

7. Learning Objectives

S/L	Learning Objectives	Description
1	Understand Fundamental Concepts	Students able to grasp the basic principles of thermodynamics, heat transfer, and fluid mechanics as they apply to thermal energy systems.
2	System Design and Analysis	Students develop skills to design thermal energy systems, including heating, ventilation, air conditioning (HVAC), power generation, and refrigeration systems.
3	Fundamentals of Optimization Techniques	Students learn various optimization methods and techniques applicable to thermal energy systems.
4	Concepts of Energy Efficiency and Sustainability	Students will able to evaluate the energy efficiency of different thermal energy systems.
5	Software Tools and Simulations	Students gain proficiency in using software tools and simulation platforms for the design and optimization of thermal energy systems (e.g., MATLAB, ANSYS, TRNSYS).

8. Course Outcomes (COs) and Mapping with POs/ PSOs

Course Outcomes (COs)

COs	Description
M23MTP233.1	Formulation of design problems related to thermal Systems
M23MTP233.2	Apply methods of optimization to solve a linear, non-linear programming problem by various methods.
M23MTP233.3	Optimize engineering problem of nonlinear programming with/without constraints, by using this technique
M23MTP233.4	Use of dynamic programming problem in controlling in industrial managements.
M23MTP233.5	Simulate Thermal engineering system problem. Understand integer programming and stochastic programming to evaluate advanced optimization techniques.

CO-PO-PSO Mapping

COs/POs	PO1	PO2	PO3
M23MTP233.1	3		
M23MTP233.2			3
M23MTP233.3			3
M23MTP233.4			3
M23MTP233.5			3

9. Assessment Plan

Continuous Internal Evaluation (CIE)

	CO1	CO2	CO3	CO4	CO5	**Total**
Module 1	**20**					**20**
Module 2		**20**				**20**
Module 3			**20**			**20**
Module 4				**20**		**20**
Module 5					**20**	**20**
Total	**20**	**20**	**20**	**20**	**20**	**100**

Semester End Examination (SEE)

	CO1	CO2	CO3	CO4	CO5	**Total**
Module 1	**20**					**20**
Module 2		**20**				**20**
Module 3			**20**			**20**
Module 4				**20**		**20**
Module 5					**20**	**20**
Total	**20**	**20**	**20**	**20**	**20**	**100**

Conditions for SEE Paper Setting:

Each module of SEE question paper should be allocated with questions for 20% of the total SEE marks

10. Future with this Subject

The future of the subject "Design and Optimization of Thermal Energy Systems" looks promising, driven by several emerging trends and technological advancements. Here are some key aspects that highlight the future directions and importance of this field:

1. **Integration of Renewable Energy Sources**: Increasing emphasis on integrating renewable energy sources, such as solar thermal, geothermal, and biomass, into thermal energy systems.
2. **Advanced Materials and Technologies**: Innovations in advanced materials, such as phase-change materials (PCMs) and nano-materials, enhancing the performance of thermal energy storage and transfer.
3. **Energy Efficiency and Sustainability**: Growing focus on optimizing thermal systems for maximum energy efficiency to reduce carbon footprints and comply with environmental regulations.

4. **Smart and IoT-Enabled Systems**: Integration of Internet of Things (IoT) technologies and smart sensors for real-time monitoring, control, and optimization of thermal energy systems.
5. **Advanced Simulation and Modeling Tools**: Advancements in computational tools and simulation software to model complex thermal systems more accurately and efficiently.
6. **Micro and Nano Thermal Systems**: Exploration of micro and nanoscale thermal systems for applications in electronics cooling, medical devices, and small-scale energy harvesting. Research into the unique thermal properties and behaviors at micro and nano scales to develop innovative solutions.

2nd Semester	Professional Elective Course (PE) CRYOGENICS	M23MTP234

1. **Prerequisites**

S/L	Proficiency	Prerequisites
1	**Basic Mathematics**	Proficiency in differential and integral calculus, vectors, matrices, and linear transformations to solve ordinary and partial differential equations which relates to the cryogenics applications
2	**Physics**	Basic understanding the laws of thermodynamics, heat transfer, and temperature. Basic principles of quantum mechanics are often essential, as cryogenics deals with quantum effects at low temperatures. Basic understanding of electromagnetism can be useful in selection of materials for cryogenic engineering.
3	**Chemistry**	Knowledge of physical properties of materials, phase transitions, and chemical thermodynamics.
4	**Mechanical Engineering Fundamentals**	Understanding of basic mechanical engineering design principles like mechanics of materials, fluid mechanics, dynamics of machines provides a concrete platform to study the behavioral aspects in cryogenics
5	**Laboratory Experience**	Hands-on experience in laboratory settings, including conducting experiments, usage of test rigs, and performing material testing, can enhance understanding of physical material behavior
6	**Previous Coursework**	Completion of under graduation course in mechanical engineering with more focus on materials, design and thermal aspects projects the advanced level of implementation of cryogenics in par with real time and ongoing trends

2. **Competencies**

S/L	Competency	KSA Description
1	**Cryogenics & its fluids**	**Knowledge:** Understanding of basic terminologies involved in cryogenics Knowledge about cryogenic fluids **Skills:** Ability to apply knowledge of cryogenics to identify the properties at cryogenic temperatures **Attitudes:** Appreciation for the importance of cryogenic technology and its influence on present trends in material and production at low temperatures
2	**Refrigeration systems**	**Knowledge:** Understanding on various types of refrigeration cycles and refrigeration systems **Skills:** Analyzing the adaptability of various refrigeration systems based on Ideal thermodynamic cycle and Various liquefaction cycles **Attitudes:** Appreciation on the influence of various refrigeration systems towards cryogenic material handling
3	**Gas separation in cryogenic systems**	**Knowledge:** Understanding the basic principles of gas separation based on the properties of mixtures of gases **Skills:** Identify the parameters related to rectification and plates used in gas separation **Attitudes:** Appreciation towards the capacities of gas separation and Cryocooler
4	**Vacuum technology**	**Knowledge:** Understanding the vacuum fundamentals and its need **Skills:** Identify the pumping speed and pump down time in vacuum pumps **Attitudes:** Valuing the importance of conductance and electrical analogies
5	**Instrument and measurement**	**Knowledge:** Understanding the operating principles of cryogenic sensors, thermometers and related measurement tools **Skills:** Identify and handle instruments for measuring low temperature and other properties **Attitudes:** Appreciation towards instruments contributing various measurements in cryogenic environment
6	**Cryogenic systems and equipment**	**Knowledge:** Understanding the operation of cryogenic systems such as refrigerators, liquefiers, and storage vessels. **Skills:** Ability to interpret the maintenance of cryogenic systems based on knowledge acquired on their design and operations **Attitudes:** Appreciation towards the familiarity on cryogenic piping, valves, and insulation techniques.

3. Syllabus

CRYOGENICS
SEMESTER – II

Course Code	**M23MTP234**	CIE Marks	**50**
Number of Lecture Hours/Week(L: T: P: S)	**(2:0:0:2)**	SEE Marks	**50**
Total Number of Lecture Hours	**40 hours Theory**	Total Marks	**100**
Credits	**03**	Exam Hours	**03**

Course objectives:

- To understand the basic principles of cryogenic engineering.
- Understand the principles of cryogenic fluid dynamics and heat transfer.
- Apply theoretical knowledge to practical problems in cryogenics.
- Select appropriate materials for cryogenic applications based on their properties.

Module -1

Introduction: Cryogenics and its applications, Cryogenic Fluids, Properties of cryogenic fluids, Properties of materials at cryogenic temperature.
Gas Liquefaction and Refrigeration Systems: Basics of Refrigeration/Liquefaction, Production of low temperatures, Ideal thermodynamic cycle and Various liquefaction cycles: Linde–Hampson system, Linde Dual –Pressure System, Claude System, Kapitza System, Heylandt System and Collins System.

Module -2

Gas Separation: Basics of Gas Separation, Ideal Gas Separation System, Properties of Mixtures and the Governing Laws, Principles of Gas Separation, Rectification and Plate Calculations. **Cryocoolers**: Classification and application of Cryocooler, Recuperative Cryocoolers, Regenerative Cryocoolers, JT Cryocooler, Stirling Cryocooler, G-M Cryocooler and Pulse Tube Cryocooler.

Module -3

Vacuum Technology: Need of Vacuum in Cryogenics, Vacuum fundamentals, Conductance and Electrical analogy, Pumping Speed and Pump down time and Vacuum Pumps.

Module -4

Instrumentation in Cryogenics: Need of Cryogenic Instrumentation, Measurement of Thermo physical Properties and Various Sensors.

Module -5

Cryogenic Insulations: Importance of Cryogenic insulation, Types of Cryogenic insulations and application Safety in Cryogenics Need for Safety, basic hazards and protection from hazards.

Suggested Learning Resources:

Books

1. Randall F. Barron, "Cryogenics Systems", Second Edition Oxford University Press New York, Clarendon Press, Oxford, 1985.
2. Timmerhaus, Flynn, "Cryogenics Process Engineering", Plenum Press, New York.
3. Pipkov, "Fundamentals of Vacuum Engineering", Meer Publication.
4. G.M Walker. "Cryocooler-Part 1 Fundamentals" Plenum Press, New York and London.
5. G.M Walker. "Cryocooler-Part 2" Plenum Press, New York and London.

Web links and Video Lectures (e-Resources):

1. https://archive.nptel.ac.in/courses/112/101/112101004/
2. http://www.nist.gov/index.html

4. Syllabus Timeline

S/L	Syllabus Timeline	Description
1	**Week 1-2**	• Cryogenics and its applications • Cryogenic Fluids • Properties of cryogenic fluids & materials at cryogenic temperature. • Basics of Refrigeration/Liquefaction • Production of low temperatures, Ideal thermodynamic cycle • Various liquefaction cycles: Linde–Hampson system, Linde Dual –Pressure System, Claude System, Kapitza System, Heylandt System and Collins System.
2	**Week 3-4**	• Basics of Gas Separation • Ideal Gas Separation System • Properties of Mixtures and the Governing Laws

		• Principles of Gas Separation • Rectification and Plate Calculations
3	**Week 5-6**	• Classification and application of Cryocooler • Recuperative Cryocoolers • Regenerative Cryocoolers • JT Cryocooler • Stirling Cryocooler • G-M Cryocooler and • Pulse Tube Cryocooler.
4	**Week 7-8**	• Need of Vacuum in Cryogenics • Vacuum fundamentals • Conductance and Electrical analogy • Pumping Speed and Pump down time and • Vacuum Pumps.
5	**Week 9-10**	• Need of Cryogenic Instrumentation, • Measurement of Thermo physical Properties • Study on various Sensors.
6	**Week 11-12**	• Importance of Cryogenic insulation • Types of Cryogenic insulations and application • Safety in Cryogenics

5. Teaching-Learning Process Strategies

S/L	TLP Strategies:	Description
1	Lecture Method	Utilize Chalk and talk lecture format to reinforce competencies.
2	Video/Animation	Incorporate visual aids like videos/animations to enhance understanding the fundamentals of cryogenics and its relative applications.
3	Collaborative Learning	Encourage collaborative learning through groups for improved competency application.
4	Problem-Based Learning (PBL)	Implement PBL to enhance analytical skills and practical application of cryogenics
5	Multiple Representations	Introduce topics in various representations like verbal, graphical and mathematical representations to reinforce competencies
6	Real-World Application	Discuss practical applications to connect theoretical concepts with real-world competencies in the field of cryogenics
7	Flipped Class Technique	Utilize a flipped class approach, providing materials before class to facilitate deeper understanding of competencies in cryogenics
8	Socratic Questioning	Pose questions like what? Why? Is it true? Is that the only way? to stimulate critical thinking among students and encourage meaningful discussions

6. Assessment Details (both CIE and SEE)

CIE

Components		Number	Weightage	Max. Marks	Min. Marks
(i)	Internal Assessment-Tests (A)	2	50%	25	10
(ii)	Assignments/Quiz/Activity (B)	2	50%	25	10
	Total Marks			**50**	**20**

Final CIE Marks = (A) + (B)

SEE

1. Question paper pattern will be ten questions. Each question is set for 20marks. The medium of the question paper shall be English unless otherwise it is mentioned.
2. There shall be 2 question from each module, each of the two questions under a module (with a maximum of 3 sub questions), may have mix of topics under that module if necessary.
3. The students have to answer 5 full questions selecting one full question from each module.
4. Marks scored will be proportionally scaled down to 50 marks

7. Learning Objectives

S/L	Learning Objectives	Description
1	Understanding the fundamentals	Students will be able to explain the basic principles of cryogenics, including the definitions of cryogenic temperatures and the historical development of the field. Understand the thermodynamic principles relevant to cryogenics, such as the laws of thermodynamics, entropy, and enthalpy at low temperatures.
2	Designing of cryogenic systems	Students will be able to design and analyze components of cryogenic systems, such as storage vessels, transfer lines, and insulation techniques. Apply safety standards and protocols in the design, operation, and maintenance of cryogenic equipment.
3	Proficiency in cryogenic systems selection	Students will be able to evaluate the performance and efficiency of cryogenic refrigeration systems and propose improvements. Identify changes in physical properties (thermal, electrical, and mechanical) of materials at cryogenic temperatures. Select appropriate materials for cryogenic applications based on their properties at low temperatures
4	Experimental techniques and measurement	Students will be able to conduct experiments to measure the low-temperature properties of materials and systems. Use cryogenic measurement techniques such as resistance thermometry, capacitance thermometry, and superconducting magnetometers. Analyze and interpret experimental data, and troubleshoot common issues in cryogenic experiments.
5	Project & Research Skills	Students will develop and conduct a research project on a cryogenic topic, demonstrating the ability to formulate a research question, design an experiment, and analyze results. Apply theoretical knowledge to solve practical problems in cryogenics. Present research findings effectively through written reports and oral presentations.
6	Ethical and Environmental impact	Students will understand the ethical considerations in the development and application of cryogenic technologies. Evaluate the environmental impact of cryogenic processes and propose sustainable practices. Discuss the future trends in cryogenics and the potential societal implications of advancements in the field

8. Course Outcomes (COs) and Mapping with POs/ PSOs

Course Outcomes (COs)

COs	Description
M23MTP234.1	Interpret the working principles and applications of different types of gas liquefaction and refrigeration systems.
M23MTP234.2	Apply the governing laws and principles of gas separation in cryogenic applications.
M23MTP234.3	Make use of the concepts of Ideal separation, properties of mixtures, Rectifiers column, separation of air, and purification to highlight its importance in cryogenics
M23MTP234.4	Assess the importance of cryogenics insulations and Safety in Cryogenics.
M23MTP234.5	Identify insulation and storage systems in cryogenic engineering

CO-PO-PSO Mapping

COs/POs	PO1	PO2	PO3
M23MTP234.1	3	-	-
M23MTP234.2	3	-	-
M23MTP234.3	3	-	-
M23MTP234.4	3	-	-
M23MTP234.5	3	-	-

9. Assessment Plan

Continuous Internal Evaluation (CIE)

	CO1	CO2	CO3	CO4	CO5	**Total**
Module 1	**20**					**20**
Module 2		**20**				**20**
Module 3			**20**			**20**
Module 4				**20**		**20**
Module 5					**20**	**20**
Total	**20**	**20**	**20**	**20**	**20**	**100**

Semester End Examination (SEE)

	CO1	CO2	CO3	CO4	CO5	**Total**
Module 1	**20**					**20**
Module 2		**20**				**20**
Module 3			**20**			**20**
Module 4				**20**		**20**
Module 5					**20**	**20**
Total	**20**	**20**	**20**	**20**	**20**	**100**

Conditions for SEE Paper Setting:
Each module of SEE question paper should be allocated with questions for 20% of the total SEE marks

10. Future with this Subject

The "Cryogenics" course included in the 1st year of study in M.Tech program for Thermal Power Engineering concretes the fundamentals of production and effects at low temperatures. The contributions from this course lead to advanced learning and innovations in the field of thermal systems. Here are some notable contributions:

- Quantum Computing: Cryogenics is crucial for operating quantum computers, which require extremely low temperatures to maintain quantum coherence and minimize thermal noise.
- Medical Applications
  - Cryosurgery: Improved precision and control in cryogenic procedures for treating various medical conditions, including cancerous tumors.
  - Cryopreservation: Enhanced techniques for preserving biological samples, organs, and potentially whole organisms for extended periods.
  - Cryogenic Imaging: Development of advanced cryogenic imaging techniques for high-resolution, low-noise medical imaging.
- Space Exploration
  - Rocket Propulsion: Cryogenics plays a critical role in the storage and handling of cryogenic propellants like liquid hydrogen and liquid oxygen for rockets.
  - Spacecraft Cooling: Advanced cryogenic systems for cooling infrared sensors and other instruments on satellites and space telescopes.
  - Life Support Systems: Development of cryogenic technologies to support long-duration space missions, including potential human missions to Mars.
- Energy and Environment
  - Superconducting Power Grids: Utilizing cryogenics to develop efficient superconducting materials for power transmission, reducing energy loss and improving grid stability.
  - Liquefied Natural Gas (LNG): Advances in the liquefaction and transportation of natural gas, making it a more viable alternative to traditional fossil fuels.
  - Hydrogen Economy: Cryogenic storage and transportation solutions for hydrogen fuel, supporting the development of a hydrogen-based energy infrastructure.
- Fundamental Science
  - Particle Physics: Continued use of cryogenics in large-scale experiments like those conducted at CERN, where maintaining superconducting magnets at cryogenic temperatures is essential.
  - Astronomy and Astrophysics: Enhancements in cryogenic detectors and instruments for ground-based and space-based telescopes, enabling the observation of faint cosmic signals.
- Industrial and Manufacturing
  - Materials Science: Development of new materials with unique properties that emerge at cryogenic temperatures, including high-performance superconductors and cryogenic insulators.

