VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELAGAVI.

Scheme of Teaching and Examinations and Syllabus
M.Tech., Program
in
Thermal Power Engineering

(Effective from the Academic year 2022-23)

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VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELAGAVI
Scheme of Teaching and Examinations – 2022-23
M.Tech., in Thermal Power Engineering (MTP)
Choice Based Credit System (CBCS) and Outcome-BasedEducation (OBE)

I SEMESTER

Sl. No	Course	Course Code	Course Title	Teaching Hours per Week			Examination				Credits
				Theory	Practical/Seminar	Tutorial/ Skill Development Activities	Duration in hours	CIE Marks	SEE Marks	Total Marks	
				L	P	T/SDA					
1	BSC	22MTP11	Applied Mathematics	03	00	00	03	50	50	100	3
2	IPCC	22MTP12	Theory and Design of Modern IC Engine	03	02	00	03	50	50	100	4
3	PCC	22MTP13	Advanced Fluid Mechanics	03	00	02	03	50	50	100	4
4	PCC	22MTP14	Advanced Thermodynamics and Combustion	02	00	02	03	50	50	100	3
5	PCC	22MTP15	Finite Element Method in Heat Transfer	02	00	02	03	50	50	100	3
6	MCC	22RMI16	Research Methodology and IPR	03	00	00	03	50	50	100	3
7	PCCL	22MTPL17	FEM & Simulation Lab	01	02	00	03	50	50	100	2
8	AUD/AEC	22AUD18/ 22AEC18	NPTEL/MOOC/Coursera/MIT	Classes and evaluation procedures are as per the policy of the online course providers.							PP
			TOTAL	**17**	**04**	**06**	**21**	**350**	**350**	**700**	**22**

Note: BSC-Basic Science Courses, PCC: Professional core. IPCC-Integrated Professional Core Courses, MCC- Mandatory Credit Course,
AUD/AEC –Audit Course / Ability Enhancement Course (A pass in AUD/AEC is mandatory for the award of the degree), PCCL-Professional Core Course lab, **L-Lecture, P-Practical, T/SDA-Tutorial / Skill Development Activities** (Hours are for Interaction between faculty and students)

Integrated Professional Core Course (IPCC): **Integrated Professional Core Course (IPCC)**: Refers to Professional Theory Core Course Integrated with practical of the same course. The theory part of the IPCC shall be evaluated both by CIE and SEE. The practical part shall be evaluated by only CIE (no SEE). However, questions from the practical part of IPCC shall be included in the SEE question paper.

Audit Courses /Ability Enhancement Courses Suggested by BOS (ONLINE courses): Audit Courses: These are prerequisite courses suggested by the concerned Board of Studies. Ability Enhancement Courses will be suggested by the BoS if prerequisite courses are not required for the programs.

Ability Enhancement Courses:

- These courses are prescribed to help students to enhance their skills in in fields connected to the field of specialisation as well allied fields that leads to employable skills. Involving in learning such courses are impetus to lifelong learning.
- The courses under this category are online courses published in advance and approved by the concerned Board of Studies.
- Registration to Audit /Ability Enhancement Course shall be done in consultation with the mentor and is compulsory during the concerned semester.
- In case a candidate fails to appear for the proctored examination or fails to pass the selected online course, he/she can register and appear for the same course if offered during the next session or register for a new course offered during that session, in consultation with the mentor.
- The Audit Ability Enhancement Course carries no credit and is not counted for vertical progression. However, a pass in such a course is mandatory for the award of the degree.

Skill development activities: Under Skill development activities in a concerning course, the students should

1. Interact with industry (small, medium, and large).

2. Involve in research/testing/projects to understand their problems and help creative and innovative methods to solve the problem.
3. Involve in case studies and field visits/ fieldwork.
4. Accustomed to the use of standards/codes etc., to narrow the gap between academia and industry.
5. Handle advanced instruments to enhance technical talent.
6. Gain confidence in modelling of systems and algorithms for transient and steady-state operations, thermal study, etc.
7. Work on different software/s (tools) to simulate, analyze and authenticate the output to interpret and conclude.

All activities should enhance student's abilities to employment and/or self-employment opportunities, management skills, Statistical analysis, fiscal expertise, etc.

Students and the course instructor/s to involve either individually or in groups to interact together to enhance the learning and application skills of the study they have undertaken. The students with the help of the course teacher can take up relevant technical –activities which will enhance their skill. The prepared report shall be evaluated for CIE marks.

Program Outcome of this course

POs	Description
PO1:	Acquire, demonstrate, and apply basic knowledge in the field of Thermal power engineering.
PO2:	Identify problems in the field of Thermal power engineering, formulate them and solve by using advanced techniques.
PO3:	Conduct independent research and generate new knowledge for the benefit of community, society, Industry, and nation.
PO4:	Apply various computational methods using advanced software and engineering tools to model, analyze and solve thermal engineering problems.
PO5:	Work effectively in interdisciplinary teams for solving real life problems in achieving multidisciplinary tasks required for the project in the related field.
PO6:	Effectively communicate through technical reports, presentations, scientific publications, intellectual integrity, ethics of research and scholarly standards with the engineering community as well as society at large.
PO7:	Engage in life-long reflective and independent learning with high level of enthusiasm and commitment.

Semester – I

Applied Mathematics			
Course Code	**22MTP11**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	3:0:0	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	03	Exam Hours	3 Hr

Course Learning objectives:

- The course is aimed to develop the basic Mathematical skills of engineering students that are imperative for effective understanding of Thermal engineering subjects.
- The topics introduced will serve as basic tools for specialized studies in the fields of Thermal engineering and technology.
- An understanding of Fourier Series and Laplace Transform to solve real world problems.
- 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.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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.	
Teaching-Learning	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Process	

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.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks.**
2. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks** to attain the COs and POs.

The sum of three tests, two assignments/skill Development Activities, will be **scaled down to 50 marks.**

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

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.

Suggested Learning Resources:

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.

Web links and Video Lectures (e-Resources):

https://archive.nptel.ac.in/courses/111/107/111107119/
https://archive.nptel.ac.in/courses/111104145/
https://onlinecourses.nptel.ac.in/noc21_ma64/preview
https://archive.nptel.ac.in/courses/111/102/111102133/
https://archive.nptel.ac.in/courses/111/105/111105091/
https://archive.nptel.ac.in/courses/111/104/111104024/

Skill Development Activities Suggested

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	Acquire the idea of significant figures, types of errors during numerical computation.	
CO2	Develop the mathematical models of thermal system using ODE's and PDE's.	
CO3	Learn the deterministic approach for statistical problems by using probability distributions.	
CO4	Classify and analyze mathematical tools applied to thermal engineering study cases.	

Mapping of COS and POs

POs → COs↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	**3**	**2**	**1**	**1**	**2**	**1**	**1**
CO2	**3**	**2**	**1**	**2**	**2**	**1**	**1**
CO3	**3**	**2**	**1**	**2**	**2**	**1**	**1**
CO4	**3**	**2**	**1**	**2**	**2**	**1**	**1**

Semester - I

Theory and Design of Modern IC Engine			
Course Code	**22MTP12**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	3:0:2	SEE Marks	50
Total Hours of Pedagogy	40 hours Theory + 10-12 Lab slots	Total Marks	100
Credits	04	Exam Hours	3 Hr

Course objectives:

1. To provide the sufficient knowledge of concept, applications, importance of IC engines.
2. To understand the mechanism of combustion in SI and CI engine and its effect on engine performance.
3. To familiarize the students about the IC engines systems, processes, alternative fuels etc.
4. Knowledge ofdifferent 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 data. Energy flow through IC engines, Various Auxiliary systems. Environment friendly engines. Fuel –Air and Actual Engines: Modelling 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.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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, Hydrogen fuels, Biogas, Dual fuels, other possible fuels.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

MODULE-4

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. **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.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.
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.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

PRACTICAL COMPONENT OF IPCC (May cover all / major modules)

Sl.NO	Experiments
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

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 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the

academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

CIE for the theory component of IPCC

1. Two Tests each of **20 Marks.**
2. Two assignments each of **10 Marks/One Skill Development Activity of 20 marks.**
3. Total Marks of two tests and two assignments/one Skill Development Activity added will be CIE for 60 marks, marks scored will be proportionally scaled down to **30 marks**.

CIE for the practical component of IPCC

- On completion of every experiment/program in the laboratory, the students shall be evaluated, and marks shall be awarded on the same day. The **15 marks** are for conducting the experiment and preparation of the laboratory record, the other **05 marks shall be for the test** conducted at the end of the semester.
- The CIE marks awarded in the case of the Practical component shall be based on the continuous evaluation of the laboratory report. Each experiment report can be evaluated for 10 marks. Marks of all experiments' write-ups are added and scaled down to 15 marks.
- The laboratory test at the end /after completion of all the experiments shall be conducted for 50 marks and scaled down to 05 marks**.**
- Scaled-down marks of write-up evaluations and tests added will be CIE marks for the laboratory component of IPCC for **20 marks**.

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).

Suggested Learning Resources:

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/

Activity Based Learning (Suggested Activities in Class)/ Practical Based learning

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	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.	
CO2	Analyze combustion and apply remedial measures to avoid abnormal combustion in SI and CI Engine.	
CO3	Specify and interpret data of alternative fuels and its emission which effect the environment.	
CO4	Analyze different electronic fuel injection system, supercharging and its effect on performance of SI and CI engine.	
CO5	Apply various emission control system and modification to take corrective actions to reduce pollution.	

Mapping of COS and POs

POs → COs↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	**3**	**2**	**1**	**-**	**-**	**1**	**1**
CO2	**3**	**2**	**1**	**2**	**-**	**1**	**1**
CO3	**3**	**2**	**1**	**2**	**-**	**1**	**1**
CO4	**3**	**2**	**1**	**2**	**-**	**1**	**1**
CO5	**3**	**2**	**1**	**-**	**-**	**1**	**1**

Semester - I

Advanced Fluid Mechanics			
Course Code	22MTP13	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	3:0:2	SEE Marks	50
Total Hours of Pedagogy	50	Total Marks	100
Credits	04	Exam Hours	3 Hr

Course Learning objectives:

- To understand the kinematics of fluids, their governing equations, Mechanics of laminar and turbulent flow, NS Equations.
- Advanced knowledge of boundary layer equation, as well as a fundamental understanding of the drag and lift force.
- Understanding of the fundamental of the Flow across Normal Shock and Oblique Shock and Comparison of isentropic and 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).	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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 models; turbulent flow through pipes; losses in bends, valves etc; analysis of pipe network - Hard cross method.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks**
2. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks** to attain the COs and POs
3. The sum of three tests, two assignments/skill Development Activities, will be **scaled down to 50 marks**

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

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.

Suggested Learning Resources:

Textbooks

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

Reference Books

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

Web links and Video Lectures (e-Resources):

- https://archive.nptel.ac.in/courses/112/105/112105218/
- https://archive.nptel.ac.in/courses/112105269/
- https://archive.nptel.ac.in/courses/112/105/112105287/
- https://archive.nptel.ac.in/courses/112/106/112106311/
- https://archive.nptel.ac.in/courses/103/102/103102211/
- https://archive.nptel.ac.in/courses/112/103/112103290/

Skill Development Activities Suggested

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	Illustrate the basic concepts fluid flow and their governing equations	
CO2	Analyse the laminar and turbulent flow problems.	
CO3	Demonstrate the concept of boundary layer equations and drag and lift force	
CO4	Distinguish normal and oblique shocks and their governing Equations.	
CO5	Explain thePropagation of sound waves and Comparison of isentropic and adiabatic processes in fluid mechanics.	

Mapping of COS and POs

POs → COs↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	**3**	**2**	**1**	**-**	**-**	**1**	**1**
CO2	**3**	**2**	**1**	**2**	**-**	**1**	**1**
CO3	**3**	**2**	**1**	**2**	**-**	**1**	**1**
CO4	**3**	**2**	**1**	**2**	**-**	**1**	**1**
CO5	**3**	**2**	**1**	**-**	**-**	**1**	**1**

Semester - I

Advanced Thermodynamics and Combustion			
Course Code	22MTP14	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

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 exergy & irreversibility, Exergy analyses of open and closed system.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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 behaviour of Gas mixtures Ideal and Real gases. Equations of statesand properties of ideal and real gas mixtures, Property relations for mixtures and Psychrometry, Change in entropy in mixing.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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.

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 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks.**
2. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks** to attain the COs and POs.
3. The sum of three tests, two assignments/skill Development Activities, will be **scaled down to 50 marks.**

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

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.

Suggested Learning Resources:

Textbooks

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.
7. Advanced Thermodynamics for Engineers, Kenneth Wark, McGraw Hill.

Web links and Video Lectures (e-Resources):

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/

Skill Development Activities Suggested

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	Illustrate the basic concepts on First & Second Law Analysis,entropy, and exergy analysis in thermodynamic systems.	
CO2	Analyse the Thermodynamic property relations and its application to gas mixtures, phase change processes.	
CO3	Demonstrate the Combustion fundamentals involving premixed and non-premixed flames for laminar and turbulent combustion.	
CO4	Explain thefundamental of properties of gas mixtures, chemical reactions, and chemistry of combustion.	
CO5	Applications ofCombustion phenomena in practical occurring applications such IC and GT engines.	

Mapping of COS and POs

POs → COs↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	**3**	**2**	**1**	**-**	**1**	**1**	**1**
CO2	**3**	**2**	**1**	**-**	**1**	**1**	**1**
CO3	**3**	**2**	**1**	**2**	**1**	**1**	**1**
CO4	**3**	**2**	**1**	**-**	**1**	**1**	**1**
CO5	**3**	**2**	**1**	**2**	**1**	**1**	**1**

Semester – I

Finite Element Method in Heat Transfer			
Course Code	22MTP15	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

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.

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.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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 (usingGalerkin's method). Examples of heat transfer in a fluid flowing between parallel planes.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

CIE for the theory component of IPCC

1. Two Tests each of **20 Marks.**
2. Two assignments each of **10 Marks/One Skill Development Activity of 20 marks.**
3. Total Marks of two tests and two assignments/one Skill Development Activity added will be CIE for 60 marks, marks scored will be proportionally scaled down to **30 marks**.

CIE for the practical component of IPCC

- On completion of every experiment/program in the laboratory, the students shall be evaluated, and marks shall be awarded on the same day. The **15 marks** are for conducting the experiment and preparation of the laboratory record, the other **05 marks shall be for the test** conducted at the end of the semester.
- The CIE marks awarded in the case of the Practical component shall be based on the continuous evaluation of the laboratory report. Each experiment report can be evaluated for 10 marks. Marks of all experiments' write-ups are added and scaled down to 15 marks.
- The laboratory test at the end /after completion of all the experiments shall be conducted for 50 marks and scaled down to 05 marks**.**
- Scaled-down marks of write-up evaluations and tests added will be CIE marks for the laboratory component of IPCC for **20 marks**.

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).

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.
4. The Finite Element Method: Zeincowicz: 4 Vol set. 4th Edition, Elsevier 2007.
5. 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):

http://nptel.ac.in/courses/112104116/
https://archive.nptel.ac.in/courses/112/105/112105308/
https://archive.nptel.ac.in/courses/112/103/112103295/
https://archive.nptel.ac.in/courses/112/104/112104116/
https://archive.nptel.ac.in/courses/112/104/112104115/#

Activity Based Learning (Suggested Activities in Class)/ Practical Based learning

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	Recall Governing Equations for Heat Conduction for solving 1-D thermal problems using Approximate methods, Rayleigh – Ritz Methods and Galerkin's methods.	
CO2	Formulate the element characteristic for linear and Quadratic matrices and vectors for1-D and 2-D problems.	
CO3	Explain the Formulation of Heat Conduction Equations for 1D, 3-D, Fin, and Nonlinear Heat conduction for developing mathematical models.	
CO4	Demonstrate the Application of numerical methods on heat transfer problems, Convective Heat Transfer and Fluid Mechanics Problems.	

