ಬಿ.ಎಂ.ಎಸ್.ತಾಂತ್ರಿಕ ಮಹಾವಿದ್ಯಾಲಯ, ಬೆಂಗಳೂರು

(ಸ್ವಾಯತ್ತ ವಿದ್ಯಾಸಂಸ್ಥೆ)

B.M.S. COLLEGE OF ENGINEERING, BENGALURU.

(Autonomous College under VTU)

DEPARTMENT OF MECHANICAL ENGINEERING

M.TECH. – THERMAL ENGINEERING

SCHEME & SYLLABUS

A. Y. 2019-20 ONWARDS

ಬಿ.ಎಂ.ಎಸ್.ತಾಂತ್ರಿಕ ಮಹಾವಿದ್ಯಾಲಯ

ಬಸವನ ಗುಡಿರಸ್ತೆ, ಬೆಂಗಳೂರು–೫೬೦ ೦೧೯.

B.M.S. COLLEGE OF ENGINEERING

Bull Temple Road, Bengaluru-560 019.

VISION	MISSION
Promoting Prosperityof mankindbyaugmenting humanresourcecapital throughQualityTechnical Education& Training	Accomplishexcellenceinthe fieldof TechnicalEducationthrough Education,Research andService needs ofsociety

DEPARTMENT OF MECHANICAL ENGINEERING

DEPARTMENT VISION	DEPARTMENT MISSION
To become a center of excellence in educating students to become successful Mechanical Engineers	• To empower the students with the fundamentals for a successful career in the field of Mechanical engineering. • To continue their education through post-graduation, Research & Development. • To provide service to the society.

Schemeand Syllabus for M.Tech. (Thermal Engineering)

With effect from A. Y. 2019 – 20

M.Tech. (Thermal Engineering)

Programme Educational Objectives

PEO1	Graduates will have knowledge in the discipline of Thermal Engineering with hands on skill in using modern engineering tools to address real world engineering problems and be socially responsible.
PEO2	Graduates shall be successful in their career as analysts and designers of structural components of conventional and advanced materials, participating in a team or individually in an industry, research or academia.
PEO3	Graduates shall be proficient in their communication, presentation and will be prepared to engage in the process of life-long learning through professional development and research.

Programme Outcomes

PO No.	Programme Outcomes (PO)
PO1	An ability to independently carry out research /investigation and development work to solve practical problems
PO2	An ability to write and present a substantial technical report/document
PO3	An ability to demonstrate mastery in the domain of the specialization of the program

M. Tech.(Thermal Engineering)

Scheme of Instruction for **FirstSemester M. Tech. in Thermal Engineering** 2019-2020

Sl. No.	Course Code	Name of the Course	Credits				Total Credits
			L	T	P	S	
1	19METHPCAM	Applied Mathematics	3	0	0	0	3
2	19METHPCAF	Advanced Fluid Mechanics	3	0	0	0	3
3	19METHPCAT	Advanced Thermodynamics	3	0	0	0	3
4	19METHPCFE	Finite Element Methods for Heat Transfer Analysis	3	0	1	0	4
5	19METHPEXX	Elective-I	3	0	0	0	3
6	19METEPEXX	Elective-II	3	0	0	0	3
7	18ALLPICRM	Research Methodology	2	0	0	0	2
8	19METHPLTE	Thermal Engineering Lab	0	0	1	0	1
	Total		**20**	**0**	**2**	**0**	**22**

Note: Electives to be chosen one from each group.
Elective will be offered for a minimum strength of six candidates (out of 18) / eight candidates (out of 24)

Elective I	
Course Code	Course
19METHPEIC	Theory of IC Engines
19METHPENC	Non-Conventional Energy Resources
19METHPECG	Cryogenics Engineering

Elective II	
Course Code	Course
19METHPEGD	Gas Dynamics
19METHPERA	Refrigeration and Air Conditioning
19METHPEEF	Engine Flow and Combustion

B. M. S. COLLEGE OF ENGINEERING, BENGALURU-19
(Autonomous College under VTU | Accredited by NBA | Approved by AICTE)

DEPARTMENT OF MECHANICAL ENGINEERING

M. Tech.(Thermal Engineering)

Scheme of Instruction for **Second Semester M. Tech. in Thermal Engineering** 2019-2020

Sl. No.	Course Code	Name of the Course	Credits				Total Credits
			L	T	P	S	
1	19METHPCAH	Advanced Heat Transfer	3	1	0	0	4
2	19METHPCSG	Steam & Gas Turbines	3	0	0	0	3
3	19METHPCCF	Computational Fluid Dynamics	3	0	1	0	4
4	19METHPEXX	Elective-III	3	0	0	0	3
5	19METHPEXX	Elective-IV	3	0	0	0	3
6	19XXXXIEXX	Elective-V (Institutional)	4	0	0	0	4
7	19METHPLSL	Simulation Lab	0	0	1	0	1
	Total		**19**	**1**	**2**	**0**	**22**

Note: Electives to be chosen one from each group.
Elective will be offered for a minimum strength of six candidates (out of 18) / eight candidates (out of 24)

Elective III	
Course Code	**Course**
19METHPECR	Convective and Radiative Heat Transfer
19METHPENE	Nuclear Engineering
19METHPEDH	Design of Heat Transfer Equipments

Elective IV	
Course Code	**Course**
19METHPEAP	Advanced Power Plant Cycles
19METHPESA	Solar Thermal Technologies and its Applications
19METHPEPC	Phase change Phenomena in Fluids

Elective V (Institutional)	
Course Code	**Course**
19METHIEMF	Micro Fluidics

M. Tech.(Thermal Engineering)

Scheme of Instruction for **Third Semester M. Tech. in Thermal Engineering** 2019-2020

Sl. No.	CourseCode	Name of the Course	Credits				Total Credits
			L	T	P	S	
1	19METHPCIN	Internship/Industrial training	0	0	10	0	10
2	19METHPCEM	Experimental Methods in Thermal Engineering	3	0	0	0	3
3	19METHPRP1	Project Work Phase: I	0	0	8	0	8
4	19METHPCTS	Technical Seminar	0	0	1	0	1
5	19METHNCPE / 19METHNCWM	Professional English / Work Stress Management (Non-Credit Mandatory Course)	0	0	0	0	0
		Total	**3**	**0**	**19**	**0**	**22**

NOTE: III Semester:

- **Internship:** The student shall undergo Internship/Industrial training for 16 weeks.

  Preliminary Report submission and Evaluation after 8th week of Internship to be carried out by the Internal Guide of the college and a senior faculty for 100 marks

  Final Report submission and Evaluation after 16th week of Internship to be carried out by the Internal Guide of the college and a senior faculty of Department. Report Evaluation to be completed within two weeks of submission for 100 marks.

  Viva-Voce on Internship - To be conducted by the Internal Guide (from the college) and the External Guide / Examiner within 2 weeks of Submission with a senior faculty / HoD as chairman for 100 marks

- **Project Phase: I**

  Problem formulation and submission of **synopsis** within 8 weeks from the commencement of 3rd semester, which shall be evaluated for 50 marks by the committee constituted for the purpose by the Head of the Department comprising the guide, senior faculty of the department with HoD as Chairman.

  Literature survey and progress done after 16 weeks shall be evaluated by guide and external examiner with senior faculty / HoD as chairman for 50 marks.

M. Tech.(Thermal Engineering)

Scheme of Instruction for **Fourth Semester M. Tech. in Thermal Engineering** 2019-2020

Sl. No.	Course Code	Subject	Credits				Credits
			L	T	P	S	
1	19METHPRP2	Project Work Phase - II	0	0	20	0	20
2	19METHPCEA	Energy Auditing	2	0	0	0	2
3	19METHNCYG/ 19METHNCPD/ 19METHNCMO	Yoga / Personality Development and Professional Ethics/ MOOCs (Non-Credit Mandatory Course)	0	0	0	0	0
		Total	**2**	**0**	**20**	**0**	**22**

IV Semester:

- **Project Work Phase-II** - Internal Evaluation of progress in Project work shall be evaluated after 8 weeks for 50 marks by the committee constituted for the purpose by the Head of the Department comprising the guide and senior faculty of the department with HoD as Chairman
- Internal Evaluation of Project Demonstration shall be evaluated after 15 weeks for 50 marks by the committee constituted for the purpose by the Head of the Department.
- **Final Evaluation of Project Work and Viva-voce**.
  - Finalevaluation of project to be carried out after 16 weeks from the date of commencement of 4th semester.
  - The Internal Examiner (the project guide with a teaching experience of at least three years) and External Examiner with HoD as chairman will complete the final evaluation of Project.
- Internal and External Examiners shall carry out the evaluation of thesis for 100 Marks each and the average of these marks shall be the final marks of the Project Evaluation.
- **Viva – Voce** : The Viva-Voce shall be conducted jointly by Internal Examiner and External Examiner with HoD as chairman for 100 Marks.

Course		Credits : 03				Marks	
Name	APPLIED MATHEMATICS	L	T	P	S	CIE	SEE
Code	19METHPCAM	3	0	0	0	50	50

Course Content:

UNIT - I

Error definition, round off errors and truncation errors.Mathematical modeling and Engineering problem solving: Simple mathematical model, Conservation Laws of Engineering.Roots of Equations by numerical methods: Secant Method, Newton- Raphson method, Horner's Method.