2nd Semester	Professional Elective Course (PE) NUCLEAR ENGINEERING IN POWER GENERATION	M23MTP235

1. Prerequisites

S/L	Proficiency	Prerequisites
1	**Mathematics**	Proficiency in calculus, differential equations, linear algebra, and numerical methods. Understanding of statistics and probability.
2	**Physics**	Fundamental concepts of classical mechanics, electromagnetism, and modern physics. Specialized knowledge in nuclear physics, including atomic and nuclear structure, radioactivity, and nuclear reactions.
3	**Chemistry**	Basic principles of general and physical chemistry. Understanding of chemical reactions, thermodynamics, and material properties.
4	**Basic Engineering principles**	Core principles of mechanical and electrical engineering. Knowledge of fluid dynamics, heat transfer, and control systems.
5	**Laboratory skills**	Hands-on experience with laboratory equipment and experimental techniques. Ability to conduct experiments, collect the data and analyze results.
6	**Course work**	Basic knowledge on energy resources during under graduation study in mechanical engineering program through courses like renewable energy sources, energy engineering, power plant engineering etc.

2. Competencies

S/L	Competency	KSA Description
1	**Nuclear Physics & Reactor theory**	**Knowledge:** Understanding of atomic and nuclear structure, radioactivity, neutron interactions, and nuclear reactions. Knowledge of reactor kinetics, neutron diffusion, and moderation. **Skills:** Ability to apply knowledge of nuclear physics to interpret the nuclear fission and fusion mechanism **Attitudes:** Appreciation for the importance of nuclear physics and the operating conditions of various reactors
2	**Nuclear fuel cycle**	**Knowledge:** Understanding the various nuclear elements that can serve the purpose of fueling in nuclear reactions **Skills:** Identify the properties of various nuclear fuel materials **Attitudes:** Valuing the importance of nuclear fuel processing methods
3	**Radiation protection & shielding**	**Knowledge:** Understanding the basic principles of radiation and its shielding principles **Skills:** Identify the components based on their operating conditions satisfying engineering design **Attitudes:** Appreciation towards the capacities of radiation protection and shielding
4	**Thermal Hydraulics**	**Knowledge:** Understanding on various types of heat transfer properties of water, gas, liquid metals and their correlation **Skills:** Analyzing the stability aspects of single phase and two phase flows in pressure drop **Attitudes:** Appreciation on the influence of basic Carnot, Rankine and Brayton cycles
5	**Instrument and measurement**	**Knowledge:** Understanding the operating principles of different types of nuclear and thermal reactors

		Skills: Identify instruments or reactors that leads to the generation of power based on requirement specified **Attitudes:** Appreciation towards instruments contributing towards power generation using nuclear resources
6	**Reactor Design and Safety**	**Knowledge:** Understanding the design principles of various types of reactor **Skills:** Ability to interpret the safety systems, risk management and accident mitigation strategies **Attitudes:** Appreciation towards developing and managing safety procedures to ensure compliance with regulatory requirements.

3. Syllabus

NUCLEAR ENGINEERING IN POWER GENERATION SEMESTER – II			
Course Code	**M23MTP235**	CIE Marks	**50**
Number of Lecture Hours/Week(L: T: P: S)	**(2:0:0:2)**	SEE Marks	**50**
Total Number of Lecture Hours	**40 hours Theory**	Total Marks	**100**
Credits	**03**	Exam Hours	**03**

Course objectives:

- To provide the sufficient knowledge of concept, applications, importance of Nuclear Power plant
- To familiarize the students about the design of Nuclear Power plant
- To understand the environment impact and policies about the NPP

Module -1	
Introduction to Nuclear Physics: Motivation for nuclear energy, Nuclear model of the atom, Equivalence of mass and energy, Binding energy, Mechanism of nuclear fission and fusion, Radio activity, Half-life, Radiation interactions with matter, Cross sections, Principles of Radiation detection, Decay Heat. **Nuclear Fuel Cycle**: Uranium exploration, mining, Uranium production, Fuel fabrication, spent fuel handling, reprocessing (Purex, Urex, Diamex), Pyro processing, Fuel transportation between facilities, Radioactive waste management: Types, treatment, compaction, Vitrification etc., Materials: Fuel, Structural, Coolants, Control, Moderator, and Shielding.	L1, L2, L3
Module -2	
Types of Nuclear Reactors: Components of a nuclear reactor, Types of nuclear reactors, Pressurized Water Reactor, Boiling water Reactor, Pressurized Heavy Water Reactor, Gas Cooled reactor; Liquid Metal cooled fast breeder reactors, Gen IV Concepts.	L1, L2, L3
Module -3	
Thermal Power Reactors: Layout of nuclear power plant; Zoning requirements: layout in the reactor building; Material selection for components, Operating environment. Zone control, Regulating rods, Absorbers, Shutdown systems. Fuel and Fuel transfer system; Primary heat Transport System; Emergency core cooling system; Moderator system; Auxiliary System.	L1, L2, L3
Module -4	
Fast Power Reactors: Breeding ratio, doubling time, Core design features - Static and Dynamic, control rod design, Shielding principles, Fuel management, and safety. Core & important design parameters, Comparison of core components, Major primary and secondary system components. Description, choice of core materials, engineering design of core, High temperature design methods. Decay heat removal system. Instrumentation & control.	L1, L2, L3
Module -5	
Reactor Thermal Hydraulics: Heat Transfer in Fuel, Fuel to coolant, one dimensional heat conduction with heat generation, Heat Transfer properties of water, gas, liquid metals, Correlations, Pressure drop: Single Phase, Two Phase, Instability of two-phase flow, Basic Carnot, Rankine and Brayton Cycles.	L1, L2, L3
Suggested Learning Resources: **Books** 1. Nuclear Reactor Engineering-Concepts & Principles - G. Vaidyanathan, S. Chand co., Delhi, 2013. 2. Nuclear Reactor Engineering (3rd Edition) - S. Glasstone and A.Sesonske, Von Nostrand,1981	

3. Comprehensive Nuclear Materials- Rudy J.M. Konings, vol. 1-5, Elsevier Ltd, 2012
4. Nuclear Power Plant Instrumentation and Control Systems for Safety and Security-M.Yastrebenetsky, V. Kharchenko, February 2014.
5. Fast Breeder Reactor- A.E.Walter and A.B.Reynolds, Pergamon Press, 1981
6. Fundamentals of Nuclear Reactor Physics-E. Lewis, Academic Press, 2008

Web links and Video Lectures (e-Resources):

- https://drive.google.com/file/d/1t6C-l37sGiIM4OrapMI-fzN8Bsyc_FPp/view
- https://archive.nptel.ac.in/courses/112/103/112103243/

4. Syllabus Timeline

S/L	Syllabus Timeline	Description
1	**Week 1-2**	• Motivation for nuclear energy, • Nuclear model of the atom, • Equivalence of mass and energy, Binding energy, • Mechanism of nuclear fission and fusion, • Radio activity, • Half-life, Radiation interactions with matter, • Cross sections, Principles of Radiation detection, Decay Heat.
2	**Week 3-4**	• Uranium exploration, mining, • Uranium production, Fuel fabrication, • Spent fuel handling, reprocessing (Purex, Urex, Diamex), • Pyro processing, • Fuel transportation between facilities, • Radioactive waste management: Types, treatment, compaction, Vitrification etc., • Materials: Fuel, Structural, Coolants, Control, Moderator, and Shielding.
3	**Week 5-6**	• Components of a nuclear reactor, • Types of nuclear reactors, • Pressurized Water Reactor, • Boiling water Reactor, • Pressurized Heavy Water Reactor, • Gas Cooled reactor; • Liquid Metal cooled fast breeder reactors, • Gen IV Concepts.
4	**Week 7-8**	• Layout of nuclear power plant • Zoning requirements: layout in the reactor building; • Material selection for components, Operating environment. • Zone control, Regulating rods, Absorbers, Shutdown systems. • Fuel and Fuel transfer system; • Primary heat Transport System; • Emergency core cooling system; • Moderator system; Auxiliary System.
5	**Week 9-10**	• Breeding ratio, doubling time, • Core design features - Static and Dynamic, control rod design, Shielding principles, • Fuel management and safety. • Core & important design parameters, • Comparison of core components, Major primary and secondary system components. • Description, choice of core materials, engineering design of core, • High temperature design methods. • Decay heat removal system. Instrumentation & control.
6	**Week 11-12**	• Heat Transfer in Fuel, Fuel to coolant, one dimensional heat conduction with heat generation, • Heat Transfer properties of water, gas, liquid metals, Correlations,

		• Pressure drop: Single Phase, Two Phase, • Instability of two-phase flow, • Basic Carnot, Rankine and Brayton Cycles.

5. Teaching-Learning Process Strategies

S/L	TLP Strategies:	Description
1	Lecture Method	Utilize Chalk and talk lecture format to reinforce the competencies focused on nuclear energy harnessing using various machines
2	Video/Animation	Incorporate visual aids like videos/animations to enhance understanding the fundamentals of nuclear energy and its engineering involved in power generation.
3	Collaborative Learning	Encourage collaborative learning through group discussion for improved competency in various available nuclear resources across the world
4	Problem-Based Learning (PBL)	Implement PBL to enhance analytical skills and possible implementation attributes of nuclear energy
5	Multiple Representations	Introduce topics in various representations like verbal, graphical and mathematical representations to reinforce competencies in selection of nuclear reactors and allied machine components based on their performance
6	Real-World Application	Discuss practical applications to connect theoretical concepts with real-world competencies in the field power generation through nuclear resources
7	Flipped Class Technique	Utilize a flipped class approach, providing materials before class to facilitate deeper understanding of competencies of nuclear engineering than nuclear resources
8	Socratic Questioning	Pose questions like what? Why? Is it true? Is that the only way? to stimulate critical thinking among students and encourage meaningful discussions

6. Assessment Details (both CIE and SEE)

CIE

Components		Number	Weightage	Max. Marks	Min. Marks
(i)	Internal Assessment-Tests (A)	2	50%	25	10
(ii)	Assignments/Quiz/Activity (B)	2	50%	25	10
	Total Marks			**50**	**20**

Final CIE Marks = (A) + (B)

SEE

- The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
- The question paper will have ten full questions carrying equal marks.
- Each full question is for 20 marks. There will be two full questions (with a maximum of four sub questions) from each module.
- Each full question will have a sub-question covering all the topics under a module.
- The students will have to answer five full questions, selecting one full question from each module.

7. Learning Objectives

S/L	Learning Objectives	Description
1	Understand the fundamental principles of nuclear science	Understand the basic principles of nuclear physics, including atomic and nuclear structure, radioactivity, and nuclear reactions. Comprehend the principles of neutron behavior and interactions, including neutron diffusion and moderation.
2	Reactor theory and radiation shielding	Learn the theoretical and practical aspects of nuclear reactor design and operation. Study different types of reactors, including their components, functioning, and safety mechanisms. Understand the principles of radiation protection, biological effects of radiation, and methods for radiation shielding. Learn to calculate and design shielding for various radiation sources.
3	Reactor design and safety analysis	Develop the ability to design nuclear reactors and perform safety analyses using industry-standard codes and tools.

		Understand the principles of reactor kinetics, control, and safety systems.
4	Proficiency in nuclear material selection	Learn about materials used in nuclear reactors, their properties, and their behavior under irradiation. Properties include radiation resistance, thermal properties, corrosion resistance, mechanical properties, fabrication capacities and availability
5	Instrument and measurement	Gain proficiency in using instrumentation for nuclear measurements and control systems. Learn to design and implement measurement systems for reactor monitoring and diagnostics.
6	Safety and risk management	Understand the principles of risk assessment and management in nuclear engineering. Learn to evaluate and mitigate risks associated with nuclear power plants and other nuclear technologies.
7	Ethical and professional conduct	Develop a strong sense of professional ethics, including responsibilities towards public safety and environmental protection. Understand the regulatory and legal framework governing the use of nuclear technology.

8. Course Outcomes (COs) and Mapping with POs/ PSOs

Course Outcomes (COs)

COs	Description
M23MTP235.1	Apply the acquired knowledge of nuclear energy to describe nuclear fuel cycle
M23MTP235.2	Infer the capacities of basic concepts of nuclear fuel manufacturing and spent fuel handling in harnessing energy from nuclear resources
M23MTP235.3	Classify various types of nuclear reactors based on their operations
M23MTP235.4	Assess the functionality of thermal reactor
M23MTP235.5	Analyze the thermal hydraulics of nuclear reactors

CO-PO-PSO Mapping

COs/POs	PO1	PO2	PO3
M23MTP235.1	**3**		
M23MTP235.2			**3**
M23MTP235.3			**3**
M23MTP235.4			**3**
M23MTP235.5			**3**

9. Assessment Plan

Continuous Internal Evaluation (CIE)

	CO1	CO2	CO3	CO4	CO5	**Total**
Module 1	**20**					**20**
Module 2		**20**				**20**
Module 3			**20**			**20**
Module 4				**20**		**20**
Module 5					**20**	**20**
Total	**20**	**20**	**20**	**20**	**20**	**100**

Semester End Examination (SEE)

	CO1	CO2	CO3	CO4	CO5	**Total**
Module 1	**20**					**20**
Module 2		**20**				**20**
Module 3			**20**			**20**
Module 4				**20**		**20**
Module 5					**20**	**20**
Total	**20**	**20**	**20**	**20**	**20**	**100**

Conditions for SEE Paper Setting:
Each module of SEE question paper should be allocated with questions for 20% of the total SEE marks

10. Future with this Subject

The "Nuclear Engineering in power generation" course included in the 1st year of study in M.Tech program for Thermal Power Engineering concretes the fundamentals of nuclear energy resources availability and its utilization in generation of power. The future of nuclear engineering is poised for significant evolution and innovation, driven by the need for sustainable and clean energy, advancements in technology, and addressing global challenges such as climate change and energy security. Here are key areas where nuclear engineering is expected to develop:

- Advanced Nuclear Reactors
    - Small Modular Reactors (SMRs): SMRs are designed to be more cost-effective, flexible, and safer than traditional large reactors. They can be deployed in remote locations and integrated with renewable energy sources.
    - Generation IV Reactors: These reactors promise enhanced safety, efficiency, and sustainability
- Nuclear Fusion
    - Fusion Research: Significant investments in fusion research, with projects like ITER (International Thermonuclear Experimental Reactor) aiming to demonstrate the feasibility of fusion as a practical energy source.
    - Private Sector Innovations: Companies like Commonwealth Fusion Systems and TAE Technologies are making strides toward commercializing fusion technology.
- Safety and Waste Management
    - Enhanced Safety Systems: Development of passive safety systems that rely on natural physical laws rather than active controls to ensure reactor safety.
    - Spent Fuel Recycling: Advances in fuel reprocessing to reduce the volume of high-level waste and reclaim valuable materials.
    - Deep Geological Repositories: Establishment of secure, long-term storage solutions for high-level nuclear waste.
- Digital and AI Integration
    - Digital Twins: Virtual models of reactors that simulate their physical counterparts in real-time, allowing for predictive maintenance and optimization.
    - AI and Machine Learning: Enhancing reactor operation, safety, and efficiency through advanced data analytics and automation.
- Nuclear Medicine and Industrial Applications
    - Medical Isotopes: Increasing production and application of radioisotopes for cancer treatment, medical imaging, and diagnostics.
    - Industrial Uses: Utilization of nuclear technology in areas such as material testing, food preservation, and space exploration.
- Regulatory and Policy Developments
    - Streamlined Regulations: Efforts to simplify and harmonize regulatory frameworks to encourage innovation while maintaining safety standards.
    - Public Acceptance and Education: Initiatives to improve public understanding and acceptance of nuclear technology through education and transparent communication.
- Climate Change Mitigation
    - Low-Carbon Energy Source: Expansion of nuclear power as a critical component of the global strategy to reduce carbon emissions and combat climate change.
    - Hybrid Energy Systems: Integration of nuclear power with renewable energy sources to provide reliable, low-carbon energy.
- Global Energy Security
    - Energy Independence: Use of nuclear power to reduce dependence on fossil fuels and enhance national energy security.
    - International Collaboration: Strengthening global partnerships for nuclear research, safety standards, and non-proliferation efforts.
- Economic Factors
    - Cost Competitiveness: Reducing the costs of nuclear power through modular construction, improved supply chains, and economies of scale.
    - Investment in R&D: Continued investment in research and development to drive innovation and reduce the costs of new technologies.