Mapping of COS and POs

POs → COs↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	**3**	**2**	**1**	**2**	**2**	**1**	**1**
CO2	**3**	**2**	**1**	**2**	**2**	**1**	**1**
CO3	**3**	**2**	**1**	**2**	**2**	**1**	**1**
CO4	**3**	**2**	**1**	**2**	**2**	**1**	**1**

Semester - I

Research Methodology and IPR			
Course Code	22RMI16	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	3:0:0	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	03	Exam Hours	3 Hr

Course Learning objectives:

- Identify an appropriate research problem in their interesting domain.
- Understand ethical issues Understand the Preparation of a research project thesis report.
- Understand the Preparation of a research project thesis report
- Understand the law of patent and copyrights.
- Understand the Adequate knowledge on IPR

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.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.
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 Organisation (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.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks.**
2. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks** to attain the

COs and POs.

3. The sum of three tests, two assignments/skill Development Activities, will be **scaled down to 50 marks.**

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

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.

Suggested Learning Resources:

Textbooks

1. Research Methodology: Methods and Techniques, C.R. Kothari, Gaurav Garg, New Age International,4th Edition, 2018.
2. Research Methodology a step-by-step guide for beginners. (For the topic Reviewing the literature under module 2), Ranjit Kumar, SAGE Publications,3rd Edition, 2011.
3. Study Material (For the topic Intellectual Property under module 5), Professional Programme Intellectual Property Rights, Law and Practice, The Institute of Company Secretaries of India, Statutory Body Under an Act of Parliament, September 2013.
4. Research Methods: the concise knowledge base, Trochim, Atomic Dog Publishing, 2005.
5. Conducting Research Literature Reviews: From the Internet to Paper, Fink A, Sage Publications, 2009.
6. Stuart Melville and Wayne Goddard, " Research methodology: an introduction for science & engineering students"

Web links and Video Lectures (e-Resources):

https://archive.nptel.ac.in/courses/110/105/110105091/
https://archive.nptel.ac.in/courses/127/106/127106227/
https://archive.nptel.ac.in/courses/107/108/107108011/

Skill Development Activities Suggested

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	Discuss research methodology and the technique of defining a research problem	
CO2	Explain the functions of the literature review in research, carrying out a literature search, developing theoretical and conceptual frameworks and writing a review.	
CO3	Explain various research designs, sampling designs, measurement and scaling	

	techniques and different methods of data collections.	
CO4	Explain several parametric tests of hypotheses, Chi-square test, art of interpretation and writing research reports	
CO5	Discuss various forms of the intellectual property, its relevance and business impact in the changing global business environment and leading International Instruments concerning IPR	

Mapping of COS and POs

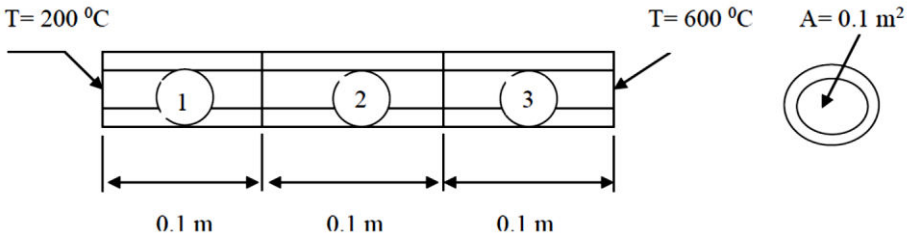
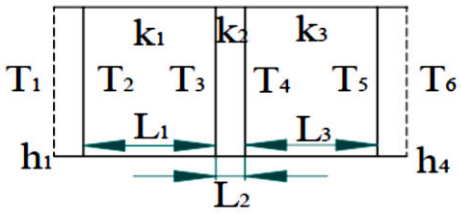
POs → COs↓	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**
CO1	**3**	**2**	**1**	**-**	**1**	**1**	**1**
CO2	**3**	**2**	**2**	**-**	**1**	**1**	**1**
CO3	**3**	**2**	**2**	**-**	**1**	**1**	**1**
CO4	**3**	**2**	**1**	**2**	**1**	**1**	**1**
CO5	**3**	**2**	**1**	**-**	**1**	**2**	**1**

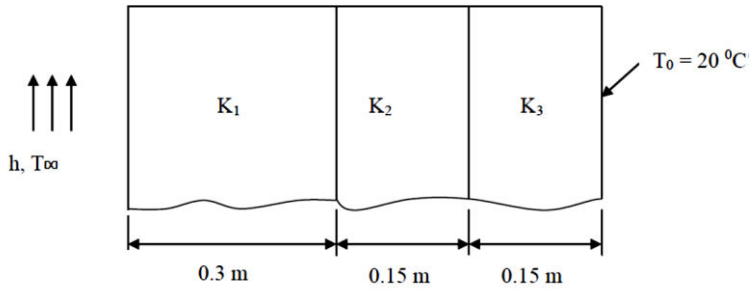
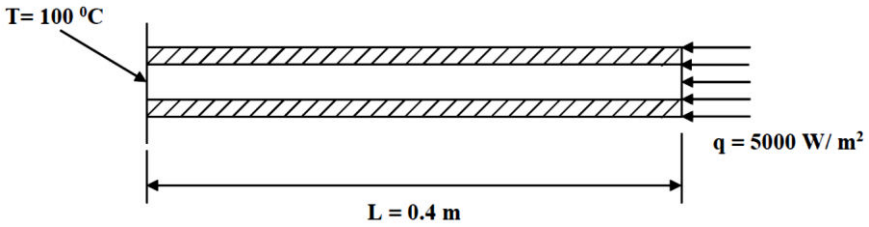
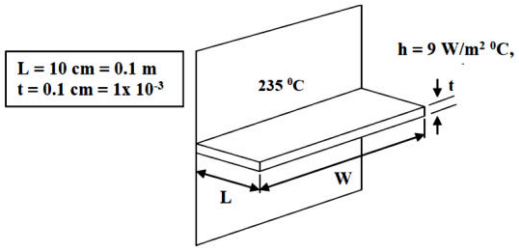
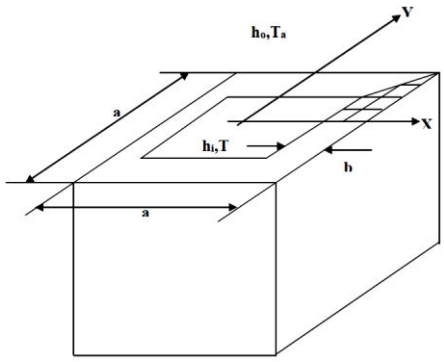
Semester – I

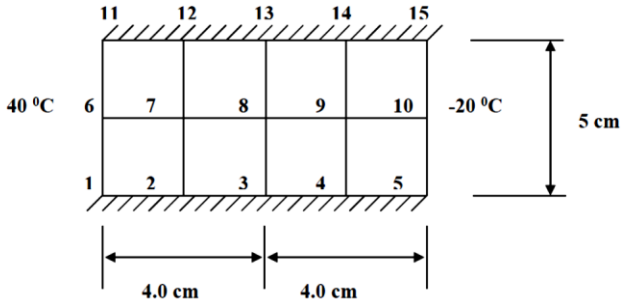
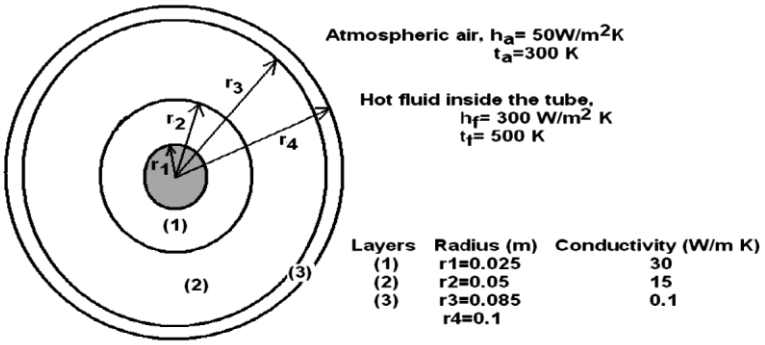
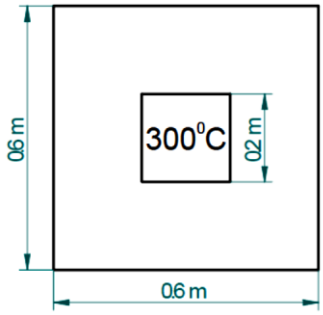
FEM & Simulation Lab			
Course Code	22MTPL17	CIE Marks	50
Teaching Hours/Week (L:T:P: S)	1:2:0	SEE Marks	50
Credits	2	Exam Hours	3 hr

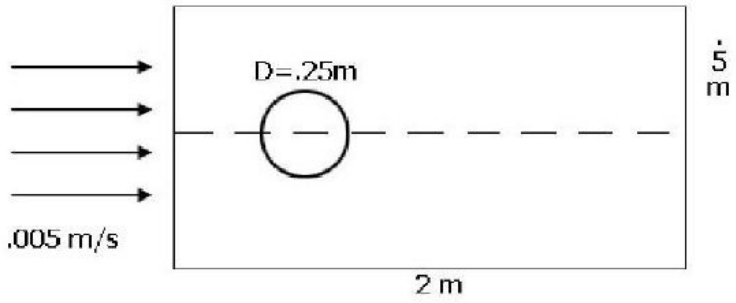
Course objectives:

- 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.

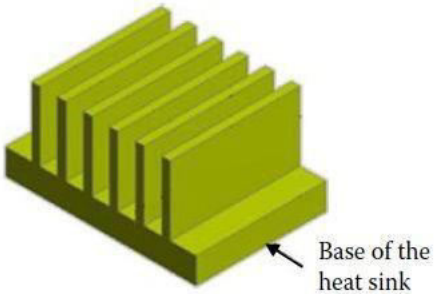
Sl.NO	Experiments
1	For the composite wall idealized by the 1-D model shown in figure below, determine the interface temperatures. For element 1, let K_1 = 5 W / m °C, for element 2, K_2 = 10 W / m °C and for element 3, K_3 = 15 W / m °C. The left end has a constant temperature of 200 °C and the right end has a constant temperature of 600 °C 
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 0.001m² K/W the heat transfer co-efficient for inner and outer surfaces is equal to 35W/m² K. Find the heat flow through the wall per unit area per unit time and temperature distribution across the wall 
3	A composite wall consists of three materials as shown. The outer temperature is T_0 = 20 °C. Convection heat transfer takes place on the inner surface of the wall with T_∞ = 800°C and h = 25 W/m²°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/m²°C, T_∞ = 800°C.

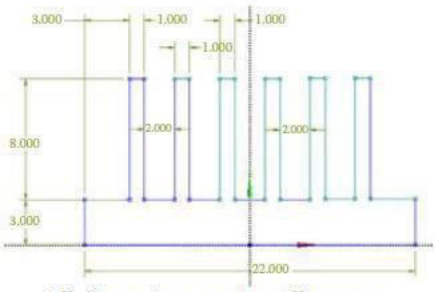
	
4	The fin shown in figure is insulated on the perimeter. The left end has a constant temperature of 100°C. A positive heat flux q*= 5000 W / m2 acts on the right end. Let Kxx = 6 W/ m°C and cross sectional area A = 0.1 m2 . Determine the temperatures at and $\frac{L}{4}, \frac{L}{2}, \frac{3L}{4}, and\ L$ Where L = 0.4 m. 
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. 
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 T_g = 311 K, the inside convection coefficient is h_i, the surrounding air temp is T_a = 255 K and the outside convection coefficient is h_o. 
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. 
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). 
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 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.



	Demonstration Experiments (For CIE) if any
11	Model Fully developed laminar flow and turbulent flow through a circular pipe using ANSYS Workbench
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.
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.
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/m^3 , 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/(m^2 °C).





All dimensions are in millimeters.

Material: Aluminum

k = 170 W/(m · K)

ρ = 2800 kg/m^3; c = 870 J/(kg · K)

E = 70 GPa; ν = 0.3

α = 22 × 10^{-6}/°C

Boundary conditions:

Air temperature of 28°C; h = 30 W/(m^2 · °C).

Steady state: q' = 1000 W/m^2 on the base.

Transient: Square wave heat flux on the base.

Initial conditions:

Steady state: Uniform temperature of 28°C.
Transient: Steady-state temperature results.

Course outcomes (Course Skill Set):

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

CO1	Develop skills in making geometry and meshing for various configurations using ANSYS Workbench.
CO2	Develop knowledge in CFD simulation of Convective heat transfer and phase change problems using ANSYS Workbench.
CO3	Develop knowledge in simulation of lamina and turbulent flow using ANSYS Workbench.
CO4	Develop MATLAB programme for simulation of IC engine performances.

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 50% of the maximum marks. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each course. The student has to secure not less than 40% of maximum marks in the semester-end examination(SEE). In total of CIE and SEE student must secure 50% maximum marks of the course.

Continuous Internal Evaluation (CIE):

CIE marks for the practical course is **50 Marks**.

The split-up of CIE marks for record/ journal and test are in the ratio **60:40**.

- Each experiment to be evaluated for conduction with observation sheet and record write-up. Rubrics for the evaluation of the journal/write-up for hardware/software experiments designed by the faculty who is handling the laboratory session and is made known to students at the beginning of the practical session.
- Record should contain all the specified experiments in the syllabus and each experiment write-up will be evaluated for 10 marks.
- Total marks scored by the students are scaled downed to 30 marks (60% of maximum marks).
- Weightage to be given for neatness and submission of record/write-up on time.
- Department shall conduct 02 tests for 100 marks, the first test shall be conducted after the 8th week of the semester and the second test shall be conducted after the 14th week of the semester.
- In each test, test write-up, conduction of experiment, acceptable result, and procedural knowledge will carry a weightage of 60% and the rest 40% for viva-voce.
- The suitable rubrics can be designed to evaluate each student's performance and learning ability.
- The average of 02 tests is scaled down to **20 marks** (40% of the maximum marks).
- The Sum of **scaled-down** marks scored in the report write-up/journal and average marks of two tests is the total CIE marks scored by the student.

Semester End Evaluation (SEE):

SEE marks for the practical course is 50 Marks.

SEE shall be conducted jointly by the two examiners of the same institute, examiners are appointed by the University.

All laboratory experiments are to be included for practical examination.

(Rubrics) Breakup of marks and the instructions printed on the cover page of the answer script to be strictly adhered to by the examiners. **OR** based on the course requirement evaluation rubrics shall be decided jointly by examiners.

- Students can pick one question (experiment) from the questions lot prepared by the internal /external examiners jointly.
- Evaluation of test write-up/ conduction procedure and result/viva will be conducted jointly by examiners.
- General rubrics suggested for SEE are mentioned here, writeup-20%, Conduction procedure and result in -60%, Viva-voce 20% of maximum marks. SEE for practical shall be evaluated for 100 marks and scored marks shall be scaled down to 50 marks (however, based on course type, rubrics shall be decided by the examiners)
- Change of experiment is allowed only once and 10% Marks allotted to the procedure part to be made zero.
- The duration of SEE is 03 hours

Suggested Learning Resources:

VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELAGAVI.

