THAPAR UNIVERSITY

COURSES SCHEME

&

SYLLABUS

FOR

M.E.

THERMAL ENGINEERING

COURSES SCHEME & SYLLABUS FOR M.E. (THERMAL ENGINEERING)

SEMESTER – I

SR. NO.	COURSE NO.	TITLE	L	T	P	CR
1	PTH101	ADVANCED THERMODYNAMICS	3	1	0	3.5
2	PTH103	INTERNAL COMBUSTION ENGINES	3	1	2	4.5
3	PTH104	ADVANCED FLUID MECHANICS	3	1	0	3.5
4	PTH202	REFRIGERATION AND AIR CONDITIONING SYSTEM DESIGN	3	1	2	4.5
5	PCL105	STATISTICAL METHODS AND ALGORITHMS	3	0	2	4.0
6		ELECTIVE-I*	3	2/0	0/2	4.0
TOTAL			**18**	**6/4**	**6/8**	**24.0**

SEMESTER – II

SR. NO.	COURSE NO.	TITLE	L	T	P	CR
1	PTH102	ADVANCED HEAT TRANSFER	3	1	0	3.5
2	PTH207	ADVANCED POWER PLANT ENGINEERING AND INDUSTRIAL UTILITY	3	1	0	3.5
3	PTH206	APPLIED SOLAR ENERGY	3	1	0	3.5
4	PTH212	FUELS AND COMBUSTION	3	1	0	3.5
5	PCD312	COMPUTATIONAL FLUID DYNAMICS	3	0	2	4.0
6		ELECTIVE-II	3	1	0	3.5
TOTAL			**18**	**5**	**2**	**21.5**

SEMESTER – III and IV

SR. NO.	COURSE NO.	TITLE	L	T	P	CR
1	PTH391	SEMINAR (linked with the dissertation)	-	-	-	4.0
2	PTH392	MINOR PROJECT	-	-	-	4.0
3	PTH 491	DISSERTATION	-	-	-	16.0
TOTAL			**-**	**-**	**-**	**24**

ELECTIVE-I

SR. NO.	COURSE NO.	TITLE	L	T	P	CR
1	PTH324	HYDRODYNAMIC MACHINES	3	2	0	4.0
2	PTH214	DESIGN OF COMPRESSORS AND GAS TURBINES	3	2	0	4.0
3	PCD107	FINITE ELEMENT METHODS	3	0	2	4.0

ELECTIVE-II

SR. NO.	COURSE NO.	TITLE	L	T	P	CR
1	PTHXXX	FLUIDIZATION TECHNOLOGY	3	1	0	3.5
2	PTH203	THERMAL SYSTEMS MODELING AND ANALYSIS	3	1	0	3.5
3	PTH323	TWO-PHASE FLOW AND HEAT TRANSFER	3	1	0	3.5

PTH101: ADVANCED THERMODYNAMICS

L	T	P	Cr
3	1	0	3.5

Course Objectives: To impart knowledge on the principles of energy quality and significance of the same to analyze industrial systems. To impart knowledge on statistical/micro approach to thermodynamics using real gas behavior. To impart knowledge on different thermodynamic property relations and their applications towards constructing thermodynamic systems.

Exergy Analysis: Concept of exergy, energy analysis for open and closed systems with fixed and moving boundaries, dead state and irreversibility, exergy loss due to mixing of fluids, second law efficiency.

Real Gases: Assumptions of real gases, equations of state for real gases, compressibility factor, compressibility chart, reduced pressure and temperature, pressure and energy equations using kinetic theory, RMS velocity, equi-partition of energy, mean free path, Maxwell distribution function.

Thermodynamic Property Relations: Maxwell relations, Clapeyron equation, Clapeyron Clausius equation, Mayer equation, thermodynamic potentials, residual property functions, Helmoholtz and Gibbs functions, Tds equations, fugacity of gases, Henry and Rault's law, Gibbs phase rule, Hess's law, properties of multiphase systems

Assignment: Students in groups of 3 to 4 will select any topic of their choice (within the broad boundaries of the course) related to improving efficiency/capacity/energy supply/environmental hazard management/rural development etc. The students need to define, review, analyze, design and propose an improved system. A site visit may be required. Deliverables are typed report/oral presentation/Journal or Conference paper/ poster presentation/short video film etc.

Course Learning Outcomes (CLO):
Upon completion of this course, the students will be able to:

1. apply the principles of energy analysis, real gas behavior and thermodynamic property relations to solve thermodynamic problems.
2. analyze the micro approach to thermodynamics for defining models describing thermodynamic systems.
3. assess performance of thermodynamic systems in industry
4. develop conceptual designs of improved thermal systems

Text Books:

1. *Bejan, A., Advanced Engineering Thermodynamics, John Wiley and Sons (2006).*
2. *Wark K., Advanced Thermodynamics for Engineers, McGraw Hill (1994).*

Reference Books:

1. *Bevan, O.J. & Juliana, B.J., Chemical Thermodynamics: Principles and Applications, Elsevierr (2005).*
2. *Winterbone, D. & Turan, A., Advanced Thermodynamics for Engineers, Butterworth Heinemann (2015).*

Evaluation Scheme:

Sr. No.	Evaluation Elements	Weightage (%)
1	MST	30
2	EST	40
3	Sessionals (May include assignments/quizzes)	30

PTH103: INTERNAL COMBUSTION ENGINES

L	T	P	Cr
3	1	2	4.5

Course Objective: The students will learn to classify different types of internal combustion engines and their applications. Students will be exposed to fuel air cycles, combustion charts, two stroke engines. The students will study fuel supply systems in SI and CI engines, dual fuel and multi fuel engines, alternative fuels. Detailed study will be done on recent trends in IC engines, emission control strategies.

Introduction: Preliminary analysis, cylinder number, size and arrangement, constructional details, thermodynamic properties of fuel-air mixture before and after combustion, deviations of actual cycle from ideal conditions, analysis using combustion charts, two stroke engine scavenging.