2nd Semester	Professional Elective Course (PE) REFRIGERATION AND AIR CONDITIONING	M23MTP241

1. Prerequisites

S/L	Proficiency	Prerequisites
1.	Engineering Thermodynamics	Solid foundation in engineering thermodynamics, including first and second laws, property relations, and cycle analysis.
2.	Heat Transfer	Familiarity with heat transfer fundamentals (conduction, convection, radiation) and their application in building envelope heat gain calculations.
3.	Fluid Mechanics	Basic understanding of fluid mechanics principles (fluid properties, fluid flow regimes) applied to airflow in ducts and evaporator/condenser performance.
4.	System Controls	Knowledge of basic control systems concepts (sensors, actuators, feedback loops) relevant to air conditioning system temperature, humidity, and airflow control.
5.	Building Science	Introductory understanding of building construction, thermal insulation, and factors influencing indoor air quality (ventilation, filtration).

2. Competencies

S/L	Competency	KSA Description
1.	Analyze and optimize vapor compression refrigeration systems, considering ideal and real cycle performance, component selection, and control strategies.	**Knowledge:** Understand the principles of the vapor compression refrigeration cycle and factors affecting its Coefficient of Performance (COP). Recognize the functions and characteristics of key components in a vapor compression system (compressors, evaporators, condensers, expansion devices). **Skills:** Apply thermodynamic principles to analyze real vapor compression cycles, considering pressure drops, heat transfer inefficiencies, and component performance characteristics. Select appropriate compressor types, evaporators, condensers, and expansion devices based on application needs and implement control strategies to optimize system performance under varying load conditions. **Attitudes:** Develop a mindset focused on maximizing the Coefficient of Performance (COP) of refrigeration systems, considering both theoretical and practical limitations. Embrace a holistic approach to system optimization, recognizing the interconnectedness of components and their impact on overall performance.
2.	Select and utilize appropriate refrigerants and refrigeration systems for sustainable and efficient cooling applications.	**Knowledge:** Understand the key properties of refrigerants (chemical, thermodynamic, environmental) and their impact on system performance and environmental impact. Recognize various refrigeration cycle options (vapor compression, absorption, thermoelectric, air cycle) and their suitability for different applications. **Skills:** Select environmentally friendly refrigerants considering factors like efficiency, compatibility with system components, and adherence to environmental regulations (Montreal/Kyoto protocols). Apply knowledge of different refrigeration systems to select the most appropriate option for a specific application and utilize tools (evacuation, charging, and recovery) for proper system maintenance. **Attitudes:** Promote the use of environmentally friendly refrigerants and responsible disposal practices to minimize environmental impact. Embrace advancements in refrigeration technology, considering new refrigerants and system options for sustainable cooling solutions.
3.	Analyze and design air	**Knowledge:** Understand psychrometric properties (dry bulb temperature, humidity)and

	conditioning systems for various comfort and process applications using psychrometric principles	analyze various air conditioning processes (heating, cooling, humidification, dehumidification) using the psychrometric chart. Recognize the key considerations for designing summer and winter air conditioning systems, including sensible heat ratio (RSHF), bypass factor, and ventilation air requirements. **Skills:** Apply psychrometric principles to select and design air conditioning systems that meet comfort or process cooling needs, considering factors like latent and sensible heat loads and ventilation requirements. Analyze air conditioning processes using the psychrometric chart to optimize system performance for different applications (low vs. high latent heat loads). **Attitudes:** Strive for a balanced approach that prioritizes occupant comfort while maintaining energy efficiency in air conditioning system design. Embrace the need to adapt air conditioning system designs based on specific applications and stay informed about advancements in psychrometric technologies.
4.	Estimate cooling loads and design air conditioning control systems to maintain desired temperature, humidity, and airflow conditions.	**Knowledge:** Understand how heat transfer through solar radiation, conduction through walls and roofs, and heat gain through glasses contribute to cooling load. Recognize the key parameters for air conditioning control - temperature, humidity, and airflow. **Skills:** Apply knowledge of heat transfer mechanisms to estimate the total cooling load for a building space. Design and select appropriate air conditioning control systems (temperature, humidity, airflow) to maintain desired comfort conditions. **Attitudes:** Emphasize energy-efficient control strategies that minimize cooling load and system operation costs. Strive to optimize control systems for occupant comfort while maintaining energy efficiency.
5.	Design and optimize air distribution systems for efficient and effective delivery of conditioned air	**Knowledge:** Understand concepts like static and dynamic pressure losses in ducts and their impact on airflow distribution. Recognize different duct design methods (equal friction, friction method) and the importance of balancing airflow for optimal performance. **Skills:** Apply knowledge of pressure losses and duct design methods to design efficient air distribution systems that meet specific airflow requirements for a space. Select appropriate fans and fan arrangements (variable air volume systems) and integrate thermal insulation for optimal system performance and energy efficiency. **Attitudes:** Prioritize maintaining good indoor air quality by considering factors like air filtration and proper system maintenance. Emphasize the importance of balancing air distribution systems to ensure efficient delivery of conditioned air and minimize energy consumption.

3. Syllabus

Refrigeration and Air Conditioning SEMESTER – II			
Course Code	**M23MPT241**	CIE Marks	**50**
Teaching Hours/Week (L:P:SDA)	**(2:0:2)**	SEE Marks	**50**
Total Number of Lecture Hours	**40 hours**	Total Marks	**100**
Credits	**03**	Exam Hours	**03**

Course objectives:

- To provide the sufficient knowledge of concept, applications, importance of refrigeration.
- To familiarize the students about the refrigeration processes and component design.
- To provide the understanding of the industrial applications of refrigeration.

Module -1
Refrigeration cycles – analysis: Development of Vapor Compression Refrigeration Cycle from Reverse Carnot Cycle- conditions for high COP-deviations from ideal vapor compression cycle, Multi pressure Systems, Cascade Systems-Analysis. Main system components: Compressor- Types, performance, Characteristics of Reciprocating Compressors, Capacity Control, Types of Evaporators & Condensers and their functional aspects, Expansion Devices and their Behavior with fluctuating load
Module -2
Refrigerants: Classification of Refrigerants, Refrigerant properties, Oil Compatibility, Environmental Impact-Montreal/ Kyoto protocols-Eco Friendly Refrigerants. Different Types of Refrigeration Tools, Evacuation and Charging Unit, Recovery and Recycling Unit, Vacuum Pumps. Other refrigeration cycles: Vapor Absorption Systems-Aqua Ammonia & LiBr Systems, Steam Jet Refrigeration Thermo Electric Refrigeration, Air Refrigeration cycles
Module -3
Psychrometry: Moist Air properties, use of Psychrometric Chart, Various Psychrometric processes, Air Washer, Adiabatic Saturation. Summer and winter air conditioning: Air conditioning processes- RSHF, summer Air conditioning, Winter Air conditioning, and Bypass Factor. Applications with specified ventilation air quantity- Use of ERSHF, Application with low latent heat loads and high latent heat loads
Module -4
Load estimation & air conditioning control: Solar Radiation-Heat Gain through Glasses, Heat transfer through roofs and walls, Total Cooling Load Estimation. Controls of Temperature, Humidity and Airflow.
Module -5
Air distribution: Flow through Ducts, Static & Dynamic Losses, Air outlets, Duct Design–Equal, Friction Method, Duct Balancing, Indoor Air Quality, Thermal Insulation, Fans & Duct System Characteristics, Fan Arrangement Variable Air Volume systems, Air Handling Units and Fan Coil units. Central air condition systems.

Suggested Learning Resources:

Books

Textbook

1. Roy J. Dossat, *Principles of Refrigeration*, Wiley Limited 2002.
2. Arora C.P., *Refrigeration and Air-conditioning*, 3rdedition, Tata McGraw –Hill, New Delhi 2008.
3. Stoecker W.F., and Jones J.W., *Refrigeration and Air-conditioning*, 2nd edition McGraw - Hill, New Delhi.
4. Data Books: *Refrigerant and Psychrometric Properties (Tables & Charts) SI Units*, Mathur M.L. & Mehta F.S., Jain Brothers. 2010.

Reference Books

1. *Principles and Refrigeration*- Goshnay W.B., Cambridge, University Press, 1985.
2. *Solid state electronic controls for HVACR*'-Langley, Billy C., _Prentice-Hall 1986.
3. *Handbook of Air Conditioning Systems design*- Carrier Air Conditioning Co., McGraw Hill,
4. *Refrigeration and Air Conditioning (3/e)* - Langley Billy C., Engie wood Cliffs (N.J) PHI.
5. *Fundamentals and equipment*- 4 volumes-ASHRAE Inc. 2005.
6. *Air Conditioning Engineering*-Jones, Edward Amold pub. 2001.

Web links and Video Lectures (e-Resources):

- ***https://archive.nptel.ac.in/courses/112/107/112107208/***
- ***https://archive.nptel.ac.in/courses/112/105/112105128/***
- ***https://archive.nptel.ac.in/courses/112/105/112105129/***
- ***https://drive.google.com/file/d/1sNh-s8Nk4S_tWvOXQJLobbZJrLwbEuLi/view***

4. Syllabus Timeline

S/L	Syllabus Timeline	Description
1	Week 1-2: **Refrigeration Cycles**	Introduction to refrigeration cycles (Vapor Compression, Reverse Carnot Cycle). Vapor Compression Refrigeration Cycle analysis; Components: Compressors, Evaporators, Condensers, Expansion Devices
2	Week 3-4: **Refrigerants and Other Refrigeration Cycles**	Refrigerants: Classification, properties, environmental impact. Other refrigeration cycles (Vapor Absorption, Steam Jet, Thermo Electric, Air Refrigeration)
3	Week 5-6: **Psychrometry and Air Conditioning**	Psychrometry: Moist air properties, Psychrometric chart, Psychrometric processes. Summer and winter air conditioning: Processes, RSHF, Bypass Factor
4	Week 7-8:	Load estimation: Solar radiation, Heat transfer through roofs and walls.

	Load Estimation & Air Conditioning Control	Air conditioning control: Temperature, Humidity, Airflow controls
5	Week 9-10: **Air Distribution and Systems Design**	Air distribution: Flow through ducts, Static & Dynamic losses, Air outlets. Duct design: Equal friction method, Duct balancing, Indoor Air Quality, Thermal insulation
6	Week 11-12: **Application and Review**	Fans & Duct system characteristics, Variable Air Volume systems, Air Handling Units, Fan Coil units Review, Case studies, Assignments, Preparation for assessments

5. Teaching-Learning Process Strategies

S/L	TLP Strategies:	Description
1	Lecture Method	Utilize various teaching methods within the lecture format to reinforce competencies.
2	Collaborative Learning	Encourage collaborative learning for improved competency application.
3	Digital Learning	Utilize digital tools and resources to enhance learning experiences and accessibility. Explore online simulations of refrigerant properties and their environmental impacts. Integrate virtual tours of HVAC systems and interactive modules for understanding fan and duct system characteristics.
4	Flipped Class Technique	Utilize a flipped class approach, providing materials before class to facilitate deeper understanding of competencies
5	Case-Based Learning	Apply theoretical knowledge to real-world scenarios, fostering critical thinking and problem-solving skills. Present case studies on designing air conditioning systems for different climatic conditions. Analyze case scenarios of controlling temperature and humidity in various settings.

6. Assessment Details (both CIE and SEE)

Continuous Internal Evaluation:

Components		Number	Weightage	Max. Marks	Min. Marks
(i)	Internal Assessment-Tests (A)	2	50%	25	10
(ii)	Assignments/Quiz/Activity (B)	2	50%	25	10
	Total Marks			**50**	**20**

Semester-End Examination

1. The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
2. The question paper will have ten full questions carrying equal marks.
3. Each full question is for 20 marks. There will be two full questions (with a maximum of four sub questions) from each module.
4. Each full question will have a sub-question covering all the topics under a module.
5. The students will have to answer five full questions, selecting one full question from each module.

7. Learning Objectives

S/L	Learning Objectives	Description
1	Understanding of Refrigeration Cycles and Systems:	Explain the principles and components of vapor compression refrigeration cycles. Analyze deviations from ideal cycles and their impact on system performance. Compare and contrast multi-pressure and cascade refrigeration systems.
2	Knowledge of Refrigerants and Environmental Impact:	Classify refrigerants based on their properties and applications. Evaluate the environmental impact of refrigerants in compliance with international protocols (Montreal Protocol, Kyoto Protocol). Recommend eco-friendly refrigerants considering performance and environmental criteria.