Scheme of Teaching and Examinations and Syllabus
M.Tech., Program
in
Thermal Power Engineering

(Effective from the Academic year 2022-23)

Registrar,
Visvesvaraya Technological University
JnanaSangam, Machhe, Belagavi-590018
E-Mail: registrar@vtu.ac.in
Contact: 0831-2498112

VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELAGAVI

Scheme of Teaching and Examinations – 2022-23

M.Tech., in Thermal Power Engineering (MTP)

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

II SEMESTER

Sl. No	Course	Course Code	Course Title	Teaching Hours /Week			Examination				Credits
				Theory	Practical/ Seminar	Tutorial/ Skill Development Activities	Duration in hours	CIE Marks	SEE Marks	Total Marks	
				L	P	T/SDA					
1	PCC	22MTP21	Advanced Power Plant Cycles	02	00	02	03	50	50	100	3
2	IPCC	22MTP22	Advanced Heat Transfer	03	02	00	03	50	50	100	4
3	PEC	22MTP23x	Professional Elective - 1	02	00	02	03	50	50	100	3
4	PEC	22MTP24x	Professional Elective - 2	02	00	02	03	50	50	100	3
5	MPS	22MTP25	Mini Project with Seminar	00	04	02	--	100	--	100	3
6	PCCL	22MTPL26	CFD and Numerical Lab	01	02	00	03	50	50	100	02
7	AUD/ AEC	22AUD27	Suggested ONLINE courses	Classes and evaluation procedures are as per the policy of the online course providers.							PP
TOTAL				**10**	**08**	**08**	**15**	**350**	**250**	**600**	**18**

Note: PCC: Professional core courses,PEC: Professional Elective Courses, IPCC-Integrated Professional Core Courses. MPS-Mini Project with Seminar; AUD/AEC; Audit Courses / Ability Enhancement Courses (Mandatory), PCCL-Professional Core Course lab,

L-Lecture, P-Practical, T/SDA-Tutorial / Skill Development Activities(Hours are for Interaction between faculty and students)

Professional Elective 1		Professional Elective2	
Course Code under 22XXX23X	**Course title**	**Course Code under 22XXX24X**	**Course title**
22MTP231	Steam and Gas Turbines	22MTP241	Refrigeration and Air Conditioning
22MTP232	Renewable Energy Technology	22MTP242	Hydrogen and Fuel Cell Technologies
22MTP233	Design and Optimization of Thermal Energy Systems	22MTP243	Jet and Rocket Propulsion systems
22MTP234	Cryogenics	22MTP244	Computational Methods in Heat Transfer and Fluid Flow
22MTP235	Nuclear Engineering in Power Generation	22MTP245	Energy Conservation and Management

Note:

1 Mini Project with Seminar: This may be hands-on practice**,** survey report, data collection and analysis, coding, mobile app development, field visit and report preparation, modelling of system, simulation, analysing and authenticating, case studies, etc.

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 must complete the same during the subsequent semester. There is no SEE for this course.

2. Internship: All the students shall have to undergo a mandatory internship of **06 weeks** during the vacation of II and III semesters. A University examination shall be conducted during III semester and the prescribed internship credit shall be counted in the same semester. The internship 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 internship shall be declared as fail in the internship course and must complete the same during the subsequent University examination after satisfying the internship requirement.

Program Outcome of this course

POs	Description
PO1:	Acquire, demonstrate, and apply basic knowledge in the field of Thermal power engineering.
PO2:	Identify problems in the field of Thermal power engineering, formulate them and solve by using advanced techniques.
PO3:	Conduct independent research and generate new knowledge for the benefit of community, society, Industry, and nation.
PO4:	Apply various computational methods using advanced software and engineering tools to model, analyze and solve thermal engineering problems.
PO5:	Work effectively in interdisciplinary teams for solving real life problems in achieving multidisciplinary tasks required for the project in the related field.
PO6:	Effectively communicate through technical reports, presentations, scientific publications, intellectual integrity, ethics of research and scholarly standards with the engineering community as well as society at large.
PO7:	Engage in life-long reflective and independent learning with high level of enthusiasm and commitment.

Semester– II

Advanced Power Plant Cycles			
Course Code	22MTP21	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

Course Learning objectives:

- The objective of the subject is to acquaint the students about the new and advanced technologies of power generation.
- To study the power generation scenario, the components of thermal power plant, improved Rankin cycle, Cogeneration cycle.
- To understand details of steam condensing plant, analysis of condenser, the environmental impacts of thermal power plant, method to reduce various pollution from thermal power plant.
- To study layout, component details of hydroelectric power plant, hydrology and elements, types of nuclear power plant.

Module-1

Analysis of Steam cycles: Rankine cycle, Carnot cycle, mean temperature of heat addition, effect of variation of steam condition on thermal efficiency of steam power plant, reheating of steam, regeneration, regenerative feed water heating, feed water heaters, carnotization of Rankine cycle, optimum degree of regeneration, Super critical pressure cycle, steam power plant appraisal, Deaerator, typical layout of steam power plant, efficiencies in a steam power plant, Cogeneration of Power and Process Heat, Numerical Problems. Combined cycle power generation: Flaws of steam as working fluid in Power Cycle, Characteristics of ideal working fluid in vapor power cycle, Binary vapor cycles, coupled cycles, combined cycle plants, gas turbine- steam turbine power plant, MHD-steam power plant, Thermionic- Steam power plant.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Module-2

Steam Generators: Basic type of steam generators, fire tube boilers, water tube boilers. Economizers, super heaters, re heaters, steam generator control, air preheater, fluidized bed boilers, electrostatic precipitator, fabric filters and bag houses, ash handling system, feed water treatment, de-aeration, evaporation, internal treatment, boiler blow down, steam purity, Numerical problems. Condenser, feed water and circulating water systems: Need of condenser, direct contact condensers, feed water heaters, circulating water system, cooling towers, calculations, Numerical Problems.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Module-3

Nuclear Power Plants: Chemical and nuclear reactions, nuclear stability and binding energy, radioactive decay and half-life, nuclear fission, chain reaction, neutron energies. Neutron flux and

reaction rates, moderating power and moderating ratio, variation of neutron cross sections with neutron energy, neutron life cycle. Reflectors, Types of Reactors, PWR, BWR, gas cooled reactors. Liquid metal fast breeder reactor, heavy water, and Fusion Power reactors. Safety in nuclear power plants.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.
Module-4	
Hydro Electric Power Plant: Introduction, advantages and disadvantages of waterpower, optimization of hydro – thermal mix, hydrological cycles, storage and pondage Power plant Economics: Definitions, Principles, Location of power plant, cost analysis selection of type of generation, selection of power plant equipment‘s	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.
Module-5	
Pollution and its effects: Definition, Cause, effects and control measures of - Air pollution, Water pollution, Soil pollution, Marine pollution, Noise pollution, Thermal pollution and nuclear hazards, Solid waste Management, Disaster management Role of an individual in prevention of pollution, Pollution case studies. **Social Issues and the Environment:** Climate change, global warming, acid rain, ozone layer depletion, nuclear accidents, and holocaust. Case Studies. Wasteland reclamation, Consumerism and waste products, Environment Protection Act, Air (Prevention and Control of Pollution) Act, Water (Prevention and control of Pollution) Act, Wildlife Protection Act, Forest Conservation Act, Issues involved in enforcement of environmental legislation.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks.**
2. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks** to attain the COs and POs.
3. The sum of three tests, two assignments/skill Development Activities, will be **scaled down to 50 marks.**

CIE methods /question paper is designed to attain the different levels of Bloom’s taxonomy as per the outcome defined for the course.

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.

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, AddisonWesley, 1983.

Web links and Video Lectures (e-Resources):

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

Skill Development Activities Suggested:

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	Describe the power generation scenario, the layout components of thermal power plant and analyze the improved Rankin cycle, Cogeneration cycle.	
CO2	Analyze the steam condensers, recognize the environmental impacts of thermal power plant and method to control the same.	
CO3	Recognize the layout, component details of hydroelectric power plant and nuclear power plant	
CO4	Describe the different power plant electrical instruments and basic principles of economics of power generation.	

Mapping of COS and POs

POs → COs↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	3	2	1	2	1	1	1
CO2	3	2	1	2	1	1	1
CO3	3	2	1	-	1	1	1
CO4	3	2	1	-	1	1	1

Semester – II

Advanced Heat Transfer			
Course Code	22MTP22	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

Course Learning objectives:

- To present a comprehensive and rigorous treatment of conductive, Fins, and unsteady state heat transfer by emphasizing the engineering and engineering arguments.
- To develop the ability to use the analysis of convection heat transferfor various applications like boundary layer, laminar and turbulent boundary layer flows.
- To understand the natural and forced convection heat transfer process applied toindustrial applications.
- To develop an intuitive understanding of radiative heat transfer and different types of heat exchangers to learn real engineering problems.

Module-1

Introduction and one-dimensional heat transfer: The 3-D differential equation of heat conduction in cartesian, cylindrical and spherical coordinates,Steady state heat conduction in one dimensional, With heat generation, Critical thickness of insulation, two-dimensional steady state heat conduction, Problems.

Conduction Unsteady State: Lumped heat capacity, Transient heat flow, Extended Surfaces- Fins of uniform cross section and non-uniform cross sections, Thermal resistance networks and applications. problems.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Module-2

Analysis of Convection Heat Transfer: Boundary layer fundamentals evaluation of convection heat transfer coefficient, Hydrodynamic and thermal boundary layer,Dimensional analysis for forced and free convection, Blasius solution for laminar boundary layer flow over a flat plate, Approximate integral boundary layer analysis, Integral energy equation, Turbulent boundary layer, Analogy between momentum and heat transfer in turbulent flow over a flat surface, Reynolds Analogy for Turbulent Flow Over Plane Surfaces, Mixed boundary layer.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Module-3

Natural and Forced convection Heat Transfer: Introduction, Similarity Parameters for Natural Convection, Approximate analysis of natural convection on vertical plate, Empirical Correlation for Various Shapes, Rotating Cylinders, Disks, and Spheres, Natural convection from finned surfaces.

Forced convection: Turbulent tube flow, Empirical Correlations in laminar and turbulent flow over various shapes, Flow across bluff objects, packed beds and bank of tubes, combined natural and

forced convection.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.
Module-4	
Thermal radiation: Basic concepts and laws of thermal radiation, the shape factor, Heat Exchange Between Non-Black Bodies, Enclosures with Black Surfaces and Grey surfaces, radiation shields and Radiation Effect on temperature measurements. Radiation properties of participating Medium, Emissivity and absorptivity of Gases and Gas Mixtures, problems. **Boiling and Condensation:**Boiling heat transfer, Pool Boiling Correlations, Laminar Film Condensation on a Vertical Plate, Turbulent Film Condensation, Condensation in Horizontal Tubes, Problems.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.
Module-5	
Heat exchangers: Basic concepts, types of heat exchangers, Analysis of heat exchangers, LMTD and NTU of Parallel flow and Counter-Flow Heat Exchangers, Multi pass and Crossflow Heat Exchangers, Use of a Correction Factor, Selection of Heat Exchangers such as Heat Transfer Rate, Cost, Pumping Power, Size and Weight, Type, Materials, Other Considerations, Compact Heat Exchangers, Heat Exchangers for multi-phase flow.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

PRACTICAL COMPONENT OF IPCC

Sl.NO	Experiments
1	To find out the overall thermal conductance and plot the temperature distribution in case of a composite wall
2	To calculate the overall heat transfer coefficient for parallel flow and counter current flow heat exchanger.
3	To find out the Heat Transfer Coefficient of vertical cylinder in natural convection
4	To find out the temp. Distribution along the length of a Pin Fin under free convection and forced convection
5	Determination of Thermal Conductivity of Insulating Material and Thermal Conductivity of Liquid
6	To find the heat transfer co-efficient for Drop-wise condensation and Film-wise condensation process.
7	Determination of Heat Transfer Coefficient in a free Convection on a vertical tube.
8	Determination of Heat Transfer Coefficient in a Forced Convention Flow through a Pipe.
9	Determination of Critical Heat Flux.
10	Determination of Emissivity of a Surface.
11	Determination of Stefan Boltzman Constant.
12	Performance Test on Vapour Compression Refrigeration.

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 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks.**
2. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks** to attain the COs and POs.

The sum of three tests, two assignments/skill Development Activities, will be **scaled down to 50 marks.**

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

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.

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 P. Incropera, David P. Dewitt seventh edition John Wiley & Sons, Inc
6. Heat and mass Transfer: Er. R.K. Rajput, S. Chand & Company Ltd., 5th Edition.

Web links and Video Lectures (e-Resources):

- https://archive.nptel.ac.in/courses/103/105/103105052/
- https://archive.nptel.ac.in/courses/103/105/103105140/
- https://archive.nptel.ac.in/courses/112/107/112107256/
- https://archive.nptel.ac.in/courses/112/103/112103297/
- https://archive.nptel.ac.in/courses/103/101/103101137/
- https://archive.nptel.ac.in/courses/112/108/112108246/

Skill Development Activities Suggested

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	Ability to understand modes of heat transfer with energy equation and develop models for physical problems and analyze steady state, fins, and transient heat conduction problems of real-life thermal systems	
CO2	Identify and explain the concepts of Boundary layers using Laminar and turbulent conditions.	
CO3	Understand and recognize the free and forced convection problems in real time applications.	
CO4	Apply different methods for solution of radiative heat transfer problems in non-participating and participating medium and applications of boiling and condensation in industry.	
CO5:	Demonstrate the importance of heat exchanger and its applications in industry.	

Mapping of COS and POs

POs → COs↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	**3**	**2**	**1**	**2**	**1**	**1**	**1**
CO2	**3**	**2**	**1**	**2**	**1**	**1**	**1**
CO3	**3**	**2**	**1**	**-**	**1**	**1**	**1**
CO4	**3**	**2**	**1**	**-**	**1**	**1**	**1**
CO5	**3**	**2**	**1**	**-**	**1**	**1**	**1**

Semester – II

Steam and Gas Turbines			
Course Code	22MTP231	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

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, Supersaturated Flow in Nozzles, Effect of Variation of Back Pressure, Parameters Affecting the Performance of Nozzles, Experimental Methods to Determine Velocity Coefficient, Experimental Results.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Module-4

Centrifugal Compressors: Componentsof 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, flow through blade rows, flow losses, performance characteristics, comparison of axial and centrifugal compressor.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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, 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.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks.**
2. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks** to attain the COs and POs.

The sum of three tests, two assignments/skill Development Activities, will be **scaled down to 50 marks.**

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

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.

Suggested Learning Resources:

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.

Web links and Video Lectures (e-Resources):

- 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/

Skill Development Activities Suggested

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	Describe the working principles of Gas and steam turbine nozzles and diffusers.	
CO2	Designate the working principles of impulse and reaction turbines using velocity triangles.	
CO3	Use the concepts of State Point Locus Reheat Factor and Identify the various losses associated with the turbines.	
CO4	Illustrate the concepts of axial flow and centrifugal compressors and its application in gas turbine.	
CO5:	Explain the concepts of open and closed cycle gas turbine and its application in jet propulsion.	

Mapping of COS and POs

POs → COs↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	**3**	**2**	**1**	**2**	**1**	**1**	**1**
CO2	**3**	**2**	**1**	**2**	**1**	**1**	**1**
CO3	**3**	**2**	**1**	**-**	**1**	**1**	**1**
CO4	**3**	**2**	**1**	**-**	**1**	**1**	**1**
CO5	**3**	**2**	**1**	**-**	**1**	**1**	**1**

Semester – II

Renewable Energy Technology			
Course Code	22MTP232	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

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.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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, 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.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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.

Teaching-Learning	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Process	
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.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.
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.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks.**
2. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks** to attain the COs and POs.

The sum of three tests, two assignments/skill Development Activities, will be **scaled down to 50 marks.**

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

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.

Suggested Learning Resources:

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, Tata McGraw Hill, 2017.
6. Solar Energy, Sukhatme. S.P., Tata McGraw Hill Publishing Company Ltd., 1997.
7. Renewable Energy, Power for a Sustainable Future, Godfrey Boyle, Oxford University Press, U.K., 1996.
8. Biogas Technology – A Practical Handbook, Khandelwal, K.C., Mahdi, S.S., Tata McGraw-Hill, 1986.
9. Solar Energy – Fundamentals Design, Modelling & Applications, Tiwari. G.N., Narosa Publishing House, New Delhi, 2002.
10. Wind Energy Conversion Systems, Freris. L.L., Prentice Hall, 1990.
11. Principles of Solar Energy, Frank Krieth & John F Kreider, John Wiley, New York, 1987.

Web links and Video Lectures (e-Resources):

- 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

Skill Development Activities Suggested

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	Describe measurement of direct, diffuse, and global solar radiations falling on horizontal and inclined surfaces, Basic earth sun angles, Beam and diffuse radiations, Radiation on titled surfaces.	
CO2	Analyze the performance by conducting research on flat plate collector, air heater and concentrating type collector. Understand test procedures and apply these while testing different types of collectors.	
CO3	Demonstrate and Design various types of thermal energy storage systems. Analyze payback period and annual solar savings due to replacement of conventional systems	
CO4	Demonstrate the importance of solar energy effectively to increase awareness of it in society.	
CO5:	Describe measurement of direct, diffuse, and global solar radiations falling on horizontal and inclined surfaces, Basic earth sun angles, Beam and diffuse radiations, Radiation on titled surfaces.	

