MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

DEPARTMENT /CENTER: Department of Mechanical Engineering

Master of Technology in Thermal Engineering

Semester. I

S. No.	Course Code	Course Title	Course Category	Type	Credit	L	T	P
1	21MET565	Design of Thermal System	Theory	PC	**3**	**3**	**0**	**0**
2	21MET562	Advanced Fluid Mechanics	Theory	PC	**3**	**3**	**0**	**0**
3	21MET561	Advance Heat Transfer	Theory	PC	**3**	**3**	**0**	**0**
4	21MET564	Computational Fluid Dynamics	Theory	PC	**3**	**3**	**0**	**0**
5	21MET563	Advanced Thermodynamics	Theory	PC	**3**	**3**	**0**	**0**
6	21MEP566	Thermal Lab	Laboratory	PC	**2**	**0**	**0**	**4**
		Total Semester Credits			**17**			

Semester. I

S. No.	Course Code	Course Title	Course Category	Type	Credit	L	T	P
1		Program Elective-I	Theory	PE	**3**	**3**	**0**	**0**
2		Program Elective-II	Theory	PE	**3**	**3**	**0**	**0**
3		Program Elective-III	Theory	PE	**3**	**3**	**0**	**0**
4		Program Elective-IV	Theory	PE	**3**	**3**	**0**	**0**
5		Program Elective-V	Theory	PE	**3**	**3**	**0**	**0**
6	21MEP567	CFD Lab	Laboratory	PC	**2**	**0**	**0**	**4**
		Total Semester Credits			**17**			

Semester. III

S. No.	Course Code	Course Title	Course Category	Type	Credit	L	T	P
1	21MES662	Seminar	Seminar	Seminar	**4**	**0**	**0**	**4**
2	21MED661	Dissertation	Research	Research	**8**	**0**	**0**	**8**
		Total Semester Credits			**12**			

Semester. IV

S. No.	Course Code	Course Title	Course Category	Type	Credit	L	T	P
2	21MED663	Dissertation	Research	Research	**12**	**0**	**0**	**12**
		Total Semester Credits			**12**			

	Subject Code	Course Title	Credits Total (LTP)
List of Program Electives			
1.	21MET844	Simulation and Modeling	3 (3- 0- 0)
2.	21MET840	Energy Management	3 (3- 0- 0)
3.	21MET843	Refrigeration and Air-conditioning Systems	3 (3- 0- 0)
4.	21MET837	Advanced Refrigeration	3 (3- 0- 0)
5.	21MET838	Alternative Fuels in I.C. Engine	3 (3- 0- 0)
6.	21MET846	Wind Energy Utilization	3 (3- 0- 0)
7.	21MET842	Pollution Control Technologies	3 (3- 0- 0)
8.	21MET845	Solar Thermal Engineering	3 (3- 0- 0)
9.	21MET839	Energy Conversion Technologies	3 (3- 0- 0)
10.	21MET841	Heat Exchanger Design	3 (3- 0- 0)
List of Open Electives			
Student can choose any of the OEs in consultation with his Dissertation Supervisor and Program Advisor. There is no requirement of any Open Elective course as per the scheme.			

Credit Distribution among different types of courses is as under

Type of courses	Credits	Range as per scheme
Program core (PC)	19	18-21
Program elective (PE)	15	15-21
Open elective (OE)	0	0-6
Research project, seminar, dissertation	24	16-24
Total	58	54-60

Program coordinator

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

DEPARTMENT /CENTER: Department of Mechanical Engineering

Master of Technology in Thermal Engineering

Course Code : **21MEP566**

Course Name : **Thermal Lab**

Credits : 02 **L -** 0 **T -** 0 **P -** 3

Course Type : Core / Elective

Prerequisites : Engineering Thermodynamic, Fluid Mechanics, I.C Engines, Refrigeration and Air conditioning

Course Contents

1. To measure the effectiveness of the heat recovery wheel under different indoor and outdoor condition.
2. To evaluate the performance of the box type solar cooker at:
   a) No load
   b) Full load
3. To measure the effectiveness of the heat recovery wheel under different indoor and outdoor condition.
4. Testing of the inverter based split air conditioner.
5. To study the solar air heater and calculate its performance parameter.
6. To perform tests on solar flat plate thermal collector and evaluation of performance parameter in the thermosyphon mode of operation.
7. To do a comparative study of engine performance working on a biodiesel blended (5%) diesel to that of a pure diesel.
8. To study the thermal energy storage systems and calculate its performance parameterss.

Recommended Readings

1. Text book -
   1. V Ganesan, Internal Combustion Engines, Mc Graw hill education.
   2. C.P. Arora, refrigeration and air conditioning, Mc Graw hill education
2. Reference book-
   1. SP Sukhatme & JK Nayak, Solar Energy , Mc Graw hill education.
   2. Garg, H.P., Mullick S.C., Bhargava, Vijay k, Solar Thermal Energy storage, Springer Publication
3. Online resources-

Course Code : **21MEP567**

Course Name : **CFD Lab**

Credits : 02 **L -** 0 **T -** 0 **P -** 3

Course Type : Core / Elective

Prerequisites : Basic programming skills (FORTRAN, C, MATLAB, Python etc.), Basic Fluid Mechanics/Heat Transfer/Transport Phenomena, Applied Mathematics

Course Contents

Review of numerical techniques and discretization methods: Numerical solution of one-dimensional steady state heat conduction, unsteady heat conduction. Modelling of convection diffusion problems: One dimensional convection-diffusion using central difference scheme.

