ACADEMIC REGULATIONS
COURSE STRUCTURE AND
DETAILED SYLLABUS

MECHANICAL ENGINEERING

For

M. Tech. (Thermal Engineering)

(Two Year **Full Time** Programme)

JNTUH COLLEGE OF ENGINEERING HYDERABAD
(Autonomous)
Kukatpally, Hyderabad – 500 085, Telangana, India.

2015

JNTUH COLLEGE OF ENGINEERING HYDERABAD
M.Tech. (Thermal Engineering) – Full Time w.e.f. 2015-16

I – SEMESTER

S.No.	Subject	L	T	P	Credits
1	Advanced Heat and mass Transfer	4	0	0	4
2	Advanced I.C. Engines	4	0	0	4
3	Elective - I	4	0	0	4
4	Elective - II	4	0	0	4
5	Elective - III	4	0	0	4
6	Elective - IV	4	0	0	4
7	Thermal Engineering Laboratory	0	0	4	2
8	Soft skills Lab	0	0	4	2
	Total Credits				**28**

II – SEMESTER

S.No.	Subject	L	T	P	Credits
1	Advanced Fluid Mechanics	4	0	0	4
2	Fuels And Combustion	4	0	0	4
3	Elective –V	4	0	0	4
4	Elective –VI	4	0	0	4
5	Elective –VII	4	0	0	4
6	Elective –VIII	4	0	0	4
7	Computational Methods Laboratory	0	0	4	2
8	Seminar	0	0	4	2
	Total Credits				**28**

III – SEMESTER

S.No.	Subject	L	T	P	Credits
1	Comprehensive Viva Voce				4
2	Project Phase -I				12
	Total Credits				**16**

IV – SEMESTER

S.No.	Subject	L	T	P	Credits
	Project Phase-II & Dissertation				18
	Total credits				**18**

Elective I

1. Advanced Finite Element Analysis
2. Thermal Measurements & Process Controls
3. Direct Energy Conversion

Elective II

1. Turbo-Machineries
2. Jet Propulsions and Rocket Engineering
3. Thermal and Nuclear Power Plant

Elective –III

1. Advanced Thermodynamics
2. Solar Energy
3. Alternative Fuels and Pollution

Elective IV

1. Renewable Energy Sources
2. Fuel Cell Technology
3. Non-Conventional Energy Sources

Elective V

1. Computational Fluid Dynamics
2. Advanced CAD
3. Exergy Analysis of thermal Systems

Elective VI

1. Energy Conservation and Management
2. Convective Heat Transfer
3. Cryogenic Engineering

Elective VII

1. Equipment Design For Thermal Systems
2. Refrigeration and Air- Conditioning
3. Computer Simulations of S.I and C.I Engines

Elective VIII

1. Optimization Techniques and Applications
2. Nano Fluids
3. Advanced Materials For Thermal Systems

JNTUH COLLEGE OF ENGINEERING HYDERABAD

M.Tech. I Year I-Sem (Thermal Engineering)

L	T	P	C
4	0	0	4

ADVANCED HEAT AND MASS TRANSFER

Prerequisites: Heat and Mass Transfer

Course Objectives:
The course is intended to
- Impart the advances knowledge of heat transfer
- Get analytical solutions for 2-D steady and transient heat conduction problems.
- Deep understanding on the governing equations for convection heat transfer; knowing the dimensionless parameters (influencing the convection performance).
- Aware of turbulence concept and modeling.
- Apply the concept of natural convection for electronic cooling, HVAC etc.
- Understand the boiling and condensation mechanism.
- Understand the concept of mass transfer

Course Outcomes:
At the end of the course, the student will be able to:
- Understand both the physics and the mathematical treatment of the advanced topics pertaining to the modes of heat transfer.
- Apply principles of heat transfer to develop mathematical models for uniform and Non-uniform fins.
- Employ mathematical functions and heat conduction charts in tackling two-Dimensional and three-dimensional heat conduction problems.
- Analyze free and forced convection problems involving complex geometries with proper boundary conditions.
- Apply the concepts of radiation heat transfer for enclosure analysis.
- Understand physical and mathematical aspects of mass transfer.

UNIT-I:
BRIEF INTRODUCTION TO DIFFERENT MODES OF HEAT TRANSFER: Conduction: General heat Conduction equation-initial and boundary conditions.
Transient heat conduction: Lumped system analysis-Heisler charts-semi infinite solid-use of shape factors in conduction-2D transient heat conduction-product solutions.

UNIT- II:
FINITE DIFFERENCE METHODS FOR CONDUCTION: ID & 2D steady state and simple transient heat conduction problems-implicit and explicit methods.
Forced Convection: Equations of fluid flow-concepts of continuity, momentum equations-derivation of energy equation-methods to determine heat transfer coefficient: Analytical methods-dimensional analysis and concept of exact solution. Approximate method-integral analysis.

UNIT-III:
EXTERNAL FLOWS: Flow over a flat plate: integral method for laminar heat transfer coefficient for different velocity and temperature profiles. Application of empirical relations to variation geometries for laminar and turbulent flows.

Internal flows: Fully developed flow: integral analysis for laminar heat transfer coefficient-types of flow-constant wall temperature and constant heat flux boundary conditions-hydrodynamic & thermal entry lengths; use of empirical correlations.

UNIT-IV:

FREE CONVECTION: Approximate analysis on laminar free convective heat transfer-boussinesque approximation-different geometries-combined free and forced convection.

Boiling and condensation: Boiling curve-correlations-Nusselts theory of film condensation on a vertical plate-assumptions & correlations of film condensation for different geometries.

UNIT-V:

RADIATION HEAT TRANSFER: Radiant heat exchange in grey, non-grey bodies, with transmitting. Reflecting and absorbing media, specular surfaces, gas radiation-radiation from flames.

Mass Transfer: Concepts of mass transfer-diffusion & convective mass transfer analogies-significance of non-dimensional numbers.

REFERENCES:

1. Convective Heat & Mass Transfer – Ghiaasiaan – Cambridge
2. Fundamentals of Heat & Mass Transfer – Thirumaleshwar – Pearson
3. Heat Transfer – Gregory Nellis & Sanford Klein – Cambridge University Press
4. Principals of Heat Transfer/Frank Kreith/Cengage Learning
5. Elements of Heat Transfer/E. Radha Krishna/CRC Press/2012
6. Heat Transfer/RK Rajput/S.Chand
7. Introduction to Heat Transfer/SK Som/PHI
8. Engineering Heat & Mass Transfer/Mahesh Rathore/Lakshmi Publications
9. Heat Transfer / Necati Ozisik / TMH
10. Heat Transfer / Nellis & Klein / Cambridge University Press / 2012.
11. Heat Transfer/ P.S. Ghoshdastidar/ Oxford Press
12. Engg. Heat & Mass Transfer/ Sarit K. Das/Dhanpat Rai
13. Heat Transfer/ P.K.Nag /TMH

JNTUH COLLEGE OF ENGINEERING HYDERABAD

M.Tech. I Year I-Sem (Thermal Engineering)

L	T	P	C
4	0	0	4

ADVANCED I.C. ENGINES

Prerequisites: Thermodynamics, Thermal Engineering -I & II

Course objectives:
The course is intended to
- Analyze engine cycles and the factors responsible for making the cycle different from the Ideal cycle.
- Apply principles of thermodynamics, fluid mechanics, and heat transfer to influence the engine's performance
- Understand the delay period and fuel injection system
- Become aware of the relevance of environmental and social issues on the design process of internal combustion engines

Course Outcomes:
At the end of the course, the student will be able to:
- Apply thermodynamic analysis to IC engines and describe combustion phenomena in spark ignition and compression ignition engines.
- Describe the working of major systems used in conventional and modern engines.
- Summarize the methods used to improve engine performance and estimate performance parameters.
- Describe engine emission control techniques and implement viable alternate fuels.

UNIT-I: Introduction – Historical Review – Engine Types – Design and operating Parameters.
Cycle Analysis: Thermo-chemistry of Fuel – Air mixtures, properties – Ideal Models of Engine cycles – Real Engine cycles - differences and Factors responsible for – Computer Modeling.

UNIT - II:
GAS EXCHANGE PROCESSES: Volumetric Efficiency – Flow through ports – Supercharging and Turbo charging.
Charge Motion: Mean velocity and Turbulent characteristics – Swirl, Squish – Pre-chamber Engine flows.