3	Proficiency in Psychrometry and Air Conditioning Principles:	Apply psychrometric principles to analyze moist air properties and processes. Design air conditioning systems for summer and winter conditions, considering factors like RSHF, ERSHF, and bypass factor. Calculate cooling loads based on solar radiation, heat gain through walls
4	Skills in Air Distribution and System Design:	Design duct systems using methods like equal friction and consider static and dynamic losses. Select appropriate air handling units, fan coil units, and ventilation strategies based on building requirements. Evaluate indoor air quality concerns and recommend solutions for thermal insulation and airflow management.
5	Application of Control Systems and Load Estimation:	Implement temperature, humidity, and airflow controls in air conditioning systems. Estimate total cooling loads for various building types and environmental conditions. Demonstrate proficiency in using tools like evacuation units, recovery systems, and vacuum pumps in refrigeration operations.
6	Critical Thinking and Problem-Solving:	Analyze and solve complex problems related to refrigeration and air conditioning systems. Propose innovative solutions to improve energy efficiency and environmental sustainability in HVAC systems

8. Course Outcomes (COs) and Mapping with POs/ PSOs

Course Outcomes (COs)

COs	Description
M23MPT241.1	Apply concepts of artificial cooling to grasp concepts of refrigeration and air-conditioning process and systems.
M23MPT241.2	Illustrate the theoretical principles to simple, complex vapour compression and vapour absorption refrigeration systems.
M23MPT241.3	Interpret the conventional and alternate refrigerants and their impact on environment.
M23MPT241.4	Analyze the heat load calculation to design the air-conditioning systems..
M23MPT241.5	Assess the concepts to design air distribution systems

CO-PO-PSO Mapping

COs/POs	PO1	PO2	PO3
M23MPT241.1	3		
M23MPT241.2			3
M23MPT241.3			3
M23MPT241.4			3
M23MPT241.5			3

9. Assessment Plan

Continuous Internal Evaluation (CIE)

	CO1	CO2	CO3	CO4	CO5	Total
Module 1	20					20
Module 2		20				20
Module 3			20			20
Module 4				20		20
Module 5					20	20
Total	20	20	20	20	20	100

Semester End Examination (SEE)

	CO1	CO2	CO3	CO4	CO5	Total
Module 1	20					20
Module 2		20				20
Module 3			20			20
Module 4				20		20
Module 5					20	20
Total	20	20	20	20	20	100

10. Future with this Subject

After completing a thorough study of the subject of refrigeration cycles, air conditioning systems, and related modules, students will be well-prepared to enter various sectors that require expertise in HVAC&R (Heating, Ventilation, Air Conditioning, and Refrigeration) engineering and technology. Here's what the future might hold for them:

1. **Career Opportunities**: Graduates can pursue careers in design, installation, operation, and maintenance of refrigeration and air conditioning systems in various industries such as HVAC companies, manufacturing plants, commercial buildings, hospitals, data centers, and residential complexes.
2. **Specialization**: They may choose to specialize in areas such as energy-efficient systems, sustainable cooling technologies, refrigerant management (especially with the shift towards eco-friendly refrigerants), or advanced control systems for HVAC&R equipment.
3. **Industry Demand**: With increasing awareness of energy efficiency and environmental impact, there is a growing demand for professionals who can design and implement systems that comply with international protocols (like Montreal and Kyoto protocols) and use eco-friendly refrigerants.
4. **Technological Advancements**: As technology evolves, there will be opportunities to work with advanced refrigeration cycles (including multi-pressure and cascade systems), vapor absorption systems, and even emerging technologies like thermo-electric refrigeration and steam jet refrigeration.
5. **Regulatory Compliance**: Understanding of regulations and standards related to refrigerants, environmental impact, and energy efficiency will be crucial. Graduates may find roles in regulatory compliance, ensuring that systems meet current environmental and safety standards.
6. **Innovation and Research**: There are opportunities for research and development in improving system efficiency, exploring new refrigerants, enhancing heat transfer technologies, and integrating renewable energy sources into HVAC&R systems.

2nd Semester	**Professional Elective Course (PE)** **HYDROGEN AND FUEL CELL TECHNOLOGIES**	**M23MTP242**

1. Prerequisites

S/L	Proficiency	Prerequisites
1.	Basic understanding of science	This includes foundational knowledge of chemistry (particularly understanding of chemical reactions and energy transfer), physics (especially concepts of thermodynamics and electrochemistry), and mathematics (algebra and basic calculus will be helpful for understanding performance models)
2.	Introduction to engineering concepts	Familiarity with basic engineering principles, such as thermodynamics, fluid mechanics, and materials science, will be beneficial in understanding fuel cell systems, component interactions, and optimization strategies.
3.	Elementary understanding of electricity	A basic grasp of electrical concepts like voltage, current, power, and efficiency is essential for comprehending fuel cell operation and power generation.
4.	Interest in sustainable energy	A general interest in clean energy technologies and their role in a sustainable future can motivate deeper exploration of hydrogen and fuel cell technologies.
5.	Critical thinking and problem-solving skills	The ability to analyze information, identify challenges, and evaluate solutions is crucial throughout the course.

2. Competencies

S/L	Competency	KSA Description
1.	Understand the infrastructure required for distributing hydrogen in an energy system	**Knowledge:** Different methods for hydrogen transportation: pipelines, trucks, and alternative delivery systems. Storage options for hydrogen, including stationary bulk storage. **Skills:** Analyze the suitability of different hydrogen distribution methods for various applications. Identify the supporting technologies needed for a functional hydrogen infrastructure (e.g., compressors, dispensers). **Attitudes:** Appreciate the importance of safety considerations in hydrogen infrastructure development. Be open to exploring and evaluating new hydrogen distribution technologies.
2.	Understand the principles, applications, and limitations of fuel cell technology.	**Knowledge:** Explain the basic structure and function of a fuel cell, including the critical functions of its components (anode, cathode, and electrolyte). Differentiate between various types of fuel cells (PEM, SOFC, etc.) based on their operating principles and characteristics. **Skills:** Analyze the advantages and disadvantages of fuel cells compared to other energy conversion technologies (e.g., internal combustion engines). Identify potential applications for fuel cells in different sectors (transportation, portable power, etc.). **Attitudes:** Appreciate the ongoing research and development efforts to improve fuel cell efficiency and cost. Recognize the importance of safety considerations in fuel cell design and operation.
3.	Analyze factors affecting fuel cell performance.	**Knowledge:** Understand the role of Gibbs Free Energy and Nernst Potential in determining the theoretical maximum voltage of a fuel cell. Explain the difference between ideal and actual fuel cell performance and the factors that contribute to performance losses. **Skills:** Identify key performance variables of a fuel cell (e.g., temperature, pressure, reactant flow rates).

		Interpret the impact of these variables on fuel cell efficiency and power output. **Attitudes:** Appreciate the value of using data collected on performance variables to optimize fuel cell design and operation. Be curious about understanding the scientific underpinnings of fuel cell performance.
4.	Integrate various components to design and optimize a functional fuel cell system.	**Knowledge:** Understand the different processes involved in a fuel cell system (fuel processing, power conditioning, system optimization). Identify the functions of key components within a fuel cell system (e.g., fuel processor, power converter). **Skills:** Analyze the interactions between different components within a fuel cell system. Evaluate strategies for optimizing fuel cell system performance and efficiency. **Attitudes:** Appreciate the importance of considering the entire fuel cell system, not just individual components, when designing and optimizing performance. Be open to exploring new technologies and approaches for integrating various components within a fuel cell system to achieve optimal efficiency and functionality.
5.	Evaluate the suitability of fuel cell technology for diverse applications.	**Knowledge:** Understand the potential applications of fuel cells across various sectors (transportation, power generation, portable power). Recognize the unique requirements and challenges associated with implementing fuel cells in different applications (e.g., range requirements for vehicles, size constraints for portable systems). **Skills:** Analyze the technical and economic feasibility of using fuel cells in specific applications. Identify potential benefits and drawbacks of fuel cell technology compared to existing solutions. **Attitudes:** Be enthusiastic about the potential of fuel cells to revolutionize various sectors and contribute to a more sustainable future. Recognize the importance of tailoring fuel cell technology to meet the specific needs and constraints of different applications.

3. Syllabus

Hydrogen and Fuel Cell Technologies
SEMESTER – II

Course Code	**M23MPT242**	CIE Marks	**50**
Number of Lecture Hours/Week(L: T: P: S)	**(2:0:2:0)**	SEE Marks	**50**
Total Number of Lecture Hours	**40 hours**	Total Marks	**100**
Credits	**03**	Exam Hours	**03**

Course objectives:

- Provide thorough understanding of performance characteristics of fuel cell power plant and its components.
- Outline the performance and design characteristics and operating issues for various fuel cells.
- Discuss the design philosophy and challenges to make this power plant economically feasible.
- The design and analysis emphasis will be on the thermodynamics and electrochemistry. Thus, at the successful end of the course, the students will have sufficient knowledge for working in a fuel cell industry or R&D organization

Module -1

Hydrogen: Production of hydrogen, Hydrogen conversion overview, Hydrogen storage options, Hydrogen transmission, Problems.
Hydrogen Distribution Infrastructure for an Energy System: Hydrogen Transport by Gaseous Pipelines, Hydrogen Transport by Road, Alternative Hydrogen Delivery Systems, Stationary Bulk Storage of Hydrogen, Supporting Technologies, Hydrogen Fueling Stations.

Module -2

Fuel Cells Technology Overview: Basic Structure, Critical Functions of Cell Components, Cell

Stacking, Fuel Cell Systems, Fuel Cell Types, Characteristics, Advantages/Disadvantages, Applications, Demonstrations, and Status. **Fuel cells:** Basic concepts, Molten carbonate cells, Solid oxide cells, Acid and alkaline cells, Proton exchange membrane cells, Direct methanol and other non-hydrogen cells, Biofuel cells, Problems
Module -3
Fuel Cell Performance: The Role of Gibbs Free Energy and Nernst Potential Ideal Performance Cell Energy Balance Cell Efficiency Actual Performance Fuel Cell Performance Variables Mathematical Models.
Module -4
Fuel Cell Systems: System Processes, Fuel Processing, Power Conditioning, System Optimization, Fuel Cell System Designs, Fuel Cell Networks, Hybrids, Fuel Cell Auxiliary Power Systems
Module -5
Fuel Cell Applications: Passenger cars, Bus, lorry, Ships, trains and airplanes, Power plants including stand-alone systems, Building-integrated systems, Portable and other small-scale systems, Problems and discussion topics
Suggested Learning Resources: **Books** **Textbook** 1. *Hydrogen and Fuel Cells: Fundamentals*, *Technologies and Applications*; Detlef Stolten 2. *Hydrogen and Fuel Cell Technologies and Market Perspectives*; Johannes Töpler, Jochen Lehmann; Springer Berlin, Heidelberg 3. *Hydrogen and Fuel Cells: Emerging Technologies and Applications;* Inde Sorensen, Bent,2nd Edition - Elsevie **Reference Books** 1. M.M. MENCH, *Fuel Cell Engines*, Wiley, 2008. 2. M. T. M. Koper (ed.), *Fuel Cell Catalysis*, Wiley, 2009. 3. J. O'M. Bockris, A. K. N. Reddy, *Modern Electrochemistry*, Springer 1998. 4. Larminie J., Dick A., *Fuel Cell Systems Explained*, 2nd Ed. Wiley, 2003
Web links and Video Lectures (e-Resources): *https://archive.nptel.ac.in/courses/103/101/103101215/* *https://archive.nptel.ac.in/courses/103/102/103102015/*

4. Syllabus Timeline

S/L	Syllabus Timeline	Description
1	Week 1-2: Hydrogen Fundamentals	Introduction to hydrogen as an energy carrier, Production methods: steam methane reforming, electrolysis, biomass conversion. Overview of hydrogen conversion technologies. Hydrogen storage and transmission Storage options: liquefaction, compression, solid-state storage, Transmission: gaseous pipelines, road transport, alternative delivery systems.
2	Week 3-4: Hydrogen Distribution Infrastructure	Infrastructure for hydrogen transport and storage, Gaseous pipeline transportation, Road transport and fueling stations Stationary bulk storage and supporting technologies, Bulk storage methods and safety considerations, Hydrogen fueling station design and operation
3	Week 5-6: Fuel Cells Technology Overview	Introduction to fuel cells, Basic structure and functioning of fuel cells, Overview of different fuel cell types: PEMFC, SOFC, MCFC, AFC, etc. Characteristics, advantages, disadvantages, and applications of fuel cells, Applications in transportation, stationary power, portable devices, Demonstrations and current status of fuel cell technology.
4	Week 7-8: Fuel Cell Performance and Systems	Fuel cell performance fundamentals Gibbs free energy and Nernst potential, Ideal vs. actual performance, energy balance, efficiency Fuel cell system components and optimization Fuel processing: reforming, purification , Power conditioning, system design, optimization strategies
5	Week 9-10: Fuel Cell Applications	Applications in transportation Passenger cars, buses, trucks, ships, trains, airplanes. Applications in stationary power and other sectors Power plants: standalone and integrated systems , Building-integrated systems, portable devices, small-scale applications
6	Week 11-12: Case Studies, Problems, and	Challenges and success stories in hydrogen and fuel cell applications Discussion on current issues and future trends Review, problems, and final assessment Recap of key concepts and topics Discussion on unresolved problems, future directions in

	Discussion	hydrogen and fuel cell technology

5. Teaching-Learning Process Strategies

S/L	TLP Strategies:	Description
1	Lecture Method	Utilize various teaching methods within the lecture format to reinforce competencies.
2	Collaborative Learning	Assign group projects on topics such as designing a hydrogen fueling station, evaluating the feasibility of hydrogen-powered transportation, or optimizing fuel cell systems.
3	Visual Aids	Utilize diagrams, charts, and multimedia presentations to illustrate complex processes and systems.
4	Flipped Class Technique	Utilize a flipped class approach, providing materials before class to facilitate deeper understanding of competencies
5	Case Studies and Examples	Present real-world applications in transportation and energy sectors. Discuss challenges and solutions based on course content.
6	Hands-On Activities	Conduct lab sessions for observing hydrogen production methods and fuel cell operation. Demonstrate components and system functionalities.

6. Assessment Details (both CIE and SEE)

Continuous Internal Evaluation:

Components		Number	Weightage	Max. Marks	Min. Marks
(i)	Internal Assessment-Tests (A)	2	50%	25	10
(ii)	Assignments/Quiz/Activity (B)	2	50%	25	10
	Total Marks			**50**	**20**

Final CIE Marks = (A) + (B)

Semester-End Examination

1. The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
2. The question paper will have ten full questions carrying equal marks.
3. Each full question is for 20 marks. There will be two full questions (with a maximum of four sub questions) from each module.
4. Each full question will have a sub-question covering all the topics under a module.
5. The students will have to answer five full questions, selecting one full question from each module.

7. Learning Objectives

S/L	Learning Objectives	Description
1	Understanding of Hydrogen Energy Systems	Explain the different methods for hydrogen production. Describe the process of hydrogen conversion from its source to usable energy. Analyze various hydrogen storage options and their suitability for different applications. Evaluate the challenges and opportunities associated with hydrogen transmission and distribution infrastructure.
2	Knowledge of Fuel Cell Technology	Describe the basic structure and function of a fuel cell. Explain the role of each component in a fuel cell stack. Differentiate between various types of fuel cells based on their operating principles, characteristics, advantages, and disadvantages. Analyze the applications of fuel cell technology in different sectors.
3	Fuel Cell Performance	Apply the concepts of Gibbs Free Energy and Nernst Potential to predict ideal fuel cell performance. Analyze the energy balance within a fuel cell system. Calculate the efficiency of fuel cells and identify factors affecting their performance. Utilize mathematical models to understand the behavior of fuel cells under different operating conditions.
4	Fuel Cell Systems	Explain the various processes involved in a complete fuel cell system, including fuel processing, power conditioning, and system optimization. Analyze different fuel cell system designs and their suitability for various applications. Evaluate the potential of fuel cell networks and hybrid systems. Understand the role of

		auxiliary power systems in fuel cell application
5	Fuel Cell Applications	Analyze the feasibility of using fuel cells in various transportation applications, including passenger cars, buses, trucks, ships, trains, and airplanes. Evaluate the potential of fuel cells for power generation, including standalone systems, building-integrated systems, and portable applications. Identify challenges and opportunities associated with implementing fuel cell technology across different sectors.

8. Course Outcomes (COs) and Mapping with POs/ PSOs

Course Outcomes (COs)

COs	Description
M23MPT242.1	Interpret the principles, production methods, storage options, transmission systems, and distribution infrastructure of hydrogen technologies.
M23MPT242.2	Analyze the structure, components, and functioning of different types of fuel cells, including proton exchange membrane, solid oxide, molten carbonate, and others.
M23MPT242.3	Identify, formulate, and solve problems related to fuel cell technology keeping in mind economic viability
M23MPT242.4	Asses the techniques, skills, and modern engineering tools necessary for design and analysis of innovative fuel cell systems..
M23MPT242.5	Analyze the impact of fuel cell technology in a global and societal context and develop enough skills to design systems or components of fuel cells

CO-PO Mapping

COs/POs	PO1	PO2	PO3
M23MPT242.1	3		
M23MPT242.2	3		
M23MPT242.3	3		
M23MPT242.4	3		
M23MPT242.5	3		

9. Assessment Plan

Continuous Internal Evaluation (CIE)

	CO1	CO2	CO3	CO4	CO5	Total
Module 1	20					20
Module 2		20				20
Module 3			20			20
Module 4				20		20
Module 5					20	20
Total	20	20	20	20	20	100

Semester End Examination (SEE)

	CO1	CO2	CO3	CO4	CO5	Total
Module 1	20					20
Module 2		20				20
Module 3			20			20
Module 4				20		20
Module 5					20	20
Total	20	20	20	20	20	100

10. Future with this Subject

The field of hydrogen energy and fuel cell technology is poised for significant growth as the world seeks sustainable and clean energy solutions. Here's a glimpse into what the future holds for students who delve into this subject:

Focus on Sustainability:

- **Green Hydrogen Production:** Widespread adoption of renewable energy sources like solar and wind will fuel the production of clean, "green" hydrogen through electrolysis.
- **Carbon Capture and Storage:** Technologies for capturing carbon emissions from industrial processes and storing them safely will become crucial for ensuring the sustainability of hydrogen production from fossil fuels (blue hydrogen).