Mapping of COS and POs

POs → COs↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	3	2	1	2	1	1	1
CO2	3	2	1	2	1	1	1
CO3	3	2	1	-	1	1	1
CO4	3	2	1	-	1	1	1
CO5	3	2	1	-	1	1	1

Semester – II

Design and Optimization of Thermal Energy Systems			
Course Code	22MTP233	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

Course Learning objectives:

- To Understand the concept of optimization and its importance in the background of reallife 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.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Module-4	
Thermo-economic analysis and evaluation: Fundamentals of thermo-economics, Thermo-economic variables for component evaluation; thermo-economic evaluation; additional costing considerations.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks.**
2. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks** to attain the COs and POs.

The sum of three tests, two assignments/skill Development Activities, will be **scaled down to 50 marks.**

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

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.

Suggested Learning Resources:

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.
4. Design of thermal systems, W. F. Stoecker, Mc Graw Hill, 1989.
5. Introduction to optimum design, J. S. Arora, Mc Graw Hill, 1989.
6. Optimization for engineering design - algorithms and examples, K. Deb, Prentice Hall, 1995.

Web links and Video Lectures (e-Resources):

https://archive.nptel.ac.in/courses/112/106/112106064/

Skill Development Activities Suggested

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	Formulation of design problems related to thermal Systems.	
CO2	Apply methods of optimization to solve a linear, non-linear programming problem by various methods.	
CO3	Optimize engineering problem of nonlinear programming with/without constraints, by using this technique	
CO4	Use of dynamic programming problem in controlling in industrial managements.	
CO5	Simulate Thermal engineering system problem. Understand integer programming and stochastic programming to evaluate advanced optimization techniques.	

Mapping of COS and POs

POs → COs↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	**3**	**2**	**1**	**2**	**1**	**1**	**1**
CO2	**3**	**2**	**1**	**2**	**1**	**1**	**1**
CO3	**3**	**2**	**1**	**-**	**1**	**1**	**1**
CO4	**3**	**2**	**1**	**-**	**1**	**1**	**1**
CO5	**3**	**2**	**1**	**-**	**1**	**1**	**1**

Semester – II

Cryogenics			
Course Code	22MTP234	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

Course Learning objectives:

- To cover the basic principles of cryogenic engineering.
- To develop an intuitive understanding of cryogenics for the student who are interested to study the science technology of low temperatures.

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.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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, J-T Cryocooler, Stirling Cryocooler, G-M Cryocooler and Pulse Tube Cryocooler.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Module-3	
Vacuum Technology: Need of Vacuum in Cryogenics, Vacuum fundamentals, Conductance and Electrical analogy, Pumping Speed and Pump down time and Vacuum Pumps.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Module-4	
Instrumentation in Cryogenics: Need of Cryogenic Instrumentation, Measurement of Thermo-physical Properties and Various Sensors.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks.**
2. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks** to attain the COs and POs.

The sum of three tests, two assignments/skill Development Activities, will be **scaled down to 50 marks.**

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

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.

Suggested Learning Resources:

Books

1. Randall F. Barron, "Cryogenics Systems", Second Edition Oxford Univesity 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):

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

Skill Development Activities Suggested

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	Understand the working principles and applications of different types of gas liquefaction and refrigeration systems.	
CO2	Understanding the governing laws and principles of gas separation.	
CO3	Illustrate Ideal separation, properties of mixtures, Rectifiers column, separation of air, purification.	
CO4	Understanding the importance of cryogenics insulations and Safety in Cryogenics.	
CO5	Study and describe Insulation and storage systems in cryogenic engineering	

Mapping of COS and POs

POs → COs↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	**3**	**2**	**1**	**2**	**1**	**1**	**1**
CO2	**3**	**2**	**1**	**2**	**1**	**1**	**1**
CO3	**3**	**2**	**1**	**-**	**1**	**1**	**1**
CO4	**3**	**2**	**1**	**-**	**1**	**1**	**1**
CO5	**3**	**2**	**1**	**-**	**1**	**1**	**1**

Semester – II

Nuclear Engineering in Power Generation			
Course Code	22MTP235	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

Course Learning 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, Shielding.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks.**
2. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks** to attain the COs and POs.

The sum of three tests, two assignments/skill Development Activities, will be **scaled down to 50 marks.**

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

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.

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/

Skill Development Activities Suggested

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	Understand the basic physics of nuclear reactions	
CO2	Basic concepts of nuclear fuel manufacturing and spent fuel handling	
CO3	Classification of nuclear reactors	
CO4	Understand working principle of thermal reactor	
CO5	Analyse the thermal hydraulics of nuclear reactors	

Mapping of COS and POs

POs → COs↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	**3**	**2**	**1**	**2**	**1**	**1**	**1**
CO2	**3**	**2**	**1**	**2**	**1**	**1**	**1**
CO3	**3**	**2**	**1**	**-**	**1**	**1**	**1**
CO4	**3**	**2**	**1**	**-**	**1**	**1**	**1**
CO5	**3**	**2**	**1**	**-**	**1**	**1**	**1**

Semester – II

Refrigeration and Air Conditioning			
Course Code	22MTP241	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

Course Learning 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.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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,

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks.**
2. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks** to attain the COs and POs.

The sum of three tests, two assignments/skill Development Activities, will be **scaled down to 50 marks.**

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

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.

Suggested Learning Resources:

Books

Textbook

1. Roy J. Dossat, Principles of Refrigeration, Wiley Limited 2002.
2. Arora C.P., Refrigeration and Air-conditioning, 3rd edition,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

Skill Development Activities Suggested

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	Understand concepts of refrigeration and air-conditioning process and systems.	
CO2	Employ the theoretical principles to simple, complex vapour compression and vapour absorption refrigeration systems.	
CO3	Understand conventional and alternate refrigerants and their impact on environment.	
CO4	Apply the heat load calculation to design the air-conditioning systems.	
CO5	Describe the concepts to design air distribution systems.	

Mapping of COS and POs

POs → COs↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	3	2	1	2	1	1	1
CO2	3	2	1	2	1	1	1
CO3	3	2	1	-	1	1	1
CO4	3	2	1	-	1	1	1
CO5	3	2	1	-	1	1	1

Semester – II

Hydrogen and Fuel Cell Technologies			
Course Code	22MTP242	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

Course Learning 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.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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.	
Teaching-Learning	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Process	
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	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.
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	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks.**
2. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks** to attain the COs and POs.

The sum of three tests, two assignments/skill Development Activities, will be **scaled down to 50 marks.**

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

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.

Suggested Learning Resources:

Books

1. Hydrogen and Fuel Cells: Fundamentals, Technologies and Applications; Detlef Stolten
2. Hydrogen and Fuel CellTechnologies and Market Perspectives; Johannes Töpler, Jochen

Lehmann;Springer Berlin, Heidelberg
3. Hydrogen and Fuel Cells: Emerging Technologies and Applications; Inde Sorensen, Bent,2nd Edition - Elsevier
4. M.M. MENCH, Fuel Cell Engines, Wiley, 2008.
5. M. T. M. Koper (ed.), Fuel Cell Catalysis, Wiley, 2009.
6. J. O'M. Bockris, A. K. N. Reddy, Modern Electrochemistry, Springer 1998.
7. 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/

Skill Development Activities Suggested

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	Apply know-how of thermodynamics, electrochemistry, heat transfer, and fluid mechanics principles to design and analysis of this emerging technology.	
CO2	Have thorough understanding of performance behaviour, operational issues and challenges for all major types of fuel cells.	
CO3	Identify, formulate, and solve problems related to fuel cell technology keeping in mind economic viability.	
CO4	Use the techniques, skills, and modern engineering tools necessary for design and analysis of innovative fuel cell systems.	
CO5	Understand the impact of this technology in a global and societal context. Develop enough skills to design systems or components of fuel cells.	

Mapping of COS and POs

POs → COs↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	3	2	1	2	1	1	1
CO2	3	2	1	2	1	1	1
CO3	3	2	1	-	1	1	1
CO4	3	2	1	-	1	1	1
CO5	3	2	1	-	1	1	1

Semester – II

Jet and Rocket Propulsion systems			
Course Code	22MTP243	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

Course Learning 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.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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, 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 atomization and drop size distribution, propellant tank design.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.
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	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.
Module-5	
RAMJET AND INTEGRAL ROCKET RAMJET PROPULSIONSYSTEM: 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.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks.**
2. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks** to attain the COs and POs.

The sum of three tests, two assignments/skill Development Activities, will be **scaled down to 50 marks.**

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

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.

Suggested Learning Resources:

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 DistributorsEdition 2014.
4. Rocket Propulsion Elements; George P. Sutton, Oscar Biblarz; Ninth Edition John Wiley & Sons, Inc., Hoboken, New Jersey 2017.
5. Gas Turbines;V Ganesan; 3rd Edition2017; McGraw Hill Education.

Web links and Video Lectures (e-Resources):

- https://archive.nptel.ac.in/courses/101/104/101104019/
- https://archive.nptel.ac.in/courses/112/103/112103262/

Skill Development Activities Suggested

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	Understand the aero thermo chemistry of the combustion products.	
CO2	Apply knowledge of features and capabilities of chemical and non-chemical rocket propulsion systems.	
CO3	Apply the concepts to ramjet ant jet propulsion system.	
CO4	Calculate the specific impulse and mass flow for a rocket engine with the fluid considered as an ideal gas with constant specific heats.	
CO5	Estimate the specific impulse and mass flow for a rocket engine accounting for chemical reaction and non-constant specific heats.	

Mapping of COS and POs

POs → COs↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	3	2	1	2	1	1	1
CO2	3	2	1	2	1	1	1
CO3	3	2	1	-	1	1	1
CO4	3	2	1	-	1	1	1
CO5	3	2	1	-	1	1	1

Semester – II

Computational Methods in Heat Transfer and Fluid Flow			
Course Code	22MTP244	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

Course Learning objectives:

- To inculcate subject knowledge of numerical methods applied to thermal engineering
- applications
- To learn the numerical techniques useful to apply in the areas such as CFD etc.
- To extent the learning of Numerical method applying the computer programming
- To Understand the concept of fluid dynamics, CFD techniques, convergence criteria
- To familiarize the students about the implementation of CFD in fluid mechanics and heat transfer problems

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.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Module-2

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. **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.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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 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-dimensionalizing the equations, MacCormack technique of discretization, Stability condition, Boundary conditions, Solution for shock flows	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks.**
2. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks** to attain the COs and POs.

The sum of three tests, two assignments/skill Development Activities, will be **scaled down to 50**

marks.

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

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.

Suggested Learning Resources:

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.
3. Computational fluid flow and heat transfer - K. Murlidhar and T. Sounderrajan, Narosa Publishing Co.
4. Computational fluid mechanics and heat transfer - D. A. Anderson, J. C. Tannehill, R.H. Pletcher, Tata McGraw-Hill Publications 2002.
5. Computational fluid dynamics - J.A. Anderson, McGraw-Hill Publications 1995.
6. An Introduction to Computational Fluid DynamicsVersteeg, 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/

Skill Development Activities Suggested

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	To derive the stepwise procedure to completely solve a fluid dynamics problem usingcomputational methods.	
CO2	To explain the governing equations and understand the behaviour of the equations.	
CO3	To determine the consistency, stability, and convergence of various discretization schemes forparabolic, elliptic and hyperbolic partial differential equations.	
CO4	To verify variations of SIMPLE schemes for incompressible flows and Variations of FluxSplitting algorithms for compressible flows.	
CO5:	To identify various methods of grid generation techniques and application of finite differenceand finite volume methods to various thermal problems.	

Mapping of COS and POs

POs → COs↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	3	2	1	2	1	1	1
CO2	3	2	1	2	1	1	1
CO3	3	2	1	-	1	1	1
CO4	3	2	1	-	1	1	1
CO5	3	2	1	-	1	1	1

Semester – II

Energy Conservation and Management			
Course Code	22MTP245	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

Course Learning objectives:

- To provide the sufficient knowledge of concept, applications, importance of EnergyConservation and management
- To familiarize the students about the Energy audit and its applications in real lifesituations
- To carry out a energy audit on the existed thermal system

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.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks.**
2. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks** to attain the COs and POs.

The sum of three tests, two assignments/skill Development Activities, will be **scaled down to 50 marks.**

CIE methods /question paper is designed to attain the different levels of Bloom’s taxonomy as per the outcome defined for the course.

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.

Suggested Learning Resources:

Books

1. Energy management and conservation handbook Frank Kreith & D. Yogi Goswami
2. Energy Management and Conservation; K. V. Sharma, P. Venkataseshaiah; 2013
3. Turner, W. C., Doty, S. and Truner, W. C., Energy Management Handbook, 7th edition, Fairmont Press, 2009.

4. De, B. K., Energy Management audit & Conservation, 2nd Edition, Vrinda Publication, 2010.
5. Murphy, W. R., Energy Management, Elsevier, 2007.
6. 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

Skill Development Activities Suggested

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	Understand the various energy conservation and improvement techniques.	
CO2	Illustrate the Energy scenario.	
CO3	Employ the principles of thermal engineering and energy management to improve the Performance of thermal systems.	
CO4	Assess energy projects based on economic and financial criteria.	
CO5	Describe methods of energy production for improved utilization.	

Mapping of COS and POs

POs → COs↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	**3**	**2**	**1**	**2**	**1**	**1**	**1**
CO2	**3**	**2**	**1**	**2**	**1**	**1**	**1**
CO3	**3**	**2**	**1**	**-**	**1**	**1**	**1**
CO4	**3**	**2**	**1**	**-**	**1**	**1**	**1**
CO5	**3**	**2**	**1**	**-**	**1**	**1**	**1**

MINI PROJECT WITH SEMINAR			
Course Code	**22MTP25**	CIE Marks	100
Number of contact Hours/Week	**0-4-2**	SEE Marks	--
Credits	**03**	Exam Hours/Batch	--

Course objectives:

- To support independent learning and innovative attitude.
- To guide to select and utilize adequate information from varied resources upholding ethics.
- To guide to organize the work in the appropriate manner and present information (acknowledging the sources) clearly.
- To develop interactive, communication, organisation, time management, and presentation skills.
- To impart flexibility and adaptability.
- To inspire independent and team working.
- To expand intellectual capacity, credibility, judgement, intuition.
- To adhere to punctuality, setting and meeting deadlines.
- To instil responsibilities to oneself and others.
- To train students to present the topic of project work in a seminar without any fear, face audience confidently, enhance communication skill, involve in group discussion to present and exchange ideas.

Mini-Project with seminar: This may be hands-on practice**,** survey report, data collection and analysis, coding, mobile app development, field visit and report preparation, modelling of system, simulation, analysing and authenticating, case studies, etc.

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.

There is **no SEE** for this course.

Course outcomes:

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

- Present the mini-project and be able to defend it.
- Make links across different areas of knowledge and to generate, develop and evaluate ideas and information to apply these skills to the project task.
- Habituated to critical thinking and use problem solving skills.
- Communicate effectively and to present ideas clearly and coherently in both the written and oral forms.
- Work in a team to achieve common goal.
- Learn on their own, reflect on their learning and take appropriate actions to improve it.

CFD and Numerical Lab			
Course Code	22MTPL26	CIE Marks	50
Teaching Hours/Week (L:T:P: S)	1:2:0	SEE Marks	50
Credits	2	Exam Hours	3 hr

Course Objectives:

- To recognize the importance of CFD in Heat and Fluid flow and to analyze forced convection heat transfer coefficient over regular bodies like sphere, cylinder.
- To estimation of drag coefficient in circular pipe under turbulent flow and bent pipe.
- To recognize how to handle moving boundaries and wall effects in motion of fluid.
- To understand the underlying concept of the Navier Stroke Equation and to build a basic understanding of the equations used in different turbulence.

Sl.NO	Experiments
1	Geometry, meshingfor various configurationsusingANSYS 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 Convectionthrough a vertical pipe using ANSYS Workbench.
6	Melting and solidification in a rectangular cavity.
7	Fully developed turbulentflow through circular pipe using ANSYS Workbench.
8	To determine the internal pipe fluid flow using ANSYS.
	Demonstration Experiments (For CIE) if any
9	Determination of the skin friction coefficient of a rectangular plate when fluid is flowing over the surface of plate using ANSYS Flow Simulation.
10	Flow of water through a ball valve assembly using ANSYS/ Solid Works Flow Simulation. Introduction.
11	To conduct thermal stress analysis of a 2D component using ANSYS
12	To determine the temperature distribution in solid body.