UNIT - III:
ENGINE COMBUSTION IN S.I ENGINES: Combustion and Speed – Cyclic Variations – Ignition – Abnormal combustion Fuel factors, MPFI, SI engine testing.
Combustion in CI engines: Essential Features – Types off Cycle. Pr. Data – Fuel
Spray Behavior – Ignition Delay – Mixing Formation and control, Common rail fuel injection system.

UNIT - IV:
POLLUTANT FORMATION AND CONTROL: Nature and extent of problems – Nitrogen Oxides, Carbon monoxide, unburnt Hydrocarbon and particulate – Emissions – Measurement – Exhaust Gas Treatment, Catalytic converter, SCR, Particulate Traps, Lean, NOx, Catalysts.

UNIT - V:

ENGINE HEAT TRANSFER: Importance of heat transfer, heat transfer and engine energy balance, Convective heat transfer , radiation heat transfer, Engine operating characteristics.
Fuel supply systems for S.I. and C.I engines to use gaseous fuels like LPG, CNG and Hydrogen.

Modern Trends in IC Engines: Lean Burning and Adiabatic concepts, Rotary Engines, Modification in I.C engines to suit Bio – fuels, HCCI and GDI concepts.

REFERENCES:

1. I.C. Engines / V.Ganesan/TMH
2. I.C. Engines/G.K. Pathak & DK Chevan/ Standerd Publications
3. I.C. Engines Fundamentals/Heywood/TMH
4. Dual-Fuel Diesel Engines – Ghazi A. Karim – CRC Press
5. I.C. Engines /RK Rajput/Laxmi Publications
6. Internal Combustion Engines – S.S. Thipse - Jaico
7. Computer Simulation of C.I. Engine Process/ V.Ganesan/University Press
8. Fundamentals of IC Engines/HN Gupta/PHI/2nd edition
9. I.C. Engines/Fergnson/Wiley
10. The I.C. Engine in theory and Practice Vol.I / Teylor / IT Prof. And Vol.II
11. Computer Simulation of Spark-Ignition Engine Processes – V. Ganesan – Universities Press

JNTUH COLLEGE OF ENGINEERING HYDERABAD

M.Tech. I Year I-Sem (Thermal Engineering)

L	T	P	C
4	0	0	4

ADVANCED FINITE ELEMENT ANALYSIS
(ELECTIVE-I)

Prerequisites: Finite Element Analysis

Course Objectives:
The course is intended to
- Gain a fundamental understanding of the finite element method for solving boundary value problems
- Learn important concepts of variation form, minimum potential energy principles, and method of weighted residuals.
- Study one dimensional problems such as truss, beam, and frame members, two-dimensional problems such as plain stress and plain strain elasticity problems, torsion problem.
- Learn finite element analysis of static and dynamic problems and heat transfer problems.
- Provide the student with some knowledge and analysis skills in applying basic laws in mechanics and integration by parts to develop element equations and steps used in solving the problem by finite element method.

Course Outcomes:
At the end of the course, the student will be able to:
- Establish the mathematical models for the complex analysis problems and predict the nature of solution
- Formulate element characteristic matrices and vectors.
- Identify the boundary conditions and their incorporation in to the FE equations
- Solve the problems with simple geometries, with hand calculations involving the fundamental concepts
- Interpret the analysis results for the improvement or modification of the system.

UNIT-I
Introduction to FEM, basic concepts, historical back ground, applications of FEM, general description, comparison of FEM with other methods, variational approach, Glerkin's Methods. Co-ordinates, basic element shapes, interpolation function, Virtual energy principle, Rayleigh – Ritz method, properties of stiffness matrix, treatment of boundary conditions, solution of system of equations, shape functions and characteristics, Basic equations of elasticity, strain- displacement relations.

UNIT-II
1-D STRUCTURAL PROBLEMS: Axial bar element – stiffness matrix, load vector, temperature effects, Quadratic shape functions and problems.
ANALYSIS OF TRUSSES : Plane Trusses and Space Truss elements and problems
ANALYSIS OF BEAMS : Hermite shape functions – stiffness matrix – Load vector – Problems.

UNIT-III

2-D PROBLEMS: CST, LST, force terms, Stiffness matrix and load vectors, boundary conditions, Isoparametric elements – quadrilateral element, shape functions – Numerical Integration.

Finite element modeling of Axi-symmetric solids subjected to Axi-symmetric loading with triangular elements.

3-D PROBLEMS: Tetrahedran element – Jacobian matrix – Stiffness matrix.

UNIT-VI

SCALAR FIELD PROBLEMS: 1-D Heat conduction-Slabs – fins - 2-D heat conduction problems – Introduction to Torsional problems.

UNIT-V

Dynamic considerations, Dynamic equations – consistent mass matrix – Eigen Values, Eigen vector, natural frequencies – mode shapes – modal analysis.

REFERENCES:

1. Finite Element Method – Dhanraj & Nair – Oxford
2. Finite Element Methods: Basic Concepts and applications, Alavala, PHI
3. Applied Finite Element Analysis – Segerlind – Wiley India
4. The Finite Element Methods in Engineering / SS Rao / Pergamon.
5. Introduction to Finite Elements in Engineering, Chandrupatla, Ashok and Belegundu, Prentice – Hall
6. Finite Element Modeling and Simulation with ANSYS Workbench – Chen & Lui - CRC
7. Finite Element Method – Zincowitz / Mc Graw Hill
8. Introduction to Fininte element analysis- S.Md.Jalaludeen,Anuradha Publications, print-2012
9. A First Course in the Finite Element Method/Daryl L Logan/Cengage Learning/5th Edition
10. Finite Element Analysis – Theory & Programming – Krishna Moorthy / McGraw Hill
11. Finite Element Analysis – Bathe / PHI

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M.Tech. I Year I-Sem (Thermal Engineering)

L	T	P	C
4	0	0	4

THERMAL MEASUREMENTS & PROCESS CONTROLS
(ELECTIVE-I)

Prerequisites: None

Course Objectives:
The course is intended to
- Educate the student with operating principles and function of measuring instruments used in Engineering and process industries
- Make the student conversant with various working principles of instruments
- Understand and analyze the behavioral characteristics of instruments
- Make the student learn about calibration procedure the instrument
- Educate the student about the fundamental aspects of contro; systems and their use in the context of industry applications

Course Outcomes:
At the end of the course, the student will be able to:
- Understand the concepts of errors in measurements, statistical analysis of data, regression analysis, correlation and estimation of uncertainty.
- Describe the working principles in the measurement of field and derived quantities.
- Analyze sensing requirements for measurement of thermo-physical properties, radiation properties of surfaces, and vibration.
- Understand conceptual development of zero, first and second order systems.
- Interpret International Standards of measurements (ITS-90) and identify internationally accepted measuring standards for measurands.

UNIT-I
GENERAL CONCEPTS: Fundamental elements of a measuring instrument. Static and dynamic characteristics – errors in instruments – Different methods of measurement and their analysis – Sensing elements and transducers.
Measurement of pressure – principles of pressure measurement, static and dynamic pressure, vacuum and high pressure measuring – Measurement of low pressure, Manometers, Calibration methods, Dynamic characteristics- design principles.

UNIT-II
MEASUREMENT OF FLOW: Obstruction meters, variable area meters. Pressure probes, compressible fluid flow measurement, Thermal anemometers, calibration of flow measuring instruments. Introduction to design of flow measuring instruments.

UNIT-III
TEMPERATURE MEASUREMENT: Different principles of Temperature Measurement, use of bimetallic thermometers – Mercury thermometers, Vapor Pressure thermometers,
Thermo positive elements, thermocouples in series & parallel, pyrometry, measurement of heat flux, calibration of temperature measuring instruments. Design of temperature measuring instruments.

UNIT-IV

Level Measurement: Direct & indirect methods, manometric methods, float level meters, electrical conductivity, Capacitive, Ultrasonic, and Nucleonic Methods.

Measurement of density – Hydrometer, continuous weight method, Gamma rays, Gas impulse wheel.

Velocity Measurement – Coefficient of viscosity, Ostesld method, free fall of piston under gravity, torque method.

Measurement of moisture content and humidity.

Measurement of thermal conductivity of solids, liquids and gases.