Technological Advancements:

- **Solid Oxide Fuel Cells (SOFCs):** SOFCs are expected to gain traction due to their high efficiency and ability to operate on various fuels, including natural gas and biogas.
- **High-Temperature Electrolyzers:** These electrolyzers will enable more efficient hydrogen production from high-temperature heat sources like nuclear reactors or concentrated solar power.

Market Expansion and Infrastructure Development:

- **Hydrogen Economy:** Governments and industries will invest heavily in developing hydrogen refueling infrastructure for transportation applications.
- **Fuel Cell Vehicles:** Expect wider adoption of fuel cell electric vehicles (FCEVs) across various transportation sectors, from passenger cars to heavy-duty trucks.
- **Distributed Power Generation:** Fuel cells will play a growing role in providing clean and reliable power for homes, businesses, and remote communities.

2nd Semester	Professional Elective Course (PE) JET AND ROCKET PROPULSION SYSTEMS	M23MTP243

1. Prerequisites

S/L	Proficiency	Prerequisites
1	Fundamentals of jet propulsion	Understanding these fundamentals helps in appreciating the complexity and engineering involved in developing efficient and powerful jet propulsion systems.
2	Nozzle Theory and Characteristics Parameters	Understanding these parameters allows engineers to design and optimize nozzles for different applications, ensuring efficient propulsion and performance characteristics tailored to specific operational conditions.
3	Solid Propulsion System	Their design and operational characteristics are tailored to provide high thrust and operational flexibility in various aerospace scenarios.
4	heat of reaction and heat of formation	Heat of reaction and heat of formation are important thermodynamic concepts that relate to the energy involved in chemical reactions and the formation of chemical compounds.
5	Effect of binder on propellant properties	The selection and formulation of binders in solid propellants are critical to achieving desired performance, safety, and reliability in rocketry and missile applications

2. Competencies

S/L	Competency	KSA Description
1	Principles Of Jet Propulsion And Rocketry	**Knowledge:** Jet propulsion and rocketry are both forms of reaction propulsion based on Newton's third law. Jet engines, such as turbojets and turbofans, operate by combusting fuel with air to produce high-velocity exhaust gases expelled through a nozzle, generating thrust for aircraft propulsion. **Skills:** Achieving proficiency in jet propulsion and rocketry requires a blend of theoretical knowledge, practical skills, and specific competencies. **Attitudes:** Specialized expertise in propulsion systems, and the ability to apply theoretical knowledge to practical applications effectively.
2	Turbo Jet Propulsion System	**Knowledge:** Understanding how air flows through the engine, including concepts like compression, combustion, and expansion. **Skills:** ability to design, maintain, or operate turbojet engines, which are a type of gas turbine engine used primarily in aircraft propulsion **Attitudes:** Having a proactive approach to identifying and resolving issues to ensure reliable engine performance.
3	Heat transfer Thermal Engineering considerations in solid rocket motor design	**Knowledge:** Ability to conduct thermal analysis using computational tools or analytical methods to predict temperature distribution, thermal gradients, and heat fluxes within the motor. **Skills:** Skills in conducting thermal testing and validation of motor components to ensure they meet thermal performance specifications. **Attitudes:** Mastering these aspects is crucial for developing reliable and efficient propulsion systems for aerospace and jet applications.
4	Performance Parameters of Solid propellant rocket	**Knowledge:** A solid propellant rocket utilizes a solid mixture of fuel and oxidizer to generate thrust through combustion, offering simplicity, reliability, and storability. **Skills:** Ability to formulate and understand the chemistry and composition of solid

		propellants, considering factors like burn rate, energetic performance, stability, and safety. **Attitudes:** Approaching problems with a solution-oriented mindset, actively seeking root causes, and implementing effective solutions to overcome obstacles.
5	Safety and Regulatory Compliance:	**Knowledge:** Knowledge of safety protocols and practices in handling hazardous materials, conducting tests, and operating propulsion systems. **Skills:** Flexibility to adapt to evolving regulatory landscapes, technological innovations, and organizational priorities in the aerospace sector. **Attitudes:** Attitudes are crucial for effectively managing safety and regulatory compliance in rocket and jet propulsion systems. Attitudes encompass the mindset, values, and approach that professionals in this field should cultivate

3. Syllabus

Jet and Rocket Propulsion Systems SEMESTER – II			
Course Code	**M23MTP243**	CIE Marks	**50**
Number of Lecture Hours/Week(L: T: P: S)	**(2:0:2)**	SEE Marks	**50**
Total Number of Lecture Hours	**40 hours Theory**	Total Marks	**100**
Credits	**03**	Exam Hours	**03**

Course objectives:

- To understand the concept of gas dynamics.
- To familiarize the students about the Jet and rocket propulsion and its whole thermodynamics analysis.
- To understand the applications of Jet propulsion.

Module -1	
Principles Of Jet Propulsion And Rocketry: Fundamentals of jet propulsion, Rockets, and air breathing jet engines – Classification – turbo jet, turbo fan, turbo prop, rocket (Solid and Liquid propellant rockets) and Ramjet engines. Nozzle Theory and Characteristics Parameters: Theory of one dimensional convergent – divergent nozzles – aerodynamic choking of nozzles and mass flow through a nozzle – nozzle exhaust velocity – thrust, thrust coefficient, Ac / At of a nozzle, Supersonic nozzle shape, non-adapted nozzles, summer field criteria, departure from simple analysis – characteristic parameters – 1) characteristic velocity, 2) specific impulse 3) total impulse 4) relationship between the characteristic parameters 5) nozzle efficiency, combustion efficiency and overall efficiency.	L1, L2, L3
Module -2	
Aero Thermo Chemistry Of The Combustion Products: Review of properties of mixture of gases – Gibbs – Dalton laws – Equivalent ratio, enthalpy changes in reactions, heat of reaction and heat of formation – calculation of adiabatic flame temperature and specific impulse – frozen and equilibrium flows. Solid Propulsion System: Solid propellants – classification, homogeneous and heterogeneous propellants, double base propellant compositions and manufacturing methods. Composite propellant oxidizers and binders. Effect of binder on propellant properties. Burning rate and burning rate laws, factors influencing the burning rate, methods of determining burning rates.	L1, L2, L3
Module -3	
Solid Propellant Rocket Engine: internal ballistics, equilibrium motor operation and equilibrium pressure to various parameters. Transient and pseudo equilibrium operation, end burning and burning grains, grain design. Rocket motor hardware design. Heat transfer Thermal Engineering considerations in solid rocket motor design. Ignition system, simple pyro devices. Liquid Rocket. Propulsion System: Liquid propellants – classification, Mono and Bi propellants, Cryogenic and storage propellants, and ignition delay of hypergolic propellants, physical and chemical characteristics of liquid propellant. Liquid propellant rocket engine – system layout, pump and pressure feed systems, feed system components. Design of combustion chamber, characteristic length, constructional features, and chamber wall stresses. Heat transfer and cooling aspects. Uncooled engines, injectors – various types, injection patterns, injector characteristics, and	L1, L2, L3

atomization and drop size distribution, propellant tank design.	
Module -4	
Turbo Jet Propulsion System: Gas turbine cycle analysis –layout of turbo jet engine. Turbo machinery- compressors and turbines, combustor, blade aerodynamics, engine off design performance analysis. Flight Performance: Forces acting on vehicle – Basic relations of motion – multistage vehicles.	L1, L2, L3
Module -5	
Ramjet And Integral Rocket Ramjet Propulsion system: Fuel rich solid propellants, gross thrust, gross thrust coefficient, combustion efficiency of ramjet engine, air intakes and their classification – critical, super critical and sub-critical operation of air intakes, engine intake matching, classification, and comparison of IIRR propulsion systems.	L1, L2, L3

Text Books:

1. Fundamentals of Aircraft and Rocket Propulsion; Ahmed F. El-Sayed; Springer-Verlag London 2016.
2. Fundamentals of Rocket Propulsion; D.P. Mishra; CRC Press Taylor & Francis Group2017.
3. Gas Turbines and Jet and Rocket Propulsion; Dr. M.L. Mathur and R.P. Sharma; Standard Publishers Distributors Edition 2014.

Reference Books:

- Rocket Propulsion Elements; George P. Sutton, Oscar Biblarz; Ninth Edition John Wiley & Sons, Inc., Hoboken, New Jersey 2017.
- Gas Turbines; V Ganesan ; 3rd Edition2017; McGraw Hill Education.

4. Syllabus Timeline

S/L	Syllabus Timeline	Description
1	Week 1-2: **Principles Of Jet Propulsion And Rocketry**	Fundamentals of jet propulsion, Rockets, and air breathing jet engines and its classification. Nozzle Theory and Characteristics Parameters. Departure from simple analysis – characteristic parameters Combustion efficiency and overall efficiency.
2	Week 3-4: **Aero Thermo Chemistry Of The Combustion Products**	Review of properties of mixture of gases. Calculation of adiabatic flame temperature and specific impulse. Solid Propulsion System Composite propellant oxidizers and binders. Effect of binder on propellant properties. Factors influencing the burning rate, methods of determining burning rates.
3	Week 5-6: **Solid Propellant Rocket Engine**	Internal ballistics Equilibrium motor operation and equilibrium pressure to various parameters. Transient and pseudo equilibrium operation Heat transfer Thermal Engineering considerations in solid rocket motor design and Liquid Rocket. Liquid propulsion systems.
4	Week 7-8: **Turbo Jet Propulsion System**	Gas turbine cycle analysis –layout of turbo jet engine. Turbo machinery- compressors and turbines, combustor, blade aerodynamics. Engine off design performance analysis. Flight Performance.
5	Week 9-10: **Ramjet And Integral Rocket Ramjet Propulsionsystem**	Fuel rich solid propellants. Combustion efficiency of ramjet engine. Air intakes and their classification Comparison of IIRR propulsion systems.
6	Week 11-12:	Apply learned concepts and competencies to real-world scenarios.

5. Teaching-Learning Process Strategies

S/L	TLP Strategies:	Description
1	Lecture Method	Utilize various teaching methods within the lecture format to reinforce competencies.
2	Video/Animation	Incorporate visual aids like videos/animations to enhance understanding of

		Verilog concepts.
3	Collaborative Learning	Encourage collaborative learning for improved competency application.
4	Higher Order Thinking (HOTS) Questions:	Pose HOTS questions to stimulate critical thinking related to each competency.
5	Problem-Based Learning (PBL)	Implement PBL to enhance analytical skills and practical application of competencies
6	Multiple Representations	Introduce topics in various representations to reinforce competencies
7	Real-World Application	Discuss practical applications to connect theoretical concepts with real-world competencies.
8	Flipped Class Technique	Utilize a flipped class approach, providing materials before class to facilitate deeper understanding of competencies

6. Assessment Details (both CIE and SEE)

CIE

Components		Number	Weightage	Max. Marks	Min. Marks
(i)	Internal Assessment-Tests (A)	2	50%	25	10
(ii)	Assignments/Quiz/Activity (B)	2	50%	25	10
	Total Marks			**50**	**20**

Final CIE Marks = (A) + (B)

SEE

5. Question paper pattern will be ten questions. Each question is set for 20marks. The medium of the question paper shall be English unless otherwise it is mentioned.
6. There shall be 2 question from each module, each of the two questions under a module (with a maximum of 3 sub questions), may have mix of topics under that module if necessary.
7. The students have to answer 5 full questions selecting one full question from each module.
8. Marks scored will be proportionally scaled down to 50 marks.

7. Learning Objectives

S/L	Learning Objectives	Description
1	Fundamentals of Propulsion	Students will understand the basic principles of jet and rocket propulsion and also differentiate between various types of propulsion systems
2	Fundamentals of Thermodynamic Cycles	Students will able to analyze the thermodynamic cycles used in jet and rocket engines, such as the Brayton cycle for jet engines and the thermodynamic principles governing rocket propulsion.
3	Fundamental knowledge on Engine Components	Students will identify and explain the function of key components in jet and rocket engines, including compressors, turbines, combustors, nozzles, and afterburners.
4	Aerodynamics of Propulsion	Students will understand the aerodynamic principles related to propulsion, including shock waves, expansion waves, and nozzle flow.
5	Fundamentals of combustion and Thermochemistry	Students will Analyze the combustion processes and thermochemistry involved in propulsion systems and also apply principles of chemical kinetics and thermodynamics to understand fuel-air mixing, combustion efficiency, and emissions.

8. Course Outcomes (COs) and Mapping with POs/ PSOs

Course Outcomes (COs)

COs	Description
M23MTP243.1	Understand the aero thermo chemistry of the combustion products.
M23MTP243.2	Apply knowledge of features and capabilities of chemical and non-chemical rocket propulsion systems.
M23MTP243.3	Apply the concepts to ramjet ant jet propulsion system.
M23MTP243.4	Calculate the specific impulse and mass flow for a rocket engine with thefluid

	considered as an ideal gas with constant specific heats.
M23MTP243.5	Estimate the specific impulse and mass flow for a rocket engine accountingfor chemical reaction and non-constant specific heats.

CO-PO-PSO Mapping

COs/POs	PO1	PO2	PO3
M23MTP243.1	3		
M23MTP243.2			3
M23MTP243.3			3
M23MTP243.4			3
M23MTP243.5	-	-	3

9. **Assessment Plan**

Continuous Internal Evaluation (CIE)

	CO1	CO2	CO3	CO4	CO5	**Total**
Module 1	**20**					**20**
Module 2		**20**				**20**
Module 3			**20**			**20**
Module 4				**20**		**20**
Module 5					**20**	**20**
Total	**20**	**20**	**20**	**20**	**20**	**100**

Semester End Examination (SEE)

	CO1	CO2	CO3	CO4	CO5	**Total**
Module 1	**20**					**20**
Module 2		**20**				**20**
Module 3			**20**			**20**
Module 4				**20**		**20**
Module 5					**20**	**20**
Total	**20**	**20**	**20**	**20**	**20**	**100**

Conditions for SEE Paper Setting:
Each module of SEE question paper should be allocated with questions for 20% of the total SEE marks

10. **Future with this Subject**

The future of the subject of jet and rocket propulsion systems is influenced by advancements in technology, environmental considerations, and evolving demands in aerospace applications. Here are some key trends and potential developments:

1. **Advancements in Propulsion Efficiency:** Continued research into increasing the efficiency of propulsion systems to reduce fuel consumption and increase performance.
2. **Environmental Considerations:** Emphasis on reducing emissions and developing eco-friendly propulsion technologies and Exploration of alternative fuels, such as biofuels, hydrogen, and synthetic fuels, to reduce the carbon footprint of propulsion systems.
3. **Hypersonic Propulsion:** Advances in hypersonic propulsion technologies, including scramjets and dual-mode ramjet/scramjets, for high-speed air travel and defense applications.
4. **Electric and Hybrid Propulsion:** Integration of electric and hybrid propulsion systems in aircraft to reduce dependency on fossil fuels and lower operational costs.
5. **Reusable Rocket Technologies:** Continued progress in reusable rocket technologies to reduce the cost of space access and Enhancements in rapid reusability, turnaround times, and reliability of reusable launch vehicles.
6. **Advanced Materials and Manufacturing:** Use of advanced materials, such as lightweight composites and high-temperature alloys, to improve the performance and durability of propulsion systems.
7. **Miniaturization and Micropropulsion:** Development of miniaturized propulsion systems for small satellites and CubeSats to enable more efficient and cost-effective space missions.
8. **Autonomous and AI-Driven Propulsion Systems:** Integration of artificial intelligence and machine learning to optimize propulsion system performance and maintenance.
9. **Research Opportunities:** Encourage research in cutting-edge propulsion technologies through funding and collaboration with industry and government agencies.