Upwind scheme, numerical diffusion (artificial viscosity); Modelling fluid flow; Flow visualization. Introduction to open source/commercial CFD tool: Pre-processor, solver, post processor; Grid Independence; Errors in CFD Simulation; Research Ethics in CFD Simulation..

List of Experiments

1. Discretization and numerical solution of 1D steady state heat transfer through a simple fin.
2. Numerical solution of transient heat conduction in a square metallic block subjected to Dirichlet, Neumann and mixed boundary conditions at different faces.
3. Numerical solution of potential flow problem.
4. Solution convergence monitoring, flow visualization and post processing techniques and tools.
5. Introduction to open source CFD software and setup test case-1 for laminar flow in Lid driven cavity.
6. Mesh generation for test case-1 using inbuilt tool and open-source mesh generation software.
7. Grid independence test, results reporting and visualization for test case-1.
8. Investigating the false diffusion in various discretization schemes.
9. CFD study of laminar flow past a backward facing step (test case-2).
10. CFD study of natural convection in a square cavity (test case-3).
11. CFD study of conjugate heat transfer in a heat exchanger (test case-4).
12. CFD study of flow behind a rotating cylinder (test case-5; setting up case with Arbitrary Moving Interface AMI).

Recommended Readings

1. Text book -
    1. W Malalasekera. An introduction to computational fluid dynamics: the finite volume method. Pearson Prentice Hall, 2007.
    2. Suhas Patankar. Numerical heat transfer and fluid flow. CRC press, 1980
2. Reference book-
    3. Bengt Andersson, Ronnie Andersson, Love Hakansson, Mikael Mortensen, Rahman Sudiyo, and Berend VanWachem. Computational fluid dynamics for engineers. Cambridge University Press, 2011
3. Online resources-

Course Code : **21MET844**

Course Name : Simulation and Modeling

Credits : 3 **L -** 3 **T -** 0 **P -** 0

Course Type : Core / Elective

Prerequisites : Nil

Course Contents

Definition of a system, System concepts, type of system, continuous & discrete systems, modelling process verification & validation. Introduction; classification of simulation models; advantages, and disadvantages of simulation. Concept of simulation time and real-time. Discrete system simulation. Monte Carlo method, Random number generators. Introduction of Probability Distributions and random processes, Central limit theorem. Estimation of mean and variance, Confidence interval, Hypothesis testing, Normal distribution, t-test, ANOVA- an Introduction, Markov chains: CTMC and DTMC, Queuing models: Basic queuing models. Little's theorem and network of queues. Simulation of inventory systems. Introduction to simulation environment and software tools.

Recommended Readings

1. Text book -
    1. Principles of Operations Research, Wagner, PHI.
    2. Simulation modelling and analysis, Law and Kelton, McGraw Hill
    3. Zeigler B.P., Praehofer. H. and Kim I.G. "Theory of modeling and simulation", 2nd Edition. Academic press 2000
2. Reference book-
    1. Probability and Statistics with Reliability, Queuing and Computer Science Application, Kishore S Trivedi, Wiley.
    2. System simulation, Gorden G., Prentice Hall of India.
3. Online resources-
    1. https://nptel.ac.in/courses/112/107/112107220/#

Course Code : 21MET565

Course Name : Design of Thermal Systems

Credits : 3 **L -** 3 **T -** 0 **P -** 0

Course Type : Core / Elective

Prerequisites : MET-201 Engineering Thermodynamics, MET-202 Fluid Mechanics and Machines, MET-221 Heat Transfer, MET-302 Turbo machinery, and MET-325 Refrigeration and air conditioning

Course Contents

Mathematical Modeling of thermal Systems: Development of equations based on number-processing operation and physical laws for simulation and optimization of thermal systems. The art of equation fitting to performance data; development of performance equations for heat exchangers, distillation separators and turbo machinery. Simulation of thermal Systems: Uses of system simulation, classes of simulation; Information-flow diagrams; sequential and simultaneous calculations; simulation of continuous, deterministic steady-state systems, e.g., gas turbine system; simulation of dynamic behavior of thermal systems. Optimization of Thermal Systems: Optimization criteria; use of Lagrange Multipliers, search methods, dynamic programming and geometric programming for optimum design of thermal systems

Recommended Readings

1. Text book -
    1. W.F. Stocker; "Design of thermal Systems", McGraw Hill International, 1989.
    2. C. Balaji, "Essentials of Thermal System Design and Optimization", Ane Books Pvt. Ltd
2. Reference book-
    1. B.K. Hodge, "Analysis and Design of Energy Systems", Prentice-Hall Inc., 1990
3. Online resources-
    1. https://nptel.ac.in/courses (Design of Thermal System - Video course)