06 Hours

UNIT - II

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. **10 Hours**

UNIT – III

Probability distributions: Binomial, Poisson. Normal.
Sampling Theory: Testing of hypothesis for large and small samples, Goodness of fit.**10 Hours**

UNIT – IV

F-test, Analysis of Variance: One – way with/without interactions, problems related to ANOVA, Design of experiments. **07 Hours**

UNIT - V

Engineering Applications on :

i) The swinging Pendulum (Article No:28.4, P.No:793, Ref. 3)
ii) Vibrating string(Article No:4.5, P.No: 151, Ref. 2)

06 Hours

Text Books:

1. C. Ray Wylie and Louis C Barrett, "Advanced Enginee ring Mathematics". 6th edition, McGraw-Hill, 1995.
2. K Shankar Rao, "Introduction to Partial Differentia l Equations" Prentice - Hall of India Pvt. Lt. , 1995 Edition.
3. Steven C Chapra and Raymond P Canale, "Numerical Me thods for Engineers," 7 th 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 engg computation, New Age International, 2003.

Course Outcomes:

Upon completion of this course, student will be able to:

CO 1	Acquire the idea of significant figures, types of errors during numerical computation.
CO 2	Develop the mathematical models of thermal system using ODE's and PDE's.
CO 3	Learn the deterministic approach for statistical problems by using probability distributions.
CO 4	Demonstrate the validity of the hypothesis for the given sampling distribution using standard tests and understand the randomization on design of experiments.
CO 5	Classify and analyze mathematical tools applied to thermal engineering study cases.

Scheme of Examination for Semester End Examination:

Answer Five Full questions selecting one from each unit.

To set One question each from unit I, IV, V and Two questions each from units II& III.

Course		Credits : 03				Marks	
Name	ADVANCED FLUID MECHANICS	L	T	P	S	CIE	SEE
Code	19METHPCAF	3	0	0	0	50	50

Course Content:

UNIT - I

Introduction: Concept of continuum, Body and surface forces, stress tensor, principle of local stress equilibrium. Scalar and vector fields, Eulerian and Lagrangian description of fluid flow. Motion of fluid element: translation, rotation and deformation; vorticity and strain-rate tensors. Continuity equation, Derivation of N-S equations, Reynold's Transport theorem, Integral form of continuity and momentum equations. **10 Hours**

UNIT - II

Exact and Approximate solutions of N-S Equations: Introduction; Parallel flow past a sphere; Oseen's approximation; hydrodynamic theory of lubrication; Hele-Shaw Flow. **06 Hours**

Boundary Layer Theory: Introduction; Boundary layer equations; displacement and momentum thickness, shape factor; flow over a flat plate similarity transformation, integral equation for momentum and energy; skin friction coefficient and Nusselt number; separation of boundary layer; critical Reynolds number; control of boundary layer separation. **06 Hours**

UNIT - III

Turbulent flows: Description of turbulent flow, velocity correlations, Reynolds stresses. Equations for turbulence kinetic energy and kinetic energy of mean flow. Eddy viscosity models of turbulence: zero equation, one-equation and two-equation models. Prandtl's Mixing Length Theory. Empirical laws: law of the wall, velocity defect law, universal velocity distribution.
05 Hours

UNIT - IV

Flow across Normal Shock and Oblique Shock: Basic Equations Normal Shock – Prandtl Meyer Equation, Oblique shock-Property variations. **06 Hours**

UNIT – V

Flow through a constant area duct with Friction: Flow through a constant area duct with Friction- Fanno Line, Fanno Flow. Flow through a constant area duct with Heat Transfer-Rayleigh Line, Rayleigh Flow. **05 Hours.**

Text Books:

1. **"Fluid Mechanics"**- R N Fox and A T McDonald, Wiley Publications,
2. **"Fluid Mechanics"**- P K Kundu and I M Kohen, Academic Press

References Books:

1. **"Introduction to fluid dynamics - Principles of analysis & design"** - Stanley Middleman, Wiley Publications.
2. **"Advanced Fluid Mechanics"**- Graebel, W,P., Academic Press, 2007.
3. **"Boundary Layer Theory"**-Schlichting, H., Springer series.
4. "Foundations of fluid mechanics" - S.W. Yuan ., Foundations of Fluid Mechanics, Prentice Hall

Ebooks:

1. Fluid Mechanics, Pijush K Kunda and Ira M Cohen, 5th Edition, Elsevier
2. Fluid Mechanics Fundamentals and Application, Yunus Cengel and John Cimbala, Kindle Edition.

MOOCs:

1. https://ocw.mit.edu/courses/mechanical-engineering/2-25-advanced-fluid-mechanics-fall-2013/
2. https://nptel.ac.in/courses/112105218/#

Course Outcomes:

Upon completion of this course, the student will be able to

CO1	Apply the concepts of governing equations for fluid flow problems
CO2	Formulate and solve one dimensional incompressible and compressible low problems
CO3	Evaluatethe properties of fluid flow using boundary layer theory

Scheme of Examination for Semester End Examination:
Answer Five Full questions selecting one from each unit.
To set One question each from unit III, IV, V and Two questions each from units I & II.

Course		Credits : 03				Marks	
Name	ADVANCED THERMODYNAMICS	L	T	P	S	CIE	SEE
Code	19METHPCAT	3	0	0	0	50	50

Course Content:

UNIT - I

Recapitulation of Fundamentals: First law of thermodynamics applied for unsteady flows with energy transaction, Available energy, Exergy, Availability analysis of open and closed systems, Maxwell Relations, Joules Thompson coefficient, Pure Substances, P-V-T surfaces, phase diagram, phase changes, 1st order phase transition and 2nd order phase transition, Clapeyron's equation.

10 Hours

UNIT-II

Thermodynamics of Refrigerants and Psychrometry: Enthalpy calculations, Enthalpy from residual internal energy, Entropy calculations, RedlichKwong and Martin Hou Equation of states, Thermodynamic properties, Procedure to construct Psychrometric chart and First law applied to Psychometry

7 Hours

UNIT – III

Chemical Thermodynamics and Combustion: *Reactive systems:*Reaction Equilibrium, Law of Mass Action, Heat of Reaction, Temperature Dependence of the Heat of Reaction, Temperature Dependence of the Equilibrium Constant, Gibbs Function Change, Fugacity and Activity, Displacement of Equilibrium due to a change in Temperature or Pressure, Heat Capacity of Reacting Gases in Equilibrium

Combustion: Enthalpy of Formation, First Law for Reactive Systems, Adiabatic Flame Temperature Enthalpy and Internal Energy of Combustion: Heating Value, Second Law Analysis of Reactive Systems, Chemical Exergy, Second Law Efficiency of a Reactive System, Fuel Cells

. **10 Hours**

UNIT - IV

Thermodynamics applied to compressible flows: Velocity of Pressure Pulse in a Fluid, Stagnation Properties, One Dimensional Steady lsentropic Flow, Critical Properties choking in lsentropic Flow, Normal Shocks, Adiabatic Flow with Friction and Diabetic Flow without Friction

06 Hours

UNIT – V

Irreversibility Thermodynamics: Entropy Flow and Entropy Production, Onsager Equations, Phenomenological Laws, Rate of Entropy Generation: Principleof Superposition, Proof of Onsager's Reciprocal Relations, Thermoelectric Phenomena-Seeback, Peltier and Thomson effect, Thermo mechanical Phenomena, Stationary States

06 Hours

Text Books:

1. Engineering Thermodynamics - P.K. Nag, Tata McGraw-Hill Publications.
2. Refrigeration and Air conditioning - CP Arora, McGraw-Hill Companies

References Books:

1. Fundamental Thermodynamics – Claus Borgnakke and Richard E. Sonntag, Wiley Publication

E Books/Web references

1. https://nptel.ac.in/courses/112103016/

MOOCS

1. https://www.mooc-list.com › tags › thermodynamics
2. https://bookboon.com › engineering-thermodynamics-ebook

Course Outcomes:

Upon completion of this course, the student will be able to

CO1	Apply the concepts of basic thermodynamic for analyses of thermal energy systems
CO2	Construct Psychrometric chart and to develop the thermodynamic properties of refrigerants
CO3	Understand the concepts of combustion phenomena and chemical reaction in energy conversion devices.
CO4	Apply the knowledge of compressible flow and design flow devices
CO5	Understand the irreversibility for designing thermoelectric and thermo mechanical instruments

Scheme of Examination for Semester End Examination:

Answer Five Full questions selecting one from each unit.
To set one question each from unit II, IV, V and Two questions each from units I& III.

Course		Credits : 04				Marks	
Name	FINITE ELEMENT METHODS FOR HEAT TRANSFER ANALYSIS	L	T	P	S	CIE	SEE
Code	19METHPCFE	3	0	1	0	50	50

Course Content:

UNIT - I

Introduction to FEM: Historical Perspective of FEM and applicability to Thermal Engineering problems like heat flow in composite slab, fluid flow network, heat transfer in heat sinks (combined conduction-convection), analysis of heat exchanger and transient heat transfer problem. **04 Hours**

Conduction Heat Transfer and Formulation: Modelling heat conduction; formulation of governing equation, differential and Variational formulation. Initial, boundary and interface conditions. Finite element approximation and basic concepts. **02 Hours**

UNIT - II

Linear Steady state problems: Introduction, elements and shape functions, Modeling of Heat Conduction, Ritz method, Rayleigh-Ritz method (Variational method), method of weighted residuals: collocation method, sub-domain method, Galerkins method and Least square method approach for one-dimensional linear element, quadratic element, two-dimensional linear triangular elements, area coordinates, quadratic triangular elements, quadratic elements, and three-dimensional elements, Isoparametric elements. **10 Hours**

UNIT – III

Steady State Heat Conduction in One-dimension: Introduction, Plane wall: Homogeneous wall, Composite wall, Finite element discretization, Wall with varying cross-sectional area, Plane wall with heat source: solution by linear elements, quadratic elements and modified quadratic elements (static condition), heat transfer in thin fins, Radial heat flow in cylinder, cylinder with heat source, conduction-Convection systems.