Fuel Supply Systems: S. I. engines: carburetion multi-jet, Carter, Zenith, Solex carburetors, MPFI, combustion, Ignition systems Gasoline injection, EFI system, MPFI system, electronic control system, injection timing, C.I. engines: in-line injection, rotary injection, electronic diesel injection system and control.

Recent Trends in I.C. Engines: Dual-fuel engines, multi-fuel engines, stratified charge engine, Sterling engine, variable compression ratio engine, bench marking, combustion chamber design in SI and CI engines, swirl &inlet ports design, DI models, combustion chambers in S.I. engines, Supercharging, turbo-charging & matching of turbo-charging, friction and lubrication, Performance.

Alternate Fuels for IC Engines: Liquid alternative fuels, advantages, potential, problems associated with utilization, vegetable oils, bio-diesel, emulsified fuels, effect on lubricating oils, gaseous alternative fuels, hydrogen, compressed natural gas, liquefied petroleum gas, di-methyl ether, multi-fuel engines.

Engine Emissions & Control: Air pollution due to IC engines, norms, engine emissions, HC, CO, NOx particulates, other emissions, Emission control methods, exhaust gas recirculation, modern methods.

Simulation Technique: Application of simulation techniques for engine tuning, engine selection parameters,

Laboratory Work:
Performance characteristics of CRDI engine, variable compression ratio diesel engine, dual fuel engine, Kirloskar four stroke engine, Ruston diesel engine, two stroke petrol engine.

Minor Project:
Preparation of Diesel emulsion with nanoparticles, biofuel and check for thermo physical, chemical properties of fuel and emission characteristics at various loads. Case studies of spark ignition and compression ignition engines and new technologies involve in fuel supply systems. Waste heat recovery in IC engines.

Course Learning Outcome (CLO):
The students will be able to:

1. analyse the engine thermodynamic characteristics using fuel air cycles and

combustion charts.
2. analyse S. I., C. I., and dual fuel engine performance.
3. analyse the effects of fuel composition on engine operation and mechanical limitations for ideal performance.
4. analyse the air induction and fuel supply processes for both si and ci engines.
5. analyse the effect of spark timing, valve timing and lift , cylinder dimensions, compression ratio, combustion chamber design shape.

Recommended Books:

1. *Heywood, J.B., Internal Combustion Engine Fundamentals, McGraw Hill (1988).*
2 *Stone, R., Introduction to Internal Combustion Engines, MacMillan (1999).*
3. *Pulkrabek, W., Engineering Fundamentals of the Internal Combustion Engine, Prentice Hall (2007).*
4. *Ferguson Colin R. and Kirkpatrick, Allan T. Internal Combustion Engines: Applied Thermal Sciences, John Wiley and Sons, NY, (2000).*
5. *Taylor, C.F., The Internal Combustion Engine in Theory and Practice, The MIT Press (1985).*
6. *Heisler, H., Advance Engine Technology, ButterWorth Hienemann, USA (2000).*

Evaluation Scheme:

S. No.	**Evaluation Elements**	**Weightage (%)**
1.	MST	25
2.	EST	35
3.	Sessionals (May include Assignments/Projects/Tutorials/Quizes/Lab Evaluations)	40

PTH 104 : ADVANCED FLUID MECHANICS

L	T	P	Cr
3	**1**	**0**	**3.5**

Course Objective: To impart knowledge of boundary layer flows, governing equations of fluid flow for different flow regimes, different geometries under the effect of various boundary conditions. Also to get familiar with turbulent flows and its models.

Governing Equations of Fluid Motion: Navier stokes equations, boundary layer equations, exact solutions of N -S equations, flow between concentric rotating cylinders.

Potential Theory: Kelvin's theorem, source, sink, vortex and doublet, development of complex potentials by super position, singularities – plane flow past bodies – Dirchlet theorem, conformal transformation thin aerofoil theory.

Laminar Boundary Layers: Blasius solution, boundary layers with non-zero pressure gradient, separation and vortex shedding.

Turbulent Flow: Mechanism of turbulence, derivation of governing equations for turbulent flow, K-E model of turbulence, universal velocity distribution law and friction factor, kinetic energy of the mean flow and fluctuations.

Research Assignment: Students in a group (3-5 students) will submit a project report on the computational techniques in fluid mechanics/ turbulence modelling/ practical applications in fluid flow. The report may be written by collection of literature from library, plant visit and formulation, analysis of the problem and recommendation. Each group will deliver a presentation.

Course Learning Outcomes (CLO):
The students will be able to

1. solve the boundary layer equations for laminar flows
2. obtain the exact solutions to N-S equations for different geometries
3. solve the equations for turbulent flow and its models
4. apply the numerical techniques for fluid flow problems

Recommended Books:

1. *Schlichting, H., Boundary layer Thoery, Mc Graw Hill, (1987).*
2. *Hinze, Jo., Turbulence, McGraw Hill, (1975).*
3. *Anderson D. A., Tannhill, I.C., and Pletcher, R.H., Computational Fluid Mechanics and Heat Transfer, Hemisphere Publication, (1984).*
4. *Fox, R. W. and McDonald, A. T., Introduction to fluid Mechanics, John, Wiley & Sons, (1985).*
5. *Tennekes, H. and Lumley, J. L., A First Course in Turbulence, M.I.T. Press, (1972).*
6. *Streeter, V.L. and Wylie, E.B., Fluid Mechanics, McGraw Hill, (1979).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1.	MST	30
2.	EST	45
3.	Sessionals (assignments/projects/presentations tutorials/quizes/lab evaluations)	25

PTH202 REFRIGERATION AND AIR CONDITIONING SYSTEM DESIGN

L	T	P	Cr
3	1	2	4.5

Course Objectives: To impart knowledge about principles of producing low temperatures by using multi-pressure systems and cascade systems. To provide concepts about designing, installation and servicing of air conditioning systems in residential, commercial and industrial buildings. To educate about various system components and accessories of refrigeration and air-conditioning systems.