Course Outcomes (Course Skill Set):

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

- Develop knowledge in coding to simulate the flow in a Lid driven cavity.
- Develop skills in coding for natural convection heat transfer in enclosures.

- Develop skills in making geometry and meshing for various configurations using ANSYS Workbench.
- Develop knowledge in CFD simulation of Convective heat transfer and phase change problems using ANSYS Workbench.
- Develop knowledge in simulation of turbulent flow using ANSYS Workbench.

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 50% of the maximum marks. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each course. The student must secure not less than 40% of maximum marks in the semester-end examination(SEE). In total of CIE and SEE student must secure 50% maximum marks of the course.

Continuous Internal Evaluation (CIE):

CIE marks for the practical course is **50 Marks**.

The split-up of CIE marks for record/ journal and test are in the ratio **60:40**.

- Each experiment to be evaluated for conduction with observation sheet and record write-up. Rubrics for the evaluation of the journal/write-up for hardware/software experiments designed by the faculty who is handling the laboratory session and is made known to students at the beginning of the practical session.
- Record should contain all the specified experiments in the syllabus and each experiment write-up will be evaluated for 10 marks.
- Total marks scored by the students are scaled downed to 30 marks (60% of maximum marks).
- Weightage to be given for neatness and submission of record/write-up on time.
- Department shall conduct 02 tests for 100 marks, the first test shall be conducted after the 8th week of the semester and the second test shall be conducted after the 14th week of the semester.
- In each test, test write-up, conduction of experiment, acceptable result, and procedural knowledge will carry a weightage of 60% and the rest 40% for viva-voce.
- The suitable rubrics can be designed to evaluate each student's performance and learning ability.
- The average of 02 tests is scaled down to **20 marks** (40% of the maximum marks).

The Sum of **scaled-down** marks scored in the report write-up/journal and average marks of two tests is the total CIE marks scored by the student.

Semester End Evaluation (SEE):

SEE marks for the practical course is 50 Marks.

SEE shall be conducted jointly by the two examiners of the same institute, examiners are appointed by the University.

All laboratory experiments are to be included for practical examination.

(Rubrics) Breakup of marks and the instructions printed on the cover page of the answer script to be strictly adhered to by the examiners. **OR** based on the course requirement evaluation rubrics shall be decided jointly by examiners.

Students can pick one question (experiment) from the questions lot prepared by the internal /external examiners jointly.

Evaluation of test write-up/ conduction procedure and result/viva will be conducted jointly by

examiners.

General rubrics suggested for SEE are mentioned here, writeup-20%, Conduction procedure and result in -60%, Viva-voce 20% of maximum marks. SEE for practical shall be evaluated for 100 marks and scored marks shall be scaled down to 50 marks (however, based on course type, rubrics shall be decided by the examiners)

Change of experiment is allowed only once and 10% Marks allotted to the procedure part to be made zero.

The duration of SEE is 03 hours

Suggested Learning Resources:

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VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELAGAVI.

Scheme of Teaching and Examinations and Syllabus
M.Tech., Program
in
Thermal Power Engineering

(Effective from the Academic year 2022-23)

Registrar,
Visvesvaraya Technological University
JnanaSangam, Machhe, Belagavi-590018
E-Mail: registrar@vtu.ac.in
Contact: 0831-2498112

04082022/V3

VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELAGAVI
Scheme of Teaching and Examinations – 2022 - 23
M.Tech., in Thermal Power Engineering (MTP)
Choice Based Credit System (CBCS) and Outcome-Based Education (OBE)

III SEMESTER

Sl. No	Course	Course Code	Course Title	Teaching Hours /Week			Examination				Credits
				Theory	Practical/ Mini–Project/ Internship	Tutorial/ Skill Development Activities	Duration in hours	CIE Marks	SEE Marks	Total Marks	
				L	P	SDA					
1	PCC	22MTP31	Design of Heat Transfer Equipment's	03	00	02	03	50	50	100	4
2	PEC	22MTP32X	Professional elective - 3	03	00	00	03	50	50	100	3
3	OEC	22MTP33X	**Professional Elective 4**	03	00	00	03	50	50	100	3
4	PROJ	22MTP34	Project Work Phase -1	00	06	00	--	100	--	100	3
5	SP	22MTP35	Societal Project	00	06	00	--	100	--	100	3
6	INT	22MTPI36	Internship	(06 weeks Internship Completed during the intervening vacation of II and III semesters.)			03	50	50	100	6
TOTAL				**09**	**12**	**03**	**12**	**400**	**200**	**600**	**22**

Note: PCC: Professional core courses, PEC: Professional Elective Courses, IPCC-Integrated Professional Core Courses. MPS-Mini Project with Seminar; AUD/AEC; Audit Courses / Ability Enhancement Courses (Mandatory), PCCL-Professional Core Course lab, **L-Lecture, P-Practical, T/SDA-Tutorial / Skill Development Activities** (Hours are for Interaction between faculty and students)

Professional Elective - 3		**Professional Elective 4**	
Course Code under 22MTP31X	**Course title**	**Course Code under 22MTP32X**	**Course title**
22MTP321	Alternative Fuels for IC Engines	22MTP331	Theory of IC Engines
22MTP322	Thermal Power Station	22MTP332	Environmental Engineering and Pollution Control
22MTP323	Convective Heat and Mass Transfer	22MTP333	Safety in Engineering Industry
22MTP324	Gas Dynamics	22MTP334	Biomass Energy Conversion Techniques
22MTP325	Measurement Systems in Thermal Engineering	22MTP335	Non-Conventional Energy Sources

Note:

1. Project Work Phase-1: The project work shall be carried out individually. However, in case a disciplinary or interdisciplinary project requires more participants, then a group consisting of not more than three shall be permitted.Students in consultation with the guide/co-guide (if any) in disciplinary project or guides/co-guides (if any) of all departments in case of multidisciplinary projects, shall pursue a literature survey and complete the preliminary requirements of the selected Project work. Each student shall prepare a relevant introductory project document and present a seminar.

CIE marks shall be awarded by a committee comprising of HoD as Chairman, all Guide/s and co-guide/s (if any) and a senior faculty of the concerned departments. The CIE marks awarded for project work phase -1, shall be based on the evaluation of Project Report, Project Presentation skill, and performance in the Question-and-Answer session in the ratio of 50:25:25.

2. Societal Project: Students in consultation with the internal guide as well as with external guide (much preferable) shall involve in applying technology to workout/proposing viable solutions for societal problems.

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

Those, who have not pursued /completed the Societal Project, shall be declared as fail in the course and have to complete the same during subsequent semester/s after satisfying the Societal Project requirements. There is no SEE (University examination) for this course.

3. Internship: Those, who have not pursued /completed the internship, shall be declared as fail in the internship course and have to complete the same during subsequent University examinations after satisfying the internship requirements. Internship SEE (University examination) shall be as per the University norms.

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. The CIE marks awarded for project work phase -1, shall be based on the evaluation of Project Report, Project Presentation skill, and performance in the Question-and-Answer session in the ratio of 50:25:25.

VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELAGAVI

Scheme of Teaching and Examinations – 2022 - 23

M.Tech., in Thermal Power Engineering (MTP)

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

IV SEMESTER

Sl. No	Course	Course Code	Course Title	Teaching Hours /Week		Examination				Credits
				Theory	Practical/ Field work	Duration in hours	CIE Marks	SEE Marks Viva voce	Total Marks	
				L	P					
1	Project	22MTP41	Project Work Phase - 2	--	08	03	100	100	200	18
			TOTAL	--	**08**	**03**	**100**	**100**	**200**	**18**

Note:

1. Project Work Phase-2:

Students in consultation with the guide/co-guide (if any) in disciplinary project or guides/co-guides (if any) of all departments in case of multidisciplinary projects, shall continue to work of Project Work phase -1to complete the Project work. Each student / batch of students shall prepare project document and present a seminar.

CIE marks shall be awarded by a committee comprising of HoD as Chairman, all Guide/s and co-guide/s (if any) and a senior faculty of the concerned departments. The CIE marks awarded for project work phase -2, shall be based on the evaluation of Project Report, Project Presentation skill, and performance in the Question-and-Answer session in the ratio of 50:25:25.

SEE shall be at the end of IV semester. Project work evaluation and Viva-Voce examination (SEE), after satisfying the plagiarism check, shall be as per the University norms.

Program Outcome of this course

POs	Description
PO1:	Acquire, demonstrate, and apply basic knowledge in the field of Thermal power engineering.
PO2:	Identify problems in the field of Thermal power engineering, formulate them and solve by using advanced techniques.
PO3:	Conduct independent research and generate new knowledge for the benefit of community, society, Industry, and nation.
PO4:	Apply various computational methods using advanced software and engineering tools to model, analyze and solve thermal engineering problems.
PO5:	Work effectively in interdisciplinary teams for solving real life problems in achieving multidisciplinary tasks required for the project in the related field.
PO6:	Effectively communicate through technical reports, presentations, scientific publications, intellectual integrity, ethics of research and scholarly standards with the engineering community as well as society at large.
PO7:	Engage in life-long reflective and independent learning with high level of enthusiasm and commitment.

Semester – III

Semester – III

Design of Heat Transfer Equipment's			
Course Code	22MTP31	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	2:0:2	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	04	Exam Hours	3 Hr

Course Learning objectives:

- To provide the sufficient knowledge of concept, applications, importance of thermal design of Heat exchanger.
- To familiarize the students about the heat exchanger design and its applications in real life situations.
- To carry out a computer simulation of heat exchanger design.

Module-1	
CLASSIFICATION OF HEAT EXCHANGERS: Introduction, Recuperation & regeneration, Tabular heat exchangers, Double pipe, shell & tube heat exchanger, Plate heat Exchangers, Gasketed plate heat exchanger. Spiral plate heat exchanger, Lamella heat exchanger, extended surface heat exchanger, Plate fin and Tabular fin. Basic Design Methods of Heat Exchanger: Introduction, Basic equations in design, Overall heat transfer coefficient, LMTD method for heat exchanger analysis, Parallel flow, Counter flow. Multi pass, cross flow heat exchanger design calculations.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Module-2	
DOUBLE PIPE HEAT EXCHANGER: Film coefficient for fluids in annulus, fouling factors, Calorific temperature, Average fluid temperature, The calculation of double pipe exchanger, Double pipe exchangers in series parallel arrangements. **Shell & Tube Heat Exchangers:** Tube layouts for exchangers, Baffle heat exchangers, Calculation of shell and tube heat exchangers, Shell side film coefficients, Shell side equivalent diameter, The true temperature difference in a 1-2 heat exchanger. Influence of approach temperature on correction factor. Shell side pressure drop, Tube side pressure drop, Analysis of performance of 1-2 heat exchanger and design of shell & tube heat exchangers, Flow arrangements for increased heat recovery, the calculation of 2-4 exchangers.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Module-3	
CONDENSATION OF SINGLE VAPOURS: Calculation of horizontal condenser, Vertical condenser, De-Super heater condenser, Vertical condenser-sub-Cooler, Horizontal Condenser-Sub cooler, Vertical reflux type condenser. Condensation of steam.	
Teaching-	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective

Learning Process	Class Discussions and Assignments at home.

Module-4

VAPORIZERS, EVAPORATORS AND REBOILERS: Vaporizing processes, forced circulation vaporizing exchanger, Natural circulation vaporizing exchangers, Calculations of a re-boiler. Extended Surfaces: Longitudinal fins. Weighted fin efficiency curve, Calculation of a Double pipe fin efficiency curve. Calculation of a double pipe finned exchanger, Calculation of a longitudinal fin shell and tube exchanger.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Module-5

DIRECT CONTACT HEAT EXCHANGER: Cooling towers, relation between wet bulb & dew point temperatures, The Lewis number and Classification of cooling towers, Cooling tower internals and the roll of fill, Heat Balance. Heat Transfer by simultaneous diffusion and convection, Analysis of cooling tower requirements, Deign of cooling towers, Determination of the number of diffusion units, Calculation of cooling tower performance.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks.**
2. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks** to attain the COs and POs.

The sum of three tests, two assignments/skill Development Activities, will be **scaled down to 50 marks.**

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

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.

Suggested Learning Resources:

Books

1. James R. Couper; W. Roy Penney, James R. Fair, Stanley M. Walas, Chemical Process Equipment:selection and design, Elsevier Inc., 2nd ed. 2005.
2. Process heat transfer- Donald Q. Kern, Tata McGraw Hill Publishing Company Ltd.
3. Heat Exchangers Selection, Rating and Thermal Design- SadikKakac and Hongtan Liu, CRC Press.
4. Process Heat Transfer- Sarit K.Das, Narosa Publishing House Pvt. Ltd.

Web links and Video Lectures (e-Resources):

- https://archive.nptel.ac.in/courses/103/105/103105210/
- https://archive.nptel.ac.in/courses/103/107/103107207/

Skill Development Activities Suggested

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	Understand the physics and the mathematical treatment of typical heat exchangers and employ LMTD and Effectiveness methods in the design of heat exchangers	
CO2	Design, analyze and examine the performance of double-pipe counter flow (hair-pin) and shell and tube heat exchanger	
CO3	Understand the fundamental, physical and mathematical aspects of and condensation.	
CO4	Demonstrate the importance of Vaporizers, Evaporators and Reboilers as heat exchangers	
CO5	Classify cooling towers and explain their technical features.	

Mapping of COS and POs

POs → COs↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	3	2	1	2	1	1	1
CO2	3	2	1	2	1	1	1
CO3	3	2	1	-	1	1	1
CO4	3	2	1	-	1	1	1
CO5	3	2	1	-	1	1	1

Semester – III

Alternative Fuels for IC Engines			
Course Code	22MTP321	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

Course Learning objectives:

- To Understand the need of alternative fuels, environment impact, types of alternative fuels, preparation of alternative fuels
- To familiarize the students about engine alteration to use alternative fuels
- To understand the current status of alternative fuels

Module-1

Conventional Fuels: Introduction, Current fuel scenario and consumption, per capita consumption Indianscenario, Structure of petroleum, refining process, Products of refining process, Fuels for spark ignition,Knock rating of SI enginefuels, Octane number requirement, Diesel fuels.

Properties of petroleum products: Specific gravity, Density, Molecular weight, Vapour pressure,Viscosity, Flash point, Fire point, Cloudpoint, Pour point, Freezing point, Smoke point & Char value,

Aniline point, Octane Number, Performance Number, Cetane Number, Emulsification, Oxidation Stability,Acid Value/Number, Distillation Range, and Sulphur content.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Module-2

Alternative fuels for I.C. engines: Need for alternative fuels such as Ethanol, Methanol, LPG, CNG,Hydrogen, Biogas and Producer gas andtheir methods of manufacturing.

Single Fuel Engines: Properties of alternative fuels, Use of alternative fuels in SI engines, Enginemodifications required, Performance andemission characteristics of alternative fuels in SI mode of

operation v/s gasoline operation.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Module-3

Dual fuel Engine: Need and advantages, The working principle, Combustion in dual fuel engines,Factors affecting combustion in dual fuelengine, Use of alcohols, LPG, CNG, Hydrogen, Biogas andProducer gas in CI engines in dual fuel mode. Engine modifications required. Performance and emissioncharacteristics of alternative fuels (mentioned above) in Dual Fuel mode of operation v/s Dieseloperation.

Teaching-Learning	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Process	
Module-4	
Biodiesels: What arebiodiesels Need of biodiesels, Properties of bio-diesels v/s Petro-diesel,Performance and emission characteristics of bio-diesels v/s Petro diesel operation. **Availability:** Suitability & Future prospects of these gaseous fuels in Indian context.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.
Module-5	
Environmental pollution: with conventional and alternate fuels, Pollution control methods andpackages. Euro norms, Engine missions, Emission control methods, EPA. Air quality emission standards	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks.**
2. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks** to attain the COs and POs.

The sum of three tests, two assignments/skill Development Activities, will be **scaled down to 50 marks.**

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

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.