Course Code : 21MET564

Course Name : Computational Fluid Dynamics

Credits : 3 **L -** 3 **T -** 0 **P -** 0

Course Type : Core / Elective

Prerequisites : Engineering Thermodynamics, Fluid Mechanics and Heat Transfer at UG Level

Course Contents

Introduction: What is CFD; Applications of CFD; Future of CFD; Advantages and Limitations of CFD. Governing Equations: Local, Convective, and Substantial derivative; divergence; continuity equation for - finite control volume fixed in space and moving with the fluid, infinitesimally small element fixed in space and element moving with the flow; momentum equation; energy equation; Navier—Stokes equations; Euler's equations; types of physical boundaries and corresponding conditions; Turbulence: Definition of turbulence; its source; its impact on solution methodology, k-e two equation model; other models for turbulence – k-w, RANS, LES, DNS; limitations of turbulence models. Classification of PDEs – Hyperbolic, parabolic and elliptic equations; mathematical behaviour of PDEs. Discretization - FDM: Introduction to finite difference; finite difference equations, explicit and implicit formulations; consistency; error and stability analysis - von Neumann approach; convergence. Discretization - FVM: Introduction to finite volume method; finite difference equations for first order and second order partial derivatives using FVM. Comparison between FDM and FVM. CFD Solution Procedure: Creation of geometry; meshing; specification of fluid properties; specification of boundary conditions;

numerical solution – initialization, solution control, convergence, post processing – x-y plots, vector plots, contours plots, animation, reports. Miscellaneous: Finite volume approach; TDMA; Exposure to commercial CFD Codes such as Hyperworks and Ansys with some examples

Recommended Readings

1. Text book -
    1. Computational Fluid Dynamics: The Basics with Applications, John D. Anderson, Jr., McGraw-Hill.
    2. Computational Fluid Dynamics: A Practical Approach, Jiyuan Tu, Guan Heng Yeoh, and Chaoqun Liu, Butterworth-Heinemann (20071109)
2. Reference book-
    1. S.V. Patankar, Numerical Heat Transfer and Fluid Flow, McGraw-Hill.
    2. T. J. Chung, Computational Fluid Dynamics, Cambridge, University Press
    3. J. H. Ferziger and M. Peric, Computational Methods for Fluid Dynamics, Springer
    4. John C. Tannehill, Dale A. Anderson and Richard H. Pletcher, Computational Fluid Mechanics and Heat Transfer, Taylor & Francis
    5. J. Blazek, Computational Fluid Dynamics: Principles and Applications, Elsevier
3. Online resources-
    1. https://nptel.ac.in/courses/112/105/112105045/ (Computational Fluid Dynamics - Video course)
    2. https://nptel.ac.in/courses/112/107/112107080/ (Introduction to CFD)

Course Code : 21MET840

Course Name : Energy Management

Credits : 3 **L -** 3 **T -** 0 **P -** 0

Course Type : Core / Elective

Prerequisites : Proper understanding of the various forms of energy and basic of power plant engineering. Student should also have good idea of distribution of resources globally.

Course Contents

Introduction to energy management: Aims and approaches of auditing, types of energy audit, energy indices in residential, commercial, and industrial sector, data collection. Energy in manufacturing: Energy and environment analysis of products, energy consumption in manufacturing, laws of energy and materials flow. Energy in Residential sector: Supply of energy for rural and urban housing, fuel substitution, efficiency improvement of domestic appliances. Instrumentation of energy management: Measurement of heat flux, radiation, psychrometric variables, fluid flow & velocities, data analysis. Life cycle analysis: LCA of energy systems, concept of life cycle costing and its use. Demand side management: Principle of DSM, rules and tools of DSM, fundamentals of demand response, DSM tools and practices.

Recommended Readings

1. Text book -
    1. C.B. Smith, Energy Management Principles, Pergamon Press, New York, 1981.
    2. Hamies, Energy Auditing and Conservation: Method, Measurement, Management & case study, hemisphere, Washington, 1980
    3. Diamant R.M., Total Energy, Pergamon Press, Oxford, 1970
2. Reference book-
3. Online resources-

Course Code : 21MET562

Course Name : Advanced Fluid Mechanics

Credits : 3 **L -** 3 **T -** 0 **P -** 0

Course Type : Core / Elective

Prerequisites : Engineering Thermodynamics and Basic fluid mechanics

Course Contents

Basic Equations: Deformation and the rate of strain, the deformation tensor; skew-symmetry of the deformation tensor; symmetry of the stress tensor; polar and non-polar fluids; Stokessian and Newtonian fluids; derivation of the general differential equation of continuity; Momentum and Energy in vector form; Euler's and Navier-Stoke's equations, Integration of the momentum equation and the generalized Bernoulli's equation. Two Dimensional Irrotational Flow: Two-dimensional flow in rectangular and polar coordinates; continuity equation and the stream function, irrotationality and the velocity potential function, vorticity and circulation, plane potential flow and the complex potential function. Sources, sinks, doublets and vortices, Superposition of uniform stream with above; flow around corners; Rankine ovals, flow around circular cylinders with the without circulation, pressure distribution on the surface of these bodies; elements of two-dimensional aerofoil's theory, symmetrical aerofoil theory, lift and moment. Vortex Motion: Definitions, vortex lines, surfaces and tubes, vorticity, circulation; Kelvin's circulation theorem, Helmholtz's vorticity theorems; the convection and diffusion of vorticity. Viscous Flow: Exact solution, plane Poiseuille and Couette flows; Hagen Poiseuille flow through pipes. Flows with very small Reynolds number; Flows with very large Reynolds number; elements of two dimensional boundary layer theory; displacement thickness and momentum thickness; skin friction; Blassius solution for boundary layer on a flat plate without pressure gradient; the Karman-Pohlhausen integral method for obtaining approximate solutions; drag on bodies: form drag and skin friction drag profile drag and its measurement.