UNIT-V

PROCESS CONTROL: Introduction and need for process control principles, transfer functions, block diagrams, signal flow graphs, open and closed loop control systems – Analysis of First & Second order systems with examples of mechanical and thermal systems.

Control System Evaluation – Stability, steady state regulations, transient regulations.

REFERENCES:

1. Mechanical Measurements – Beckwith, Leinhard & Marangoni - Pearson
2. Measurement System, Application & Design – E.O. Doeblin.
3. Mechanical and Industrial Measurements – R.K. Jain – Khanna Publishers.
4. Mechanical Measurements – Buck & Beckwith – Pearson.
5. Control Systems, Principles & Design, 2nd Edition – M. Gopal – TMH.
6. Principles of Measurement Systems – John Bentley – Pearson

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M.Tech. I Year I-Sem (Thermal Engineering)

L	T	P	C
4	0	0	4

DIRECT ENERGY CONVERSION
(Elective-I)

Prerequisites: The students should have basic knowledge of semiconductor physics.

Course Objectives:
- Conventional energy conversion techniques
- Direct energy conversion systems
- Need and necessity of energy storage systems and their desirable characteristics & Fuel cells

Course Outcomes:
At the end of the course, the student will be able to:
- Energy Conversion and Direct Energy Conversion
- All kind of Fuel Cells, Fuel Cell Efficiency, Termianic Exchanger, Practical Efficiency of Termianic
- Thermoelectric Phenomena, Power Thermoelectric Exchanger, Application in Cooling
- Photovoltaic Phenomena, General Theory of Cell and Connection Magnetohydrodynamics: Hal Effects of Photovoltaic and experimental results.

Unit 1: Energy Balance of the earth:
The Greenhouse effect – Physical Source of sunlight – Planck's black-body radiation distribution from different black body temperatures – The earth and Solar Constant – Spectral distribution of extra-terrestrial radiation – Basic earth-sun angles – Solar time and equation of time – attenuation of solar radiation by the atmosphere – Direct and diffuse radiation at the ground – Empirical equations for predicting the availability of solar radiation – Computation of radiation on inclined surfaces - Angstrom's turbidity, Solar charts – Measurement of diffuse, global and direct solar radiation – Calibration and standardization – Duration of Sun hours – Solar radiation data – Peak Sun hours – Standard terms and definitions.

Unit 2: Photovoltaics (PV):
History, review of semiconductor physics and Operating principle – Silicon as PV material - Direct and indirect band-gap material – Flow of Silicon material – Single crystal Silicon Solar cell – Structure – Important electrical parameters – Ideal and approximate equivalent circuits - Manufacturing processes (wafer and cell) of single crystal, multi-crystalline and Edge Defined Film Fed Growth Silicon - Temperature and Irradiation effects – Energy Losses – Absorption coefficient and reflectance - Review of other PV technologies – Silicon film, Cadmium telluride (cdTe), Copper Indium Gallium Diselenide, amorphous silicon – Comparison of 'Thin film' and 'Bulk crystal' technology – manufacturing (module making) processes of amorphous silicon on glass, stainless steel and plastic substrates – Typical materials used - Concentrator technology and the importance of tracking – Comparison of efficiencies of various technologies – Recent trends in technology and manufacturing.

Unit 3 : PV modules and arrays:
Design requirements of PV modules – Rating of PV modules – Standard Test Conditions (STC), Normal Operating Cell Temperature (NOCT) and Standard Operating Conditions (SOC) – Output curves ('Current Voltage' or 'I-V' and 'Power-Voltage' or 'P-V') under various irradiance and temperature conditions – Mounting structure for PV modules/arrays – Orientation and array layout – Effects of shading - Other balance of systems (BOS) and protective devices: blocking and bypass diodes, movistors – Roof mounted arrays – Building integrated PV (BIPV) – Typical faults and diagnosis – Hot Spot problem in a PV module and safe operating area - Performance measurement of typical parameters of cells/modules under natural and simulated light – Indoor sun simulators - Outdoor PV array testers – ASTM and IEEE standards for Class A and Class B simulators – Pulsed, steady state and single flash types – Determination of temperature coefficients, series and shunt resistances, curve correction factor - Computation of efficiency and fill factor – Translation of parameters actually measured to STC – Reliability Testing: Qualification tests, IEC Standards 61215 & 61646 – Reliability test – Field stress testing

Unit 4 : PV Systems :
Stand alone and grid connected – Load estimation – Daily load demand – Solar radiation/irradiance table for a particular location - Sizing of the PV array, battery, inverter and other BOS – Maximizing efficiency of sub-systems – Balance of systems – Single axis and two axis tracking at optimum inclination of the PV array – Power conditioning and control – Maximum Power Point Trackers, Charge controllers/regulators, DC/DC Converters, DC/AC inverters – Alarms, indicators and monitoring equipment – Energy Storage: Batteries, Deep cycle lead acid type, Battery Design and construction, Other types of batteries, Battery Selection criteria, Safety issues – Typical applications of PV – Hybrid systems: PV-Wind, PVDiesel engine, PV-Mains - System Sizing examples: Domestic loads, Water pumping, Lighting (using CFLs, White LEDs) - hybrid systems, village power packs – Installation practices – Trouble shooting – Economic analysis: Life Cycle Cost analysis – Environment impacts of PV – Green buildings – Potential for GHG emission reduction of installed PV systems.

Unit 5 : The Hydrogen economy:
Advantages of hydrogen as an energy carrier – Components of the hydrogen economy - Generation of hydrogen - Transport and storage of hydrogen: physical and chemical - Fuel Cells – Classification of fuel cells based on (a) Type of electrolyte (b) Type of the fuel and oxidant (c) operating temperature (d) application and (e) chemical nature of electrolyte

Reference Books:
a. Solar Electricity /Edited by Tomas Markvart/John Wiley and Sons
b. Solar Cells – Operating Principles, Technology and System Applications /Martin A. Green/Prentice Hall Inc
c. Modelling Photovoltaic Systems using P Spice/Luis Castaner and Santiago Silvestre/John Wiley and Sons
d. Solar Energy – Fundamentals and Applications/H.P. Garg and J. Prakash/Tata McGraw-Hill
e. Generating Electricity from the Sun/Edited by Fred C. Treble/Pergamon Press
f. Amorphous Silicon Solar Cells/K.Takahashi and M.Konagai/North Oxford Academic
g. Photovoltaic Systems Engineering/Roger Messenger/CRC Press
h. Fuel Cells/Livin Oniciu/Abacus Press 1976

JNTUH COLLEGE OF ENGINEERING HYDERABAD

M.Tech. I Year I-Sem (Thermal Engineering)

L	T	P	C
4	0	0	4

TURBO MACHINERIES
(Elective-II)

Prerequisites: Thermodynamics 1 & 2

Course Objectives:
The course is intended to
- Understand the fundamental concepts of turbo machines
- Apply concepts of fluid mechanics in turbo machines.
- Understand the thermodynamic analysis of steam nozzles and turbines.
- Understand the different types of compressors and evaluating their performances in the form of velocity triangles.
- Familiarize the basic concepts of gas dynamics and analyze the performance of axial flow gas turbines

COURSE OUTCOMES: At the end of the course, the student will be able to:
- To design and analyse the performance of Turbo machines for engineering applications
- To understand the energy transfer process in Turbo machines and governing equations of various forms.
- To understand the structural and functional aspects of major components of Turbo machines.
- To design various Turbo machines for power plant and aircraft applications
- Understand the design principles of the turbo machines
- Analyze the turbo machines to improve and optimize their performance

UNIT-I:
FUNDAMENTALS OF TURBO MACHINES: Classifications, Applications, Thermodynamic analysis, isentropic flow. Energy transfer. Efficiencies, Static and Stagnation conditions, Continuity equations, Euler's flow through variable cross sectional areas, unsteady flow in turbo machines

UNIT -II:
STEAM NOZZLES: Convergent and Convergent-Divergent nozzles, Energy Balance, Effect of back pressure of analysis. Designs of nozzles.
Steam Turbines: Impulse turbines, Compounding, Work done and Velocity triangle, Efficiencies, Constant reactions, Blading, Design of blade passages, Angle and height, Secondary flow. Leakage losses, Thermodynamic analysis of steam turbines.