Refrigerants: Classification of refrigerants, refrigerant properties, secondary refrigerants, ozone depletion potential and global warming potential of CFC refrigerants, eco-friendly refrigerants, azeotropic and zeotropic refrigerants.

Vapour Compression System: Multiple evaporator and compressor systems, cascade systems, manufacture of solid carbon oxide (Dry Ice).

System Components and Accessories: Types of evaporators, compressors, condensers, expansion devices, driers/ filters, receiver, accumulator, functional aspects of the above components & accessories, System equilibrium and cycling controls, capacity control in compressors.

Vapor Absorption System: Aqua ammonia & Li-Br systems, temperature-concentration diagram and enthalpy-concentration diagram for binary mixtures, thermodynamic analysis of aqua ammonia & Li-Br systems using enthalpy-concentration charts.

Steam Jet Refrigeration System: Principle and working of steam jet refrigeration system, performance analysis of steam jet refrigeration system.

Air Conditioning: Applied psychrometry, psychometric processes using chart.

Ventilation and Infiltration: Requirement of ventilation air, various sources of infiltration air, ventilation and infiltration as a part of cooling load.

Load Estimation: Inside and outside design conditions, study of various sources of the internal and external heat gains, heat losses, equivalent temperature difference method for heat load calculations, RSHF, GSHF, ESHF, etc.

Air Distribution: Fundamentals of air flow in ducts, pressure drop calculations, design of ducts by velocity reduction method, equal friction method and static regain method, duct materials and properties, insulating materials, types of grills, diffusers.

Minor Project:

Students in a group of 4/5 will submit a research minor project on non-conventional refrigeration methods such as solar refrigeration, thermo-electric refrigeration, vortex tube refrigeration and magnetic cooling.

Laboratory Work:

Study of actual and theoretical COP of Cascade Refrigeration System, Rail Coach Unit, Ice plant tutor, Air Conditioning System, Absorption System, Study the Performance of Evaporative Condenser.

Course Learning Outcomes (CLO):

The students will be able to:

1. Analyse, evaluate and compare the performances of complex vapor compression systems.
2. Perform thermodynamic analysis of absorption refrigeration systems and steam jet refrigeration system.
3. Evaluate the various sources of heat load on buildings and perform a heat load estimate.
4. Design summer and winter air conditioning systems.
5. Design ducts for central air condition systems

Recommended Books:

1. *Dossat, R.J., Principles of refrigeration, Dorling Kingsley (2008).*
2. *Stoecker, W. F., Refrigeration and Air conditioning, McGraw Hill (1986).*
3. *Goshnay, W.B., Principles and Refrigeration, Cambridge University Press (1982).*
4. *Langley, B. C., Solid State Electronic Controls for HVACR, Prentice Hall (1989).*
5. *Arora, S. C. and Domkundwar, S., A Course in Refrigeration and Air Conditioning, DhanpatRai (1997).*

Evaluation Scheme:

S. No.	**Evaluation Elements**	**Weightage (%)**
1.	MST	25
2.	EST	35
3.	Sessionals (May include Assignments/Projects/Tutorials/Quizes/Lab Evaluations)	40

PCL105: STATISTICAL METHODS AND ALGORITHMS

L	T	P	Cr
3	0	2	4.0

Introduction: Nature and objectives of research, Study and formulation of research problem. Scope and formulation of hypothesis. Preparation and presentation of research proposal using statistical package.

Review of Probability: Appraisal of axiomatic approach of probability, Conditional probability, Baye's rule, Conditional distributions, and conditional expectations.

Markov Chains: Basics of markov chains, Finite state space, Markov chains, Transition and stationary markov chains. Continuous time markov process: continuous time branching processes, Kolmogorov, Forward and backward equations, Pure birth, Pure death, Birth and death process.

Analysis of Variance: One Way Classification: ANOVA for fixed effect model, ANOVA for Random Effect Model, Two-way Classification (one observation per cell): ANOVA for fixed effect model, ANOVA for Random Effect Model.

Design of Experiments: Completely Randomised Design, Randomised Block Design, Latin Square Design, their statistical analysis and variance of estimates, Analysis of Covariance.

Multivariate Data Analysis: Introduction, multivariate normal distributions, Mean vector, Variance-covariance matrix, Correlation matrix and their estimation for multivariate data., Step wise regression, Selection of best set of variables, Classification and discrimination problems. Factor analysis and principal component analysis. Illustrative examples and Multivariate data analysis using statistical package.

Time Series and Forecasting: Components of time series, Analysis of time series, Measurement of trend, Measurement of seasonal variations, Measurement of cyclic variations, Auto-Regression Analysis, Auto-correlation, Random component in time series.

Text Books:

1. *Medhi, J., Stochastic Processes, New Age International (2005).*
2. *Montgomery, Introduction to Statistical Quality Control, John Wiley and Sons (2005).*

Reference Books:

1. *Populis, A., Random Variables and Stochastic Processes, Tata McGraw Hill (2002).*
2. *Bhuyan, K. C., Multivariate Analysis and Its Applications, New Central Book Agency (2002).*

Laboratory Assignments:

1. Analysis of variance and covariance of data.
2. Evaluation of statistical parameters of Multivariate data.
3. Analysis of time series.
4. Measurement of trend.
5. Measurement of seasonal variations.

6. Measurement of cyclic variations.
7. Auto-Regression Analysis.
8. Auto-correlation analysis.
9. Random component estimation in time series.

PTH102: ADVANCED HEAT TRANSFER

L	T	P	Cr
3	1	0	3.5

Course Objective: To get familiar and understand the modes of heat transfer and heat transfer mechanisms. Write the appropriate equations, correlation for the different modes of heat transfer. To understand the analogy between fluid mechanics and heat transfer along with heat transfer during phase change. To learn some of the computational techniques to find out the solutions to the problems.