Recommended Readings

1. Text book -
    1. Advanced engineering fluid mechanics. K. Muralidhar, G. Biswas, Alpha Science International Ltd. 2005 Fundamentals of Heat Exchanger Design by Ramesh K Shah, Wiley Publication, 2003.
    2. Fluid Mechanics, Pijush K Kundu, Ira M Cohen, Academic Press, 2001
    3. Viscous fluid flow, F. M. White, I Corfield, McGraw-Hill, 2006

2. Reference book-
    1. Introduction to Fluid Dynamics, “G.K. Batchelor” Cambridge press, 2000.
    2. Introduction to Fluid Dynamics, Robert W Fox, Alan T MacDonald, Philip J Pitchard John Wiley & Sons Inc. 2010
3. Online resources-

Course Code : 21MET843

Course Name : Refrigeration and Air-conditioning Systems

Credits : 3 **L -** 3 **T -** 0 **P -** 0

Course Type : Core / Elective

Prerequisites : Engineering Thermodynamics, Heat Transfer, and Refrigeration and Airconditioning at UG level

Course Contents

Introduction: a brief introduction to history, thermodynamics, and basics of vapour compression cycle and refrigeration and air-conditioning systems. Psychrometry: introduction to psychrometry; definition of various terms, such as, - dry-bulb and wet-bulb temperatures, thermodynamic wet-bulb temperature, dew point, saturation line, relative humidity, and humidity ratio; basic processes on a psychrometric chart, such as, - constant enthalpy lines, constant specific volume lines, adiabatic saturation line, sensible heating and cooling, humidification, cooling and dehumidification, chemical dehumidification, mixing of two air streams; airflow over wetted surfaces - straight line law or Lewis relation, and heat transfer between air and a wetted surface; various approximations involved in the development of a psychrometric chart. Compressor: ideal reciprocating compressors with clearance; work done by a reciprocating compressors for isothermal, isentropic and polytropic compression and expansion processes; intercooling, isothermal, adiabatic and volumetric efficiencies of a reciprocating compressors, effect of clearance ratio, exponent of the re-expansion curve and leakage on work done by the compressor and the efficiency of the compressor, Effect of evaporator temperature, condenser temperatures, heat transfer, pressure drops and refrigerant leakage on the performance of an ideal reciprocating compressor, performance characteristics of a reciprocating compressor. Design of a reciprocating compressor. Various methods to control the capacity of a reciprocating compressor, and lubrication. Introduction to rotary compressors – vane and screw compressors. Condensers and Evaporators: overall heat transfer coefficients; fouling factor; performance characteristics and design; performance and heat transfer processes in evaporative condenser. Design of cooling and dehumidifying coils - wet cooling coil, dry cooling coil, partially wet cooling coil, dry-expansion cooling coils, chilled-water cooling coils, and performance of evaporators. Capillary: thermodynamics analysis of a capillary tube, calculation length of a capillary tube and transient and choked flow through a capillary tube. Thermal comfort: metabolism, thermal comfort, metabolic rate, bodily mechanisms of heat transfer, activity, clothing, Fanger's comfort equation, comfort scales, ASHRAE comfort chart, PMV and PPD, selecting suitable inside and outside design conditions for air conditioning.

Recommended Readings

1. Text book -

1. Refrigeration and Air-conditioning, Stoecker and Jones, McGraw Hill.
2. Refrigeration and Air Conditioning, CP Arora, McGraw Hill

2. Reference book-
    1. Refrigeration, Air Conditioning and Heat Pumps, GF Hundy, Butterworth Heinemann.
    2. Air-conditioning Design Handbook Carrier Corpn. (Ed.) McGraw Hill
    3. ASHRAE Handbooks, ASHRAE
3. Online resources-
    1. https://nptel.ac.in/courses/112/105/112105129/# (Refrigeration and Air Conditioning Modules by IIT Kharagpur)

Course Code : 21MET837

Course Name : Advanced Refrigeration

Credits : 3 **L -** 3 **T -** 0 **P -** 0

Course Type : Core / Elective

Prerequisites : Engineering Thermodynamics, Fluid Mechanics and Refrigeration & Air conditioning