UNIT-III:
GAS DYNAMICS: Fundamental thermodynamic concepts, isentropic conditions, mach numbers and area, Velocity relations, Dynamic Pressure, Normal shock relation for perfect gas. Super sonic flow, oblique shock waves. Normal shock recoveries, Detached shocks, Aerofoil theory.
Centrifugal compressor: Types, Velocity triangles and efficiencies, Blade passage design, Diffuserand pressure recovery. Slip factor, Stanitz and Stodolas formula's, Effect of inlet mach numbers, Pre whirl, Performance

UNIT-IV:

AXIAL FLOW COMPRESSORS: Flow Analysis, Work and velocity triangles, Efficiencies, Thermodynamic analysis. Stage pressure rise, Degree of reaction, Stage Loading, General design, Effect of velocity, Incidence, Performance

Cascade Analysis: Geometrical and terminology. Blade force, Efficiencies, Losses, Free end force, Vortex Blades.

UNIT-V:

AXIAL FLOW GAS TURBINES: Work done. Velocity triangle and efficiencies, Thermodynamic flow analysis, Degree of reaction, Zweifels relation, Design cascade analysis, Soderberg, Hawthrone, Ainley, Correlations, Secondary flow, Free vortex blade, Blade angles for variable degree of reaction. Actuator disc, Theory, Stress in blades, Blade assembling, Material and cooling of blades, Performances, Matching of compressors and turbines, Off design performance.

References:

1. Principles of Turbo Machines/DG Shepherd / Macmillan
2. Fundamentals of Turbomachinery/William W Perg/John Wiley & Sons
3. Element of Gas Dynamics/Yahya/TMH
4. Principles of Jet Propulsion and Gas Turbine/NJ Zucrow/John Wiley & Sons/Newyork
5. Turbines, Pumps, Compressors/Yahya/TMH
6. Practice on Turbo Machines/ G.Gopal Krishnan & D. Prithviraj/ Sci Tech Publishers, Chennai
7. Theory and practice of Steam Turbines/ WJ Kearton/ELBS Pitman/London
8. Gas Turbines Theory and Practice/Zucrow/John Wiley & Sons/Newyork
9. Element of Gas Dynamics/Liepeman and Roshkow/ Dover Publications
10. Elements of Gas Turbine Propulsion /Jack D. Mattingly
11. Turbines, Compressors and Fans/S M Yahya /MGH

JNTUH COLLEGE OF ENGINEERING HYDERABAD

M.Tech. I Year I-Sem (Thermal Engineering)

L	T	P	C
4	0	0	4

JET PROPULSION AND ROCKET ENGINEERING
(Elective-II)

Prerequisites: None

Course Objectives:
The course is intended to
- Develop an understanding of how air-breathing engines and chemical rockets produce thrust;
- Analyze the overall engine performance
- Analyze the characteristics of the nozzle
- Carry out performance analysis rockets;
- Understanding of solid and liquid propellants engines

Course Outcomes:
At the end of the course, the student will be able to:
- Understand the ideal and real thermodynamic cycles of air-breathing engines and Industrial gas turbines
- Design the blading, study the velocity triangles and estimate the performance of centrifugal and axial flow compressors.
- Understand the combustion process and design the combustion chamber of a gas Turbine.
- Design the blading, study the velocity triangles and estimate the performance of axial and radial in-flow turbines
- Analyze the off-design performance and matching of the components of a gas turbine

UNIT - I:
TURBO JET PROPULSION SYSTEM: Gas turbine cycle analysis – layout of turbo jet engine. Turbo machinery- compressors and turbines, combustor, blade aerodynamics, engine off design performance analysis.
Flight Performance: Forces acting on vehicle – Basic relations of motion – multi stage vehicles.

UNIT - II:
PRINCIPLES OF JET PROPULSION AND ROCKETRY: Fundamentals of jet propulsion, Rockets and air breathing jet engines – Classification – turbo jet , turbo fan, turbo prop, rocket (Solid and Liquid propellant rockets) and Ramjet engines.
Nozzle Theory and Characteristics Parameters: Theory of one dimensional convergent – divergent nozzles – aerodynamic choking of nozzles and mass flow through a nozzle – nozzle exhaust velocity – thrust, thrust coefficient, A_c / A_t of a nozzle, Supersonic nozzle shape, non-adapted nozzles, summer field criteria, departure from simple analysis – characteristic parameters – 1) characteristic velocity, 2) specific impulse 3) total impulse 4) relationship between the characteristic parameters 5) nozzle efficiency, combustion efficiency and overall efficiency.

UNIT - III:
AERO THERMO CHEMISTRY OF THE COMBUSTION PRODUCTS: Review of properties of mixture of gases – Gibbs – Dalton laws – Equivalent ratio, enthalpy changes in reactions,

heat of reaction and heat of formation – calculation of adiabatic flame temperature and specific impulse – frozen and equilibrium flows.
Solid Propulsion System: Solid propellants – classification, homogeneous and heterogeneous propellants, double base propellant compositions and manufacturing methods. Composite propellant oxidizers and binders. Effect of binder on propellant properties. Burning rate and burning rate laws, factors influencing the burning rate, methods of determining burning rates.

UNIT - IV:
Solid propellant rocket engine – internal ballistics, equilibrium motor operation and equilibrium pressure to various parameters. Transient and pseudo equilibrium operation, end burning and burning grains, grain design. Rocket motor hard ware design. Heat transfer considerations in solid rocket motor design. Ignition system, simple pyro devices.
Liquid Rocket Propulsion System: Liquid propellants – classification, Mono and Bi propellants, Cryogenic and storage propellants, ignition delay of hypergolic propellants, physical and chemical characteristics of liquid propellant. Liquid propellant rocket engine – system layout, pump and pressure feed systems, feed system components. Design of combustion chamber, characteristic length, constructional features, and chamber wall stresses. Heat transfer and cooling aspects. Uncooled engines, injectors – various types, injection patterns, injector characteristics, and atomization and drop size distribution, propellant tank design.

UNIT - V:
RAMJET AND INTEGRAL ROCKET RAMJET PROPULSION SYSTEM: Fuel rich solid propellants, gross thrust, gross thrust coefficient, combustion efficiency of ramjet engine, air intakes and their classification – critical, super critical and sub-critical operation of air intakes, engine intake matching, classification and comparison of IIRR propulsion systems.

References:

1. Mechanics and Dynamics of Propulsion/ Hill and Peterson/John Wiley & Sons
2. Rocket propulsion elements/Sutton/John Wiley & Sons/8th Edition
3. Gas Turbines/Ganesan /TMH
4. Gas Turbines & Propulsive Systems/Khajuria & Dubey/Dhanpat Rai & Sons
5. Rocket propulsion/Bevere/
6. Jet propulsion /Nicholas Cumpsty/
7. Elements of Gas Turbine Propulsion/Jack D. Mattingly/TMH
8. Turbines, Compressors and Fans/S M Yahya /MGH

JNTUH COLLEGE OF ENGINEERING HYDERABAD

M.Tech. I Year I-Sem (Thermal Engineering)

L	T	P	C
4	0	0	4

THERMAL AND NUCLEAR POWER PLANTS
(Elective-II)

Prerequisites: None

Course Objective:
The course is intended to
- Provide in awareness about resources of energies available in India for Power Production by Thermal and Nuclear Processes.
- Understand and know the requirements for a Thermal Power Plant and Nuclear Power Plant, from sources to consumption and economics of power plants.
- Study and learn the processes and cycles followed in Thermal Power Plants and nuclear power plants and components used in the power plants
- Gain the knowledge on steam power plants, steam generators and gas turbine power plants, their analyses on fuel and fluidized bed combustion, ash handling systems,
- Learn the practices followed in Thermal Power Plant and Nuclear Power Plants, to better environmental conditions and the safety measures.
- Gain the knowledge on Power Load calculation, distribution and optimum loading. Etc.,
- Know various methods for the Economies of Power Generation and power plant instrumentation.