04 Hours

Steady State Heat Conduction in Multi-dimensions: Introduction, Two-dimensional Plane Problems: Triangular element, Rectangular elements, Plane with Variable thickness, Three-dimensional problems, axisymmetric problems, Galerkins method for linear triangular axisymmetric elements.

03 Hours

UNIT - IV

Transient Heat Transfer

Introduction, Lumped heat capacity system, Numerical solution: Transient governing equations and boundary and initial conditions, Galerkins method, one-dimensional transient state problem, Time discretization using Finite Element Method (FEM), Stability, Multi-dimensional Transient heat conduction. **04 Hours**

Convective Heat Transfer: Introduction, Basic equations, Finite element solutions to convection diffusion problems and transient convection-diffusion problems: one-dimensional and multi-dimensional problem. **02 Hours**

UNIT - V

Structural problems: Finite element formulation for structural problems, 1 dimensional stress analysis problems with bar, beam, truss and frame elements, Finite element formulation in plane stress, plane strain and axi-symmetric problems. **10 Hours**

Lab Components:

Case studies on Thermal analysis of one–dimensional, two-dimensional and three-dimensional numerical heat transfer
1-D:
Plane Wall, Cylindrical element,
2-D:
Rod element, pipe, Wing
3D:
Cube, Sphere, 3-D Wing

Text Books:

1. Reddy J.N., Gartling. D.K., **The Finite Element Method in Heat Transfer and Fluid Dynamics**, CRC Press, 2007.
2. Lewis R.W., et al.. **The Finite Element method in Heat Transfer Analysis**, John Wiley & Sons
3. Singiresu S. Rao, **Finite element Method in Engineering**, 5th edition, Elsevier, 2012
4. Zeincowicz, The Finite Element Method, 4 Vol set. 4th Edition, Elsevier 2007.

Reference Books:

1. Fundamentals of the finite element method for heat and fluid flow - R.W. Lewis, P. Nithiarasu and K. N. Seetharamu, , John Wileyand Sons, 2004.
2. The Finite Element Method in Heat Transfer Analysis - R.W. Lewis, K Morgan, H.R. Thomas, K.N. Seetharamu, John Wiley and Sons,1996.

CO1	Introduce the various aspects of FEM as applied to thermal engineering problems.
CO2	Apply the fundamental concepts of mathematical methods to solve Heat Conduction, Transient and Convective Heat Transfer problems.

Scheme of Examination for Semester End Examination:

Answer Five Full questions selecting one from each unit.
To set One question each from unit III, IV, V and Two questions each from units I & V.

ELECTIVE-I

Course		Credits : 03				Marks	
Name	THEORY OF IC ENGINES	L	T	P	S	CIE	SEE
Code	19METHPEIC	3	0	0	0	50	50

Course Content:

UNIT - I

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. **05 Hours**

Fuel –Air and Actual Engines: Modeling of Fuel-Air cycle Effect of operating variables on the performance of Fuel –air Cycles, Detailed analysis of difference between Fuel-Air and Real Cycle, Combustion charts and Gas Tables. **05 Hours**

UNIT – II

Carburetion : Introduction, Factors affecting carburetion ,mixture requirements at different load and speed ,principles of carburetion ,essential parts and functions of a carburetor ,compensating devices, Modern Carburetors, Altitude compensation devices, Injection in SI engine. **04 Hours**

Injection Systems: Introduction to Mechanical Injection System, Functional Requirements and classification, Fuel feed pump and Fuel Injector. **03 Hours**

Electronic injection systems: Types , Merits and Demerits ,Multi point fuel injection system (MPFI), Electronic control system, Injection timings, Common–Rail Fuel Injection System, RCCI. **04 Hours**

UNIT – III

Modelling of IC Engines : Governing Equation for open thermodynamic systems ,intake and exhaust flow models , Thermodynamic based in cylinder models,Direct-injection CI engine models, Combustion models ,Fluid Mechanics based multi-dimensional models. **06 Hours**

UNIT – IV

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 – thermalconverters, 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. **03Hours**

Measurement: Noise, Emission, Pressure, crank angle torque, valve timings, Temperature and flow measurements. **03 Hours**

UNIT –V

Alternate fuels for I.C engines: Vegetable oils, alcohol's, L.P.G, C.N.G, Hydrogen fuels, Bio gas, Dual fuels, other possible fuels. **06Hours**

Reference Books:

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: Applied Thermo sciences", John Wiley & Sons.
4. Richard stone "Introduction to IC Engines" Palgrave Publication 3rd edition
5. Charles Fayette Taylor " The Internal-Combustion Enginein Theory and Practice" MIT Press 2nd edition.

CO1	To understand the working cycle, Engine design and operating conditions, combustion phenomena, Engine emission and control,
CO2	use of alternate fuels in IC engines.
CO3	Identify the various types of emissions ,noise and their control systems
CO4	Recommend the suitable alternative fuel for IC Engine.

Scheme of Examination for Semester End Examination:

Answer Five Full questions selecting one from each unit.

To set One question each from unit I, IV, V and Two questions each from units II & III.

Course		Credits : 03				Marks	
Name	NON-CONVENTIONAL ENERGY RESOURCES	L	T	P	S	CIE	SEE
Code	19METHPENC	3	0	0	0	50	50

Course Content:

UNIT-1

Introduction to Energy Sources: Conventional energy, Consumption trend of energy resources, Advantages and disadvantages of Conventional Energy resources, Importance of Non-conventional energy resources, Environmental aspects of energy, World and Indian Energy Scenario.

03 Hours

UNIT-2

Geothermal Energy: Introduction, Classifications of geothermal resources, Hydrothermal resources, Vapour dominated systems, Liquid dominated systems, Flashed-steam system, binary- cycle system, total flow system, comparison of flash and total flow concept, Geopressured resources, Hot dry rocks, Magma resources, Hybrid geothermal- fossil fuel systems, Applications and Environmental effects.

11 Hours

UNIT-3

Ocean Energy (OTEC, Tidal and Wave Energy): Ocean thermal energy conversion (OTEC)Introduction, Methods of ocean thermal electric generation, Claude OTEC cycle, Anderson OTEC cycle, hybrid cycle.

Tidal and wave energy: Principle of tidal power generation, tidal power house, Single basin arrangement, double basin arrangement, Estimation of energy and power in single and double basin tidal systems, Advantages and limitations, Wave energy Introduction, Wave energy conversion by floats, High level reservoir wave machine, Dolphin type wave power machine.

12 Hours

UNIT-4

Thermoelectric Generators: Introduction, Basic Principles of thermoelectric power generation, Seebeck effects, Joule effect, Peltier effect, Thomson effect, Performance Analysis of Thermoelectric generator derivation, types of thermoelectric generators, economic aspects of thermoelectric generation. **07 Hours**

UNIT-5

Fuel Cells and their Applications: Introduction, Design and Principle of Operation, classifications, Phosphoric Acid Fuel Cell (PAFC), Alkaline Fuel Cell (AFC), Advantages and Disadvantages, Conversion Efficiency, V-I Characteristic, Fuel Cell Power plant, Applications & Environmental Effects **06 Hours**

Text Books:

1 G. D. Rai., "Non- Conventinal Energy Sources", Khanna Publishers, NewDelhi
2 Khan, B.H., "Non-Conventional Energy Resources", Tata McGraw Hill, 2nd Edition, New Delhi.

Reference Books:

1. Twidell& A. W. Wier, Renewable energy resources, English Language book, Society I E & F N Spon.

2. N. K. Bansal, M. Kleeman& M. Mielee, Renewable Conversion Technology, Tata Mc Graw Hill, New Delhi.
3. T. John and W. Tony, Renewable Energy Resources, Taylor & Francis.

Course Outcomes:

Upon completion of this course, student will be able to:

CO 1	Apply the concepts of energy equations on Non-conventional energy technologies for their performance improvement
CO 2	Evaluate the performance of the devices working on different energies.
CO 3	Solve for performance characteristics of Non-conventional energy devices.

Scheme of Examination for Semester End Examination:

Answer Five Full questions selecting one from each unit.

To set One question each from unit I, IV, V and Two questions each from units II & III.

Course		Credits : 03				Marks	
Name	CRYOGENIC ENGINEERING	L	T	P	S	CIE	SEE
Code	19METHPECG	3	0	0	0	50	50

Course Content:

UNIT - I

Introduction: Cryogenics and its applications, Cryogenic Fluids, Properties of cryogenic fluids,Properties of materials at cryogenic temperature. **06 Hours**

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 **06 Hours**

UNIT – II

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.**06 Hours**

Cryocoolers: Classification and application of Cryocooler, Recuperative Cryocoolers, Regenerative Cryocoolers, J-T Cryocooler, StirlingCryocooler, G-MCryocooler and Pulse Tube Cryocooler. **06 Hours**

UNIT – III

Vacuum Technology: Need of Vacuum in Cryogenics,Vacuum fundamentals,Conductance and Electrical analogy,Pumping Speed and Pump down time and Vacuum Pumps. **05 Hours**

UNIT – IV

Instrumentation in Cryogenics: Need of Cryogenic Instrumentation, Measurement of Thermophysical Properties and Various Sensors. **05 Hours**

UNIT –V

Cryogenic Insulations: Importance of Cryogenic insulation, Types of Cryogenic insulations and application **03 Hours**

Safety in Cryogenics Needfor Safety, basic hazards and protection from hazards **02 Hours**

Text 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.