Conduction: General conduction equations, boundary & initial conditions, radial fins & fin optimization, multidimensional heat conduction, transient heat conduction.

Convection: Forced convection, velocity and thermal boundary layers, laminar and turbulent flow, boundary layer approximations, convection transfer equations, dimensionless parameters, empirical correlations, free convection, empirical correlations for external free convection flows for various geometries and orientations, heat pipes, Nano fluids and their applications.

Boiling and Condensation: Pool boiling, correlations, forced convection boiling, two phase flow, laminar film condensation on a vertical plate, turbulent film condensation, film condensation in horizontal tubes, drop wise condensation correlations

Thermal Radiation: Thermal radiations and associated laws, radiation exchange between surfaces, view factor, network method, reradiating surfaces. Multimode heat transfer, gaseous emission and absorption.

Research Assignment:

Students in a group (3-5 students) will submit a project report on the case studies related to heat transfer problems. The report may be written by collection of literature from library, plant visit and formulation, analysis of the problem and recommendation. Each group will deliver a presentation.

Course Learning Outcomes (CLO):

The students will be able to:

1. Develop the conduction equations for multi-dimensional heat transfer problems like; cylinder, sphere, rectangular pipe etc
2. Develop the correlations for convection heat transfer problems
3. Develop and learn the computational techniques for the heat transfer problems
4. Develop and test new heat transfer fluids like; nanofluids

Recommended Books:

1. *Frank P. Incropera, David P. Dewitt- Fundamental of Heat and Mass Transfer, Wiley India (2002).*
2. *Adrian Bejan-Convection Heat Transfer, Wiley India (2003).*
3. *Sadik, K. and Yaman, Y., Convective Heat Transfer, CRC Press (1995).*
4. *Kays, W.M. and Crawford, Convective Heat and Mass Transfer, McGraw Hill (2005).*
5. *Brewster, M.Q., Thermal Radiative Transfer and Properties, John Wiley (2006).*
6. *Holman, J.P., Heat Transfer, McGraw Hill (2007).*

Evaluation Scheme:

S. No.	**Evaluation Elements**	**Weightage (%)**
1	MST	30
2	EST	45
3	Sessionals (assignments/projects/presentations tutorials/quizes/lab evaluations)	25

PTH207: ADVANCED POWER PLANT ENGINEERING AND INDUSTRIAL UTILITY

L	T	P	Cr
3	1	0	3.5

Course Objectives: To impart knowledge on the principle of operation, layouts, components, construction, selection criteria and maintenance and troubleshooting aspects of different types of power plants and industrial utility systems. To impart knowledge on the methods of designing industrial processes and systems using design codes and standards and by developing computer program

Introduction: Energy sources for generation of electric power, types of power plant-their special features and applications, present status and future trends of energy resources, overview of utility systems, project implementation stages, load curves, tariff methods

Conventional Power Generation: site selection, plant layout, steam generators, turbines, fossil and nuclear fuels, pulverizers and coal feeding, mill reject, combustion in furnace, coal handling, ash handling, electrostatic precipitators and bag filters, water systems, condensers, cooling towers, safety aspects, waste disposals, cogeneration, hydroelectric power generation, turbine specific speeds.

Non-Conventional Power Generation: Fluidized bed combustion, energy generation through wind, geothermal, tidal and solar energy, IGCC
Process Utility Systems: Bulk solids storage and transport systems – silo/hoppers, conveyors, selection and process and instrumentation diagram for pumps, fans and compressors, piping system design, pipe supports, different valves, fittings, instrumentation and data logging systems, industrial fire protection systems, dust hazards.

Assignment (s): Students in groups of 3 to 4:
(i) Will design the piping in superheater and reheater tubes in boiler and will determine and compare the heat transfer rate at different locations. This is to be done using applicable pressure piping codes (ANSI/ASTM or equivant).
(ii) Will design an optimized material handling system (coal/ash transport system) by developing a computer program.
(iii) Will select a compressor/pump model for a given duty and prepare the process flow diagram (P&ID).
(iv) Will be introduced to the operation of a pilot plant, use of data logging and instrumentation, analysis of data and process modeling

Course Learning Outcomes (CLO):
Upon completion of this course, the students will be able to:
1. design system/process/components by applying the guidelines of codes, standards and catalogs
2. develop process flow diagrams (P&IDs)
3. assess troubleshooting requirements for selected systems, analyze and propose optimum solution
4. develop process flow models acquire/interpret/analyze data from loggers,

Text Books:

3. *Nag, P.K., Power Plant Engineering, McGraw-Hill (2007).*
4. *Raja, A.K., Srivastava, A.P. & Dwivedi, M., Power Plant Engineering, New Age Int. (2006).*

Reference Books:

3. *Elanchezhian, C., Saravankumar, L., Ramnath, B. V., Power Plant Engineering, I-K Int. (2007).*
4. *Elliot, T.C., Chen, K., Swanekamp, R., Stanadard Handbook of Power Plant Engineering, McGrawhill Education (1998).*

Evaluation Scheme:

Sr. No.	Evaluation Elements	Weightage (%)
1	MST	20
2	EST	40
3	Sessionals (May include assignments/quizzes)	40

PTH-206 APPLIED SOLAR ENERGY

L	T	P	Cr
3	1	0	3.5

Course Objectives: To introduce the fundamental concepts of solar energy and radiation measuring instruments. To impart knowledge of solar energy with respect to its availability, utilization, collection and storage. To educate about how to utilize solar energy to achieve the sustainable energy systems. To introduce various types of solar energy collecting devices and their performance analysis.

Solar Radiation: Solar constant, solar angles and basic definitions, extraterrestrial and terrestrial solar radiation, solar time, local standard time, equation of time.