Suggested Learning Resources:

Books

1. **A Course in Internal Combustion Engines -** R.P Sharma & M.L. Mathur, DanpatRai&

Sons.
2. **Elements of Fuels, Furnaces & Refractories -** O.P. Gupta, Khanna Publishers.
3. **Internal Combustion Engines -**Domkundwar V.M., I Edition, DhanpatRai& Sons.
4. **Internal Combustion Engines Fundamentals -** John B. Heywood, McGraw Hill InternationalEdition.
5. **Present and Future Automotive Fuels -** Osamu Hirao& Richard Pefley, Wiley Inter sciencePublications.
6. **Internal Combustion Engines -** V. Ganesan, Tata McGraw-Hill Publications.
7. M.K. Gajendra Babu, K.A. Subramanian, Alternative Transportation Fuels: Utilization in Combustion Engines, CRC Press, 2013.
8. Richard L. Bechfold, Alternative Fuels Guidebook - SAE International Warrendale 1997.

Web links and Video Lectures (e-Resources):

Skill Development Activities Suggested

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	Explain about the availability and usage of conventional fuels for IC engines.	
CO2	Identify possible alternative fuels for IC engines.	
CO3	Demonstrate the use of alternative fuels for different types of engines	
CO4	Assess the environmental impact standards and procedures of using alternate fuels.	
CO5	Describe and analyze Need for alternative fuels such as Ethanol, Methanol, LPG, CNG, Hydrogen and their manufacturing procedure.	

Mapping of COS and POs

POs → COs↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	**3**	**2**	**1**	**2**	**1**	**1**	**1**
CO2	**3**	**2**	**1**	**2**	**1**	**1**	**1**
CO3	**3**	**2**	**1**	**-**	**1**	**1**	**1**
CO4	**3**	**2**	**1**	**-**	**1**	**1**	**1**
CO5	**3**	**2**	**1**	**-**	**1**	**1**	**1**

Semester – III

Thermal Power Station			
Course Code	22MTP322	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

Course Learning objectives:

- To understand merits and demerits of various power plant and Criteria for selection of powerplant and economics.
- To understand various safety devices and controlling devices for power plantComparison of various power plant on efficiencies, working performance, andcharacteristics.
- To plan and design the experimental investigations efficiently and effectively.
- To practice statistical software to achieve robust design of experiments.

Module-1	
Steam Generator and Auxiliaries: High pressure boilers, classification, schemes¸ circulation, nature of fuels and its influence on design, furnaces, PF burners, PF milling plant, oil and gas burner types and location, arrangement of oil handling plant. Waste heat recovery systems. Operation and Maintenance of Steam Generators and auxiliaries: Pre commissioning activities, Boiler start up and shut down procedures, emergencies in boiler operation, Maintenance of Steam generator and auxiliaries.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Module-2	
Dust Extraction Equipment: Bag house, electrostatic precipitator, draught systems, FD, ID and PA fans, chimneys, flue and ducts, dampers, thermal insulation, and line tracing, FBC boilers and types., waste heat recovery boilers.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Module-3	
Feed Water system: Impurities in water and its effects, feed and boiler water corrosion, quality of feed water, boiler drum water treatment and steam purity, water treatment, clarification, demineralization, evaporation, and reverse osmosis plant. Circulating water system: Introduction, System classification, The circulation system, Wet-Cooling towers, Wet-cooling tower calculations, Dry cooling towers, Dry-cooling towers and plant efficiency and economics, wet-dry cooling towers, cooling-tower icing, Cooling lakes and ponds, Spray ponds and canals.	
Teaching-Learning	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Process	
Module-4	
Performance: Boiler efficiency and optimization, coal mill, fans, ESP. EIA study: Pollutants emitted, particulate matter, SOx and NOx and ground level concentration, basic study of stack sizing.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.
Module-5	
Miscellaneous of steam power plant: Methods of loading, plant selection, arrangements, useful life of plant components, pumps, cost estimation steam power plant, comparison of different power plants, current scenario of thermal power generation in India, Indian boiler act and amendments, case studies.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks.**
2. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks** to attain the COs and POs.

The sum of three tests, two assignments/skill Development Activities, will be **scaled down to 50 marks.**

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

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.

Suggested Learning Resources:

Books

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

Web links and Video Lectures (e-Resources):

- https://archive.nptel.ac.in/courses/112/107/112107291/

Skill Development Activities Suggested

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	Describe the working principle, operation, and maintenance of a various steam generators.	
CO2	Identify the arrangements of different flow systems their operation and maintenance.	
CO3	Illustrate the impact of thermal power plant exhaust on environment.	
CO4	Estimate the working expenses, current scenario and trends in power generation.	
CO5	Asses the performance and suitability of thermal power plant.	

Mapping of COS and POs

POs → COs↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	**3**	**2**	**1**	**2**	**1**	**1**	**1**
CO2	**3**	**2**	**1**	**2**	**1**	**1**	**1**
CO3	**3**	**2**	**1**	**-**	**1**	**1**	**1**
CO4	**3**	**2**	**1**	**-**	**1**	**1**	**1**
CO5	**3**	**2**	**1**	**-**	**1**	**1**	**1**

Semester – III

Convective Heat and Mass Transfer			
Course Code	22MTP323	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

Course Learning objectives:

- To analyze details of energy equation and develop models for physical problems.
- To analyze heat transfer for duct flow with different boundary conditions.
- To Implement various turbulence models for heat transfer problems and analyze problemsinvolving convection with phase changes.
- To analyzemass transfer during convection for different physical problems.

Module-1

INTRODUCTION TO FORCED, FREE & COMBINED CONVECTION – convective heat transfer coefficient – Application of dimensional analysis to convection – Physical interpretation of dimensionless numbers. Equations of Convective Heat Transfer: Continuity, Navier-Strokes equation & energy equation for steady state flows – similarity – Equations for turbulent convective heat transfer – Boundary layer equations for laminar, turbulent flows – Boundary layer integral equations.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Module-2

EXTERNAL LAMINAR FORCED CONVECTION: Similarity solution for flow over an isothermal plate– integral equation solutions – Numerical solutions – Viscous dissipation effects on flow over a flat plate. External Turbulent Flows: Analogy solutions for boundary layer flows – Integral equation solutions Effects of dissipation on flow over a flat plate. **Internal Laminar Flows:** Fully developed laminar flow in pipe, plane duct & ducts with other cross-sectional shapes – Pipe flow & plane duct flow with developing temperature field – Pipe flows & plane duct flow with developing velocity & temperature fields. Internal Turbulent Flows: Analogy solutions for fully developed pipe flow –Thermally developing pipe & plane duct flow.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Module-3

NATURAL CONVECTION: Boussineq approximation – Governing equations – Similarity – Boundary layer equations for free convective laminar flows – Numerical solution of boundary layer equations. Free Convective flows through a vertical channel across a rectangular enclosure – Horizontal enclosure – Turbulent natural convection.

Teaching-Learning	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Process	

Module-4

COMBINED CONVECTION: Governing parameters & equations – laminar boundary layer flow over an isothermal vertical plate – combined convection over a horizontal plate – correlations for mixed convection – effect of boundary forces on turbulent flows – internal flows - internal mixed convective flows – Fully developed mixed convective flow in a vertical plane channel & in a horizontal duct.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Module-5

CONVECTIVE HEAT TRANSFER THROUGH POROUS MEDIA: Area weighted velocity – Darcy flow model – energy equation – boundary layer solutions for 2-D forced convection – Fully developed duct flow – Natural convection in porous media – filled enclosures – stability of horizontal porous layers. **Convective Mass Transfer**: Basic Definitions and Formulation of a Simplified Theory, Evaluation of The Mass-Transfer Conductance, Examples for application of the Simplified Method.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks.**
2. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks** to attain the COs and POs.

The sum of three tests, two assignments/skill Development Activities, will be **scaled down to 50 marks.**

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

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.

Suggested Learning Resources:

Books

1. Bejan, A., Convection Heat Transfer, John Willey and Sons, New York, 2001.
2. Louis, C. Burmeister, Convective Heat Transfer, John Willey and Sons, New York, 2003.
3. Kays, W.M. and Crawford, M. E., Convective Heat and Mass Transfer, McGraw Hill, New York, 2001.
4. Spalding D B, "Introduction to Convective Mass Transfer", McGraw Hill, 1963.
5. Bird R. B., Stewart W. E. and Lightfoot E. N., " Transport Phenomena ", John Wiley and sons, Inc., 1960.
6. Schlichting H., " Boundary Layer Theory ", Sixth edition, McGraw Hill, 1968.

Web links and Video Lectures (e-Resources):

- https://archive.nptel.ac.in/courses/112/104/112104159/
- https://archive.nptel.ac.in/courses/112/101/112101002/

Skill Development Activities Suggested

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	Understand the fundamental and advanced principles of forced and natural convection heat transfer processes.	
CO2	Formulate and solve convective heat transfer problems	
CO3	Relate the principles of convective heat transfer to estimate the heat dissipation from devices.	
CO4	Estimate the energy requirements for operating a flow system with heat transfer.	
CO5	Relate to the current challenges in the field of convective heat transfer.	

Mapping of COS and POs

POs → COs↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	3	2	1	2	1	1	1
CO2	3	2	1	2	1	1	1
CO3	3	2	1	-	1	1	1
CO4	3	2	1	-	1	1	1
CO5	3	2	1	-	1	1	1

Semester – III

Gas Dynamics			
Course Code	22MTP324	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

Course Learning objectives:

- To formulate and solve problems in one -dimensional steady compressible flow
- To apply conservation laws to fluid flow problems
- To gain knowledge about main properties which are used for analyzing or modelling of compressible flow.
- Solve flow problems with heat addition and with friction, and simulation of One-dimensional flow in Shock tube

Module-1	
Fundamental equations of steady flow: Definition of Compressible Flow, Flow Regimes, Continuity and momentum equation and energy equation. **Isentropic flow:** Acoustic velocity, Mach number, Mach cone and Mach angle. Flow parameters, stagnation temperature, pressure and density.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Module-2	
Variable area flow: Velocity variation with Isentropic flow, Criteria for acceleration and deceleration. Flow through nozzle, Effect of pressure ratio on Nozzle operation. Convergent nozzle and convergent divergent nozzle. Effect of back pressure on nozzle flow. Isothermal flow functions and Flow Generalised one dimensional flow.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Module-3	
Flow with normal shock waves: Development of shock wave, Rarefaction wave, Governing equations, Prandtl-Meyer relation, Mach number downstream, Static pressure rise, Density ratio, Temperature ratio, Tables, and charts for normal shock.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Module-4	
Flow with oblique shock waves: Fundamental relations, Prandtl‘s equation, Rankine- Hugoniot equation, Variation of flow parameters and Gas tables for oblique shocks. Over-expanded and under expanded flows.	
Teaching-Learning	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Process	

Module-5

Flow in constant area with heat transfer: Stagnation temperature change. Rayleigh line, Pressure ratio and temperature ratio, Entropy considerations and maximum heat transfer. Flow in constant area with friction: Fanno curves, The fanning equation, Friction factor and friction parameter, Fanno line and Fanno flow equations.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks.**
2. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks** to attain the COs and POs.

The sum of three tests, two assignments/skill Development Activities, will be **scaled down to 50 marks.**

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

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.

Suggested Learning Resources:

Books

1. Fundamentals of Compressible flow: Yahya, 2nd Edn. 1991; Wieley Eastern.
2. Gas Dynamics, E Radhakrishnan PHI-2006
3. Gas Dynamics, Becker, Academic Press. Inc.
4. Introduction to Gas Dynamics: Rolty, wiley 1998
5. Elements of Gas Dynamics: Liepmann and roshko, Wiley 1994.
6. The dynamics and thermodynamics of compressible fluid flow: Shapiro Ronold press. 1994.
7. Modern Compressible Flow, Anderson John D, McGraw Hill Publication, 1990.

Web links and Video Lectures (e-Resources):

- https://archive.nptel.ac.in/courses/101/108/101108086/
- https://archive.nptel.ac.in/courses/112/106/112106196/
- https://drive.google.com/file/d/1OWSzp9FPMcwpsB1emoQp0pl2tGquncZQ/view
- https://drive.google.com/file/d/1G5nMQapAHwRk3nfpwWtovJLlwjDgp-Zp/view

Skill Development Activities Suggested

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	Apply continuity, momentum, and energy equations to compressible flows.	
CO2	Analyze isentropic and non-isentropic flows across normal shock waves.	
CO3	Solve compressible flow problems involving heat transfer and friction.	
CO4	Apply conservation laws to fluid flow problems and gain knowledge about main properties which are used for analyzing or modelling of compressible flow.	
CO5	Solve flow problems with heat addition and with friction and Simulation of One-dimensional flow in Shock tube.	

Mapping of COS and POs

POs → COs↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	3	2	1	2	1	1	1
CO2	3	2	1	2	1	1	1
CO3	3	2	1	-	1	1	1
CO4	3	2	1	-	1	1	1

Semester – III

Measurement Systems in Thermal Engineering			
Course Code	22MTP325	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

Course Learning objectives:

- To Understand the concept of design of experiments
- To familiarize the students about the design of experiments techniques and their implementation
- To design and analysis a real-life problem using technique.

Module-1	
Basics of Measurements: Introduction, General measurement system, Signal flow diagram of measurement system, Inputs, and their methods of correction. **Pressure measurement:** Different pressure measurement instruments and their comparison, Transient response of pressure transducers, dead-weight tester, low-pressure measurement.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Module-2	
Thermometry: Overview of thermometry, temperature measurement by mechanical, electrical and radiation effects. Pyrometer, Thermocouple compensation, effect of heat transfer. **Thermal and transport property measurement:** Measurement of thermal conductivity, diffusivity, viscosity, humidity, gas composition, pH, heat flux, calorimetry, etc.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Module-3	
Flow Measurement: Flow obstruction methods, Magnetic flow meters, Interferometer, LDA, flow measurement by drag effects, pressure probes, other methods. **Nuclear, thermal radiation measurement:** Measurement of reflectivity, transmissivity, emissivity, nuclear radiation, neutron detection, etc. Other measurements: Basics in measurement of torque, strain.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Module-4	
Analysis of experimental data: Causes and types of errors in measurement, Propagation of errors, Uncertainty analysis, Regression analysis, Statistical analysis of Experimental data. **Sensing Devices:** Transducers-LVDT, Capacitive, piezoelectric, photoelectric, photovoltaic, Ionization, Photoconductive, Hall-effect transducers, etc.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Module-5
Air-Pollution: Air-Pollution standards, general air-sampling techniques, opacity measurement, sulphur dioxide measurement, particulate sampling technique, combustion products measurement.

Advanced topics: Issues in measuring thermo physical properties of micro and Nano fluids. **Design of Experiments:** Basic ideas of designing experiments, Experimental design protocols with some examples and DAS.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks.**
2. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks** to attain the COs and POs.

The sum of three tests, two assignments/skill Development Activities, will be **scaled down to 50 marks.**

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

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.

Suggested Learning Resources:

Books

1. Coleman, Hugh W.; Experimentation and uncertainty analysis for engineers. ISBN: 0-471-63517-0
2. Miller, Richard W; Flow Measurement Engineering Handbook. ISBN: 0-07-042366-0
3. Guide to the Expression of Uncertainty in Measurement, ISO, Genéve, 1995
4. Holman, J. P.; Experimental methods for engineers. ISBN: 0-07-118165-2
5. Robert P. Benedict; Fundamentals of temperature, pressure, and flow measurements
6. Robert A. Granger; Experiments in heat transfer and thermodynamics. ISBN: 0-521-44925-1
7. S P Venkateshan, Mechanical Measurements, Anne Books Pvt. Ltd., 2015.2.
8. J P Holman, Experimental Methods for Engineers, McGraw-Hill, 2011.
9. J R Taylor, An Introduction to Error Analysis: The Study of Uncertainties in Physical Measurements, University Science Books, 1997
10. Doebelin, Measurement System, Tata McGraw-Hill Education, 1984
11. Beckwith, Mechanical Measurements, Pearson Education India, 2007

Web links and Video Lectures (e-Resources):

- https://archive.nptel.ac.in/courses/112/107/112107242/
- https://drive.google.com/file/d/16NM5xKdvdemE_kp_PJVSaAwPoGLWVVg7/view

Skill Development Activities Suggested

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	Understand the concepts of errors in measurements, statistical analysis of data, regression analysis, correlation, and estimation of uncertainty.	
CO2	Describe the working principles in the measurement of field and derived quantities.	
CO3	Examine sensing requirements for measurement of thermo-physical properties, radiation properties of surfaces, and vibration.	
CO4	Understand conceptual development of zero, first and second order systems.	
CO5:	Interpret International Standards of measurements (ITS-90) and identify internationally accepted measuring standards for measurands.	