Reference Books:

1. G.M Walker. "Cryocooler-Part 1 Fundamentals" Plenum Press, New York and London.
2. G.M Walker. "Cryocooler-Part 2" Plenum Press, New York and London.

Course Outcomes:

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	Study on cryocoolersand its applications
CO4	Understanding the working and applications of vacuum technology
CO5	Understanding the working of Cryogenic measuring instruments
CO6	Understanding the importance of crygonics insulations and Safety in Cryogenics

Scheme of Examination for Semester End Examination:

Answer Five Full questions selecting one from each unit.

To set One question each from unit III, IV, V and Two questions each from units I &II.

ELECTIVE-II

Course		Credits : 03				Marks	
Name	GAS DYNAMICS	L	T	P	S	CIE	SEE
Code	19METHPEGD	3	0	0	0	50	50

Course Content:

UNIT – 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. **08 Hours**

UNIT- 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 flows. **08 Hours**

UNIT – 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. **08 Hours**

UNIT – 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. **07 Hours**

UNIT – 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. **08 Hours**

Text 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.

Reference Books:

1. Introduction to Gas Dynamics: Rolty, wiley 1998
2. Elements of Gas Dynamics: Liepmann and roshko, Wiley 1994.
3. The dynamics and thermodynamics of compressible fluid flow: Shapiro Ronold press. 1994.
4. Modern Compressible Flow, Anderson John.D, McGraw Hill Publication, 1990.

E-Books:

1. Gas Dynamics, E Radhakrishnan PHI (Kindle Edition)
2. Modern compressible flow, Anderson John D, McGraw Hill (Kindle Edition)

MOOCs

1. https://nptel.ac.in/courses/112/106/112106196/
2. https://nptel.ac.in/courses/112/103/112103021/

Course Outcomes:

Upon completion of this course, student will be able to:

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.

Scheme of Examination:

Answer five full questions selecting one from each unit.

To set one question each from Unit 2, 3 & 4 and two questions each from Units 1 & 5.

Course		Credits : 04				Marks	
Name	REFRIGERATION AND AIR CONDITIONING	L	T	P	S	CIE	SEE
Code	19METHPERA	4	0	0	0	50	50

Course Content:

UNIT - I

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. **05 Hours**

Main system components: Compressor- Types, performance, Characteristics of Reciprocating Compressors, Capacity Control , Types of Evaporators & Condensers and their functional aspects, Expansion Devices and their Behaviour with fluctuating load. **05 Hours**

UNIT – II

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. **05 Hours**

Other refrigeration cycles: Vapor Absorption Systems-Aqua Ammonia & LiBr Systems, Steam Jet Refrigeration Thermo Electric Refrigeration, Air Refrigeration cycles. **05 Hours**

UNIT – III

Psychrometry: Moist Air properties, use of Psychrometric Chart, Various Psychrometric processes, Air Washer, Adiabatic Saturation. **03 Hours**

Summer and winter air conditioning: Air conditioning processes-RSHF, summer Air conditioning, Winter Air conditioning, Bypass Factor. Applications with specified ventilation air quantity-Use of ERSHF, Application with low latent heat loads and high latent heat loads. **04 Hours**

UNIT – IV

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 Air flow. **06 Hours**

UNIT –V

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. **06 Hours**

Text Books:

1. Roy J. Dossat, Principles of Refrigeration, Wiley Limited 2002
2. Arora C.P., Refrigeration and Air-conditioning, 3rdedition,Tata McGraw –Hill, New Delhi 2008
3. Stoecker W.F., and Jones J.W., Refrigeration and Air-conditioning, 2nd edition McGraw – Hill, New Delhi.

Reference Books:

1. Data Books: Refrigerant and Psychrometric Properties (Tables & Charts) SI Units, Mathur M.L. & Mehta F.S., Jain Brothers. 2010.
2. Principles and Refrigeration- Goshnay W.B., Cambridge, University Press, 1985.
3. Solid state electronic controls for HVACR' –Langley, Billy C., 'Prentice-Hall 1986
4.Refrigeration and Air Conditioning- Arora C.P., Tata McGraw Hill Pub. Company
5.Handbook of Air Conditioning Systems design- Carrier Air Conditioning Co., McGraw Hill,
6.Refrigeration and Air Conditioning (3/e) – Langley Billy C., Engie wood Cliffs (N.J) PHI.
7.Fundamentals and equipment- 4 volumes-ASHRAE Inc. 2005.
8. Air Conditioning Engineering-Jones, Edward Amold pub. 2001.

MOOCs

1. https://nptel.ac.in

CO1	Understand the working principles and applications of different types of refrigeration systems
CO2	Study the working of air conditioning systems and their applications
CO3	Identify the performance parameters and their relations of an air conditioning system
CO4	Understand conventional and alternate refrigerants and their impact on environment.

Scheme of Examination for Semester End Examination:

Answer Five Full questions selecting one from each unit.
To set One question each from unit III, IV, V and Two questions each from units I &II.

Course		Credits : 03				Marks	
Name	ENGINE FLOW AND COMBUSTION	L	T	P	S	CIE	SEE
Code	19METHPECE	3	0	0	0	50	50

Course Content:

UNIT - I

Gas exchange process: Inlet & exhaust processes in four stroke cycle, volumetric efficiency, flow through valves, residual gas fraction,exhaust gas flow rate and temperature variation, super charging, turbo charging.Intake jet flow, mean velocity turbulence characteristics, swirl, squish, pre chamber engine flows, creviceflow and blow by, flows generated by piston cylinder wall interaction. **05 Hours**

UNIT – II

Combustion in IC Engines: Combustion in SI engines: Ignition, flame velocity, Normal andabnormal combustion, knocking, pre-ignition, effect of engine variables on knocking, featuresand design consideration of combustion chambers, concept of lean burn engines, Combustion inCI engines: Air motion: Swirl and squish, spray formation and vaporization, Stages ofcombustion, physical and chemical delay, diesel knock, effect of engine variables on dieselknock, combustion chambers: design features, Combustion characteristics of Biodiesel andBiodiesel blends, Low NOx diesel combustion: homogeneous charge compression ignition engine (HCCI- combustion), pHCCI, and EGR techniques. **10 Hours**

UNIT – III

Combustion Models: Fuel spray: Factors influencing fuel spray atomization, Spray equationmodels, penetration and dispersion of fuel, fuel line hydraulics, fuel pumps and injectors, Zerodimensional modeling, quasi dimensional modeling, combustion systems: efficiency and itsapplications, Single zone models, multi zone models, Premixed and diffusive models, Heattransfer coefficients, and specific heat relations, Weibes function analysis, two zone models, heattransfer in IC engines, heat transfer correlations, data logging and acquisition, cylinder-pressuremeasurement and Gross and net release rate calculations. **05 Hours**

UNIT – IV

Engine Emissions and Air-Pollution: Emissions and its Formation: Gaseous emissions: CO,CO2, HC, NOx (NO & NO2), SOx (SO2 & SO3); particulate matter (PM), Sources of emissionformation; Emissions formation mechanisms of PM and NOx; volatile organic compounds(VOCs), poly aromatic hydrocarbons (PAH), soluble organic fraction (SOF); Mechanism of airpollution: Ozone depletion, Greenhouse effect, Photochemical smog, acid rain, Effect of air pollution on health and environment, Emission norms (passenger and commercial vehicles):National and International emission standards: BS-III and BS-IV & Euro III, IV, and V **10 Hours**

UNIT –V

Emission Control Technologies and Emission Measurements: PM reduction technologies:Diesel oxidation catalysts (DOCs), Diesel particulate filters (DPFs), closed crankcase ventilation(CCV); NOx reduction technologies: Exhaust gas recirculation (EGR), Selective catalyticreduction (SCR), Lean NOx catalysts (LNCs), Lean NOx traps (LNTs), NOxadsorber catalysts,Exhaust gas recirculation (EGR), Diesel exhaust after treatment: diesel oxidation catalyst (DOC), diesel particulate filter (DPF), Soot suppression by fuel additives, relationship: soot, combustionchamber and swirl ratio, catalytic convertors: constructional features and types: 2-way and 3-way catalytic convertors. Measurement of

gaseous emissions using thermal, chemical, magneticand optical gas analyzers: infrared gas analyzer, chemiluminescent analyzer, gaschromatography, smoke (soot) measurement, application of microprocessor in emission control. Trends of emission reduction. **06 Hours**

Text Books:

1. Combustion Modeling in Reciprocating Engines, by James N Mattavi and Charles A Amann, Plenum press, 1980
2. Thermodynamic Analysis of Combustion Engines, by Ashley S Campbell, John Wiley and Sons, 1980
3. Internal Combustion Engines and Air Pollution, by Edward .F Obert, Intext Education Publishers, 1980

Reference Books:

1. Automotive Emission Control , Crouse William, Gregg division, McGraw-Hill,
2. Internal Combustion Engine Fundamentals, John B. Heywood, Tata McGraw-Hill,1998
3. Internal combustion engine modeling, by J I Ramos, Hemisphere Publishing Corporation, 1989
4. Experimental Methods for Engineers by Holman J. P, McGraw-Hill,1988
5. VComputer Simulation of Spark Ignition Engine Processes, by Ganesan V., University press, 1995

CO1	Study the Inlet& exhaust processes of I C Engine.
CO2	Understand the combustion phenomenon of I C Engines pollutant formation
CO3	Study the combustion models and emission norms.