The future of jet and rocket propulsion systems is poised to be dynamic and transformative, driven by technological breakthroughs and a growing emphasis on sustainability and efficiency.

2nd Semester	Professional Elective Course (PE) COMPUTATIONAL METHODS IN HEAT TRANSFER AND FLUID	M23MTP244

1. Prerequisites

S/L	Proficiency	Prerequisites
1.	Fluid Mechanics and Heat Transfer Fundamentals	A strong foundation in fluid mechanics and heat transfer principles is essential. This includes understanding concepts like continuity, momentum, energy balance, boundary layers, conduction, convection, and radiation.
2.	Mathematics background	A solid grasp of calculus (including multivariable calculus), linear algebra, and ordinary differential equations is necessary. These will be used to manipulate and analyze the governing equations of fluid flow and heat transfer.
3.	Programming Fundamentals	Basic programming skills are crucial for implementing the numerical methods covered in the course. Familiarity with a language like MATLAB or Python would be beneficial.
4.	Partial Differential Equations (PDEs)	Understanding the basics of PDEs, their classification (elliptic, parabolic, hyperbolic), and solution techniques is necessary. This will be crucial for applying finite difference and finite volume methods.
5.	Numerical Methods:	Prior exposure to basic numerical methods like finite difference approximations, iterative techniques for solving linear systems, and concepts of stability and error analysis will be helpful.

2. Competencies

S/L	Competency	KSA Description
1.	Apply the fundamental governing equations of fluid dynamics for computational analysis.	**Knowledge:** Understand the physical meaning of the continuity, momentum, and energy equations. Recognize the difference between viscous (Navier-Stokes) and inviscid (Euler) flows **Skills:** Apply the governing equations to analyze simple fluid flow problems. Identify appropriate boundary conditions for CFD simulations. **Attitudes:** A desire to understand the physical principles underlying fluid flow and how they can be translated into mathematical models. An eagerness to apply the governing equations to analyze and solve engineering problems involving fluid motion
2.	Understand the mathematical behavior of governing equations for effective discretization in CFD.	**Knowledge:** Classify partial differential equations (PDEs) governing fluid flow (hyperbolic, parabolic, elliptic) based on their mathematical behavior. Recognize the impact of grid type (uniform, non-uniform, boundary fitted) on discretization accuracy. **Skills:** Identify the classification (hyperbolic, parabolic, elliptic) of governing equations for fluid flow. Apply basic finite difference methods (Taylor series expansion) to discretize simple PDEs. **Attitudes:** A desire to understand the mathematical properties of PDEs to choose appropriate discretization schemes. A willingness to explore different grid types and discretization methods for optimal CFD solutions.
3.	Analyze and implement finite difference methods for solving parabolic partial differential equations (PDEs) arising in CFD	**Knowledge:** Understand different finite difference formulations for parabolic PDEs (explicit vs. implicit methods). Recognize the concepts of consistency, stability, and error analysis in the context of finite difference methods. **Skills:** Apply explicit (FTCS, Richardson, DuFort-Frankel) and implicit (Laasonen,

		Crank-Nicolson, Beta) methods to discretize parabolic PDEs. Perform basic stability analysis (von Neumann analysis) to assess the convergence of a finite difference scheme. **Attitudes:** A strong emphasis on obtaining reliable and accurate solutions through careful selection of finite difference methods. A desire to explore efficient methods (implicit vs. explicit) that balance accuracy with computational cost.
4.	Implement appropriate finite difference methods for solving elliptic and hyperbolic partial differential equations (PDEs) in CFD.	**Knowledge:** Distinguish between elliptic and hyperbolic PDE classifications and their solution techniques in CFD. Understand common iterative algorithms for elliptic equations (Jacobi, Gauss-Siedel) and finite difference methods for hyperbolic equations (explicit/implicit, splitting methods). **Skills:** Apply iterative methods (Jacobi, Gauss-Siedel) to solve elliptic PDEs arising in CFD. Implement finite difference schemes (explicit/implicit, splitting) for solving hyperbolic PDEs relevant to fluid flow. **Attitudes:** A willingness to adapt finite difference methods based on the classification (elliptic vs. hyperbolic) of the governing equations. A desire to find a balance between efficient solution techniques (iterative methods) and achieving accurate results (higher-order finite difference schemes) for CFD problems.
5.	Apply numerical techniques to solve various fluid flow problems using the Navier-Stokes equations and finite volume methods.	**Knowledge:** Understand the discretization of the Navier-Stokes equations for CFD simulations (e.g., FTCS, MacCormack). Recognize the advantages of finite volume methods for unstructured grids (cell-centered vs. nodal). **Skills:** Implement finite difference schemes (explicit/implicit) to solve the Navier-Stokes equations for various flow conditions (subsonic, supersonic). Apply finite volume methods on unstructured grids to solve fluid flow problems. **Attitudes:** A desire to explore and utilize different numerical techniques (finite difference, finite volume) for tackling diverse fluid flow problems. A willingness to adjust the numerical approach (grid type, discretization scheme) based on the complexity of the flow (shock waves, unstructured grids).

3. Syllabus

Computational Methods in Heat Transfer and Fluid Flow SEMESTER – II			
Course Code	**M23MTP244**	CIE Marks	**50**
Number of Lecture Hours/Week(L: P: SDA)	**(2:0:2)**	SEE Marks	**50**
Total Hours of Pedagogy	**40**	Total Marks	**100**
Credits	**03**	Exam Hours	**03**

Module -1	
Introduction: History and Philosophy of computational fluid dynamics, CFD as a design and research tool, Applications of CFD in engineering, Programming fundamentals, MATLAB programming, Numerical Methods. Governing equations of fluid dynamics: Models of the flow, The substantial derivative, Physical meaning of the divergence of velocity, The continuity equation, The momentum equation, The energy equation, Navier Stokes equations for viscous flow, Euler equations for inviscid flow, Physical boundary conditions, Forms of the governing equations suited for CFD, Conservation form of the equations, shock fitting and shock capturing, Time marching and space marching.	L1, L2, L3
Module -2	

Mathematical behaviour of partial differential equations: Classification of quasi-linear partial differential equations, Methods of determining the classification, General behaviour of Hyperbolic, Parabolic and Elliptic equations. **Basic aspects of discretization**: Introduction to finite differences, Finite difference equations using Taylor series expansion and polynomials, Explicit and implicit approaches, Uniform, and unequally spaced grid points. **Grids with appropriate transformation**: General transformation of the equations, Metrics and Jacobians, the transformed governing equations of the CFD, Boundary fitted coordinate systems, Algebraic and elliptic grid generation techniques, Adaptive grids.	L1, L2, L3
Module -3	
Parabolic partial differential equations: Finite difference formulations, Explicit methods FTCS, Richardson and DuFort-Frankel methods, Implicit methods – Laasonen, Crank Nicolson and Beta formulation methods, Approximate factorization, Fractional step methods, Consistency analysis, Linearization**. Stability analysis**: Discrete Perturbation Stability analysis, von Neumann Stability analysis, Error analysis, Modified equations, artificial dissipation and dispersion.	L1, L2, L3
Module -4	
Elliptic equations: Finite difference formulation, solution algorithms: Jacobi –iteration method, a Gauss- Siedel iteration method, point- and line-successive over-relaxation methods, and alternative direction implicit methods. **Hyperbolic equations:** Explicit and implicit finite difference formulations, splitting methods, multi-step methods, applications to linear and nonlinear problems, linear damping, flux corrected transport, monotone and total variation diminishing schemes, TVD formulations, entropy condition, first-order and second order TVD schemes.	L1, L2, L3
Module -5	
Scalar representation of Navier-stokes equations: Equations of fluid motion, numerical algorithms: FTCS explicit, FTBCS explicit, Dufort-Frankel explicit, Maccormack explicit and implicit, BTCS and BTBCs implicit algorithms, applications. **Grid generation:** Algebraic Grid Generation, Elliptic Grid Generation, Hyperbolic Grid Generation, Parabolic Grid Generation. **Finite volume method for unstructured grids:** Advantages, Cell Cantered and Nodal point Approaches, Solution of Generic Equation with tetrahedral Elements, 2-D Heat conduction with Triangular Elements Numerical solution of quasi one dimensional nozzle flow: Subsonic-Supersonic isentropic flow, Governing equations for Quasi 1-D flow, non-dimensionalizing the equations, MacCormack technique of discretization, Stability condition, Boundary conditions, Solution for shock flows	L1, L2, L3

Text Books:

1. *Numerical Heat Transfer and Fluid Flow* - S.V. Patankar, Hemisphere Publishing Company.
2. *Computational Fluid Dynamics* - T.J. Chung, Cambridge University Press 2003.

Reference Books:

1. *Computational fluid flow and heat transfer* - K. Murlidhar and T. Sounderrajan, Narosa Publishing Co.
2. *Computational fluid mechanics and heat transfer* - D. A. Anderson, J. C. Tannehill, R.H. Pletcher, Tata McGraw-Hill Publications 2002.
3. *Computational fluid dynamics* - J.A. Anderson, McGraw-Hill Publications 1995.
4. *An Introduction to Computational Fluid Dynamics*, Versteeg, H.K. and Malalasekara, W, Pearson Education, 2010.

Web links and Video Lectures (e-Resources):

- *https://archive.nptel.ac.in/courses/112/104/112104302/*
- *https://archive.nptel.ac.in/courses/112/104/112104030/*

4. Syllabus Timeline

S/L	Syllabus Timeline	Description
1	Week 1-2	• **Introduction:** History and Philosophy of computational fluid dynamics, CFD as a design and research tool, Applications of CFD in engineering. • Programming fundamentals, MATLAB, Programming, and Numerical Methods. Governing equations of fluid dynamics: • Models of the flow, the substantial derivative, Physical meaning of the divergence of velocity, the continuity equation, The momentum equation.
2	Week 3-4	• The energy equation, Navier-Stokes equations for viscous flow, Euler equations for inviscid flow, Physical boundary conditions. • Forms of the governing equations suited for CFD, Conservation form of the equations, shock fitting and shock capturing, Time marching and space marching.

		• **Mathematical behavior of partial differential equations:** Classification of quasi-linear partial differential equations. • Methods of determining the classification, General behavior of Hyperbolic, Parabolic and Elliptic equations.
3	Week 5-6	• **Basic aspects of discretization**: Introduction to finite differences, Finite difference equations using Taylor series expansion and polynomials. • Explicit and implicit approaches, Uniform, and unequally spaced grid points. • **Grids with appropriate transformation**: General transformation of the equations, Metrics and Jacobians, the transformed governing equations of the CFD, Boundary fitted coordinate systems, Algebraic and elliptic grid generation techniques, Adaptive grids. • **Parabolic partial differential equations:** Finite difference formulations, explicit methods – FTCS, Richardson and DuFort-Frankel methods. • Implicit methods – Laasonen, Crank-Nicolson and Beta formulation methods, approximate factorization, Fractional step methods, Consistency analysis, Linearization.
4	Week 7-8	• **Stability analysis**: Discrete Perturbation Stability analysis, von Neumann Stability analysis, Error analysis, Modified equations, artificial dissipation and dispersion. • **Elliptic equations:** Finite difference formulation, solution algorithms: Jacobi - iteration method, a Gauss- Siedel iteration method. • Point- and line-successive over-relaxation methods and alternative direction implicit methods.
5	Week 9-10:	• **Hyperbolic equations**: Explicit and implicit finite difference formulations, splitting methods, multi-step methods. • Applications to linear and nonlinear problems, linear damping, flux corrected transport, monotone and total variation diminishing schemes, • TVD formulations, entropy condition, first-order and second-order TVD schemes. • **Scalar representation of Navier-stokes equations**: Equations of fluid motion, numerical algorithms: • FTCS explicit, FTBCS explicit, Dufort-Frankel explicit, Maccormack explicit and implicit, BTCS and BTBCs implicit algorithms, applications.
6	Week 11-12	• **Grid generation:** Algebraic Grid Generation, Elliptic Grid Generation, Hyperbolic Grid Generation, Parabolic Grid Generation. • **Finite volume method for unstructured grids:** Advantages, Cell Centered and Nodal Point Approaches, Solution of Generic Equation with tetrahedral Elements. • 2-D Heat conduction with Triangular Elements Numerical solution of quasi one-dimensional nozzle flow: • Subsonic-Supersonic isentropic flow, Governing equations for Quasi 1-D flow, non-dimensional zing the equations, MacCormack technique of discretization, Stability condition, Boundary conditions, Solution for shock flows

5. Teaching-Learning Process Strategies

S/L	TLP Strategies:	Description
1	Effective Lecturing,	• Lecture on computational techniques like Finite Difference Method (FDM), Finite Volume Method (FVM), and Finite Element Method (FEM). However, avoid excessive mathematical rigor that might overwhelm students. • Embed real-world engineering problems in industry for simulations of heat exchangers, fluid flow in turbines
2	Active Learning,	• Problem-Solving Sessions: Dedicate class time or tutorials to solve practice problems using the introduced methods. This allows students to solidify their understanding and gain confidence in applying the techniques. • Group Discussions: Encourage group discussions on specific topics or applications. This fosters peer learning, clarifies concepts, and helps students develop communication skills.
3	Digital Learning,	• Software Introduction: Introduce students to popular computational fluid dynamics (CFD) and heat transfer software packages like ANSYS Fluent, Open FOAM, or COMSOL. • Hands-on Tutorials: Provide hands-on tutorials where students learn to pre-

		process (geometry creation, mesh generation), solve problems using the software, and post-process results (visualization, data analysis).
4	Case-Based Learning,	• Setup labs for students to practice pattern making, sand mold preparation, and pouring techniques and Conduct demonstrations of melting furnaces, pouring equipment, and casting processes
5	Guest Lectures from Industry	• Invite professionals from companies that use CFD software to share their experiences and the role of these methods in industry. • This bridges the gap between theory and real-world applications.
6	Assignments and Projects	• Assign individual or group projects where students apply the learned methods to solve a specific engineering problem using CFD/heat transfer software. This strengthens their analytical and problem-solving skills.

6. Assessment Details (both CIE and SEE)

Continuous Internal Evaluation:

Components		Number	Weightage	Max. Marks	Min. Marks
(i)	Internal Assessment-Tests (A)	2	50%	25	10
(ii)	Assignments/Quiz/Activity (B)	2	50%	25	10
	Total Marks			**50**	**20**

Final CIE Marks = (A) + (B)

Semester-End Examination:

1. The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
2. The question paper will have ten full questions carrying equal marks.
3. Each full question is for 20 marks. There will be two full questions (with a maximum of four sub questions) from each module.
4. Each full question will have a sub-question covering all the topics under a module.
5. The students will have to answer five full questions, selecting one full question from each module.

7. Learning Objectives

S/L	Learning Objectives	Description
1	Fundamental Knowledge of computational fluid dynamics and its equations	• Able to Translate physical heat transfer phenomena into mathematical models using governing partial differential equations and appropriate boundary conditions. • To inculcate subject knowledge of numerical methods applied to thermal engineering applications
2	Understand the Concept of Computational Techniques	• Gain proficiency in a popular computational method like Finite Volume Method (FVM) for discretizing governing equations. • To learn about grid generation techniques for various geometries
3	Applying the knowledge computer programming in the CFD Engineering Application	• To develop the ability to use CFD (Computational Fluid Dynamics) or CHT (Computational Heat Transfer) software packages to solve practical problems. • To Become familiar with pre-processing, solving, and post-processing stages of computational analysis
4	Understand the concept of CFD techniques in convergence criteria	• To Analyse the results obtained from computational simulations and interpret them in the context of physical phenomena. • To Critically evaluate the accuracy and limitations of computational solutions
5	Implementation of CFD in fluid mechanics and heat transfer problems	• TO Explore advanced topics like turbulence modeling, multiphase flow, and conjugate heat transfer simulations

8. Course Outcomes (COs) and Mapping with POs/ PSOs

Course Outcomes (COs)

COs	Description
M23MTP244.1	Derive the stepwise procedure to completely solve a fluid dynamics problem using computational methods
M23MTP244.2	Explain the governing equations and understand the behavior of the equations.
M23MTP244.3	Determine the consistency, stability, and convergence of various discretization schemes for parabolic, elliptic and hyperbolic partial differential equations.
M23MTP244.4	Verify variations of SIMPLE schemes for incompressible flows and Variations of Flux Splitting algorithms for compressible flows.
M23MTP244.5	Identify various methods of grid generation techniques and application of finite difference and finite volume methods to various thermal problems.