Course Outcomes:
At the end of the course, the student will be able to:
- Describe how fission is accomplished and the basics of how a nuclear reactor produces energy
- Discuss the thermal cycle and describe heat transfer and fluid flow
- Identify the major components of a nuclear power plant including generators, turbines, and cooling systems
- Examine nuclear power plant safety systems and the concepts of redundancy and defense-in-depth
- Describe the requirements associated with a refuel outage and nuclear fuel reload

UNIT -I
INTRODUCTION: Sources of energy, Type of Power plants. Direct energy conversion system, Energy sources in India, Recent developments in power generation, Combustion of coal, Volumetric analysis, Gravimetric analysis. Fuel gas analysis.
Steam power plant: Introduction. General layout of steam power plant, Modern coal. Fired Steam, Steam power plant. Power plant cycle, Fuel Handling, Combustion equipment, Ash handling, Dust collectors.
Steam Generators: Types, Accessories. Feed water heaters, Performance of boiling, Water treatment, Cooling towers. Steam turbines. Compounding of turbines, Steam condensers, Jet and surface condensers.

UNIT-II
GAS TURBINE POWER PLANT: Cogeneration. Combined cycle power plant, Analysis, Waste heat recovery, IGCC power plant, Fluidized bed, Combustion, Advantages, Disadvantages

UNIT-III

NUCLEAR POWER PLANT: Nuclear physics, Nuclear Reactor, Classification, Types of reactors, Site selection. Method of enriching uranium. Application of nuclear power plant. Nuclear Power Plant Safety: Bi-Product of nuclear power generation, Economics of nuclear power plant, Nuclear power plant in India, Future of nuclear power.

UNIT-IV

ECONOMICS OF POWER GENERATION: Factors affecting the economics, Loading factors, Utilization factor, Performance and operating characteristics of power plant, Point economic load sharing, Depreciation. Energy rate, Criteria for optimum loading. Specific economic energy problem

UNIT-V

POWER PLANT INSTRUMENTATIONS: Classification, Pressure measuring instrument, Temperature measurement and Flow Measurement, Analysis of combustion gases, Pollution types, Methods of control.

References:

1. Power Plant Engineering / P.K.Nag / TMH
2. Power Plant Engineering / R.K.Rajput/ Lakshmi Publications.
3. Power Plant Engineering / P.C.Sharma/ Kotearia Publications.
4. Power Plant Technology / Wakil.

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ADVANCED THERMODYNAMICS
(ELECTIVE-III)

Prerequisites: Thermodynamics

Course Objectives:
The course is intended to

- Provide analytical methods for the determination of the direction of processes from the first and second laws of thermodynamics and to Introduce methods in using equations of potentials, availability, and excergy for thermodynamic analysis
- Gain the knowledge on non-reactive mixture properties , Psychometric Mixture properties and psychometric chart and Air conditioning processes
- Develop the ability of analyzing vapor and Gas power cycles
- Provide in depth knowledge of Direct Energy Conversion of Fuel Cells , Thermo electric energy ,Thermionic power generation ,Thermodynamic devices Magneto Hydrodynamic Generations and Photo voltaic cells
- Develop communication and teamwork skills in the collaborative course project

Course Outcomes:
At the end of the course, the student will be able to:

- Explain basic thermodynamic concepts and laws
- Describe the concepts entropy and exergy and their use in analyses of thermal energy systems
- Analyze power plants, refrigeration plants and thermal/chemical installations
- Evaluate means for minimizing exergy losses in selected processes
- Use advanced thermodynamics on a research case

UNIT -I:
REVIEW OF THERMODYNAMIC LAWS AND COROLLARIES: Transient flow analysis, Second law thermodynamics, Entropy, Availability and unavailability, Thermodynamic potential. Maxwell relations, Specific heat relations, Mayer's relation. Evaluation of thermodynamic properties of working substance

UNIT-II:
P.V.T SURFACE: Equation of state. Real gas behavior, Vander Waal's equation, Generalization compressibility factor. Energy properties of real gases. Vapour pressure, Clausius, Clapeyro equation. Throttling, Joule. Thompson coefficient. Non reactive mixtures of perfect gases. Governing laws, Evaluation of properties, Psychometric mixture properties and psychometric chart, Air conditioning processes, cooling towers. Real gas mixture.

UNIT-III:
COMBUSTION: Combustion Reactions, Enthalpy of formation. Entropy of formation, Reference levels of tables. Energy of formation, Heat reaction, Adiabatic flame temperature generated product, Enthalpies, Equilibrium. Chemical equilibrium of ideal gased, Effect of non reacting gases equilibrium in multiple reactions, The vent hoff's equation. The chemical potential and phase equilibrium. The Gibbs phase rule.

UNIT-IV:
POWER CYCLES: Review binary vapour cycle, co generation and combined cycles, Second law analysts of cycles. Refrigeration cycles. Thermodynamics off irreversible processes. Introduction, Phenomenological laws, Onsaga Reciprocity relation, Applicability of the Phenomenological relations, Heat flux and entropy production, Thermodynamic phenomena, Thermo electric circuits.

UNIT-V:
DIRECT ENERGY CONVERSION INTRODUCTION: Fuel cells, Thermo electric energy, Thermo ionic power generation, Thermodynamic devices magneto hydronamic generations, Photovoltaic cells.

REFERENCES:
1. Engineering Thermodynamics – Rogers & Mayhew - Pearson
2. Thermal Engineering / Rathore / TMH
3. Basic and Applied Thermodynamics/ P.K.Nag/ TMH
4. Applied Thermodynamics – R.K. Rajput – Laxmi Publications
5. Thermodynamics/Holman/ Me Graw Hill.
6. Thermal Engineering / Soman / PHI
7. Engg. Thermodynamics/PL.Dhar / Elsevier
8. Thermodynamics/Sonnatag & Van Wylen / John Wiley & Sons
9. Thermodynamics for Engineers/Doolittle-Messe / John Wiley & Sons
10. Irreversible Thermodynamics/HR De Groff.
11. Thermodynamics & Heat Power – Granet & Bluestein- CRC Press
12. Engineering Thermodynamics/Chatopadyaya

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SOLAR ENERGY
(Elective-III)

Prerequisites: None

Course Objectives: The course is intended to
- Learn about the solar radiation, its applications and radiation measuring instruments.
- Understand the basic concepts of solar radiation and analyze the solar thermal systems for their utilization.

Course outcomes:
After doing this course, the student should be able to
- Understand various aspects of solar radiation
- Learn about non-concentrating collectors
- Design concentrator mountings
- Understand the characteristics of photo-voltaic cells
- Learn about various ways solar energy storage

Unit 1
Source of radiation – solar constant– solar charts – Measurement of diffuse, global and direct solar radiation: pyrheliometer, pyranometer, pyregeometer, net pyradiometer-sunshine recorder Solar

Unit 2
Non-Concentrating Collectors- Design considerations – Classificationair, liquid heating collectors –Derivation of efficiency and testing of flat plate collectors –Analysis of concentric tube collector Solar green house.

Unit 3
Design – Classification– Concentrator mounting –Focusing solar concentratorsHeliostats. Solar powered absorption A/C system, water pump, chimney, drier, dehumidifier, still, cooker.

Unit 4
Photo-voltaic cell – characteristics-cell arrays-power electric circuits for output of solar panels-choppers-inverters-batteries-charge regulators, Construction concepts.

Unit 5
Energy Storage -Sensible, latent heat and thermo-chemical storage-pebble bed etc. materials for phase change-Glauber’s salt-organic compounds. Solar ponds.

TEXT BOOKS:

1. D. Yogi Goswami, Frank Kreith, Jan. F. Kreider, “Principles of Solar Engineering”, 2nd Edition, Taylor & Francis, 2000, Indian reprint, 2003
2. Edward E. Anderson, “Fundamentals for solar energy conversion”, Addison Wesley Publ. Co., 1983.

REFERENCES:

1. Duffie J. A and Beckman, W .A., “Solar Engineering of Thermal Process”, John Wiley, 1991.

2. G. N. Tiwari and M. K. Ghosal, “Fundamentals of Renewable energy Sources”, Narosa Publishing House, New Delhi, 2007
3. Energy Studies, Second Edition, by W. Shepherd and D. W. Shepherd, Imperial College Press, London, 2004 Department of Chemical Engineering 11 CL 706 BIO ENERGY ENGINEE

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ALTERNATE FUELS & POLLUTION
(Elective-III)

Prerequisites: None

Course Objectives:
The course is intended to
- Gain knowledge of various alternative fuels
- Know about Natural gas, LPG, hydrogen and bio gas.