Course Contents

Refrigeration Systems: Vapor compression; multiple evaporator and compound compression system with and without inter-cooling; dual compressors; cascade systems; vapour absorption system-analysis. Solid carbon dioxide: Principles of production; three-stage system with water and flash inter-cooler; pressure snow chambers; regenerative liquid pre-cooler; binary system. Cryogenics: Engineering applications; properties of substances at cryogenic temperature; ortho-para conversion of hydrogen; properties of helium; Lambda point; superfluidity. Liquefaction of gases: Minimum work cycle; Linde and Claude method; use of pre-cooling; liquefaction of hydrogen and neon liquefaction of helium; separation of gases from the air. Insulation, storage and transport of cryogenic fluids; magnetic and nucleate cooling. Pressure Drop and Heat Transfer: Two-phase flow; flow regimes; maps pressure drop in evaporator and condensers; Martinlli approach. Heat transfer, boiling in flooded evaporators; forced connection evaporation in tubes; inside and outside condensation for vertical and horizontal tubes

Recommended Readings

1. Text book -
2. Reference book-
    1. Mechanical Refrigeration, C.C. Sparks, N R & Dillio, McGraw- Hill, 1959.
    2. Cryogenic Systems, Randall F. Barron, McGraw- Hill, 1966
    3. ASHRAE Handbook (Fundamentals), ASHRAE
    4. Thermal Environmental Engineering, Threlkeld, Prentice Hall, 1998
    5. Convective Boiling and Condensation, John G. Collier, McGraw -Hill, 1981
    6. Refrigeration and Air conditioning, C.P. Arora, Mc-Graw-Hill, 2017
3. Online resources-

Course Code : 21MET563

Course Name : Advanced Thermodynamics

Credits : 3 **L -** 3 **T -** 0 **P -** 0

Course Type : Core / Elective

Prerequisites : Basic Thermodynamics, Partial differential equations, Statistical Mechanics

Course Contents

Review of basic thermodynamic principles; entropy; availability; irreversibility; first and second law analysis of steady and unsteady systems. General thermodynamics relations; Fundamentals of partial derivatives; relations for specific heats; internal energy enthalpy and entropy; Joule - Thompson coefficient; Clapeyron equation. Multi-component systems; Review of the equation of state for ideal and real gases; thermodynamic surfaces; gaseous mixtures; fugacity; ideal solutions; dilute solutions; activity; non-ideal liquid solutions. Multi-component phase equilibrium; Criteria of equilibrium; stability; heterogeneous equilibrium. Binary vapour liquid systems; the nucleus of condensation and the behavior of stream with formation of large and small drops; Gibbs Phase rule; higher-order phase transitions; thermodynamics of chemical reaction (combustion). Internal energy and enthalpy - first law analysis and second law analysis; basic relations involving partial pressures; third law of thermodynamics; chemical equilibrium and chemical potential equilibrium constants; thermodynamics of low temperature. Statistical mechanics - Maxwell - Boltzmann statistics; microstate and macro states; thermodynamic probability; entropy and probability Bose-Einstein statistics; Fermi Dirac statistics; elementary concepts of irreversible thermodynamics.

Recommended Readings

1. Text book -
    1. Fundamentals of engineering thermodynamics, Moran, Michael J and Shapiro, Howard N and Boettner, Daisie D and Bailey, Margaret B, John Wiley & Sons (2010).
    2. Principles of Thermodynamics, Myron Kaufman, CRC Press; 1st edition (2002)
2. Reference book-
    1. Advanced Engineering Thermodynamics, Adrian Bejan. Wiley; 4th edition (2016)
3. Online resources-

Course Code : 21MET838

Course Name : Alternate fuels in I. C. Engines

Credits : 3 **L -** 3 **T -** 0 **P -** 0

Course Type : Core / Elective

Prerequisites : Engineering Thermodynamics, Fluid Mechanics I.C. Engines

Course Contents

Introduction: Need of alternative gaseous fuels, future automotive gaseous fuels, hydrogen, CNG, LNG, and Producer gas, biogas, LPG. Stochiometric air fuel ratio, Physical properties of different gaseous fuels, mode of engine operations, spark ignition and dual fuel mode, multi fuel mode, combustion and performance of engines, specific problems, safety and environmental aspects, economic aspects, production. Alternate Liquid fuels: Use of alcohol in four stroke spark ignition engines and diesel engines, use of alcohol in two stroke engines, use of bio diesels, combustion and performance of engines, stochiometric air fuel ratio, specific problems, safety and environmental aspects, economic aspects, production. Impact of Alternative Fuels: Impacts: Impact of alternative fuels on engine test and test procedures, guidelines for emission measurements, emission norms for engines using alternative fuels. Legal Aspects: Legal aspects of blending alternative fuels into conventional liquid fuels, properties of blends, comparison of neat versus blended fuels, fuel testing. Computer Simulation: Computer simulation of engines using alternative fuels..