Mapping of COS and POs

POs → COs↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	**3**	**2**	**1**	**2**	**1**	**1**	**1**
CO2	**3**	**2**	**1**	**2**	**1**	**1**	**1**
CO3	**3**	**2**	**1**	**-**	**1**	**1**	**1**
CO4	**3**	**2**	**1**	**-**	**1**	**1**	**1**
CO5	**3**	**2**	**1**	**-**	**1**	**1**	**1**

Professional Elective 4

Theory of IC Engines			
Course Code	**22MTP331**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	3.:0:0	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	03	Exam Hours	3 Hr

Course Learning objectives:

- To Understand the concept of design of experiments
- To familiarize the students about the design of experiments techniques and their implementation
- To design and analysis a real-life problem using technique.

Module-1

Comparison of SI and CI Engines: Difference in thermodynamic and operating variables, comparison of performance characteristics, comparison of initial and maintenance costs application of SI and CI engine. **Two Stroke Engines:** Comparison of Two stroke and Four stroke engines, theoretical scavenging processes, comparison of different scavenging systems, supercharging of two stroke engines. **Air Capacity of Four Stroke Engines:** Ideal air capacity, determination of volumetric efficiency and factors affecting volumetric efficiency, Ideal and actual induction processes.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Module-2

Super Charging: Limits of super charging, super charging power problems and turbo charging methods of arrangements of exhaust manifold in multi cylinder engine limitations of turbo charging.
Carburetor: Properties of air, petrol mixture, mixture requirements of SI engine for steady state operation, transient operation various systems of complete carburetor, air compensating devices, theory of simple carburetor, air compensating devices, carburetor types, introduction to some important makes of carburetor like sole, crater, and SU carburetor, carburetor trouble, petrol injection, Lucas petrol injection system, electronic fuel injection, advantages and disadvantages of petrol injection.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Module-3

Combustion in I.C. engines: Combustion in SI engines: Limits and stages of combustion, factors affecting ignition lag, flame propagation, effect of engine variable on flame propagation, abnormal combustion, effect of detonation, detonation and engine variables and other factors affecting knocking and its prevention, theory of detonation in SI engines and chemistry of detonation, control of detonation surface ignition, design principle of combustion chamber, types of combustion chamber and their comparison. Combustion in CI engines: Stages of combustion in CI engines, air fuel ratio, delay period or ignition lag, variables effecting delay period, diesel knock, methods of controlling diesel knock, CI engine combustion chamber requirements, types of combustion chambers, cold starting of CI engine and cold starting aids.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Module-4

Fuel Injection: Principle and Heat release pattern, nozzles their construction and working, quantity of fuel per cycle, calculation of diameter and stroke of plunger, size of nozzle orifice, formation of diesel spray, atomization, penetration, dispersion factors affecting spray characteristics, resilience of components and effect of elasticity of pipe and fuel.
Ignition: Ignition timing and its advance vacuum advance, centrifugal spark advance, ignition timing and its effects on exhaust, spark plugs heat range electronic ignition system using contact breaker and contact less triggers, factors affecting energy requirements of the ignition systems.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Module-5

Rating, Testing and Performance: Measurements of speed, air flow, fuel consumption, indicated power brake power, frictional horse power, and smoke, testing of engines as per Indian Standard 10001, performance test for variable speed I C Engines, heat balance sheet, governing test for constant speed IC engines, effect of fuel injection parameters in CI engines and ignition advance of SI engines on performance of engine. Rating of internal combustion engine based on (I) continuous operation of engine (II) Maximum power an engine can develop (III) Power calculated from empirical formula.
Emission of IC engine: Emission from SI engine, effect of engine maintenance on exhaust emission control of SI engine, diesel emission, diesel smoke and control, diesel and control comparison of gasoline and diesel emission. Measurement and calculation for of emission constituents.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

3. Three Unit Tests each of **20 Marks.**
4. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks** to attain the COs and POs.

The sum of three tests, two assignments/skill Development Activities, will be **scaled down to 50 marks.**

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

Semester End Examination:

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

Suggested Learning Resources:

Textbook/ Textbooks

1. V. Ganesan, ―Internal Combustion Engines‖, Tata McGraw-Hill Publications, 4th Edition.
2. John B Heywood, ―IC Engines fundamentals‖, McGraw- Hill Publications,2011.
3. C R Fergusan, ―Internal Combustion Engines: Applie d Thermo sciences‖, John Wiley & Sons.
4. Richard stone _'Introduction to IC Engines'' Palgrave Publication 3rd edition.
5. Charles Fayette Taylor _' The Internal-Combustion Engine in Theory and Practice'' MIT Press 2nd edition.

Web links and Video Lectures (e-Resources):

- https://archive.nptel.ac.in/courses/112/107/112107242/
- https://drive.google.com/file/d/16NM5xKdvdemE_kp_PJVSaAwPoGLWVVg7/view

Skill Development Activities Suggested

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	Understand the concepts of errors in measurements, statistical analysis of data, regression analysis, correlation, and estimation of uncertainty.	
CO2	Describe the working principles in the measurement of field and derived quantities.	
CO3	Examine sensing requirements for measurement of thermo-physical properties, radiation properties of surfaces, and vibration.	
CO4	Understand conceptual development of zero, first and second order systems.	
CO5	Interpret International Standards of measurements (ITS-90) and identify internationally accepted measuring standards for measurands.	

Mapping of COS and POs

POs → COs↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	3	2	1	1	2	1	1
CO2	3	2	1	2	2	1	1
CO3	3	2	1	2	2	1	1
CO4	3	2	1	2	2	1	1
CO5	3	2	1	-	1	1	1

Environmental Engineering and Pollution Control			
Course Code	**22MTP332**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	3.:0:0	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	03	Exam Hours	3 Hr

Course Learning objectives:

- To make the students aware of history of air pollution; definition of air pollution and various types of sources and classification of air pollutants.
- To make the student aware of techniques and instrumentation of ambient air monitoring, establishment of ambient air monitoring stations; stack monitoring and experimental analysis of air gaseous and particulate air pollutants; standards and limits.
- Understanding of problems of municipal waste, biomedical waste, hazardous waste, e-waste, industrial waste etc.
- Industrial waste generation patterns, as well as management and disposal techniques. Central and state pollution control board guidelines on industrial waste management.

Module-1

Air Quality and Standards, Important air pollutants, their sources, characteristics and effects. Sampling and Analysis: Ambient air sampling, stack sampling, Air quality standards. Air Pollution Meteorology and Dispersion Models, Atmospheric motion, Lapse rate, atmospheric stability, inversion, atmospheric dispersion, maximum mixing depth, Diffusion models, plume rise. Control of Particulates, Characteristics of particulates. Filters, gravitational, centrifugal-multiple type cyclones, prediction of collection efficiency, pressure drop, wet collectors, Electrostatic Precipitation theory-particle charging-particle collection-ESP design procedure.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Module-2

Control of Gaseous Pollutants. Adsorption, absorption. Emission control in coal-fired power plants and other important industries. Condensation and incineration Automobile Pollution, Legislation for motor vehicle emission control, control of automobile pollution, internal combustion engines, modification of IC engines to reduce emission, air fuel ratio, catalytic converters. Odour pollution and control, Indoor air pollution, Noise pollution and control.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Module-3

Solid waste sources - nature and characteristics - Quantities and Qualities - generation rates – Potential of disease - nuisance and other problems. Collection and Storage Solid waste management – Functional elements of solid waste-on-site storage, collection and separation. – Containers and its location – collection systems- vehicle routing- route balance- transfer station - Processing- recovery and reuse. Disposal methods – sanitary land filling, planning, site selection, design. hazardous waste – Bioremediation of hazardous waste – Treatment of nuclear waste and Radio-active waste.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Module-4

Industrial waste source, Nature and characteristics, quantity and quality of industrial wastes and their impact on the environment, waste volume reduction, waste strength reduction, neutralization, removal of suspended and colloidal solids, removal of inorganic and organic dissolved solids, disposal of sludge solid – treatment of cyanide waste – heavy metal and radio activity.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Module-5

Management of industrial waste for various industries like dairy, sugar, paper, distillery, textile, tannery, food processing, fertilizer, pharmaceutical industrial. Development of integrated treatment for waste water – physico chemical treatment tertiary treatment methodologies - recent trends in clean technologies – zero polluting industry concept – Reuse and recycle of waste water.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks.**
2. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks** to attain the COs and POs.

The sum of three tests, two assignments/skill Development Activities, will be **scaled down to 50 marks.**

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

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.

Suggested Learning Resources:

1. Air Pollution Control Engineering by De Nevers, McGraw-Hill, New York.
2. Air Pollution Its Origin and Control by Wark K, Warner C F and Davis W., Harper and Row, New York.
3. Air Pollution by Rao M N, Tata McGraw Hill, New Delhi.
4. Principles of Air Quality Management by Griffin R D, CRC Press, Boca Raton, USA.
5. Municipal Solid Waste Management: Pollution Technologies Review by David Rimbers, Noyes Data Corporation, London.
6. Hazardous Waste Management by Michael D. Lagrega, Phillip L. Buckingham, Jeffrey C. Evans, McGraw Hill, New York.
7. Wastewater Treatment by Rao M N and Datta A K, Oxford & IBH Publishing Co. Pvt. Ltd, New Delhi.
8. Industrial Water Pollution Control by Eckenfelder, McGraw-Hill.
9. Wastewater Engineering-treatment, Disposal, Refuse by Metcalf and Eddy, T.M.H. Edition, New Delhi.

Web links and Video Lectures (e-Resources):

Skill Development Activities Suggested

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	Grasp the fundamentals of air pollution and its associated environmental impacts.	
CO2	Earn to describe the key concepts of air quality management.	
CO3	Do sampling and characterization of solid waste and analysis of hazardous waste constituents including QA/QC issues	
CO4	Apply steps in solid waste management-waste reduction at source, collection techniques, materials and resource recovery/recycling, transport, optimization of solid waste transport, treatment and disposal techniques.	
CO5	Schemes, incentives, policies on industrial waste management and Overview of product design for waste minimization.	

Mapping of COS and POs

POs → COs↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	**3**	**2**	**1**	**1**	**2**	**1**	**1**
CO2	**3**	**2**	**1**	**2**	**2**	**1**	**1**
CO3	**3**	**2**	**1**	**2**	**2**	**1**	**1**
CO4	**3**	**2**	**1**	**2**	**2**	**1**	**1**
CO5	**3**	**2**	**1**	**-**	**1**	**1**	**1**

Safety in Engineering Industry			
Course Code	**22MTP333**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	3.:0:0	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	03	Exam Hours	3 Hr

Course Learning objectives:

- To Discuss various accident causation theories and define Accident, Reportable accident, Dangerous occurrence.
- To Discuss different types of personal protective equipment and how to compare the safety performance of two industries.
- Distinguish ladders and scaffolds along with their safety features and Discuss the safety requirement for a confined space entry.
- To explain the various principles used in machine guarding and explain the issues in mechanical material handling.
- Selection of different types of fire extinguishers accordance to type of fire. Conduct a HAZOP study for a batch rector of your choice.

Module-1	
Need for safety. Safety and productivity. Definitions: Accident, Injury, Unsafe act, Unsafe Condition, Dangerous Occurrence, Reportable accidents. Theories of accident causation. Safety organization-objectives, types, functions, Role of management, supervisors, workmen, unions, government and voluntary agencies in safety. Safety policy. Safety Officer-responsibilities, authority. Safety committee-need, types, advantages.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Module-2	
Personal protection in the work environment, Types of PPEs, Personal protective equipmentrespiratory and non-respiratory equipment. Standards related to PPEs. Monitoring Safety Performance: Frequency rate, severity rate, incidence rate, activity rate. Housekeeping: Responsibility of management and employees. Advantages of good housekeeping. 5 s of housekeeping. Work permit system- objectives, hot work and cold work permits. Typical industrial models and methodology. Entry into confined spaces.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Module-3	
Introduction to construction industry and safety issues in construction Safety in various construction operations – Excavation and filling – Under-water works – Under-pinning & Shoring – Ladders & Scaffolds – Tunneling – Blasting – Demolition – Confined space – Temporary Structures. Familiarization with relevant Indian Standards and the National Building Code provisions on construction safety. Relevance of ergonomics in construction safety. Ergonomics Hazards - Musculoskeletal Disorders and Cumulative Trauma Disorders.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Module-4
Machinery safeguard-Point-of-Operation, Principle of machine guarding -types of guards and devices.

Safety in turning, and grinding. Welding and Cutting-Safety Precautions of Gas 5 welding and Arc Welding. Material Handling-Classification-safety consideration- manual and mechanical handling. Handling assessments and techniques- lifting, carrying, pulling, pushing, palletizing and stocking. Material Handling equipment-operation & maintenance. Maintenance of common elements-wire rope, chains slings, hooks, clamps. Hearing Conservation Program in Production industries.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Module-5

Hazard and risk, Types of hazards –Classification of Fire, Types of Fire extinguishers, fire explosion and toxic gas release, Structure of hazard identification and risk assessment. Identification of hazards: Inventory analysis, Fire and explosion hazard rating of process plants - The Dow Fire and Explosion Hazard Index, Preliminary hazard analysis, Hazard and Operability study (HAZOP)) – methodology, criticality analysis, corrective action and follow-up. Control of Chemical Hazards, Hazardous properties of chemicals, Material Safety Data Sheets (MSDS).	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks.**
2. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks** to attain the COs and POs.

The sum of three tests, two assignments/skill Development Activities, will be **scaled down to 50 marks.**

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

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.

Suggested Learning Resources:

1. R.K Jain (2000) Industrial Safety, Health and Environment management systems, Khanna Publications. Paul S V (2000), Safety management System and Documentation training Programme handbook, CBS Publication.
2. Krishnan, N.V. (1997). Safety management in Industry. Jaico Publishing House, New Delhi.

3. John V. Grimaldi and Rollin H.Simonds. (1989) Safety management. All IndiaTraveller Book Seller, Delhi.
4. Ronald P. Blake. (1973). Industrial safety. Prentice Hall, NewDelhi.
5. Alan Waring. (1996). Safety management system. Chapman & Hall, England.
6. Vaid, K.N., (1988). Construction safety management. National Institute of Construction Management and Research, Mumbai.
7. AIChE/CCPS. (1992). Guidelines for Hazard Evaluation Procedures. (second edition). Centre for Chemical Process Safety, American Institute of Chemical Engineers, New York.

Web links and Video Lectures (e-Resources):

Skill Development Activities Suggested

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	Describe the theories of accident causation and preventive measures of industrial accidents.	
CO2	Explain about personal protective equipment, its selection, safety performance & indicators and importance of housekeeping.	
CO3	Explain different issues in construction industries.	
CO4	Describe various hazards associated with different machines and mechanical material handling.	
CO5	Utilise different hazard identification tools in different industries with the knowledge of different types of chemical hazards.	