Course Outcomes:
At the end of the course, the student will be able to:
- Identify the need of alternate fuels and list out some prospective alternate fuels
- Categorize, interpret and understand the essential properties of fuels for petrol and diesel engines
- Infer the storage and dispensing facilities requirements
- Analyze the implement limitations with regard to performance, emission and materials compatibility
- Identify and understand possible harmful emissions and the legislation standards

UNIT-I : Need for alternate fuel : Availability and properties of alternate fuels, general use of alcohols, LPG, hydrogen, ammonia, CNG and LNG, vegetable oils and biogas, merits and demerits of various alternate fuels, introduction to alternate energy sources. Like EV, hybrid, fuel cell and solar cars.

UNIT-II : Alcohols: Properties as engine fuel, alcohols and gasoline blends, performance in SI engine, methanol and gasoline blends, combustion characteristics in CI engines, emission characteristics, DME, DEE properties performance analysis, performance in SI & CI Engines.

UNIT-III : Natural Gas, LPG, Hydrogen and Biogas: Availability of CNG, properties, modification required to use in engines, performance and emission characteristics of CNG using LPG in SI & CI engines, performance and emission of LPG. Hydrogen; storage and handling, performance and safety aspects.

UNIT-IV: Technical Background of Diesel/Bio-diesel fuels-Oil feed stocks-Transesterification-Bio-diesel production from Vegetable oils and waste cooking oil-High blend levels of bio-diesel-Testing , Bio diesel-Oxidation stability-Performance in Engines, Properties of bio-fuels and their importance in the context of IC Engines. Vegetable Oils: Various vegetable oils for engines, esterification, performance in engines, performance and emission characteristics, bio diesel and its characteristics

UNIT-V : Electric, Hybrid, Fuel Cell And Solar Cars: Layout of an electric vehicle, advantage and limitations, specifications, system components, electronic control system, high energy and power density batteries, hybrid vehicle, fuel cell vehicles, solar powered vehicles.

Reference Books:

1. Alternate Fuels - Dr. S. S. Thipse - Jaico Publications
2. Richard.L.Bechfold, Alternative Fuels Guide BooK, SAE International Warrendale - 1997.
3. Maheswar Dayal, Energy Today & tomorrow, -1 & B Horishr India-1982.
4. Nagpal, Power Plant Engineering, Khanna Publishers, 1991.
5. Alcohols as motor fuels progress in technology, Series No. 19 - SAE Publication USE - 1980.
6. SAE paper nos. 840367, 841333, 841334, 841156, Transactions, SAE, USA
7. Alternative Fuels Guidebook - Bechtold R.

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RENEWABLE ENERGY SOURCES
(ELECTIVE-IV)

Prerequisites: None

Course Objectives:
The course is intended to
- introduce to the technology of renewable sources of energy
- learn about the solar radiation, its applications and radiation measuring instruments
- learn about the various types of geothermal resources and its applications
- study the biomass energy resources , bio-mass systems
- learn the methods of energy extraction from the wind and oceans
- learn to the technology of direct energy conversion methods

Course Outcomes:
At the end of the course, the student will be able to:
- Identify the renewable energy sources and their utilization
- Understand the basic concepts of the solar radiation and analyze the solar Thermal systems for their utilization
- Understand the principle of working of solar cells and their modern
- manufacturing techniques
- Understand the concepts of the ocean thermal energy conversion systems and their applications
- Outline the methods of energy storage and identify the appropriate methods of energy storage for specific applications
- Understand the energy conversion from wind energy, geothermal energy, biomass, biogas, fuel cells and hydrogen

Unit 1 : Introduction:
Overview of the course, Examination and Evaluation patterns. Classification of energy resources, energy scenario in the world and India
Basic sun-earth relationships: Definitions. Celestial sphere, altitude-azimuth, declination-hour angle and declination-right ascension coordinate systems for finding the position of the sun, celestial triangle and coordinates of the sun. Greenwich Mean Time, Indian Standard Time, Local Solar Time, sun rise and sun set times & day length. Numerical problems
Solar radiation: Nature of solar radiation, solar radiation spectrum, solar constant, extra-terrestrial radiation on a horizontal surface, attenuation of solar radiation, beam, diffuse and global radiation. Measurement of global, diffuse and beam radiation. Prediction of solar radiation; Angstrom model, Page model, Hottel’s model, Liu and Jordan model etc. Insolation on an inclined surface, angle of incidence, Illustrative problems

Unit 2 : Solar thermal systems:
Principle of working of solar water heating systems, solar cookers, solar desalination systems, solar ponds, solar chimney power plant, central power tower power plants etc.
Solar concentrating collectors: Classification of solar concentrators, Basic definitions such as concentration ratio, angle of acceptance etc., Tracking of the sun; description of different tracking

modes of a solar collectors and the determination of angle of incidence of insolation in different tracking modes. Illustrative problems

Photovoltaic energy conversion: Introduction. Single crystal silicon solar cell, i-v characteristics, effect of insolation and temperature on the performance of silicon cells. Different types of solar cells. Modern technological methods of producing these cells. Indian and world photovoltaic energy scenario.

Unit 3 : Energy storage:

Necessity for energy storage. Classification of methods of energy storage. Thermal energy storage; sensible heat storage, latent heat storage. Reversible chemical reaction storage. Electromagnetic energy storage. Hydrogen energy storage. Chemical battery storage. Pumped hydel energy storage etc.

Wind energy : Origin of winds, nature of winds, wind data measurement, wind turbine types and their construction, wind-diesel hybrid system, environmental aspects, wind energy programme in India and the world.

Unit 4 : Ocean energy:

Ocean thermal energy; open cycle & closed cycle OTEC plants, environmental impacts, challenges, present status of OTEC systems. Ocean tidal energy; single basin and double basin plants, their relative merits. Ocean wave energy; basics of ocean waves, different wave energy conversion devices, relative merits

Fuel cells: Introduction, applications, classification, different types of fuel cells such as phosphoric acid fuel cell, alkaline fuel cell, PEM fuel cell, MC fuel cell. Development and performance fuel cells.

Unit 5 : Biomass:

Introduction, photosynthesis, biofuels, biomass resources, biomass conversion technologies, urban waste to energy conversion, biomass to ethanol conversion, biomass energy scenario in India.

Biogas: Biogas production, constant pressure and constant volume biogas plants, operational parameters of the biogas plant

Geothermal energy: Origin, applications, types of geothermal resources, relative merits

Reading:

1. B.H.Khan, Non conventional Energy Resources, Tata McGraw Hill, New Delhi, 2012
2. S.Rao and B.B.Parulekar, Energy Technology: Non-Conventional, Renewable and Conventional, Khanna Publishers, 2010
3. S.P.Sukhatme and J.K.Nayak, Solar Energy-Principles of Thermal Collection and Storage, TMH, 2008
4. J.A.Duffie and W.A.Beckman, Solar Energy Thermal Processes, John Wiley, 2010

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FUEL CELL TECHNOLOGY
(Elective-IV)

Prerequisites: None

Course Objectives:
The course is intended to
- To provide thorough understanding of performance characteristics of fuel cell power plant and its components
- Outline the performance and design characteristics and operating issues for various fuel cells
- Discuss the design philosophy and challenges to make this power plant economically feasible
- At the end of the course, the students will have sufficient knowledge for working in a fuel cell industry or R&D organization

Course outcomes:
At the end of the course, the student will be able to:
- To understand the various methods of hydrogen generation and storage
- To apply knowledge of thermodynamics, electrochemistry, heat transfer and fluid mechanics principles to design and analysis of this engineering technology.
- To have thorough understanding of performance behavior , operational issues and challenges for all major types of fuel cells.
- To understand the impact of this technology in global and societal context.
- To begin a career as an engineer in an organization developing fuel cell components and systems.

Unit I
Hydrogen as a future energy carrier, Properties, Chemical production of hydrogen, steam reforming of methanol, natural gas, coal gas etc, shift conversion and thermal decomposition, purification (removal of CO and CO_2), desulphurisation, Electrolytic hydrogen production, Electrolyser configurations

Unit II
Compressed gas storage, Cryogenic liquid storage, Solid state Storage, Adsorption in compounds and metal hydrides, hydride heat pumps and compressors

Unit III
Fundamentals of electrochemical energy conversion, Basic operation principles and Overview. Advantages and applications, Fuel cell thermodynamics; open circuit voltage; efficiency. Heat released, reasons for losses in voltage, Electrode kinetics, porous electrodes, characteristics, fabrication of electrodes, assembly of fuel cells, testing, Classification of fuel cells based on nature of electrolyte, operating temperature etc.