Recommended Readings

1. Text book -
2. Reference book-
    1. Future automotive fuels, Edited by Joseph M. Colucci and Nicoles C. Gallopoulos, Plenum press, New York.
    2. Dual fuel engines, edited by R.L. Evans, Plenum Press, 1987
    3. SAE handbook, volume III, Engines, fuels, lubricants, emissions and noise
    4. Automotive fuels and fuel systems, volume II, T.K. Garrett, Pantech Press, London
    5. Gaseous fuels for transportation I, proceedings of the conference held at Vancouver, British Columbia, Canada, 1987
    6. Alternative Fuels by S. S. Thipse “Jaico Publishing House”
3. Online resources-

Course Code : 21MET846

Course Name : Wind Energy Utilisation

Credits : 3 **L -** 3 **T -** 0 **P -** 0

Course Type : Core / Elective

Prerequisites : MET-201 Engineering Thermodynamics, MET-202 Fluid Mechanics and Machines, MET-221 Heat Transfer and Turbo machines

Course Contents

Basics of Wind Energy Technology: Wind statistics- Measurements and data Presentation, Historical developments, latest developments, state of art of wind energy technology, turbine rating, economic analysis of wind turbine, Indian scenario and worldwide developments, present status and future trends. Wind turbine aerodynamics. Characteristics of Wind Energy: Nature of atmospheric winds- Wind resource characteristics and assessment– Anemometry, speed frequency distribution, effect of

height, wind rose, Weibull distribution, atmospheric turbulence, gust wind speed, effect of topography, effect of Reynolds's number, actuator disc, Betz coefficient, design of wind turbine blade, effect of stall and blade tip speed ratio and coefficient of torque. Wind Energy Conversion System (WECS): Rotor Selection, Annual Energy Output, Horizontal axis and vertical axis wind turbines, Rotor Design Considerations-Number of Blades, Blade Profile -2/3 Blades and Teetering, Coning-Upwind/Downwind, Power Regulation, Yaw System- Tower, Synchronous and Asynchronous Generators and Loads, Integration of Wind Energy Converters to Electrical Networks, Inverters, Testing and Control System - Requirements and Strategies. Control Mechanisms: Pitch control, yaw control, Electrical and Mechanical aerodynamic braking, teeter mechanism. Wind turbine dynamics with DC and AC generators: induction and synchronous generators, variable speed operation, effect of wind turbulence, case study of design of wind-mill. Wind Energy Application: Wind pumps - Performance analysis, design concept and testing, Principle of WEG- Stand alone, grid connected and hybrid applications of WECS, Economics of wind energy utilization, wind energy in India- Case studies, and environmental impacts of wind farms.

Recommended Readings

1. Text book -
    1. Freris L.L., Wind Energy Conversion Systems, Prentice Hall 1990.
    2. Spera D.A., Wind Turbine Technology: Fundamental Concepts of Wind Turbine Engineering, ASME Press, NY 1994
2. Reference book-
    1. Steve Parker, "Wind power", Gareth Stevens Publishing, 2004.
    2. Wind Energy Handbook, Tony Burton, Nick Jenkins, David Sharpe, Ervin Bossanyi, 2011
3. Online resources-
    1. https://nptel.ac.in/courses (Wind energy utilization - Video course)

Course Code : 21MET842

Course Name : Pollution Control Technologies

Credits : 3 **L -** 3 **T -** 0 **P -** 0

Course Type : Core / Elective

Prerequisites : No Prerequisite

Course Contents

Introduction: Introduction to air pollution, classification of pollutants, their effects, impact of environment on human. Air Pollution Sources: Mobile and stationary sources, types of plume dispersion mechanisms, air quality measurement concepts. Control devices for particulate contaminants: gravitational settlement, centrifugal and wet collectors, fabric filters, cyclone separators, electrostatic precipitators. Control devices for gaseous contaminants from stationary sources: adsorption, adsorption, condensation, combustion-based pollution control systems. Automotive Emission control: Types and construction of catalytic converters, emission control

through operating parameters and engine design, alternative fuels for emission reduction. Laws and regulations: National and international standards for mobile and stationary sources of air pollution.

Recommended Readings

1. Text book -
    1. Environmental Engineering, Howard S. Peavy, Donald Rowe, Tata Mc-Graw Hill, 1989.
    2. Air Pollution: Its Origin and Control by Wark, Kenneth, Addison-Wesley, New York
    3. Air Pollution Control Equipment – H. Brauer and Y. B. G. Verma, Berlin Heidelberg, New York, latest edition.
2. Reference book-
    1. Sharma, N., Agarwal, A. K., Eastwood, P., Gupta, T., & Singh, A. P. (Eds.). (2018). Air pollution and control. Springer Singapore.
3. Online resources-
    1. Air pollution and control, NPTEL, online courses and certification
    2. U.S. Environmental Protection Agency website
    3. European Integrated Pollution Prevention and Control website
    4. Recent pollution case studies in metro cities

Course Code : 21MET845

Course Name : Solar Thermal Engineering

Credits : 3 **L -** 3 **T -** 0 **P -** 0

Course Type : Core / Elective

Prerequisites : MET-201 Engineering Thermodynamics, MET-202 Fluid Mechanics and Machines, MET-221 Heat Transfer and MET-325 Refrigeration and air conditioning

Course Contents

Solar Radiation: Solar Radiation, instruments for measuring solar radiation, solar radiation geometry, empirical equations, solar radiation on tilted surfaces. Liquid Flat Plate Collectors: Basic elements, performance analysis, transmissivity - absorptivity, heat transfer coefficients and correlations, collector efficiency and heat removal factors, effects of various parameters, types of other liquid flat-plate collectors, transient analysis. Solar Air Heaters: Type of air heaters, performance analysis of a conventional air heater, other types of air heater, and testing procedures. Concentrating Collectors: Type of concentrating collectors and their general characteristics, geometry, heat transfer correlations, tracking requirements performance analysis. Thermal Energy Storage: Basic methods, Sensible heat storage –liquids- solids-analysis, latent heat storage, thermo chemical storage. Solar Pond: Basic concept and working, description, performance analysis, transmissivity, temperature distribution and collection efficiency, experimental studies and other aspects. Solar Refrigeration: Adsorption and absorption based solar refrigeration technologies.