CO-PO-PSO Mapping

COs/POs	PO1	PO2	PO3
M23MTP244.1	3		
M23MTP244.2			3
M23MTP244.3			3
M23MTP244.4			3
M23MTP244.5			3

9. Assessment Plan

Continuous Internal Evaluation (CIE)

	CO1	CO2	CO3	CO4	CO5	**Total**
Module 1	20					20
Module 2		20				20
Module 3			20			20
Module 4				20		20
Module 5					20	20
Total	20	20	20	20	20	100

Semester End Examination (SEE)

	CO1	CO2	CO3	CO4	CO5	Total
Module 1	20					20
Module 2		20				20
Module 3			20			20
Module 4				20		20
Module 5					20	20
Total	20	20	20	20	20	100

10. Future with this Subject

1. **Increased Emphasis on Advanced Techniques:** The Computational Fluid dynamics will likely explore deeper into advanced discretization methods like Finite Element Method (FEM) alongside the traditional Finite Volume Method (FVM) for complex geometries and multiphasic problems

2. **Focus on High-Performance Computing (HPC):** The course will equip students with the ability to utilize HPC resources for large-scale simulations, including parallelization techniques and efficient code development

3. **Integration with Machine Learning (ML):** There will likely be a growing emphasis on using machine learning for tasks like data analysis, turbulence modeling (e.g., Reynolds-Averaged Navier-Stokes (RANS) with ML closures), and even automating mesh generation and boundary condition selection

4. **Rise of Multiscale Modeling:** The ability to bridge the gap between microscopic and macroscopic phenomena will be crucial. Students might explore techniques like Lattice Boltzmann Methods (LBM) for microscale simulations coupled with traditional CFD methods for macroscale problems

5. **Open-Source Software and Cloud Computing:** The use of open-source CFD packages and cloud-based computational resources will likely become more prominent, allowing for wider accessibility and flexibility in solving problems

6. **Emphasis on Industrial Applications:** The course will equip students with the ability to apply these methods to real-world problems faced in various industries, including aerospace, power generation, and microfluidics.

2nd Semester	Professional Elective Course (PE) ENERGY CONSERVATION AND MANAGEMENT	M23MTP245

1. Prerequisites

S/L	Proficiency	Prerequisites
1	Fundamentals of Engineering	A strong foundation in core engineering principles like thermodynamics, fluid mechanics, and electrical engineering is essential. This knowledge will help you understand the energy transfer processes in various industrial systems and equipment.
2	Quantitative skills	This course involves calculations, data analysis, and interpreting energy-related metrics. Proficiency in algebra, including unit conversions, and basic statistics will be helpful in performing these tasks.
3	Problem-Solving Skills	Energy conservation often involves identifying inefficiencies and implementing solutions. Strong problem-solving skills will be necessary to analyze energy consumption data, troubleshoot issues, and develop effective energy-saving strategies.
4	Sustainability and Energy Conservation Interest	A genuine interest in sustainability and energy conservation practices will enhance your motivation and engagement in the course.
5	Industrial Processes Understanding	While familiarity with a specific industry is a benefit, a general understanding of industrial processes is crucial. This will allow you to apply the course concepts to real-world scenarios and identify potential areas for energy conservation across different industries.

2. Competencies

S/L	Competency	KSA Description
1	Apply energy conservation principles to optimize industrial processes.	**Knowledge:** Indian Energy Conservation Act and its key provisions. List of energy-intensive industries and their typical energy consumption patterns. **Skills:** Identify energy waste in industrial processes through energy audits and flow analysis. Evaluate and implement appropriate energy-saving technologies and practices. **Attitudes:** Commitment to continuous improvement in energy efficiency. Proactive approach to exploring and adopting new energy conservation solutions.
2	Optimize industrial energy consumption in steam systems and equipment.	**Knowledge:** Energy efficiency principles for steam generation, distribution, and utilization. Performance optimization techniques for furnaces, fans, blowers, compressors, and pumps **Skills:** Analyze energy consumption in steam systems and equipment using pinch technology and heat exchanger networks. Develop and implement recommendations for improving energy efficiency in case studies. **Attitudes:** Problem-solving approach to identify and address energy inefficiencies. Data-driven decision making for selecting optimal energy-saving solutions.
3	Conduct and analyze energy audits to recommend cost-effective energy-saving measures.	**Knowledge:** Principles and methodologies for conducting different types of energy audits. Economic evaluation techniques for energy-saving projects, including time value of money and risk analysis. **Skills:** Develop and implement data gathering strategies for energy audits. Analyze energy audit data and recommend cost-effective energy conservation opportunities. **Attitudes:** Attention to detail and accuracy in data collection and analysis. Cost-conscious approach to evaluating and recommending energy-saving

		solutions.
4	Vaporizers, Evaporators and Reboilers	**Knowledge:** Lighting terminology, laws of illumination, and lighting standards. Characteristics and applications of different lighting technologies. **Skills:** Design energy-efficient lighting systems based on good lighting practices and control strategies. **Attitudes:** Focus on providing adequate illumination while minimizing energy consumption. Openness to adopting new and emerging energy-efficient lighting technologies.
5	Analyze the economic aspects of power generation, distribution, and utilization.	**Knowledge:** Key economic factors influencing power generation and distribution, including connected load, demand factors, power factor, and line losses. **Skills:** Calculate and interpret key economic metrics like demand factor, power factor, and loss load factor. Evaluate the economic benefits of power factor improvement and energy-efficient technologies. **Attitudes:** Cost-consciousness in analyzing power consumption and identifying cost-saving opportunities. Supportive of implementing practices that promote efficient power generation, distribution, and utilization.

3. Syllabus

Energy Conservation and Management **SEMESTER – II**			
Course Code	**M23MTP245**	CIE Marks	**50**
Number of Lecture Hours/Week(L: P: SDA)	**(2:0:2)**	SEE Marks	**50**
Total Hours of Pedagogy	**40**	Total Marks	**100**
Credits	**03**	Exam Hours	**03**

Module -1	
Energy Conservation: Introduction - Indian Energy Conservation Act - List of Energy Intensive Industries - Rules for Efficient Energy Conservation - Identification of Energy Conservation opportunities - Technologies for Energy Conservation – Energy Conservation Schemes and Measures - Energy flow networks - Critical assessment of energy use - Optimizing Energy Inputs and Energy Balance - Pinch Technology.	L1, L2
Module -2	
Energy Efficiency Improvement: Steam Generation - Distribution and Utilization –Furnaces – Fans and Blowers - Compressors Pumps - Pinch Technology - Fluidized bed Combustion - Heat Exchanger Networks - Case Studies - Analysis and recommendation.	L1, L2
Module -3	
Energy Audit: Definition and Concepts, Types of Energy Audits – Basic Energy Concepts –Energy audit questionnaire, Data Gathering – Analytical Techniques. Energy Consultant: Need of Energy Consultant – Consultant Selection Criteria, Economic Analysis: Scope, Characterization of an Investment Project – Types of Depreciation –Time Value of money – budget considerations, Risk Analysis. Introduction to SCADA software.	L1, L2
Module -4	
Energy Efficient Lighting: Terminology - Laws of illumination - Types of lamps -Characteristics - Design of illumination systems - Good lighting practice - Lighting control- Steps for lighting energy conservation. Lighting standards.	L1, L2
Module -5	
Economics of Generation and Distribution: Generation: Definitions - Connected load, Maximum demand - Demand factor –Diversity factor – Significance - Power Factor – Causes and disadvantages of low power factor – Economics of power factor improvement. Distribution: Electrical load analysis - Types of consumers & tariffs - Line losses -Corona losses - Types of distribution system - Kelvin‘s law - Loss load factor – Green Labeling – Star Rating.	L1, L2
Text Books: 1. Energy management and conservation handbook Frank Kreith & D. Yogi Goswami	

2. Energy Management and Conservation; K. V. Sharma, P. Venkataseshaiah; 2013

Reference Books:

1. Turner, W. C., Doty, S. and Truner, W. C., Energy Management Handbook, 7th edition, Fairmont Press, 2009.
2. De, B. K., Energy Management audit & Conservation, 2nd Edition, Vrinda Publication, 2010.
3. Murphy, W. R., Energy Management, Elsevier, 2007.
4. Smith, C. B., Energy Management Principles, Pergamon Press, 2007.

Web links and Video Lectures (e-Resources):

- https://archive.nptel.ac.in/courses/112/105/112105221/
- https://drive.google.com/file/d/1PFPciHPuFnfyH5V5_ZPAQhCyIUgcQaw5/view

4. Syllabus Timeline

S/L	Syllabus Timeline	Description
1	Week1-2	• **Energy Conservation:** Introduction - Indian Energy Conservation Act. • List of Energy Intensive Industries. • Rules for Efficient Energy Conservation - Identification of Energy Conservation. • opportunities - Technologies for Energy Conservation – Energy Conservation Schemes and Measures. • Energy flow networks - Critical assessment of energy use -
2	Week 3-4:	• Optimizing Energy Inputs and Energy Balance - Pinch Technology. • **Energy Efficiency Improvement:** Steam Generation - Distribution and Utilization • Furnaces – Fans and Blowers - Compressors Pumps - Pinch Technology - Fluidized bed Combustion
3	Week 5-6	• Heat Exchanger Networks - Case Studies - Analysis and recommendation. • **Energy Audit:** Definition and Concepts, Types of Energy Audits • Basic Energy Concepts –Energy audit questionnaire. • Data Gathering – Analytical Techniques. • Energy Consultant: Need of Energy, Consultant – Consultant Selection Criteria, Economic Analysis
4	Week 7-8	• Scope, Characterization of an Investment Project. • Types of Depreciation –Time Value of money – budget considerations, Risk • Analysis. Introduction to SCADA software. • **Energy Efficient Lighting:** Terminology - Laws of illumination - Types of lamps.
5	Week 9-10:	• Characteristics - Design of illumination systems – • Good lighting practice - Lighting control- Steps for lighting energy conservation. Lighting standards. • **Economics of Generation and Distribution**: Generation: Definitions - Connected load, Maximum demand -
6	Week 11-12	• Demand factor –Diversity factor – Significance. • Power Factor – Causes and disadvantages of low power factor. • Economics of power factor improvement. Distribution: Electrical load analysis. • Types of distribution system - Kelvin's law - Loss load factor – Green Labeling – Star Rating.

5. Teaching-Learning Process Strategies

S/L	TLP Strategies:	Description
1	Effective Lecturing,	• To students will gain knowledge through understanding of energy resources, utilization patterns, and conservation strategies. • Students will develop critical thinking skills to analyze energy consumption and propose solutions for industrial applications.
2	Active Learning,	• Able to spark curiosity on students at various energy sources and their conservation. • Able to solve problems, analyze data, and present findings. This fosters teamwork skills and deepens their understanding of the Energy

		conservation, audit and energy management.
3	Digital Learning,	• Virtual reality (VR) and augmented reality (AR) experiences can immerse students in real-world scenarios related to energy management in industrial settings. • Interactive digital tools like simulations, and virtual labs can make complex energy conservation concepts more engaging and relatable for students.
4	Case-Based Learning,	• Able to Apply engineering knowledge to optimize energy use in mechanical systems. • Analyze real-world scenarios of energy consumption in buildings, industries, or transportation systems. Identify inefficiencies and propose potential solutions, considering technical and economic factors. • Strengthen communication skills through case study presentations and discussions
5	Guest Lectures from Industry	• Able to Gain firsthand knowledge of industry challenges and best practices in energy conservation. • Gain exposure to potential career paths in energy management and sustainability.
6	Assignments and Projects	• Able to Conduct simulated or real-world energy audits to assess energy use patterns in a facility. • Able to design and analyze energy-efficient systems for specific applications, such as HVAC systems, lighting systems, or industrial processes.

6. **Assessment Details (both CIE and SEE)**

Components		Number	Weightage	Max. Marks	Min. Marks
(i)	Internal Assessment-Tests (A)	2	50%	25	10
(ii)	Assignments/Quiz/Activity (B)	2	50%	25	10
	Total Marks			**50**	**20**

Final CIE Marks = (A) + (B)

Semester-End Examination

1. The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
2. The question paper will have ten full questions carrying equal marks.
3. Each full question is for 20 marks. There will be two full questions (with a maximum of four sub questions) from each module.
4. Each full question will have a sub-question covering all the topics under a module.
5. The students will have to answer five full questions, selecting one full question from each module.

7 Learning Objectives

S/L	Learning Objectives	Description
1	Fundamental Knowledge on Sustainability of various energy sources & their Conservation	Ability to design and develop mechanical systems that minimize environmental impact and promote resource preservation.
2	knowledge on Applications of Energy conservation and management	To Identify and analyze opportunities for energy conservation and management in various mechanical systems like Thermal systems, Fluid systems and Power Transmission systems.
3	Understand the concepts of Energy Audit & its applications in real life situations	To identify areas of high energy consumption and recommend corrective actions. To explore practical strategies for implementing energy conservation practices in real-world mechanical engineering applications.
4	Knowledge on Energy Audit of Existing Thermal Systems	To explain the purpose and methodology of conducting an energy audit on existing thermal systems. To Identify key areas of energy consumption in various thermal systems (e.g., boilers, furnaces, HVAC systems). Apply relevant measurement techniques and data analysis methods to evaluate thermal system performance.

8 Course Outcomes (COs) and Mapping with POs/ PSOs

Course Outcomes (COs)

COs	Description
M23MTP245.1	Understand the various energy conservation and improvement techniques.
M23MTP245.2	Illustrate the Energy scenario.
M23MTP245.3	Employ the principles of thermal engineering and energy management to Improve the Performance of thermal systems.
M23MTP245.4	Assess energy projects based on economic and financial criteria.
M23MTP245.5	Describe methods of energy production for improved utilization.

CO-PO-PSO Mapping

COs/POs	PO1	PO2	PO3
M23MTP245.1	**3**		
M23MTP245.2	**3**		
M23MTP245.3	**3**		
M23MTP245.4	**3**		
M23MTP245.5	**3**		

9 Assessment Plan

Continuous Internal Evaluation (CIE)

	CO1	CO2	CO3	CO4	CO5	**Total**
Module 1	**20**					**20**
Module 2		**20**				**20**
Module 3			**20**			**20**
Module 4				**20**		**20**
Module 5					**20**	**20**
Total	**20**	**20**	**20**	**20**	**20**	**100**

Semester End Examination (SEE)

	CO1	CO2	CO3	CO4	CO5	**Total**
Module 1	**20**					**20**
Module 2		**20**				**20**
Module 3			**20**			**20**
Module 4				**20**		**20**
Module 5					**20**	**20**
Total	**20**	**20**	**20**	**20**	**20**	**100**

10 Future with this Subject

1. Integration of Renewables:

- **Hybrid Systems:** Combining renewable sources like solar and wind with traditional sources for grid stability and efficient power generation.
- **Energy Storage:** Developing advanced battery storage technologies and exploring alternative methods like pumped hydro and compressed air energy storage.
- **Smart Grids:** Designing intelligent grids that can integrate distributed renewable energy sources, optimize energy flow, and minimize losses.

2. Building Efficiency:

- **Advanced Building Materials:** Utilizing materials with high thermal insulation properties for reduced heating/cooling needs.
- **Building Automation Systems (BAS):** Implementing AI-powered BAS for real-time building energy monitoring and automated control of HVAC systems.
- **Net Zero Buildings:** Designing buildings that achieve net-zero energy consumption through efficient design, renewable energy integration, and occupant behavior changes.

3. Advanced Manufacturing Processes:

- **Additive Manufacturing (3D Printing):** Optimizing designs for lightweight structures and minimal material usage in manufacturing.
- **Energy-efficient Machining:** Developing new machining techniques with reduced energy consumption and improved tool life.