Scheme of Examination for Semester End Examination:

Answer Five Full questions selecting one from each unit.
To set one question each from unit I, III, V and Two questions each from units II & IV.

Course	**Credits : 03**	**Marks**

Name	RESEARCH METHODOLOGY	L	T	P	S	CIE	SEE
Code	18ALLPICRM	2	0	0	0	50	50

Course Content:

Module 1:

Meaning and sources of research problem, , Objectives and Characteristics of research – Errors in selecting research problem, Research methods Vs Methodology - Types of research-Criteria of good research – Developing a research plan.

Module 2:

Investigations of a research problem - Selecting the problem - Necessity of defining the problem – Data collections-analysis- Importance of literature review in defining a problem - Survey of literature - Necessary instrumentations

Module 3:

How to write paper-conference articles-poster preparation, thesis report writing, inclusion of references, journal reviewing process, journal selection process, filling about journal template, developing effective research proposal-plagiarism-research ethics

Module 4:

Nature of Intellectual property, IPRs- Invention and Creativity - Importance and Protection of Intellectual Property Rights (IPRs) – procedure for grant of patents and patenting under PCT-types of patents-technological research and innovation- international cooperation on IP.

Module 5:

A brief summary of: Patents-Copyrights-Trademarks, patent rights-licensing and transfer of technology-patent databases-case studies on IPR-Geographical indications-new developments in IPR-protection of IPR rights

REFERENCE BOOKS:

1. Garg, B.L., Karadia, R., Agarwal, F. and Agarwal, U.K., 2002. An introduction to Research Methodology, RBSA Publishers.
2. Kothari, C.R., 1990. Research Methodology: Methods and Techniques. New Age International. 418p.
3. Anderson, T. W., An Introduction to Multivariate Statistical Analysis, Wiley Eastern Pvt., Ltd., New Delhi
4. Sinha, S. C. and Dhiman, A.K., 2002. Research Methodology, EssEss Publications. 2
5. Subbarau NR-Handbook of Intellectual property law and practise- S Viswanathan Printers and Publishing Private Limited 1998.

COs and POs for Research Methodology

CO		PO
CO1	Ability to write and present a substantial technical report/document	PO2
CO2	Able to demonstrate a degree of mastery over the area of specialization	PO3

Examination patterns

Test 1	15 marks
Test 2	15 marks
Quiz 1	10 marks
Alternative Assessment (presentation)	10 marks
Final Exam	50 marks
Total marks	**100**

Course		Credits : 03				Marks	
Name	THERMAL ENGINEERING LAB	L	T	P	S	CIE	SEE
Code	19METHPLTE	0	0	1	0	50	50

Course Content:

1. Evaluate the working of Venturimeter to measure the flow rate of a fluid of and to determining the coefficient of discharge.
2. To analyse the different shapes of notches to measure the flow rate of a fluid of and to determining the coefficient of discharge.
3. Evaluate the working of orificemeter to measure the flow rate of a fluid of and to determining the coefficient of discharge.
4. Evaluate the working of fluid Flow through pipes and to determine the various losses associated with it.
5. Evaluate the different stream line bodies using Wind tunnel for static pressure measurements.
6. To perform Flow visualizationstudies on streamline and bluff bodies.
7. Determine the various properties of fuels.
8. Conduct performance test on IC engine and obtain the characteristic curves of mass flow of fuel to brake power (BP) at various operating loads and brake mean effective pressure (BMEP) show that for same BP and BMEP, two distinct values of mass flow of fuel ispossible.
9. Conduct performance test on Pelton Wheel, Francis and Kaplanturbine and evaluate the performance andoperatingcharacteristics.
10. Conduct performance test on Centrifugal Compressor, Axial flow Compressor and Centrifugal Pumpand evaluate the performance andoperating characteristics.
11. Conduct experiments on Pulsating heat pipesand to evaluate the performance andoperating characteristics.
12. Conduct experiments on Thermo Aucostic Refrigeration Systemand to evaluate the performance andoperating characteristics.

CO1	Evaluate the fluid flow properties experimentally.
CO2	Evaluate the different performance properties parameters of I.C. engines.

Course		Credits : 03				Marks	
Name	ADVANCED HEAT TRANSFER	L	T	P	S	CIE	SEE
Code	19METHPCAH	3	1	0	0	50	50

Course Content:

UNIT - I

Introduction and one-dimensional heat transfer: The differential equation of heat conduction, heat generation, two dimensional steady state heat conduction, unsteady state processes, extended surfaces- fins of uniform cross section and non uniform cross sections, Thermal resistance networks and applications. **05 Hours**

Numerical heat Transfer:Numerical techniques for solving heat conduction problems, the finite difference method for steady state situations, the finite difference method for unsteady state situations, Controlling Numerical Errors, problems. **05 Hours**

UNIT - II

Thermal radiation: basic concepts and laws of thermal radiation, the shape factor, Eradiant heat exchange in enclosures ,black and Grey surfaces ,radiation shields and Radiation Effect on temperature measurements.Radiation properties of participating Medium, Emmissivity and absorbivity of Gases and Gas Mixtures,Heat transfer from the Human Body problems. **07Hours**

UNIT – III

Analysis of Convection Heat Transfer: Boundary layer fundamentals evaluation of convection heat transfer coefficient, Analytical solution for laminar boundary layer flow over a flat plate ,Approximate integral boundary layer analysis, Analogy between momentum and heat transfer in turbulent flow over a flat surface, Reynolds Analogy for Turbulent Flow Over Plane Surfaces, Mixed Boundary Layer, Special Boundary Conditions and High-Speed Flow. **06 Hours**

UNIT - IV

Natural convection: Introduction, Similarity Parameters for Natural Convection, Empirical Correlation for Various Shapes, Rotating Cylinders, Disks, and Spheres, Finned Surfaces. **05 Hours**

Heat transfer by forced convection: Introduction, Analysis of Laminar Forced Convection in a Long Tube, Correlations for Laminar Forced Convection, Analogy Between Heat and Momentum Transfer in Turbulent Flow, Empirical Correlations for Turbulent Forced Convection, Heat Transfer Enhancement and Electronic-Device Cooling, Flow Over Bluff Bodies , Packed Beds, Free Jets.

05 Hours

UNIT - V

Heat exchangers: Basic concepts**,**types of heat exchangers, Analysis of heat exchangers, Counter-Flow Heat Exchangers, Multipass and Cross-Flow 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. **06 Hours**

Text Books:

1. **Heat Transfer – A Basic Approach -** Ozisik M.N., McGraw-Hill Publications, 1st edition.
2. **Heat Transfer -** Holmon J.P., McGraw-Hill Publications, 6th Edition.

Reference Books:

1. **Principles of Heat Transfer -** Frank Kreith,Thomson Publications, 7th Edition.
2. **Heat Transfer-** A practical Aproach,Yunus A CengelMcGraw-Hill Publications 2nd edition

Course Outcomes:

Upon completion of this course, the student will be able to

CO1	To develop the ability to use the heat transfer concepts for various applications like finned systems, turbulence flows, high speed flows.
CO2	To analyze the thermal analysis and sizing of heat exchangers and to learn the heat transfer coefficient for compact heat exchanges.
CO3	To have an understanding of the numerical technique to handle heat transfer problems

Scheme of Examination for Semester End Examination:

Answer Five Full questions selecting one from each unit.
To set One question each from unit I, IV, V and Two questions each from units II & III.

Course		Credits : 03				Marks	
Name	STEAM AND GAS TURBINES	L	T	P	S	CIE	SEE
Code	19METHPCSG	3	0	0	0	50	50

Course Content:

UNIT - I

Nozzles and diffusers: Introduction, types of nozzles, types of Diffusers, 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, ,Effect of Friction on Critical Pressure Ratio Critical Pressure Ratio in a Frictionally Resisted Expansion from a Given Initial Velocity, Effect of Variation of Back Pressure, Parameters Affecting the Performance of Nozzles.

07Hours

UNIT - II

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, Velocity Diagram for Impulse Turbines, Combination of Vector Diagram , Forces on the Blade and Work done by Blades, Blade or Diagram Efficiency ,Axial Thrust or end thrust on the rotor, Gross Stage Efficiency, Energy Converted heat by blade friction, 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, Impulse blade suctions, Choice of blade angle, Inlet blade angles, Blade heights in velocity compounded impulse turbine. **10 Hours**

UNIT - III

Flow of Steam Through Impulse-Reaction Turbine Blades: Velocity diagram, degree of reaction, impulse- reaction turbine with similarblade 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 blaring with varying heat drop or variable speed, impulse- reaction turbine section.**05 Hours**

State Point Locus Reheat Factor and Design Procedure: Introduction, stage efficiency of impulse turbines, state point locus of an impulseturbine, 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. **05 Hours**

UNIT - IV

Axial Flow and Centrifugal Compressors : Elementary theory, compressibility effects, factors affecting stage pressure ratio, blockage incompressor annulus, degree of reaction, 3-dimensional flow, design process and blade design, off design performance, compressor characteristics. **06 Hours**

UNIT – V

Energy losses in turbines: Valve, nozzle, blade, Trailing edge wake, impingement, leakage losses. Blade friction, turning of steam jet, blade windage losses, losses due to shrouding, Disc friction,radiation and conduction,mechanical losses ,leakage through the end seals. **07 Hours**

Text Books:

1. **Steam and Gas Turbines -** R. Yadav, Central Publishing House, Allahabad.7th edition
2. **Gas Turbine Theory -** H.I.H. Saravanamuttoo, G.F.C. Rogers & H Cohen, Pearson Education.8th edition.