Solar Radiation Measurement and Estimation: Measurement of solar radiation using pyranometer and pyrheliometer, sunshine recorder, atmospheric attenuation of solar radiation, estimation of average solar radiation using empirical equations.

Radiation Transmission through Glazing: Reflection and absorption by glazing, optical properties of glass cover system, transmittance for diffuse radiation, transmittance-absorptance product, effects of surface layers on transmittance.

Flat Plate Collectors: Description of flat plate collectors, liquid heating collectors, air heating collectors, collector overall heat loss coefficient, collector efficiency factor, collector heat removal factor, flow factor, thermal and thermohydraulic performance of flat plate collector.

Concentrating Collectors: Types of concentrating collectors, geometry of concentrating collectors, concentration ratio, thermal performance of concentrating collectors.

Evacuated Tube Collector (ETC): Description and working principle of ETC systems. construction details of ETC, selection and installation of ETC systems, performance parameter tests of ETC systems.

Solar Still: Basics of solar still and solar distillation, types of solar stills, single effect and multiple effect solar stills, design of solar still, heat and mass transfer analysis for basin type solar still.

Solar Energy Storage: Packed bed storage, phase change energy storage, chemical energy storage, solar ponds.

Research Assignment: Students in a group of 4/5 will submit a research assignment on the topics such as industrial process heating, desalination, solar pumps and solar refrigeration.

Research assignment will constitute collection of literature from library/internet, visit to solar parks and formulation and analysis of the problem. **(10% weightage of total marks shall be given to this assignment).**

Course Learning Outcomes (CLO):

The students will be able to:

1. Estimate the terrestrial solar radiation on an arbitrary tilted surface.
2. Use flat plate solar collector mathematical model to calculate the efficiency and performance parameters of the same.
3. Determine the useful gain and thermal efficiency of concentrating collectors.
4. Explain the selection and installation of evacuated tube collector systems.
5. Perform heat and mass transfer analysis for simple solar still.

Recommended Books:

1. *Duffie, J.A. and Beckmann, W.A., Solar Engineering of Thermal Processes, John Wiley & Sons (2006).*
2. *Goswami, D.Y., Kreith, F. and Kreider J., Principles of Solar Energy, Taylor & Francis (2003).*
3. *Kalogirou, A.S., Solar Energy Engineering: Processes and Systems, Academic Press Inc. (2014).*
4. *Sukhatma, S and Nayak, J., Solar Energy Principle of Thermal Collection and Storage, McGraw-Hill (2009).*
5. *Garg, H.P. and Prakash, J., Solar Energy: Fundamentals and Applications, Tata McGraw Hill (2000).*

Evaluation Scheme:

S. No.	**Evaluation Elements**	**Weightage (%)**
1.	MST	30
2.	EST	45
3.	Sessionals (May include Assignments/Projects/Tutorials/Quizes)	25

PTH212: FUELS AND COMBUSTION

L	T	P	Cr
3	1	0	3.5

Course Objective: The learner will be exposed to various types of fuels e.g. solid, liquid and gaseous fuels, their origin, properties, processing and applications. In addition, the learner will be exposed to combustion stoichiometry and thermodynamics, combustion related pollution and control techniques.

Fuels: Introduction and Classification.

Solid Fuels: Coal and its classification, composition of coal, analysis and properties of coal, natural coke, oxidation and hydrogenation of coal, processing of solid fuels: coal preparation, coal storage, coal carbonization and gasification, briquetting, gasification and liquefaction of solid fuels.

Liquid Fuels: Petroleum-origin and production, composition and classification of petroleum, processing of petroleum, properties of various petroleum products, petroleum refining, liquid fuels from sources other than petroleum.

Gaseous Fuels: Natural Gas, methane from coal mines, producer gas, water gas, coal gas, blast furnace gas, refinery gases, LPG, cleaning and purification of gaseous fuels, biomass gasification.

Combustion: Principles of combustion, combustion of oil, coal and gas, combustion equations, stoichiometric fuel air ratio, exhaust and flue gas analysis, practical analysis of combustion products, dissociation, internal energy and enthalpy of reaction, enthalpy of formation, calorific value of fuels, air and fuel-vapour mixtures, heat balance sheet of a boiler, boiler draft, design of chimney.

Combustion Related Pollution: Sources and effects - acid rain, smog, greenhouse gases and effect, air sampling and measurement, pollutants: classification, monitoring and control, control equipment viz. (mechanical collectors, wet scrubbers, and ESP)

Research Assignment:

(i) Investigations of rheological properties of CWS/COS slurry.

(ii) Study of performance parameters and emissions of a biomass gasification-dual fuel engine.

Course Learning Outcome (CLO):

The students will be able to:

1. determine and analyse proximate and physical properties of a given fuel sample.
2. determine and analyse heat balance sheet in a boiler.
3. design a stack /chimney.
4. analyse flue gas samples and determine combustion stoichiometry.
5. determine and analyse properties of liquid and gases fuels.

Recommended Books:

1. *Sarkar, S., Fuels and Combustion, Orient Longman (1989).*
2. *Eastop, T.D. and McConkey, A., Applied Thermodynamics, Dorling Kingsley (2008).*
3. *Glassman, I., Combustion, Academic Press (2008).*
4. *Theodore, L., Air Pollution Control Equipment Calculations, John Wiley (2008).*

Evaluation Scheme:

S. No.	**Evaluation Elements**	**Weightage (%)**
1.	MST	30
2.	EST	45
3.	Sessionals (May include Assignments/Projects/Tutorials/Quizes/Lab Evaluations)	25

PCD312: COMPUTATIONAL FLUID DYNAMICS

L	T	P	Cr
3	0	2	4

Course objective: To impart the knowledge of governing equations for fluid flow and different turbulence models. To learn about the numerical methods used to solve the partial differential equation. To solve the fluid flow problem using CFD tool.