- **Waste Heat Recovery Systems:** Capturing waste heat from industrial processes for reuse in other applications.

4. Artificial Intelligence (AI) and Machine Learning (ML):

- **Predictive Maintenance:** Utilizing AI and ML for predictive maintenance of equipment, preventing breakdowns, and optimizing energy use.
- **Demand Response Management:** Implementing AI-powered systems for dynamic pricing and demand response programs to reduce peak energy loads.
- **Behaviour Change Analysis:** Using AI to analyze energy consumption patterns and personalize recommendations for improved energy efficiency in buildings and industries.

5. Policy and Regulations:

- **Carbon Pricing Mechanisms:** Understanding the role of carbon taxes and emission trading schemes in driving energy conservation efforts.
- **Energy Efficiency Standards:** Analyzing the impact of government regulations on appliance and building energy efficiency.
- **Developing Sustainable Business Models:** Creating innovative business models that incentivize energy efficiency investments and promote renewable energy adoption.

2nd Semester	MINI PROJECT WITH SEMINAR	M23MTP205

1. **Syllabus**

MINI PROJECT WITH SEMINAR SEMESTER – II			
Course Code	23MTP25	CIE Marks	**100**
Number of Lecture Hours/Week(L: P: SDA)	**(0:0:4)**	SEE Marks	**-**
Total Number of Lecture Hours		Total Marks	**100**
Credits	03	Exam Hours	**-**

Course objectives: This course will enable students to:

- Conduct independent research & propose a solution to a real-world problem in your field.
- Develop clear & concise communication skills for written project reports & presentations.
- Demonstrate effective time management & project organization for individual execution.
- Enhance confidence & public speaking skills through an individual seminar presentation.
- Critically analyze & ethically utilize information from varied resources.

"Mini Project with Seminar" course in mechanical engineering provides hands-on experience through a chosen project activity. This could involve building a device, analyzing data, coding simulations, visiting a relevant facility, or other options. You'll present your findings in a seminar, developing communication and critical thinking skills as you delve into a specific area of mechanical engineering.

2. **Assessment Details:**

CIE :

CIE marks shall be awarded by a committee comprising of HoD as Chairman, Guide/co-guide, if any, and a senior faculty of the department. Students can present the seminar based on the completed mini-project. Participation in the seminar by all postgraduate students of the program shall be mandatory.

The CIE marks awarded for Mini-Project work and Seminar, shall be based on the evaluation of Mini Project work and Report, Presentation skill and performance in Question-and-Answer session in the ratio **50:25:25**.

Mini-Project with Seminar shall be considered as a head of passing and shall be considered for vertical progression as well as for the award of degree. Those, who do not take-up/complete the Mini Project and Seminar shall be declared as fail in that course and have to complete the same during the subsequent semester.

3. **Learning Objectives**

S/L	Learning Objectives	Description
1	Apply core mechanical engineering knowledge	Students will select a project activity that allows them to apply the principles of mechanics, thermodynamics, materials science, or other core mechanical engineering disciplines.
2	Develop hands-on skills	Through project activities like building a device, conducting experiments, or working with simulations, students will gain practical experience in relevant mechanical engineering techniques.
3	Enhance data analysis and interpretation skills	Students will learn to collect and analyze data related to their chosen project, identifying trends and drawing meaningful conclusions.
4	Refine critical thinking and problem-solving abilities	The project selection and execution process will require students to critically assess challenges, propose solutions, and adapt their approach as needed.
5	Strengthen communication and presentation skills	Students will present their project findings in a seminar setting, effectively communicating technical information to a peer audience.

4. **Course Outcomes (COs) and Mapping with POs/ PSOs**

Course Outcomes (COs)

COs	Description
M23MTP205.1	Design and execute a mini-project that utilizes core mechanical engineering principles to address a specific challenge or problem.
M23MTP205.2	Critically evaluate the data and findings generated from the project, identifying key trends, limitations, and potential for further investigation.

M23MTP205.3	Effectively communicate the project's objectives, methodology, results, and conclusions in a well-organized seminar presentation, demonstrating clear technical understanding and engaging the audience.

CO-PO-PSO Mapping

COs/POs	PO1	PO2	PO3
M23MTP205.1	3	-	-
M23MTP205.2	-	-	3
M23MTP205.3	-	3	-

3rd Semester	Professional Core Course (PC) COMPUTATIONAL FLUID DYNAMICS AND NUMERICAL LAB	M23MTPL206

1. **Prerequisites:**

S/L	Proficiency	Prerequisites
1.	Fundamental Fluid Mechanics	Should have a solid understanding of fluid properties (viscosity, density), fluid flow regimes (laminar, turbulent), and basic conservation laws (mass, momentum, energy) governing fluid behavior.
2.	Heat Transfer Principles:	Knowledge of heat transfer mechanisms (conduction, convection, radiation), Nusselt number for various geometries, and basic concepts of natural and forced convection is essential.
3.	Basic Engineering Mathematics	Proficiency in solving differential equations (particularly partial differential equations for CFD) and applying mathematical tools for data analysis is required.
4.	Computer Literacy	Familiarity with using computers and basic software skills are necessary for navigating ANSYS Workbench and post-processing results.
5.	Geometry Creation & Meshing	Students will be proficient in creating geometries and applying appropriate meshing techniques for various CFD simulations.

2. **Competencies:**

S/L	Competency	KSA Description
1.	Fluid Mechanics & Heat Transfer	**Knowledge:** Fluid properties (viscosity, density) - Flow regimes (laminar, turbulent) - Heat transfer mechanisms (conduction, convection, radiation) **Attitudes:** Appreciation for the importance of these principles in engineering analysis
2.	ANSYS Workbench	**Knowledge:** Geometry creation tools for CFD simulations - Meshing techniques (structured, unstructured) for various geometries - Boundary condition types and settings - Material property definition - Solution methods and post-processing techniques **Skills:** Create and manipulate geometries for CFD analysis - Apply appropriate meshing strategies for different scenarios - Set up simulations with accurate boundary conditions and material properties - Run CFD simulations and interpret results using visualization and data analysis tools **Attitudes:** Attention to detail and accuracy when defining simulation parameters - Willingness to learn and explore different functionalities of ANSYS Workbench
3.	Problem-Solving & Analysis	**Knowledge:** Formulating CFD problems for engineering applications - Selecting appropriate simulation approaches - Interpreting CFD results to understand flow behavior, heat transfer, and other relevant parameters **Skills:** Apply CFD knowledge to analyze practical engineering problems - Evaluate the influence of different simulation parameters on results - Effectively communicate findings through reports or presentations **Attitudes:** Critical thinking and problem-solving skills to address engineering challenges using CFD - Commitment to continuous learning and improvement of CFD expertise
4.	Software Proficiency	**Knowledge:** Basic computer literacy and software skills **Skills:** Navigate ANSYS Workbench interface efficiently - Utilize relevant features and tools effectively **Attitudes:** Adaptability to learn new software if necessary

3. **Syllabus:**

COMPUTATIONAL FLUID DYNAMICS AND NUMERICAL LAB SEMESTER – II			
Course Code	**M23MTPL206**	CIE Marks	**50**
Number of Lecture Hours/Week(L: T: P: S)	**(0:0:2:0)**	SEE Marks	**50**
Total Number of Lecture Hours	**12 Sessions**	Total Marks	**100**
Credits	**02**	Exam Hours	**03**
Course objectives: This course will enable students to:			

➢ Utilize ANSYS Workbench to create and mesh complex geometries for engineering simulations. ➢ Simulate forced convection heat transfer and analyze temperature distribution and coefficients on objects. ➢ Analyze fully developed laminar flow through a circular pipe using ANSYS Workbench. ➢ Model shell and tube heat exchangers and employ CFD to calculate a key heat transfer parameter. (Optional, choose one for point ➢ Simulate natural convection heat transfer through a pipe and analyze relevant parameters. ➢ Simulate turbulent flow through a pipe and analyze relevant parameters using ANSYS Workbench.	
Experiments	
1.	Geometry, meshing for various configurations using ANSYS Workbench.
2.	Forced convection over two cylinders in tandem arrangement.
3.	Calculation of Nusselt number for staggered and in line arrangement of shell and tube heat exchanger
4.	Fully developed laminar flow through a circular pipe using Workbench.
5.	Natural Convection through a vertical pipe using ANSYS Workbench.
6.	Melting and solidification in a rectangular cavity.
7.	Fully developed turbulent flow through circular pipe using ANSYS Workbench.
8.	To determine the internal pipe fluid flow using ANSYS.
Demonstration Experiments (For CIE only – not to be included for SEE)	
1.	Determination of the skin friction coefficient of a rectangular plate when fluid is flowing over the surface of plate using ANSYS Flow Simulation.
2.	Flow of water through a ball valve assembly using ANSYS/ Solid Works Flow Simulation.
3.	To conduct thermal stress analysis of a 2D component using ANSYS
4.	To determine the temperature distribution in solid body.
Learning Resources: **ANSYS Learning Hub:** https://courses.ansys.com/ **ANSYS Academic Support:** https://courses.ansys.com/ (Free online tutorials and textbooks on geometry and meshing) "Fundamentals of Heat and Mass Transfer" by Incropera & DeWitt (Provides the theoretical foundation for forced convection)	

4. Syllabus Timeline:

S/L	Syllabus Timeline	Description
1	Week 1-2: Introduction and Experiment -01	Introduction to CFD and Ansys workbench. Geometry, meshing for various configurations using ANSYS Workbench.
2	Week 3-4: Experiment-2 & Experiment-3	Forced convection over two cylinders in tandem arrangement. Calculation of Nusselt number for staggered and in line arrangement of shell and tube heat exchanger
3	Week 5-6: Experiment-4 & Assessment-01	Fully developed laminar flow through a circular pipe using Workbench. Assessment-01 to be scheduled after the completion of 4 experiments.
4	Week 7-8: Experiment-5 & Experiment-6	Natural Convection through a vertical pipe using ANSYS Workbench. Melting and solidification in a rectangular cavity.
5	Week 9-10: Experiment-7 & Experiment-8	Fully developed turbulent flow through circular pipe using ANSYS Workbench. To determine the internal pipe fluid flow using ANSYS.
6	Week 11-12: Demonstrations Experiments and Assessment - 02	Demonstration experiments Assessment-02 to be scheduled after the completion of all experiments.

5. Teaching-Learning Process Strategies:

S/L	TLP Strategies:	Description
1	Lecture/Demonstration	Utilize various teaching methods to explain concepts and demonstrates code examples.
2	Practice-based Learning	Focus on coding practice through exercises, challenges, and projects to solidify understanding.
3	Break down Complex Topics	Present complex topics in smaller, manageable steps with clear explanations.

4	Problem-Based Learning (PBL)	Implement PBL to enhance analytical skills and practical application of competencies
5	Multiple Representations	Introduce topics in various representations to reinforce competencies
6	Real-World Application	Discuss practical applications to connect theoretical concepts with real-world competencies.
7	Flipped Class Technique	Utilize a flipped class approach, providing materials before class to facilitate deeper understanding of competencies
8	Programming Assignments	Assign programming tasks to reinforce practical skills associated with competencies.

6. **Assessment Details (both CIE and SEE) :**

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 40% of the maximum marks (20 marks out of 50) and for the SEE minimum passing mark is 35% of the maximum marks (18 out of 50 marks). A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures a minimum of 40% (40 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation (CIE):

- CIE marks for the practical course are **50 Marks.**
- The split-up of CIE marks for record and test are in the ratio **60:40.**

Class Work:-A

SL. No.	Description	% of Marks	In Marks
1	Write-up, Conduction, result and Procedure	60%	30
2	Viva-Voce	40%	20
Total		**100%**	**50**

The Test marks should be scaled down to **30marks** (60% of the maximum Marks)

Laboratory Test: -B

SL. No.	Description	% of Marks	In Marks
1	Write-up, Conduction, result and Procedure	60%	30
2	Viva-Voce	40%	20
Total		**100%**	**50**

The Test marks should be scaled down to **20marks** (40% of the maximum Marks)

SL. No.	Description	% of Marks	In Marks
1	Scaled Down marks of record/journal-A	60% of the maximum	30
2	Scaled Down marks of test-B	40% of the maximum	20
Total		**100%**	**50**

Final CIE Marks = (A) + (B)

Semester End Evaluation (SEE):

SL. No.	Description	% of Marks	Marks
1	Write-up, Procedure	20%	20
2	Conduction and result	60%	60
3	Viva-Voce	20%	20
Total		**100%**	**100**

1. SEE marks for practical course shall be 50 marks
2. SEE for practical course is evaluated for 100 marks and scored marks shall be scaled down to 50 marks.
3. Change of experiment/program is allowed only once and 20% marks allotted to the procedure/write-up part to be made zero.
4. Duration of SEE shall be **3 hours**.

7. **Learning Objectives:**

S/L	Learning Objectives	Description
1	Master ANSYS Workbench	Learn to create complex geometries and meshes for engineering simulations.
2	Simulate Forced Convection	Analyze heat transfer, temperature distribution, and coefficients on objects in flowing fluids.
3	Analyze Laminar Pipe Flow	Utilize ANSYS Workbench to understand flow behavior in circular pipes under laminar conditions.
4	Model Shell & Tube Heat	Employ CFD to calculate key heat transfer parameters (e.g., Nusselt

	Exchangers	number) for shell and tube heat exchangers.

8. Course Outcomes (COs) and Mapping with POs/ PSOs

Course Outcomes (COs)

COs	Description
M23MTPL206.1	**Apply** their knowledge of ANSYS Workbench and fundamental engineering principles to **simulate and analyze** heat transfer phenomena in various configurations (e.g., forced convection, shell and tube heat exchangers).
M23MTPL206.2	**Analyze** the results of their ANSYS simulations, including temperature distribution, flow patterns, and heat transfer coefficients.
M23MTPL206.3	**Compare and Contrast** the performance of different heat transfer configurations (e.g., laminar vs. turbulent flow, different exchanger designs) based on their simulation results.

CO-PO-PSO Mapping

COs/POs	PO1	PO2	PO3
M23MTPL206.1	3	-	-
M23MTPL206.2	-	3	-
M23MTPL206.3	-	-	3
M23MTPL206	3	3	3

9. Assessment Plan

Continuous Internal Evaluation (CIE)

	CO1	CO2	CO3	Total
Total	**14**	**18**	**18**	**50**

Semester End Examination (SEE)

	CO1	CO2	CO3	Total
Total	**20**	**40**	**40**	**100**

SEE for practical course is evaluated for 100 marks and scored marks shall be scaled down to **50 marks.**

10. Future with this Subject

Focusing on computational engineering simulations with ANSYS Workbench, is incredibly promising and intertwined with several exciting advancements:

1. Increased Automation and AI Integration:

- Machine Learning (ML) algorithms will play a bigger role in automating tasks like mesh generation, boundary condition selection, and even some post-processing analysis.
- AI-powered tools will assist users in selecting the most appropriate simulation setup and parameters for their specific problem, reducing the need for extensive upfront knowledge.

2. Multi physics Simulations and Multi scale Modeling:

- The ability to couple different physics – thermal, fluid, structural – within a single simulation will become more robust, allowing for more comprehensive analysis of complex engineering systems.
- Multiscale modeling will bridge the gap between microscopic and macroscopic phenomena, enabling simulations that incorporate the behavior of materials at different length scales.

3. Cloud Computing and High-Performance Computing (HPC):

- Cloud-based platforms will make ANSYS Workbench and similar software more accessible, allowing users to run simulations on powerful remote servers without needing expensive hardware locally.
- Advancements in HPC will enable faster and more complex simulations, facilitating the analysis of larger and more intricate engineering problems.

4. Democratization of Simulation Tools:

- User interfaces will become more user-friendly and intuitive, making these powerful tools accessible to a broader range of engineers and scientists, even those with less computational expertise.
- Open-source alternatives to ANSYS and other commercial software will continue to develop, providing more affordable options for education and research.

5. Integration with Other Engineering Workflows:

- ANSYS and similar tools will seamlessly integrate with other engineering design and analysis software, enabling a more holistic design-simulation-optimization workflow.
- This will facilitate rapid design iterations and optimization of engineering systems based on simulation results.