Reference Books:

1. **Gas Turbines -** V. Ganesan, Tata McGraw-Hill Publications.3rd edition
2. **Elements of Gas Turbine Propulsion-** Jack D Mattingley ,McGraw-Hill Publications 1st edition

Course Outcomes:

Upon completion of this course, the student will be able to

CO1	To understand the working principle, operations and analysis of nozzles, diffusers, steam and gas turbines.
CO2	Summarize the working principles of Gas and steam turbines nozzle and diffusers.
CO3	Use the principles of thermodynamics to determine the performance of steam and gas turbines.
CO4	Identify the various losses associated with the turbines.

Scheme of Examination for Semester End Examination:

Answer Five Full questions selecting one from each unit.
To set One question each from unit I, III, V and Two questions each from units II &III.

Course		Credits : 03				Marks	
Name	COMPUTATIONAL FLUID DYNAMICS	L	T	P	S	CIE	SEE
Code	19METHPCCF	3	0	0	0	50	50

Course Content:

UNIT - I

Introduction: History and Philosophy of computational fluid dynamics, CFD as a design and research tool, Applications of CFD in engineering, Programming fundamentals, MATLAB or SCILAB or GNU Octave programming, Numerical Methods. **03 Hours**

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. **06 Hours**

UNIT – II

Partial differential equations: Classification of quasi-linear partial differential equations, Methods of determining the classification, General behaviour of Hyperbolic, Parabolic and Elliptic equations. **03 Hours**

Basic aspects of discretisation: Introduction to finite differences, Finite difference equations using Taylor series expansion and polynomials, Explicit and implicit approaches, Uniform and unequally spaced grid points. **04 Hours**

UNIT – III

Finite difference method: Applied to Linear Convection equation, Laplace Equations, Convection Diffusion equations, Burgers equations, modified equations • Explicit methods and Implicit methods – as applied to applied to linear convection equation, Laplace equations, convection-diffusion equation◦ FTCS,FTFS,FTBS,CTCS ◦ Jacobi Method, Gauss- Siedel, Successive Over Relaxation Method, TDMA.• Von Naumann stability (linear stability) analysis. Upwind Method in Finite Difference method. **07 Hours**

UNIT – IV

Finite volume method: 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, Governing equations for Quasi 1-D flow, Non-dimensionalizing the equations, MacCormack technique of discretization, Stability condition, Boundary conditions. **05 Hours**

Central schemes: Lax-Friedrichs Method, Lax-Wendroff Method, Two-Step Lax-Wendroff Method and MacCormack Method. **04 Hours**

UNIT – V

Upwind Method in Finite Volume methods: Flux Splitting Method Steger and Warming, vanLeer, Roe's Method and finding Roe's Averages. **04 Hours**

Introduction to Turbulence Modeling: Derivation of RANS equations and k-epsilon model. **03 Hours**

Text Books:

1. Numerical Heat Transfer and Fluid Flow - S.V. Patankar, Hemisphere Publishing Company.
2. Computational Fluid Dynamics, T.j.chung, , Cambridge University Press

Reference Books:

1. Computational fluid flow and heat transfer - K. Murlidhar and T. Sounderrajan, Narosa
2. **Computational fluid dynamics** - J.A. Anderson, McGraw-Hill Publications

E-Books:

1. Hirsch, c., Numerical computation of internal and external flows, 2nd ed., Butterworth- Heinemann, Kindle edition.
2. An Introduction to Computational Fluid Dynamics, Malalasekhara,

MOOCs

5. https://nptel.ac.in/courses/112/105/112105254/
2. https://nptel.ac.in/courses/112/107/112107080/

Lab course component:

Computer CFD codes need to be generated to validate 1-D, 2-D and 3-D Test cases.

1-D Case:

1.Oblique Shock
2.Couette thermal flow
3.Burger's equation

2-D Cases:

1. Lid driven cavity
2. NACA series aerofoils

3-D Cases:

1. Flow around a blunt body

Note: Individually student must submit a comprehensive report on the problems solved using any of the programming languages for internal evaluation. Computer programs can be developed in MATLAB 'or' Scilab 'or' GNU Octave 'or' C language.

Course Outcome:

CO1	Apply stepwise procedure to completely solve a fluid dynamics problem using computational methods.
CO2	Identify and implement numerical techniques for space and time integration of partial differential equations.
CO3	Computationally solve the fluid properties for inviscid and viscous flows
CO4	Evaluate the fluid flow properties using governing equations for different fluid flow phenomenon

Scheme of Examination for Semester End Examination:
Answer Five Full questions selecting one from each unit.
To set one question each from unit II, III, V and Two questions each from units I& IV.

ELECTIVE III

Course		Credits : 03				Marks	
Name	CONVECTIVE AND RADIATIVE HEAT TRANSFER	L	T	P	S	CIE	SEE
Code	19METHPECR	3	0	0	0	50	50

Course Content:

UNIT - I

Analysis of Convective Heat Transfer: Boundary Layer Fundamentals, Dimensionless Boundary Layer Equations-Momentum and Energy, Principle of Similarity, Similarity solution for a flow over flat plate for steady and unsteady Laminar flow, Boundary Layer Approximation. **06 Hours**

UNIT-II

Natural Convection: Similarity parameters for Natural convection, Empirical correlations for various shapes-Vertical and Horizontal plates, Cylinder, Spheres, Cones and enclosed space. Finned surface-Finns on horizontal Tubes, Horizontal Triangular Fins, Rectangular Fins on Horizontal Surface, Rectangular Fins on Vertical Surfaces. **06 Hours**

UNIT – III

Forced Convection: Tubes and Ducts**:** Analysis of Forced convection in long Tubes-Uniform Heat Flux, Uniform Surface Temperature, Effect of Property Variation, Heat transfer correlation for Turbulent flows-Ducts, Tubes and Non circular shapes, Enhancement of Forced convection in tubes and Forced convection in electronic device cooling. **06 Hours**

Exterior Surfaces: Flow over Bluff Bodies-Cylinders and Spheres, Hot-Wire Anemometer, Packed Beds, Tube Bundles in Cross flow, Finned Tube Bundles in cross flow, Free Surface Jets. **05 Hours**

UNIT - IV

Phase change in Heat Pipes: Heat Pipe with associated flow, Sonic Limitations, Entrainment Limitations, Wicking Limitations, Boiling Limitations, Freezing and Melting. **05 Hours**

UNIT – V

Radiative Heat Transfer: Thermal Radiation, Blackbody Radiation, Radiation Properties, The Radiation Shape Factor, Enclosures with Black Surfaces, Enclosures with Gray Surfaces, Matrix Inversion, Radiation Properties of Gases and Vapors, Radiation Combined with Convection and Conduction. **11 Hours**

Text Books:

3. Principles of Heat Transfer – Frank Krieth, Raj M Mangalik and Mark. S Bon, Seventh Edition, Cengage Learning.
4. Fundamentals of Heat and Mass Transfer-Frank.P Incropera, David P.Dewit, Seventh Edition, John Wiley and Sons.

References Books:

1. Heat Transfer, J.P Holman, Sixth Edition, McGraw-Hill Book Company

E Books/Web references

1. https://nptel.ac.in/courses/103105052/
2. https://nptel.ac.in/courses/112104159/

Course Outcomes:

Upon completion of this course, the student will be able to

CO1	Understand the concept of boundary layer and determine the flow parameters in any heat transfer devices
CO2	Analyse heat dissipative cooling equipments and heat pipes by knowing the concept of natural and forced convection
CO3	Evaluate a radiation shape factor for radiative heat transfer between different surfaces
CO4	Model the fundamentals of radiation in gaseous media.

Scheme of Examination for Semester End Examination:

Answer Five Full questions selecting one from each unit.

To set one question each from unit I, II, IV and Two questions each from units III & V.

Course	Credits : 03	Marks

Name	Nuclear Engineering	L	T	P	S	CIE	SEE
Code	19METHPCNE	3	0	0	0	50	50

Course Content:

UNIT - I

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. **05 Hours**

Nuclear Fuel Cycle: Uranium exploration, mining, Uranium production, Ffuel fabrication, Spent fuel handling, Reprocessing (Purex, Urex, Diamex), Pyroprocessing, Fuel transportation between facilities, Radioactive waste management: Types, treatment, compaction, Vitrification etc., Materials: Fuel, Structural, Coolants, Control, Moderator, Shielding **05 Hours**

UNIT - II

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. **07 Hours**

UNIT - III

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. **07 Hours**

UNIT - IV

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 **07 Hours**

UNIT – V

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. **08 Hours**

Text 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.