Introduction: Motivation and role of computational fluid dynamics, concept of modeling and simulation.
Governing equations of fluid dynamics: Continuity equation, momentum equation, energy equation, various simplifications, dimensionless equations and parameters, convective and conservation forms, incompressible invisid flows, source panel method and vortex panel method.
Nature of equations: Classification of PDE, general behaviour of parabolic, elliptic and hyperbolic equations, boundary and initial conditions.
Finite difference method: Discretization, various methods of finite differencing, stability, method of solutions.
Finite volume method: Steady one dimension convection and diffusion, Properties of discretization schemes, various methods of finite volume scheme.
Turbulence modelling: Turbulence, effect of turbulence on N-S equations, different turbulent modelling scheme
Incompressible Viscous Flows: Stream function-vorticity formulation, solution for pressure, applications to internal flows and boundary layer flows
Laboratory work: Use of commercial software for CFD analysis. Introduction to open foam software .
Minor Project: Design of energy conversion system using commercial software like ANSYS FLUENT/CFX
Course learning outcome (CLO):
The students will be able to

- acquire knowledge of various types of fluid flow governing equations.
- analyse the internal fluid flow phenomena of thermal and fluid system.
- acquire enough knowledge to design of the Engineering systems using commercial computational code
- design the thermal system using CFD

Recommended Books:

1. *Ghosdastidar, P. S., Computer Simulation of Flow and Heat Transfer, McGraw Hill (1998)*
2. *Roache, P. J., Computational Fluid Dynamics, Hermosa (1998).*
3. *Wendt, J. F., Computational Fluid Dynamics An Introduction, Springer-Verlag (2008).*
4. *Muralidhar, K. and Sundararajan, T., Computational Fluid Flow and Heat Transfer, Narosa (2008) 2nd ed.*
5. *Jaluria, Y. and Torrance, K. E., Computational Heat Transfer, Taylor & Francis (2003).*
6. *Patankar, S. V., Numerical Heat Transfer and Fluid Flow, Taylor & Francis (2007).*

Evaluation Scheme:

S.No.	Evaluation Elements	Weightage (%)
1.	MST	30
2.	EST	45
3.	Sessionals (May include Assignments/Projects/Tutorials/Quizes/Lab Evaluations)	25

PTH321: HYDRODYNAMIC MACHINES

L	T	P	Cr
3	2	0	4.0

Course Objective: The learner will be exposed to the basic fundamentals of momentum equation, boundary layer theory of the fluid. The learner will also be study the working principle of the hydropower plant, selection of design parameter of hydro turbine, centrifugal pump, reciprocating pump and axial flow pump.

Introduction: Basic fluid mechanics of turbo machinery, Euler's equation, two-dimensional theory.

Hydraulic Turbines: Classification of turbines; Forms of runners, general theory of impulse turbines, design of nozzles and wheel, bucket size, reaction turbine theory, francis and Kaplan turbines, design of guide and runner blades, design of spiral casing, draft tube theory, speed control and performance curves, cavitations, performance characteristics.

Hydraulic Pumps: Pumps and its classification, theory of pumps and design of impellers, classification, selection, installation, centrifugal pumps, head, vane shape, pressure rise, velocity vector diagrams, work, efficiency, design parameters, multistage, operation in series and parallel, axial thrust, balancing devices , self-priming arrangements ,head slip – correction ,off-design performance, hydraulic losses ,volumetric losses, Disc friction ,Mechanical losses, cavitations, NPSH, specific speed, Submersible pumps.

Reciprocating Pumps: Indicator diagram, work, efficiency, effect of acceleration and friction, air vessels.

Minor Project (if any):

Erosion and Cavitation phenomena of fluid machinery component, Design the fluid machinery component using CFD Tools.

Course Learning Outcome (CLO):

The students will be able to:

1. Develop dimensionless groups using buckingham's pi method
2. Determine the drag and lift forces of various shapes
3. Determine the various flow characteristics of pumps and turbine
4. Design the fluid machinery system

Recommended Books:

1. *Dixon, S.L., Fluid Mechanics, Thermodynamics of Turbomachinery, Elsevier Butterworth Heinemann (2005).*

2. *Turton, R.K., Principles of Turbomachinery, Springer (2009).*

3. *Earl, Logan Jr. and Roy, R., Turbomachinery, CRC Press (2003).*

4. *Japikse, D. and Baines, N.C., Introduction to Turbomachinery, Concept (1997).*

5. *Douglas, J.F., Gasiorek, J. M. and Swaffield, J. A., Fluid Mechanics, prentice Hall (2000).*

6. *Kovats, A., Design and Performance at Centrifugal and Axial Flow Pumps and Compressors, Pergamon (1964).*

7. *Stepanoff, A.J., Centrifugal and Axial Flow Pump, Krieger (1992).*

Evaluation Scheme:

S. No.	**Evaluation Elements**	**Weightage (%)**
1.	MST	25
2.	EST	35
3.	Sessionals (May include Assignments/Projects/Tutorials/Quizes)	40

PTH213 DESIGN OF COMPRESSORS AND GAS TURBINES

L	T	P	Cr
3	2	0	4.0

Course Objective: To provide students with a thorough understanding of energy systems, heat transfer and thermodynamic applications to gas turbines and compressors. The student will be exposed to design and operation of compressors and turbines. In addition, the student will also learn about gas turbine cycles and modifications of gas turbine cycles. Three-dimensional flows in turbo machines, design of individual components, and the prediction of design off-design performance blade materials, blade attachments and cooling, gas turbine power, plant performance and matching, applications of gas turbine power plants.

Review: Development, classification and field of application of gas turbines, Gas turbine cycle, Multistage compression, Reheating, Regeneration combined and cogeneration, Energy transfer between fluid and rotor, Axi-symmetric flow in compressors and gas turbines.