Recommended Readings

1. Text book -
    1. Garg H.P. and Prakash J., Solar energy fundamentals and application, TATA McGraw Hill Publishing Company limited, New Delhi, 2000.
    2. Sukhatme S.P., Solar Energy Principle of thermal collection and storage, TATA McGraw Hill Publishing Company limited, New Delhi, 1996.
2. Reference book-
    1. Krith F. and Krelder J.F., Principles of Solar Engineering, McGraw hill Book Company, 1978.
    2. John A, Duffie, William A. Beckman; Solar Engineering of thermal processes, John Wiley and Sons, 1991.
3. Online resources- https://nptel.ac.in/courses (Solar Thermal Engineering - Video course)

Course Code : 21MET839

Course Name : Energy Conservation Technologies

Credits : 3 **L -** 3 **T -** 0 **P -** 0

Course Type : Core / Elective

Prerequisites : basic courses of Engineering, Thermodynamics, Heat Transfer, Fluid Mechanics, Refrigeration and Air conditioning

Course Contents

Radiant heating equipment: Panel of heaters-steam-water, electrical radiant heaters, tubular radiant heaters, reflectors, heat transfer, comfort conditions, reduction pf heat loss, installation. Prime movers and Generators: Energy conversion and efficiency, steam turbines, gas turbines, diesel and gas engines, electrical motors and DG sets selection, factor affecting performance, load matching, PF improvement, and maintenance practice. Heat pumps: General principles, appropriate conditions for using heat pumps, theoretical and practical COP, refrigerants, absorption heat pump, application of heat pumps, gas driven heat pumps.

Heat recuperators: Basic concepts, liquid/liquid heat exchanger, liquid/gas and gas/liquid heat exchanger, gas/gas exchanger, heat transfer calculation and area determination. Heat regenerators: Thermal wheel- Basic principle, construction, flue gas as energy source, preheating combustion air, installation, regenerative heat recovery, double effect operation and coupling of columns. Heat pipe basic: basic concepts, design of heat pipes, heat transfer rate, thermodynamic efficiency, influencing factors, wick design, heat recovery form exhaust air, classification of heat pipes and practical application. Heating Ventilation and Air conditioning: Comfortable environment, effective temperature, heating and cooling systems, reheat systems, variable systems, variable air volume, dual duct system, air water system, design consideration.

Recommended Readings

1. Text book- R.M.E. Diamant, Energy Conservation equipment, The Architectural Press, 1984
2. Reference book-

1. S. David Hu, Handbook of Industrial energy conservation, Van Nostrand, Reinhold Pub, 1983..
2. S.C Tripathy, Electrical energy utilization and conservation, Tata McGraw Hill, 1986.

3. Online resources-
4.

Course Code : 21MET561

Course Name : Advanced Heat Transfer

Credits : 3 **L -** 3 **T -** 0 **P -** 0

Course Type : Core / Elective

Prerequisites : Basic Fluid Mechanics/Heat Transfer/Transport Phenomena, Applied Mathematics

Course Contents

Review: Review of the basic laws of conduction, radiation and convection; Conduction: one dimensional steady state conduction with variable thermal conductivity and with internal distributed heat sources; local heat source in non-adiabatic plate; thermo-couple condition error. Extended surfaces-review; optimum fin of rectangular profile; straight fins of triangular and rectangular profile; spines; design considerations; two-dimensional steady state conduction; semi-infinite and finite at plates; temperature field in finite cylinders and infinite semi-cylinders; spherical shells; graphical method; relaxation technique. Unsteady state conduction; sudden changes in the surface temperature of infinite plates, cylinders and spheres; solutions using Groeber's and Heisler's chart for plates, cylinders and spheres suddenly immersed in fluids. Radiation: Review of radiation principles; diffuse surfaces and the Lambert's cosine law. Radiation through one-absorbing media; Hottel's method of successive reflections; Gebhart's unified method; Poljak's method. Radiation through absorbing media; logarithmic decrement of radiation; apparent absorptivity of simple shaped gas bodied; net heat exchange between surfaces separated by absorbing medium; radiator of luminous gas flames. Convection: Heat transfer in laminar flow; free convection between parallel plates; forced internal flow through circular tubes; fully developed flow; velocity and thermal entry lengths; solutions with constant wall temperature and with constant heat flux. Forced external flow at flat plate; the two-dimensional velocity and temperature boundary layer equations; Karman Pohlhausen approximate integral method. Heat transfer in turbulent flow; eddy heat diffusivity; Reynold's analogy between skin friction and heat transfer; Prandtl-Taylor, Von Karman and Martinelli's analogies; turbulent flow through circular tubes.