References Books:

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

4. **Fundamentals of Nuclear Reactor Physics-**E. Lewis, Academic Press, 2008

Course Outcomes:
Upon completion of this course, student will be able to:

CO 1	Understand the basic physics of nuclear reactions
CO 2	Basic concepts of nuclear fuel manufacturing and spent fuel handling
CO 3	Classification of nuclear reactors
CO 4	Understand working principle of thermal reactor
CO 5	Understand working principle of fast reactor
CO6	Analyse the thermal hydraulics of nuclear reactors

Scheme of Examination for Semester End Examination:
Answer Five Full questions selecting one from each unit.
To set **One** question each from units II, III, IV and **Two** questions from unitsI and V

Course		**Credits : 03**				**Marks**	
Name	**DESIGN OF HEAT TRANSFER EQUIPMENTS**	**L**	**T**	**P**	**S**	**CIE**	**SEE**

Code	19METHPEDH	3	0	0	0	50	50

Course Content:

UNIT – 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. **06 Hours**

UNIT – 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. **06 Hours**

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. **06 Hours**

UNIT – 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. **06 Hours**

UNIT – 4

VAPORIZERS, EVAPORATORS AND REBOILERS: Vaporizing processes, Forced circulation vaporizing exchanger, Natural circulation vaporizing exchangers, Calculations of a reboiler. 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. **06 Hours**

UNIT – 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. **09Hours**

Text 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.

Reference Books:

1. Process Heat Transfer- Sarit K. Das, Narosa Publishing House Pvt. Ltd.

2. Standards of the Tubular Exchange Manufacturers Association, TMEA, New York.
3. Heat exchanger design- Press and N. Ozisik.
4. Heat Exchangers- Kakac, S., A.E. Bergles and F. Mayinger (Eds.) Hemisphere, 1981.
5. Compact Heat exchangers- Kays, W.M., and A.L. London, McGraw Hill.

CO1	Understand the physics and the mathematical treatment of typical heat exchangers.
CO2	Employ LMTD and Effectiveness methods in the design of heat exchangers and analyze the importance of LMTD approach over AMTD approach.
CO3	Examine the performance of double-pipe counter flow (hair-pin) heat exchangers.
CO4	Design and analyze the shell and tube heat exchanger.
CO5	Understand the fundamental, physical and mathematical aspects of boiling and condensation.
CO6	Classify cooling towers and explain their technical features.

Scheme of Examination for Semester End Examination:
Answer Five Full questions selecting one from each unit.
To set One question each from unit I, III, IV, V and Two questions each from units II & V.

ELECTIVE IV

Course		Credits : 03				Marks	
Name	ADVANCED POWER PLANT CYCLES	L	T	P	S	CIE	SEE
Code	19METHPEAP	3	0	0	0	50	50

Course Content:

UNIT-1

Analysis of Steam cycles: Rankine cycle, Carnot cycle, mean temperature of heat addition, effect of variation of steam condition on thermalefficiency 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. **05 Hours**

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. **05 Hours**

UNIT-2

Fuels and combustion : Coal, fuel oil, natural and petroleum gas, emulsion firing, coal – oil and coal – water mixtures, synthetic fuels, bio-mass, combustion reactions, heat of combustion and enthalpy of combustion, theoretical flame temperature, free energy of formation, equilibrium constant, effect of dissociation. **05 Hours**

Combustion Mechanisms : Kinetics of combustion, mechanisms of solid fuel combustion, kinetic and diffusion control, pulverized coal firingsystem, fuel-bed combustion, fluidized bed combustion, coal gasifiers, combustion of fuel oil, combustion of gas, combined gas fuel oil burners, Requirements for efficient combustion ,Recent trends in furnace /combustionchamber. **05 Hours**

UNIT-3

Steam Generators: Basic type of steam generators, fire tube boilers, water tube boilers. Economizers, superheaters, reheaters, 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. **04 Hours**

Condenser, feed water and circulating water systems: Need of condenser, direct contact type condensers, feed water heaters, circulating watersystem, cooling towers, calculations, Numerical Problems. **02 Hours**

UNIT-4

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 Reactor, PWR, BWR, gas cooled reactors. Liquid metal fast breeder reactor, heavy water and Fusion Power reactors. **06 Hours**

UNIT-5

Hydro Electric Power Plant: Introduction, advantages and disadvantages of water power, optimization of hydro – thermal mix, hydrological cycles, storage and pondage. **04 Hours**

Power plant Economics: Definitions, Principles, Location of power plant, cost analysis selection of type of generation, selection of power plant equipment's. **03Hours**

Text 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

Reference Books:

1. Power plant engineering –R.K.Rajput ,Laxmi Publications 3rd edition

CO1	To provide a knowledge about the analysis of various cycles used for power generation, Combustion, kinetics involved in combustion.
CO2	To impart knowledge about feed water circulation, working of FWH.
CO3	Differentiate axial flow and radial flow gas turbines for their analysis.
CO4	Identify the design parameters and economics of power plant.

Scheme of Examination for Semester End Examination:
Answer Five Full questions selecting one from each unit.
To set One question each from unit III, IV, V and Two questions each from units II & II.

Course		**Credits : 03**				**Marks**	
Name	**SOLAR THERMAL TECHNOLOGIES AND ITS APPLICATIONS**	**L**	**T**	**P**	**S**	**CIE**	**SEE**
Code	**19METHPESA**	**3**	**0**	**0**	**0**	**50**	**50**

Course Content:

UNIT-1

Solar Radiation: Location on earth, celestial sphere, horizon and equatorial system, Instruments for measuring solar radiation and sunshine, description of the various angles depicting the relation between sun and earth, coordinates transformation, solar time, obliquity and declination of the sun, apparent motion of the sun, sun rise and sun set time, east west time, analysis of the direct daily solar radiation on any arbitrarily located surface. **06 Hours**

UNIT-2

Flat Plate Collectors: Performance analysis, transmissivity of the cover system, overall loss coefficient and heat transfer correlations, collector efficiency factor, collector heat removal factor, effects of various parameters on the performance. Evacuated Tube Collectors Principle of working, advantages of ETC over FPC, Types of evacuated tubes. **10 Hours**

UNIT-3

Concentrating Collectors: Types, description of cylindrical parabolic collector, orientation and tracking modes, performance analysis, parametric study of collector performance in different modes of operation, compound parabolic collector geometry, tracking requirements, parabolic dish collector. **11 Hours**

UNIT-4

Thermal Energy Storage: Introduction, sensible heat storage: liquids, solids, analysis of liquid storage tank in well mixed condition and thermal stratification, analysis of packed-bed storage, latent heat storage, thermo chemical storage. **06 Hours**

UNIT-5

Applications: Water heating systems (Natural and Forced), Industrial process heating system, Active and passive space heating, Solar absorption refrigeration, Power generation (Low Temperature, Medium Temperature, High Temperature), Distillation, Drying, Cooking, Solar Pond. **06 Hours**

Text Books:

1. S.P. Sukhatme, J K Nayak "Solar Energy- Principles of Thermal Collection and Storage", Tata McGraw Hill Company Ltd., New Delhi.
2. G. D. Rai., "Non- Conventinal Energy Sources", Khanna Publishers, NewDelhi

Reference Books:

1. G.N. Tiwari and S. Suneja, Solar Thermal Engineering Systems, Narosa Publishers.
2. Khan, B.H., "Non-Conventional Energy Resources", Tata McGraw Hill, 2nd Edition, New Delhi.

Course Outcomes:

Upon completion of this course, student will be able to:

CO 1	Analyse the energy concepts on solar devices for various thermal properties.
CO 2	Analyse the solar thermal devices for various tracking modes.

CO 3	Evaluate the performance of various solar thermal technologies.

Scheme of Examination for Semester End Examination:

Answer Five Full questions selecting one from each unit.

To set One question each from unit I, IV, V and Two questions each from units II & III.

Course		Credits : 03				Marks	
Name	PHASE CHANGE PHENOMENAN IN FLUIDS	L	T	P	S	CIE	SEE
Code	19METHPEPC	3	0	0	0	50	50

Course Content:

UNIT – I

Fundamentals: Thermodynamic Equilibrium of Binary and Multi-component mixtures: Fugacity and Fugacity Coefficient of Pure Substance and Mixture, Gibbs Phase Rule.

Binary Mixtures: Phase Equilibrium Diagrams for Binary Mixtures, Ideal Mixtures, Numerical on phase diagrams of ideal mixtures, Raoult's law of mixture, Zeoptrope and Azoetrope mixture

Basic Equations on two phase flow: Mass, Momentum and Energy

10 Hours

UNIT – II

Pool Boiling: Boiling regimes, Dimensional Analysis, Nucleate boiling of ordinary fluids, Numerical on nucleate boiling, Film boiling of ordinary fluids, Passive and Active enhancement techniques in heat transfer enhancement.

07 Hours

UNIT – III

Flow boiling: Boiling regimes in Horizontal and vertical flow, Nucleate boiling in flow, Saturated boiling in flow, Film boiling in flow, Flow boiling for binary mixtures and Augmentation techniques in flow boiling.

07 Hours

UNIT – IV

Flow Patterns and Bubble Dynamics:

Flow pattern in Horizontal and vertical tubes: Bubbly flow, plug flow, Stratified flow, Wavy flow, Slug flow and Annular flow.

Two phase flow instability: Taylor and Helmholtz instabilities

Homogenous and Heterogeneous Nucleation, Rayleigh-Plesset Equation, Bubble Nucleation site density, Bubble size, Bubble departure, Bubble waiting period, Bubble departure and Simple Numerical.

10 Hours

UNIT – V

Condensation: Film wise condensation: Laminar condensation of vapour, Condensation on tube banks and Numerical.