Compressors: Classification, Centrifugal compressors, Adiabatic efficiency, Slip factor, Design consideration for impeller and diffuser systems, Performance characteristics, Axial flow compressors, Vortex theory, Degree of reaction, Simple design, Aerofoil theory, Cascade theory, Stages, Stage efficiency and overall efficiency, performance characteristics. Combustion systems, Design considerations, Flame stabilization

Turbines: Classification - axial flow and radial flow turbines, Impulse and reaction turbines, Elementary vortex theory, Aerodynamic and thermodynamic design considerations, Blade materials, Blade attachments and cooling, Gas turbine power plants, Plant performance and matching, Applications of gas turbine power plants.

Fans and Blowers: Fan applications, Types, Fan stage parameters, Design parameters.

Research Assignments:

Axial flow gas turbine design. Radial flow gas turbine design, centrifugal and axial flow compressor design. Methodology for improving power to weight ratio, turbine efficiency, blade design calculations. Turbine blade cooling and attachment methods to rotor drum gas turbine maintenance and trouble shooting.

Course Learning Outcome (CLO):

The students will be able to:

1. Analyse and design centrifugal compressor.
2. Analyse and design axial flow compressors for various blade configurations.
3. Analyse and design axial and radial flow gas turbine
4. Design for matching of the components of gas turbine power plant.
5. Analyse and evaluate gas turbine cycle performance.

Recommended Books:

1. *Cohen, H., Rogers, G.F.C., and Saravanamuttoo, H.I.H., Gas Turbine Theory, Longman (2008).*
2. *Oates, G.C., Aero-thermodynamics of Gas Turbine and Rocket Propulsion AIAA Education Series (1997).*
3. *Yahya, S.M, Turbines, Compressors and Fans, Tata McGrawHill (2005).*
4. *Dixon, S.L., Fluid Mechanics and Thermodynamics of Turbomachinery, Elsevier .*
5. *Ganesan, V., Gas Turbines, Tata McGrawHill (2003)*

Evaluation Scheme:

S. No.	**Evaluation Elements**	**Weightage (%)**
1.	MST	30
2.	EST	45
3.	Sessionals (May include Assignments/Projects/Tutorials/Quizes/Lab Evaluations)	25

PCD107 FINITE ELEMENT METHODS

L	T	P	Cr
3	0	2	4.0

Course objective: To develop the skills needed to apply Finite Element Methods to problems in Mechanical Engineering.

Approximate Solution Methods: Finite Difference Method, Finite Element Methods, Ritz and Rayleigh Ritz methods, Method of weighed residuals, General concepts, Point collocation, Subdomain collocation, least squares, Galerkin method.

Introduction to Finite Element Method: Introduction to variational calculus, The differential of a function, Euler-Lagrange equation, Geometric & natural boundary conditions, Basic Concept of Finite Element Method, Principle of potential energy, 1D elements, Derivation of Stiffness and Mass matrices for a bar, A beam and A shaft, Comparison with Analytical results, Interpolation and shape functions, Solution of static problems and case studies in stress analysis of mechanical components, FEA using 2D and 3D elements, Plain strain and plain stress problems, FE using plates / shell elements, analysis using Isoparametric Elements.

Laboratory Work:

Programming of the different concepts covered in lectures using C++/MATLAB language, demonstration of analysis software for finite element analysis.

Minor Project:

Students will be given different 2D /3D components for structural/thermal/ fluid flow FEM analysis to be done using C++/MATLAB programming. The components are to be analyzed using different linear / higher order elements *i.e.*, triangular, axisymmetric, quadrilateral, tetrahedral and hexahedral elements.

Course Learning Outcomes (COL):
The students will be able to:

1. Apply the procedure involved to solve a structural problem using Finite Element Methods.
2. Develop the element stiffness matrices using different approach.
3. Analyze a 2D problem using line, triangular, axisymmetric and quadrilateral element.
4. Analyze a 3D problem using tetrahedral and hexahedral elements.

Recommended Books:

1. *Zienkiewicz, O. C., The Finite Element Method, Butterworth Heinemann (2002).*
2. *Huebner, K. H., Dewhirst, D. L., Smith, D. E. and Byrom, T. G., The Finite Element Methods for Engineers, John Wiley (2000).*
3. *Reddy, J. N., An Introduction to the Finite Element Method, McGraw Hill (2001).*
4. *Bathe, K. J., Finite Element Procedures, Prentice Hall of India (2008).*
5. *Cook, R. D., Concepts and Applications of Finite Element Analysis, John Wiley and Sons (2001).*
6. *Buchman, G. R., Finite Element Analysis, Schaum's Outlines, McGraw Hill (1995).*
7. *Chandrupatla, T. R. and Belgundu, A. D., Introduction to Finite Elements in Engineering, Prentice Hall of India (1997).*
8. *Jordan, C. Calculus of Finite Differences, American Mathematical Society (1979).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1.	MST	30
2.	EST	45
3.	Sessionals (Lab Evaluations/ Quizzes/ Minor Projects)	25

PTHXXX FLUIDIZATION TECHNOLOGY

L	T	P	Cr
3	**1**	**0**	**3.5**

Course Objective:
To learn the fluidization phenomena, industrial applications of fluidized beds and their operational and design aspects.

Introduction: The phenomena of fluidization, Liquid-like behaviour of fluidized beds, Comparison with other contacting methods, Fluidization quality.

Industrial Applications of Fluidized Beds: Drawbacks of pulverised fuel fired boilers, Coal gasification and combustion, incineration of solid waste, thermal cracking, Biofluidization.

Fluidization and Mapping of Regimes: Characterization of particles, Determination of effective sphericity, Fluidization without carryover of particles, Fluidization with carryover of particles, Mapping of fluidization regimes.

Dense Fluidized Beds: Distributors, gas entry region, gas jets, pressure drop across distributors, design of distributors, bubbles in dense beds, free-board behaviour, estimation of TDH, entrainment and elutriation from fluidized beds.

Bubbling Fluidized Beds: Estimation of bed properties, Heat and mass transfer, Flow models for bubbling beds (simple two phase models), three phase models.