Unit IV
Alkaline Fuel cells (AFC), Phosphoric Acid Fuel cells (PAFC), Polymer Electrolyte Membrane Fuel cells (PEMFC), Direct Methanol Fuel cells (DMFC), Molten Carbonate Fuel

cells(DMFC), Solid Oxide Fuel cells (SOFC), Regenerative Fuel Cells (RFC), Specific characteristics, advantages and applications.

Unit V

Fuel cell plants and sub systems, efficiency of systems, performance; emissions, Heat balance, Environmental benefits. Heat rate of various Fuel Cell plants, Direct Fuel cells, Natural gas and coal based Fuel cell power plant concepts, Cogeneration and CHP, Fuel cell Hybrids, Fuel cell systems for portable, automotive, stationary applications, Future challenges.

Text Books

1. B.Viswanathan and Aulice Scibioh , (2006), Fuel Cells Principles and Applications, Universities Press, Hyderabad.
2. J. Larminie & A. Dicks, (2003), Fuel Cell Systems Explained, Wiley, ISBN # 0-471-49026-1

Reference Books:

1. Fuel Cell Handbook-7th Edition, US Department of Energy, (2004).
2. M. M. Mench, (2008) Fuel Cell Engines, Wiley, (ISBN: 978-0-471-68958-4)
3. X. Li, (2005) Principles of Fuel Cells, Taylor & Francis.
4. Gregor Hoogers, (2003), Fuel Cell Technology Handbook (FCTH), CRC Press, Current Edition. ISBN # 0-8493-0877-1
5. N. Sammes, (2006),Fuel Cell Technology - Reaching Towards Commercialization by ISBN-10: 1852339748-Springer
6. S. Srinivasan, (2006), Fuel Cells: From Fundamentals and Applications, Springer.

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NON CONVENTIONAL ENERGY SOURCES
(Elective-IV)

Prerequisites: None

Course Objectives:
The course is intended to
- Provide a fundamental treatment of fluid flows controlled by viscous or turbulent stress gradients and the subsequent heat transfer between fluids and solid surfaces.
- Provide analytical solutions to the momentum and energy conservation equations for both laminar and turbulent flows will be considered.
- Provide solid foundation for the engineering practitioner engaged in single phase convective thermal transport.
- Provide solid foundation for further studies in multiphase convective transport

Course Outcomes:
At the end of the course, the student will be able to:
- Unconventional energy sources: solar energy, wind energy, tidal energy, geothermal energy, thermonuclear fusion, cold fusion
- Power plants utilizing unconventional energy sources
- Special methods of energy production: fuel cells, MHD power plants
- Unconventional energy transport and accumulation: hydrogen
- Measurements at the biogas station and Rankine cycle generator

UNIT-I
Introduction, Energy Scenario, Survey of energy resources. Classification and need for conventional energy resources.
Solar Energy: The Sun-sun-Earth relationship, Basic matter to waste heat energy circuit, Solar Radiation, Attention, Radiation measuring instruments.
Solar Energy Applications: Solar water heating. Space heating, Active and passive heating. Energy storage. Selective surface. Solar stills and ponds, solar refrigeration, Photovoltaic generation.

UNIT -II
GEOTHERMAL ENERGY: Structure of earth, Geothermal Regions, Hot springs. Hot Rocks, Hot Aquifers. Analytical methods to estimate thermal potential. Harnessing techniques, Electricity generating systems.

UNIT-III
DIRECT ENERGY CONVERSION: Nuclear Fusion: Fusion, Fusion reaction, P-P cycle, Carbon cycle, Deuterium cycle, Condition for controlled fusion, Fuel cells and photovoltaic. Thermionic & thermoelectric generation, MHD generator.
Hydrogen Gas as Fuel: Production methods, Properties, I.C. Engines applications, Utilization strategy, Performances.

UNIT-IV
BIO-ENERGY: Biomass energy sources. Plant productivity, Biomass wastes, aerovic and Anaerobic bioconversion processed, Raw metrical and properties of bio-gas, Bio-gas plant

technology and status, the energetics and economics of biomass systems, Biomass gasification

UNIT-V

WIND ENERGY: Wind, Beaufort number, Characteristics, Wind energy conversion systems, Types, Betz model. Interference factor. Power coefficient, Torque coefficient and Thrust coefficient, Lift machines and Drag machines. Matching, Electricity generation.

Energy from Oceans: Tidal energy. Tides. Diurnal and semi-diurnal nature, Power from tides, Wave Energy, Waves, Theoretical energy available. Calculation of period and phase velocity of waves, Wave power systems, Submerged devices. Ocean thermal Energy, Principles, Heat exchangers, Pumping requirements, Practical considerations.

References:

1. Non-conventional Energy Resources – Khan – McGraw Hill
2. Energy Resources Utilization & Technologies – Y.Anjaneyulu & T. Francis – BS Publications
3. Renewable Energy Resources- Basic Principles and Applications/ G.N.Tiwari and M.K.Ghosal/ Narosa Publications
4. Renewable Energy Resources/ John Twidell & Tony Weir/Taylor & Francis/2nd edition
5. Alternative Energy Sources & Systems – Steeby – Cengage Learning
6. Biological Energy Resources/ Malcolm Fleischer & Chris Lawis/E&FN Spon
7. Renewable Energy Sourse – Tasneem & S.A. Abbasi - PHI
8. Solar Energy – Sukhatme & Nayak – McGraw Hill

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THERMAL ENGINEERING LABORATORY

Prerequisites: None

Course Objectives:
The lab is mainly intended to

- Analyze the performance and exhaust emissions of an IC engine by conducting the performance test on IC Engines.
- Evaluate the performance of the Vapor compression and Air conditioning units
- Analyze the flame propagation velocity of the gaseous fuels
- Evaluate the performance of the Solar flat plate collector and evacuated tube concentrator

Course Outcomes:
At the end of the course, the student will be able to:

- Perform experiments to determine the properties of fuels and oils.
- Determine the volumetric efficiency of a two-stage reciprocating air compressor as a function of receiver pressure.
- Evaluate heat transfer coefficient using forced convection set-up.
- Interpret the theoretical and experimental findings of free convection experiments.
- Apply Fourier law of conduction for composite slab and Newton's law of cooling for pin-fin apparatus.
- Perform experiments on engines and draw characteristics.

1. Compressibility factor measurement of different real gases.
2. Dryness fraction estimation of steam.
3. Flame propagation analysis of gaseous fuels.
4. Performance test and analysis of exhaust gases of an I.C. Engine.
5. Heat Balance sheet, Volumetric Efficiency and air fuel ratio estimation of an I.C. Engine.
6. COP estimation of vapour compression refrigeration test.
7. Performance analysis of Air conditioning unit.
8. Performance analysis of heat pipe.
9. Solar Flat Plate Collector
10. Evacuative tube concentrator

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SOFT SKILLS LAB
(Activity-based)

Course Objectives

- To improve the fluency of students in English
- To facilitate learning through interaction
- To illustrate the role of skills in real-life situations with case studies, role plays etc.
- To train students in group dynamics, body language and various other activities which boost their confidence levels and help in their overall personality development
- To encourage students develop behavioral skills and personal management skills
- To impart training for empowerment, thereby preparing students to become successful professionals

Learning Outcomes

- Developed critical acumen and creative ability besides making them industry- ready.
- Appropriate use of English language while clearly articulating ideas.
- Developing insights into Language and enrich the professional competence of the students.
- Enable students to meet challenges in job and career advancement.

INTRODUCTION

Definition and Introduction to Soft Skills – Hard Skills vs Soft Skills – Significance of Soft/Life/Self Skills – Self and SWOT Analysis ***and***

1. **Exercises on Productivity Development**
   - Effective/ Assertive Communication Skills (Activity based)
   - Time Management (Case Study)
   - Creativity & Critical Thinking (Case Study)
   - Decision Making and Problem Solving (Case Study)
   - Stress Management (Case Study)
2. **Exercises on Personality Development Skills**
   - Self-esteem (Case Study)
   - Positive Thinking (Case Study)
   - Emotional Intelligence (Case Study)
   - Team building and Leadership Skills (Case Study)
   - Conflict Management (Case Study)
3. **Exercises on Presentation Skills**
   - Netiquette
   - Importance of Oral Presentation – Defining Purpose- Analyzing the audience- Planning Outline and Preparing the Presentation- Individual & Group Presentation- Graphical Organizers- Tools and Multi-media Visuals
   - One Minute Presentations (Warming up)
   - PPT on Project Work- Understanding the Nuances of Delivery- Body Language – Closing and Handling Questions – Rubrics for Individual Evaluation (Practice Sessions)
4. **Exercises on Professional Etiquette and Communication**
   - Role-Play and Simulation- Introducing oneself and others, Greetings, Apologies, Requests, Agreement & Disagreement….etc.