Drop wise Condensation: Condensation of steam-Factors effecting

05 Hours

Text Books:

1. Convective boiling and condensation by John G. Collier and John R. Thome, Third edition, Oxford Science Publication
2. Boiling heat transfer and Multiphase flow by L.S Tong, Second edition, Taylor and Francis Publication

3. Hand book of Phase Change in Boiling and Condensation by Sathish G. Kandlikar by Taylor and Francis

Reference Books

1. Fundamentals of Multiphase Flows by Christopher E. Brennen, Cambridge University Press 2005.

E Books/Web references

1. https://nptel.ac.in/courses/103105058/
2. https://nptel.ac.in/courses/112107207/

MOOCS

https://www.cambridge.org/core/books/twophase-flow-boiling-and-condensation

COURCE OUTCOMES

Upon completion of this course, the student will be able to

CO1	Solve for temperature, pressure and enthalpy of Binary mixtures
CO2	Solve the basic equations to determine velocity, pressure and temperature of multiphase flow
CO3	Analyse pool and flow boiling phenomena to design the heat dissipative cooling equipments
CO4	Understand different flow pattern and its instability with bubble behavior
CO5	Analyse condensation phenomena in the industrial and commercial equipments

Scheme of Examination for Semester End Examination:

Answer Five Full questions selecting one from each unit.
To set one question each from unit II, III, V and Two questions each from units I& IV.

ELECTIVE-V (Institutional)

Course		Credits : 04				Marks	
Name	MICRO FLUIDICS	L	T	P	S	CIE	SEE
Code	19METHPEMF	4	0	0	0	50	50

Course Content:

UNIT-1

Microfluidic Transport and Micro-scale Flow Physics: An Overview: Introduction, Microfluidics versus Traditional Fluidics, Interfacial Boundary Condition: Slip Versus No-Slip (Nanobubbles on a microchannel substrate, Apparent slip due to nanobubble formation only), General Considerations.

Liquid Micro-flow Actuation in Continuous Systems: Fundamental Principles, Conservation Equations, Pressure-Driven Flow Actuation and Its Microfluidics Perspective, Surface Tension Driven Flow. **13 Hours**

UNIT-2

Bio-microfluidics: Introduction to Coupling Biology and Fluid Physics at the Scale of microconfinement,Diffusive Transport of Biochemical Species, Particle Transport, Dispersion and Mixing in Bio-microfluidics, Dispersion, Mixing , Separation Processes.

Experimental Approaches: Optical and Fluorescence Microscopy, Confocal Microscopy, Optofluidics, Flow Visualization, Non-Optical Detection. **12 Hours**

UNIT-3

Mechanical Micro manufacturing: An Overview Introduction, The Problems in Micro-manufacturing and Solutions, Futuristic Manufacturing (Laser Based) **06 Hours**

UNIT-4

Molecular Simulation: Introduction, Wetting Transition of Fluid Near Surfaces, Fitting Method, Center of Mass Method, Fluid in Nanopores, Phase Equilibria Under Confinement, Flow Properties of Fluids in Nano-Channels. **10 Hours**

UNIT-5

Nanofluidics : Introduction, Introduction to Molecular Dynamics Simulations, Nano fluidic Energy Conversion **09 Hours**

Text Books:

1. Suman Chakraborty., "Microfluidics and Microfabrication", Sprnger Publishers

Reference Books :

1. Nam-Trung Nguyen, Steven T. Wereley - Fundamentals And Applications of Microfluidics (Integrated Microsystems) Second Edition -Artech Print on Demand (2006)
2. HenrikBruus - Theoretical Microfluidics-Oxford University Press (2008)
3.Sarit K. Das, Stephen U. S. Choi, Wenhua Yu T. Pradeep NANOFLUIDS

Ebooks:

1. Suman Chakraborty., "Microfluidics and Microfabrication", Sprnger Publishers
2.Patrick Tabeling - IntroductiontoMicrofluidics-Oxford UniversityPress (2005)

MOOCs:

1. https://nptel.ac.in/courses/112/105/112105187/
2. https://nptel.ac.in/courses/102/105/102105068/

Course Outcomes:
Upon completion of this course, student will be able to:

CO 1	Differentiate between traditional flow and microfluidics.
CO 2	Derive expressions for microfluidic parameters.
CO 3	Apply the principles of micro fluidics forcoupling biology and fluid physics at microconfinement scale.
CO 4	Identify problems in micro manufacturing.
CO 5	Understand molecular simulation and Nano-fluidics (Theoretical Treatise)

Scheme of Examination for Semester End Examination:
Answer Five Full questions selecting one from each unit.
To set one question each from unit III, IV, V and Two questions each from units I & II.

Course		Credits : 03				Marks	
Name	EXPERIMENTAL METHODS IN THERMAL ENGINEERING	L	T	P	S	CIE	SEE
Code	19METHPEEM	3	0	0	0	50	50

Course Content:

UNIT-1

Measurement: Basic concepts of measurement methods, single and multi-point measurement in space and time, Processing of experimental data, Process of Measurement, Methods of measurement, Types of measuring instruments, Scale Range & Scale span, Static Calibration, Error Calibration Curve, Static & Dynamic characteristics of measurement, Accuracy, Sensitivity, Reproducibility, Repeatability, Drift, Static error, Dead zone, Error analysis and estimation, Types of errors, Random error, Systematic error, True value, Absolute error, Relative static error, Curve fitting, Regression analysis, Analog and Digital instruments, Noise, Signal to Noise ratio, various sources of Noise.

10 Hours

UNIT-2

Measurement of Temperature: Thermocouple, analysis of effect of bead size and shielding on time constant and frequency response characteristics of thermocouples, Errors due to conduction and radiation in well type thermocouple, thermocouple installations, resistance and resonant quartz thermometer, Pyrometry, Low temperature measurement, Measurement of heat flux and thermal conductivity. **08 Hours**

UNIT -3

Measurement of pressure: Manometers, bourdon tube pressure gage, diaphragm gage, bellowgage, McLeod gage, Pirani gage and ionization gage. **07 Hours**

UNIT – 4

Measurement of flow rate and velocity: Principle and theory of Rotameter, Venturi-meter, Nozzle, Orifice meter, Hot wire anemometer, Non-intrustive measurement. Gas-flow meter. **07 Hours**

UNIT – 5

Optical techniques: Flow visualisation techniques, wind tunnel; analysis of experimental uncertainty-types of error, estimation of uncertainty, Shado graph, Schliren Technique, Interferometer. **07 Hours**

Text Books:

1. Mechanical Measurement by R.S. Sirohi, S.C. Radhakrishna
2. Experimental Method for Engineers by J P Holman, McGraw Hill Publications,

Reference Books:

1. Mechanical Measurement and Instrumentation by R K Rajput, S K Kataria& sons
2. Mechanical Measurements by S P Venkatesan, Anne Publications

E-Books:

1. Experimental Method for Engineers by J P Holman, McGraw Hill Publications, Kindle Edition
2. Mechanical Measurements by Beckwith and Buck, Pearsons Edition, Kindle Edition

MOOCs

1. https://nptel.ac.in/courses/112/106/112106140/
2. https://nptel.ac.in/courses/112/107/112107242/

Course Outcome:

CO1	Apply the concepts of measurement on mechanical systems
CO2	Carry out error and uncertainty analysis of thermal systems
CO3	Analyse different measurement techniques for measurements of pressure and fluid flow

Scheme of Examination for Semester End Examination:

Answer Five Full questions selecting one from each unit.

To set one question each from unit III, IV, V and Two questions each from units I & II.

Course		Credits : 02				Marks	
Name	ENERGY AUDITING	L	T	P	S	CIE	SEE
Code	19METHPCEA	2	0	0	0	50	50

Course Content:

UNIT-1

History of Energy Management: Energy forecasting, limitations of energy resources, renewable energy recourses, load management, energy management, demand side management (DSM), energy conservation in realistic distribution system, short term load forecasting for de-centralized load management. **03 Hours**

UNIT-2

Energy Situation and Global Energy Sources: World energy consumption, energy in developing countries, firewood crises, Indian energy sources, non-conventional renewable energy sources, potential of renewable energy sources. **03 Hours**

UNIT 3

Energy Auditing as Applicable to an Industry: Classification of energy audit system optimization, power factor improvement, preventive maintenance, process modification, non-conventional energy sources, electricity tariffs, types of off-peak tariffs. **07 Hours**

UNIT-4

Elements of Energy Auditing and Metering Methodologies: Capacity utilization, technology up-gradation, fine tuning, energy conservation, concept and methods of energy conservation. **05 Hours**

UNIT-5

Demand Side Management: Introduction,concept of DSM, benefits from DSM, DSM techniques, time of day pricing, multi-utility exchange model, time of day pricing models for planning, load management, load priority technique, peak clipping, peak shifting, valley filling, strategic conservation, energy efficient equipment. **08 Hours**

Text Books

1. D.P.Sen Gupta, K.R.Padiyar, IndranilSen, M.A, "Recent Advances in Control and Management of Energy Systems", Interline Publishers, Bangalore, 1993.

2. Munasinghe, Mohan Desai, Ashok V –"Energy Demand: Analysis, Management and Conservation", Wiley Eastern Ltd., New Delhi, 1990.

Reference Books

1. N.K.Bansal, KleemanMillin, "Renewable Energy Sources and Conservation Technology", Tata McGraw-Hill Publishers, 1990.

Course Outcomes:

Upon completion of this course, student will be able to:

CO 1	Forecast the short term load for decentralised load management
CO 2	Predict energy potential locally and globally
CO 3	Estimate electricity Tariff
CO 4	Optimise energy audit system
CO 5	Determine energy consumed by various thermal machines
CO6	Plan demand side load management

Scheme of Examination for Semester End Examination:

Answer Five Full questions selecting one from each unit.

To set One question each from unit I, II, IV and Two questions each from units III & V.