Course learning outcomes (CLOs):
The students will be able to

1. design various types of gas distributers for fluidized beds and determine effectiveness of gas mixing at the bottom region
2. estimate pressure drop, bubble size, TDH, voidage, heat and mass transfer rates for the fluidized beds
3. develop mathematical modeling for fluidized bed combustors.

Recommended Books:

1. *Kunni, D., and Levenspiel, O., Fluidization Engineering, Butterworth-Heinemann (1991).*
2. *Yang, W., and Amin, N.D., Fluidization Engineering: Fundamentals and Applications, American Institute of Chemical Engineers (1988).*
3. *Fan, L.S., Gas-Liquid-Solid Fluidization Engineering, Butterworths (1989).*
4. *Yang, W.C., Handbook of Fluidization and Fluid-particle Systems, CRC Press (2003).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1.	MST	30
2.	EST	40
3.	Sessionals (May include Assignments/Projects/Tutorials/Quizes/Micro-Projects/Lab Evaluations)	30

PTH203: THERMAL SYSTEMS MODELING AND ANALYSIS

L	T	P	Cr
3	1	0	3.5

Course Objective: To get familiar with the design, thermal modeling and its objectives. Also, to understand and apply optimization in the analysis of various types of thermal equipments.

Thermal System Design: Design principles, workable systems, optimal systems, matching of system components, economic analysis, depreciation, gradient present worth factor

Mathematical Modeling: Equation fitting, empirical equation, regression analysis, different modes of mathematical models, selection, computer programmes for models

Thermal Equipments Modeling: Modeling of heat exchangers, evaporators, condensers, absorption and rectification columns, compressor, pumps, simulation studies, information flow diagram, optimization of thermal systems.

Dynamic Behavior of Various Thermal Systems: Steady state simulation, Laplace transformation, feedback control loops, stability analysis, non-linearties

Research Assignment: Students in a group (3-5 students) will submit a project report on the modeling, optimization of the various types of actual thermal equipments/systems. The report may be written by collection of literature from library, plant visit and formulation, analysis of the problem and recommendation. Each group will deliver a presentation.

Course Learning outcomes (CLO):

The students will be able to:

1. Design and select the materials/equipments for a particular application based upon its thermal response
2. Model the thermal equipments
3. Analyze and optimize the thermal problems
4. Apply the mathematical techniques for control loops, stability analysis.

Recommended Books:

1. *Hodge, B.K. and Taylor, R.P., Analysis and Design of Energy Systems, Prentice Hall (1999).*
2. *Bejan, A., Tsatsaronis, G. and Moran, M., Thermal Design and Optimization, John Wiley (1996).*
3. *Jaluria, Y., Design and Optimization of Thermal Systems, CRC Press (2008).*
4. *Ishigai, S., Steam Power Engineering Thermal and Hydraulic Design Principle, Cambridge University Press (1999).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1.	MST	30
2.	EST	45
3.	Sessionals (assignments/projects/presentations tutorials/quizes/lab evaluations)	25

PTH323: TWO PHASE FLOW AND HEAT TRANSFER

L	T	P	Cr
3	1	0	3.5

Course Objective: To study and understand the role of heat exchangers in many heat transfer problems. To learn different types of heat exchangers, their design, functioning and related concepts. Also to understand the working and design methodology of heat exchangers where fluid undergoes phase change.

Basic Design Methods for Heat Exchangers: Introduction, arrangement of flow path in heat exchangers, basic equations in design, overall heat transfer coefficient, log mean temperature difference method for heat exchanger analysis, NTU method for heat exchanger analysis, heat exchanger design calculations, variable overall heat transfer coefficient and heat exchanger design methodology.

Design for Condensers and Evaporators: Introduction, condensation, film condensation on a single horizontal tube-laminar film condensation, forced convection, film condensation in tube bundles-effect of condensate inundation, flow boiling-sub-cooled boiling, shell-and-tube condensers, steam turbine exhaust condensers, plate condensers, air-cooled condensers, direct contact condensers, condensers for refrigeration and air-conditioning applications.

Shell and Tube Heat Exchangers: Introduction, basic components-shell types, tube bundle types, Tubes and tube passes, Tube layout, Baffle type and geometry, Allocation of streams, Basic design procedure of a heat exchanger-preliminary estimation of unit size, Rating of preliminary design, Shell-slide heat transfer and pressure drop-shell-side heat transfer coefficient, shell-side pressure drop, tube-side pressure drop, Bell-Delaware method.

Compact Heat Exchangers: Introduction, plate-fin heat exchangers, tube-fin heat exchangers, heat transfer and pressure drop-heat transfer, pressure drop for finned-tube exchangers, pressure drop for plate-fin exchangers.

Research Assignment:

Students in a group (3-5 students) will submit a project report on design of various types of heat exchangers involved in actual thermal systems. The report may be written by collection of iterature from library, plant visit and formulation, analysis of the problem and recommendation. Each group will deliver a presentation.

Course Learning Outcomes (CLO):

Students will be able to:

1. Apply the designing methods for heat exchangers
2. Design the heat exchangers for various thermal applications where fluid does not change its phase
3. Design the heat exchangers for various thermal applications where fluid undergo phase change
4. Investigate the performance of the compact heat exchangers

Recommended Books:

1.	*Krieth. F. and Bohn. M.S., Principles of Heat Transfer, Asian Books Pvt. Ltd. Delhi (1977).*
2.	*Whalley, P.B., Boiling, Condensation and Gas-Liquid Flow, Oxford University Press (1990).*
3.	*Sadik, K. and Yaman, Y., Convective Heat Transfer, CRC Press (1995).*

Evaluation Scheme:

S. No.	**Evaluation Elements**	**Weightage (%)**
1.	MST	30
2.	EST	45
3.	Sessionals (assignments/projects/presentations tutorials/quizes/lab evaluations)	25