Recommended Readings

1. Text book-
    a. Bergman, Theodore L and Incropera, Frank P and DeWitt, David P and Lavine, Adrienne S. Fundamentals of heat and mass transfer. John Wiley & Sons, 2011.
    b. Kays, W and Crawford, M and Weigand, B. Convective Heat and Mass Transfer. McGraw- Hill, 2005.
    c. Howell, John R and Menguc, M Pinar and Siegel, Robert. Thermal radiation heat transfer. CRC press, 2010.
2. Reference book-
    1. Hahn, David W and Ozisik, M Necati, Heat conduction. John Wiley and Sons, New York, 2012.
    2. Eckert, Ernst Rudolf Georg and Drake Jr, Robert M. Analysis of heat and mass transfer. John Wiley & Sons, 2010.

3. Online resources-

Course Code : 21MET841

Course Name : Heat Exchanger Design

Credits : 3 **L -** 3 **T -** 0 **P -** 0

Course Type : Core / Elective

Prerequisites : Fluid Mechanics (MET 202), Heat Transfer (MET 221)

Course Contents

Basic Design Methodologies: Classification of heat exchanger, selection of heat exchanger, thermo-hydraulic fundamentals, Overall heat transfer coefficient, LMTD method for heat exchanger analysis for parallel, counter, multi-pass and cross flow heat exchanger, e-NTU method for heat exchanger analysis, Rating and sizing problems, heat exchanger design methodology. Fouling of Heat Exchangers: Basic consideration, effect of fouling on heat transfer and pressure drop, design of heat exchangers subject to fouling, fouling resistance, cleanliness factor, fouling prevention techniques. Design of Double Pipe Heat Exchangers: Thermal design of inner tube and annulus, hairpin heat exchanger with bare and finned inner tube, parallel and series arrangements, pressure drop. Design of Shell & Tube Heat Exchangers: Basic components, preliminary design procedure, TEMA code, J-factors, pressure drop and heat transfer calculations, conventional design methods, Bell-Delaware method. Design of Compact Heat Exchangers: Heat transfer enhancement, fundamental of extended surfaces (fins). Finned tube heat exchanger, types, heat transfer and pressure drop. Plate fin heat exchanger (PFHE), construction, types, design, application, performance characteristics, flow arrangements, heat transfer and pressure drop. Phase change Heat Exchangers: Evaporators and condensers, types, design and operational considerations, applications for refrigeration and air conditioning, analysis and correlations. Heat pipes, construction, working principle, wick selection, application, performance characteristics, basic relations, effect of working fluid and operating temperatures, types of heat pipes. Unit VII: Direct contact Heat Exchangers: Cooling towers, types, application, basic relations, heat balance, thermal characteristics, effect of packing, spray design, selection of pumps, fans, testing, maintenance, environmental effects, wind load, typical installations.

Recommended Readings

1. Text book- 1. Fundamentals of Heat Exchanger Design by Ramesh K Shah, Wiley Publication, 2003.
2. Reference book-
    1. Heat Exchanger Selection, Rating and Thermal Design by Sadik, K. CRC Press.
    2. Compact Heat Exchangers by Kays, V.A. and London, A.L., McGraw Hill.
    3. Heat Exchanger Design Handbook by Kuppan, T, Macel Dekker, CRC Press.
    4. Process Heat transfer by Donald Q Kern, McGraw Hill.
3. Online resources-

Course Code : **21MES-662**

Course Name : **Seminar**

Credits : 04 **L -** 0 **T -** 0 **P -** 4

Course Type : Seminar

Prerequisites : Basic knowledge of the subjects of thermal engineering

Course Contents

1. Search the literature, and identify a problem related to thermal engineering.
2. Identify, study, analyze, compare technical, economical and practical issues related to the identified problem.
3. Find background, developments and recent trends related to the problem from the case studies in the literature.
4. Prepare a report as per the specified format employing elements of critical thinking and technical writing.
5. Demonstrate the ability to describe, interpret and analyze technical issues and develop competence in presenting.

Course Code : **21MED-661**

Course Name : **Dissertation**

Credits : 08 **L -** 0 **T -** 0 **P -** 8

Course Type : Research

Prerequisites : Basic knowledge of the subjects of thermal engineering

Course Contents

1. Search the literature, find the research gap, and identify the problem in an area of Thermal Engineering.
2. Formulate the problem and specify the objective of the study.
3. Prepare the work plan based on experiment/modelling/ software methods.
4. Set up the experiment and/or develop a computational/ simulation model to meet the objectives of the work.

Course Code : **21MED-663**

Course Name : **Dissertation**

Credits : 12 **L -** 0 **T -** 0 **P -** 12

Course Type : Research

Prerequisites : Basic knowledge of the subjects of thermal engineering

Course Contents

1. Further, review the literature in line with the objective of the problem and develop a methodology/ plan to carry out the work.
2. Set up the experiment and/or develop a computational/ simulation model to meet the objectives of the work.

3. Conduct the experiments/ simulation, analyse, and interpret the results.
4. Prepare a report as per the recommended format, present, and defend the work.
5. If possible, present/ publish paper in conference and/or national/ international journals.