Mapping of COS and POs

POs → COs↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	3	2	1	1	2	1	1
CO2	3	2	1	2	2	1	1
CO3	3	2	1	2	2	1	1
CO4	3	2	1	2	2	1	1
CO5	3	2	1	-	1	1	1

Biomass Energy Conversion Techniques			
Course Code	**22MTP334**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	3.:0:0	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	03	Exam Hours	3 Hr

Course Learning objectives:

- To introduce the energy conversion technologies related to biomass
- To familiarize the properties of biomass and its energy products
- To analyze the feasibility of power production from biomass sources

Module-1

Introduction: World energy scenario, consumption pattern, fossil fuel depletion and environmental issues. Biomass: Availability and abundance, photosynthesis, composition and energy potential, Biomass as energy source, Sources, Biomass conversion processes, Biological, Thermal,, Chemical, Hybrid conversions, Application of biomass conversion products, Biomass properties for conversion process, Physical properties: Particle size, distribution, heat capacity and thermal conductivity, Thermal properties: Proximate, Ultimate and heating value analysis, biorefinery potential, microalgae as feedstock for biofuels and biochemical, enhancing biomass properties for biofuels, challenges in conversion.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Module-2

Biorefinery: Basic concept, types of biorefineries, biorefinery feedstocks and properties, economics. Biomass Pretreatment: Barriers in lignocellulosic biomass conversion, pretreatment technologies such as acid, alkali, autohydrolysis, hybrid methods, role of pretreatment in the biorefinery concept. Physical and Thermal Conversion Processes: Types, fundamentals, equipments and applications; thermal conversion products, commercial success stories.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Module-3

Biomass gasification, chemistry, types of gasifiers: TDR, throughput, A/F ratio and equivalence ratio calculations, fluidized bed gasifier, Biomass combustion, types of combustors, Microbial Conversion Process: Types, fundamentals, equipments and applications, products, commercial success stories. Biodiesel: Diesel from vegetable oils, microalgae and syngas; transesterification; FT process, catalysts; biodiesel purification, fuel properties. Biooil and Biochar: Factors affecting biooil, biochar production, fuel properties, biooil upgradation.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Module-4

Bioethanol and Biobutanol: Corn ethanol, lignocellulosic ethanol, microorganisms for fermentation, current industrial ethanol production technology, cellulases and their role in hydrolysis, concepts of SSF and CBP, advanced fermentation technologies, ABE fermentation pathway and kinetics, product recovery technologies. Hydrogen, Methane and Methanol: Biohydrogen generation, metabolic basics,

feedstocks, dark fermentation by strict anaerobes, facultative anaerobes, thermophilic microorganisms, integration of biohydrogen with fuel cell; fundamentals of biogas technology, fermenter designs, biogas purification, methanol production and utilization.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.
Module-5	
Organic Commodity Chemicals from Biomass: Biomass as feedstock for synthetic organic chemicals, lactic acid, polylactic acid, succinic acid, propionic acid, acetic acid, butyric acid, 1,3-propanediol, 2,3-butanedioil, PHA. Integrated Biorefinery: Concept, corn/soybean/sugarcane biorefinery, lignocellulosic biorefinery, aquaculture and algal biorefinery, waste biorefinery, hybrid chemical and biological conversion processes, techno- economic evaluation, life-cycle assessment.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks.**
2. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks** to attain the COs and POs.

The sum of three tests, two assignments/skill Development Activities, will be **scaled down to 50 marks.**

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

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.

Suggested Learning Resources:

1. Donald L. Klass, Biomass for Renewable Energy, Fuels, and Chemicals, Academic Press, Elsevier, 2006.
2. Sergio C. Capareda "Introduction to Biomass Energy Conversions", 2019, CRC Press, Taylor and Francis Group.
3. Prabir Basu, Biomass Gasification, Pyrolysis and Torrefaction, Academic Press, Elsevier, 2013.
4. A. Vertes, N. Qureshi, H.P. Blaschek, H. Yukawa (Eds.), Biomass to Biofuels: Strategies for Global Industries, Wiley, 2010.

5. S. Yang, H.A. El-Enshasy, N. Thongchul (Eds.), Bioprocessing Technologies in Biorefinery for Sustainable Production of Fuels, Chemicals and Polymers, Wiley, 2013.
6. Shang-Tian Yang (Ed.), Bioprocessing for Value Added Products from Renewable Resources, Elsevier, 2007.
7. Erik Dahlquist, "Biomass as Energy Source: Resources, systems and applications", Sustainable Energy Developments series, 2012, CRC Press, Taylor and Francis Group.
8. Anju Dahiya, "Bioenergy: Biomass to Biofuels", 2014, Academic press, Elsevier Publication.
9. D. P. Kothari, K.C Singal and Rakesh Ranjan "Renewable Energy Sources and Emerging Technologies", 2011, PHI Learning Private Ltd, New Delhi.

Web links and Video Lectures (e-Resources):

https://archive.nptel.ac.in/courses/103/103/103103207/

https://drive.google.com/file/d/1U7ShntkXCdtCA981zzbKXVzC64faudqf/view

Skill Development Activities Suggested

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	Develop knowledge in properties of biomass and energy conversion process.	
CO2	Compare the characteristics of products obtained from biomass pyrolysis.	
CO3	Understand the basics of biomass gasification and gasifier design.	
CO4	Assess the potential of electrical power production from biomass.	

Mapping of COS and POs

POs → COs↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	3	2	1	1	2	1	1
CO2	3	2	1	2	2	1	1
CO3	3	2	1	2	2	1	1
CO4	3	2	1	2	2	1	1

Non-Conventional Energy Sources			
Course Code	**22MTP335**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	3.:0:0	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	03	Exam Hours	3 Hr

Course Learning objectives:

- To provide a survey of the most important renewable energy resources and the technologies for harnessing these resources within the framework of a broad range of simple to state- of -the-art energy systems.
- To create awareness about sources of energy and able to estimate how long the available conventional fuel reserves will last.
- To learn the fundamental concepts about solar energy systems and devices.
- To design wind turbine blades and know about applications of wind energy for water pumping and electricity generation.
- To understand the working of OTEC system and different possible ways of extracting energy from ocean, know about Biomass energy, mini-micro hydro systems and geothermal energy system.

Module-1

Introduction: Energy source, India's production and reserves of commercial energy sources, need for nonconventional energy sources, energy alternatives, solar, thermal, photovoltaic. Water power, wind biomass, ocean temperature difference, tidal and waves, geothermal, nuclear (Brief descriptions). Solar Radiation: Extra-Terrestrial radiation, spectral distribution of extra-terrestrial radiation, solar constant, solar radiation at the earth's surface, beam, diffuse and global radiation, solar radiation data. Measurement of Solar Radiation: Pyrometer, shading ring pyrheliometer, sunshine recorder, schematic diagrams and principle of working.

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Module-2

Solar Radiation Geometry: Flux on a plane surface, latitude, declination angle, surface azimuth angle, hour angle, zenith angle, solar altitude angle expression for the angle between the incident beam and the normal to a plane surface (No derivation) local apparent time. Apparent motion of sum, day length, numerical examples. Solar Thermal systems: Flat plate collector; Evacuated Tubular Collector; Solar air collector; Solar concentrator; Solar distillation; Solar cooker; Solar refrigeration and air conditioning; Thermal energy storage systems. Solar pond, principle of working. Solar Photovoltaic systems: Introduction; Solar cell Fundamentals; Characteristics and classification; Solar cell: Module, panel and Array construction

Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Module-3

Wind Energy: Properties of wind, availability of wind energy in India, wind velocity and power from wind; major problems associated with wind power, wind machines; Types of wind machines and their characteristics, horizontal and vertical axis wind mills, elementary design principles; coefficient of performance of a wind mill rotor, aerodynamic considerations of wind mill design, numerical examples.

Teaching-Learning	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

Process	
Module-4	
Tidal Power: Tides and waves as energy suppliers and their mechanics; fundamental characteristics of tidal power, harnessing tidal energy, limitations. Ocean Thermal Energy Conversion: Principle of working, Rankine cycle, OTEC power stations in the world, problems associated with OTEC.	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.
Module-5	
Geothermal Energy Conversion: Principle of working, types of geothermal station with schematic diagram, geothermal plants in the world, problems associated with geothermal conversion, scope of geothermal energy. Energy from Bio Mass: Photosynthesis, photosynthetic oxygen production, energy plantation, bio gas production from organic wastes by anaerobic fermentation, description of bio-gas plants, transportation of biogas, problems involved with bio-gas production, application of bio-gas, application of bio-gas in engines, advantages	
Teaching-Learning Process	Effective Lecturing, Active Learning, Digital Learning, Case-Based Learning, Effective Class Discussions and Assignments at home.

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 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks.**
2. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks** to attain the COs and POs.

The sum of three tests, two assignments/skill Development Activities, will be **scaled down to 50 marks.**

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

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.

Suggested Learning Resources:
TEXT BOOK

1. Non-Conventional Energy Sources, G.D Rai, Khanna Publishers, 2003.
2. Non-Convention Energy Resources, B H Khan, McGraw Hill Education (India) Pvt. Ltd. 3rd Edition
3. Solar energy, Subhas P Sukhatme, Tata McGraw Hill, 2nd Edition, 1996.
4. Renewable Energy Sources and Conversion Technology, N K Bansal, Manfred Kleeman &Mechael Meliss, Tata McGraw Hill. 2004.
5. Non-Conventional Energy, Ashok V Desai, Wiley Eastern Ltd, New Delhi, 2003.
6. Renewable Energy Technologies, Ramesh R & Kumar K U, Narosa Publishing House, New Delhi.

Web links and Video Lectures (e-Resources):

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

Skill Development Activities Suggested

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	Demonstrate the generation of electricity from various Non-Conventional sources of energy, have a working knowledge on types of fuel cells.	
CO2	Estimate the solar energy, Utilization of it, Principles involved in solar energy collection and conversion of it to electricity generation.	
CO3	Explore the concepts involved in wind energy conversion system by studying its components, types and performance.	
CO4	Illustrate ocean energy and explain the operational methods of their utilization.	
CO5	Acquire the knowledge on Geothermal energy.	

Mapping of COS and POs

POs → COs↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	**3**	**2**	**1**	**1**	**2**	**1**	**1**
CO2	**3**	**2**	**1**	**2**	**2**	**1**	**1**
CO3	**3**	**2**	**1**	**2**	**2**	**1**	**1**
CO4	**3**	**2**	**1**	**2**	**2**	**1**	**1**
CO5	**3**	**2**	**1**	**-**	**1**	**1**	**1**

PROJECT WORK PHASE – 1			
Course Code	**22MTP34**	CIE Marks	100
Number of contact Hours/Week	**0-6-0**	SEE Marks	**--**
Credits	**03**	Exam Hours	**--**

Course objectives:

- Support independent learning.
- Guide to select and utilize adequate information from varied resources maintaining ethics.
- Guide to organize the work in the appropriate mannerand present information (acknowledging the sources) clearly.
- Develop interactive, communication, organisation,time management, and presentation skills.
- Impart flexibility and adaptability.
- Inspire independent and team working.
- Expand intellectual capacity, credibility, judgement, intuition.
- Adhere to punctuality, setting and meeting deadlines.
- Instil responsibilities to oneself and others.
- Train students to present the topic of project work in a seminar without any fear, face audience confidently, enhance communication skill, involve in group discussion to present and exchange ideas.

Project Phase-1: The project work shall be carried out individually. However, in case a disciplinary or interdisciplinary project requires more participants, then a group consisting of not more than three shall be permitted.
Students in consultation with the guide/co-guide (if any) in disciplinary project or guides/co-guides (if any) of all departments in case of multidisciplinary projects, shall pursue a literature survey and complete the preliminary requirements of the selected Project work. Each student shall prepare a relevant introductory project document, and present a seminar.

Course Outcomes:

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

- Demonstrate a sound technical knowledge of their selected project topic.
- Undertake problem identification, formulation, and solution.
- Design engineering solutions to complex problems utilisinga systems approach.
- Communicate with engineers and the community at large in written an oral forms.
- Demonstrate the knowledge, skills and attitudes of a professional engineer.

Continuous Internal Evaluation

- CIE marks shall be awarded by a committee comprising of HoD as Chairman, all Guide/s and co-guide/s (if any) and a senior faculty of the concerned departments. The CIE marks awarded for project work phase -1, shall be based on the evaluation of Project Report, Project Presentation skill, and performance in the Question-and-Answer session in the ratio of **50:25:25**.
- There will be **no SEE**.

INTERNSHIP			
Course Code	**22MTPI36**	CIE Marks	50
Number of contact Hours/Week	**6 Weeks**	SEE Marks	50
Credits	**06**	Exam Hours	03

Course Objectives:

Internship/Professional practice provide students the opportunity of hands-on experience that include personal training, time and stress management, interactive skills, presentations, budgeting, marketing, liability and risk management, paperwork, equipment ordering, maintenance, responding to emergencies etc.

The objectives are further,

- To put theory into practice.
- To expand thinking and broaden the knowledge and skills acquired through course work in the field.
- To relate to, interact with, and learn from current professionals in the field.
- To gain a greater understanding of the duties and responsibilities of a professional.
- To understand and adhere to professional standards in the field.
- To gain insight to professional communication including meetings, memos, reading, writing, public speaking, research, client interaction, input of ideas, and confidentiality.
- To identify personal strengths and weaknesses.
- To develop the initiative and motivation to be a self-starter and work independently.

Internship: Students under the guidance of internal guide/s and external guide shall take part in all the activities regularly to acquire as much knowledge as possible without causing any inconvenience at the place of internship.

Each student, is required to

- Present the seminar on the internship orally and/or through power point slides.
- Answer the queries and involve in debate/discussion.
- Submit the report duly certified by the external guide.
- The participants shall take part in discussion to foster friendly and stimulating environment in which the students are motivated to reach high standards and become self-confident.

Course outcomes:

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

- Gain practical experience within industry in which the internship is done.
- Acquire knowledge of the industry in which the internship is done.
- Apply knowledge and skills learned to classroom work.
- Develop a greater understanding about career options while more clearly defining personal career goals.
- Experience the activities and functions of professionals.
- Develop and refine oral and written communication skills.
- Identify areas for future knowledge and skill development.
- Expand intellectual capacity, credibility, judgment, intuition.
- Acquire the knowledge of administration, marketing, finance and economics.

Continuous Internal Evaluation

CIE marks for the Internship report, presentation and question and answer session shall be awarded in the ratio of 50:25:25 for the **total CIE of 50 marks** by the committee constituted for the purpose by the Head of the Department. The committee shall consist of three faculty from the department with committee comprising of HoD as Chairman, all Guide/s and co-guide/s (if any) and a senior faculty of the concerned departments.

Semester End Examination

SEE marks for the internship report (30 marks), seminar (20 marks) and question and answer session (10 marks) shall be awarded in the ratio of 50:25:25 for the **total SEE of 50 marks** (based on the quality of report and presentation skill, participation in the question and answer session) by the examiners appointed by the University.

IV SEMESTER

PROJECT WORK PHASE -2

Course Code	**22MTP41**	CIE Marks	100
Number of contact Hours/Week	**8 Hours/Week**	SEE Marks	100
Credits	**18**	Exam Hours	03

Course Objectives:

- To support independent learning.
- To guide to select and utilize adequate information from varied resources maintaining ethics.
- To guide to organize the work in the appropriate manner and present information (acknowledging the sources) clearly.
- To develop interactive, communication, organisation, time management, and presentation skills.
- To impart flexibility and adaptability.
- To inspire independent and team working.
- To expand intellectual capacity, credibility, judgement, intuition.
- To adhere to punctuality, setting and meeting deadlines.
- To instill responsibilities to oneself and others.
- To train students to present the topic of project work in a seminar without any fear, face audience confidently, enhance communication skill, involve in group discussion to present and exchange ideas.

Project Work Phase - II: Students in consultation with the guide/co-guide (if any) in disciplinary project or guides/co-guides (if any) of all departments in case of multidisciplinary projects, shall continue to work of Project Work phase -1to complete the Project work. Each student / batch of students shall prepare project document, and present a seminar.

CIE marks shall be awarded by a committee comprising of HoD as Chairman, all Guide/s and co-guide/s (if any) and a senior faculty of the concerned departments. The CIE marks awarded for project work phase -2, shall be based on the evaluation of Project Report, Project Presentation skill, and performance in the Question-and-Answer session in the ratio of 50:25:25.

SEE shall be at the end of IV semester. Project work evaluation and Viva-Voce examination (SEE), after satisfying the plagiarism check, shall be as per the University norms.

Course Outcomes:

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

- Present the project and be able to defend it.
- Make links across different areas of knowledge and to generate, develop and evaluate ideas and information so as to apply these skills to the project task.
- Habituated to critical thinking and use problem solving skills
- Communicate effectively and to present ideas clearly and coherently in both the written and oral forms.
- Work in a team to achieve common goal.
- Learn on their own, reflect on their learning and take appropriate actions to improve it.