- Telephone Etiquette
- Active Listening
- Group Discussions (Case study)- Group Discussion as a part of Selection Procedure- Checklist of GDs
- Analysis of Selected Interviews (Objectives of Interview)
- Mock-Interviews (Practice Sessions)
- Job Application and Preparing Resume
- Process Writing (Technical Vocabulary) – Writing a Project Report-Assignments

5. **Exercises on Ethics and Values**
   Introduction — Types of Values - Personal, Social and Cultural Values - Importance of Values in Various Contexts
   - Significance of Modern and Professional Etiquette – Etiquette (Formal and Informal Situations with Examples)
   - Attitude, Good Manners and Work Culture (Live Examples)
   - Social Skills - Dealing with the Challenged (Live Examples)
   - Professional Responsibility – Adaptability (Live Examples)
   - Corporate Expectations

☞ Note: Hand-outs are to be prepared and given to students.
☞ Training plan will be integrated in the syllabus.
☞ Topics mentioned in the syllabus are activity-based.

SUGGESTED SOFTWARE:

☞ The following software from **'train2success.com'**
- Preparing for being Interviewed
- Positive Thinking
- Interviewing Skills
- Telephone Skills
- Time Management
- Team Building
- Decision making

SUGGESTED READING:

1. Alex, K. 2012. *Soft Skills.* S. Chand Publishers
2. *Management Shapers*. 2011. Collection of 28 Books by different Authors. Universities Press.
3. Sherfield, Robert M. *2005. et al Cornerstone: Developing Soft Skills*. Pearson
4. Suresh Kumar,E; Sreehari, P. & Savithri, J. 2011. *Communication Skills and Soft Skills-An Integrated Approach.* New Delhi: Pearson
5. The ACE of Soft Skills by Gopalaswamy Ramesh & Mahadevan Ramesh. 2013. Pearson Publishers. New Delhi.
6. Patnaik, P. 2011. *Group Discussion and Interview Skills.* New Delhi: Foundation
7. Sudhir Andrews. 2009. *How to Succeed at Interviews.* New Delhi: Tata McGraw Hill
8. **Sasikumar, V & Dhamija, P.V. 1993. *Spoken English - A Self-Learning Guide to Conversation Practice.* New Delhi: Tata McGraw-Hill**
9. *Dixson, Richard J. Everyday Dialogues in English. Prentice Hall India Pvt Ltd*
10. Mukhopadhyay. L *et al. 2012. Polyskills. New Delhi: CUP India Pvt Ltd*
11. Rizvi, M. A. 2005. *Effective Technical Communication.* New Delhi: Tata McGraw Hill
12. *The Hindu Speaks on Education* by the Hindu Newspaper
13. Naterop, B. Jean and Revell, Rod. 2004. *Telephoning in English*. Cambridge: CUP

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ADVANCED FLUID MECHANICS

Prerequisites: Fluid Mechanics & Hydraulic Machinery

Course Objectives:
The course is intended to
- Establish an understanding of the fundamental concepts of fluid mechanics.
- Understand and apply the potential flow equations to basic flows.
- Understand and apply the differential equations of fluid mechanics including the ability to apply and understand the impact of assumptions made in the analysis.
- Understand the boundary layer concepts with respect to fluid flow
- Understand and apply the compressible flow equations.

Course Outcomes:
At the end of the course, the student will be able to:
- Understanding the concept of fluid and the models of fluids
- Understanding the basic physical meaning of general equations
- Understanding the concept of stream function and potential function
- Ability to derive the equation for viscous flow, including laminar flow and turbulent flow
- Ability to address such problems in engineering, and to solve the problems

UNIT I:
INVISCID FLOW OF INCOMPRESSIBLE FLUIDS: Lagrangian and Eulerain Descriptions of fluid motion- Path lines, Stream lines, Streak lines, stream tubes – velocity of a fluid particle, types of flows, Equations of three dimensional continuity equation- Stream and Velocity potential functions.
Basic Laws of fluid Flow: Condition for irrotationality, circulation & vorticity Accelerations in Cartesystems normal and tangential accelerations, Euler's, Bernouli equations in 3D– Continuity and Momentum Equations

UNIT II:
Viscous Flow: Derivation of Navier-Stoke's Equations for viscous compressible flow – Exact solutions to certain simple cases : Plain Poisoulle flow - Coutte flow with and without pressure gradient - Hagen Poisoulle flow - Blasius solution.

UNIT III:
Boundary Layer Concepts : Prandtl's contribution to real fluid flows – Prandtl's boundary layer theory - Boundary layer thickness for flow over a flat plate – Approximate solutions – Creeping motion (Stokes) – Oseen's approximation - Von-Karman momentum integral equation for laminar boundary layer –– Expressions for local and mean drag coefficients for different velocity profiles.

UNIT IV:
Introduction to Turbulent Flow: Fundamental concept of turbulence – Time Averaged Equations – Boundary Layer Equations - Prandtl Mixing Length Model - Universal Velocity Distribution Law: Van Driest Model –Approximate solutions for drag coefficients – More Refined Turbulence Models – k-epsilon model - boundary layer separation and form drag – Karman Vortex Trail, Boundary layer control, lift on circular cylinders

Internal Flow: Smooth and rough boundaries – Equations for Velocity Distribution and frictional Resistance in smooth rough Pipes – Roughness of Commercial Pipes – Moody's diagram.

UNIT V:

Compressible Fluid Flow – I: Thermodynamic basics – Equations of continuity, Momentum and Energy - Acoustic Velocity Derivation of Equation for Mach Number – Flow Regimes – Mach Angle – Mach Cone – Stagnation State

Compressible Fluid Flow – II: Area Variation, Property Relationships in terms of Mach number, Nozzles, Diffusers – Fanno and Releigh Lines, Property Relations – Isothermal Flow in Long Ducts – Normal Compressible Shock, Oblique Shock: Expansion and Compressible Shocks – Supersonic Wave Drag.

REFERENCES:

1. Fluid Mechanics and Machines/Modi and Seth/Standard Book House
2. Fluid Mechanics – Jog – Cambridge
3. Fluid Mechanics with Engineering Applications – Finnemore & Franzini – McGrawHill
4. Fluid Mechanics and Machinery – Khan – Oxford
5. Fluid Mechanics/Cohen and Kundu/Elsevier/5th edition
6. Fluid Mechanics/Potter/Cengage Learning
7. Fluid Mechanics/William S Janna/CRC Press
8. Fluid Mechanics and Machines/CP Kodandaraman/New Age Publications
9. A Text book of Fluid Mechanics/RK Rajput/S. Chand
10. Boundary Layer Theory/ Schlichting H /Springer Publications
11. Dynamics & Theory and Dynamics of Compressible Fluid Flow/ Shapiro.
12. Fluid Mechanics and Machinery/ D. Rama Durgaiah/New Age Publications
13. Fluid Dynamics/ William F. Hughes & John A. Brighton/TMH

JNTUH COLLEGE OF ENGINEERING HYDERABAD

M.Tech. I Year II-Sem (Thermal Engineering)

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FUELS AND COMBUSTION

Prerequisites: Thermodynamics, Thermal Engineering 1 & 2

Course Objectives:
The course is intended to
- The fundamental of combustion phenomena in general,
- The different combustion process, its thermodynamics and kinetics
- The combustion mechanism in different types of combustion,
- The burner design for efficient combustion,
- Different combustion models.
- Provide students with knowledge of fuel quantity and engine technology effects on emissions.
- Understand the combustion phenomena.
- Understand the concept of laminar and turbulent flame propagation.
- Understand about different methods to reduce air pollution.

Course Outcomes:
At the end of the course, the student will be able to**:**
- Understand the concepts of combustion phenomena in energy conversion devices.
- Apply the knowledge of adiabatic flame temperature in the design of combustion devices
- Identify the phenomenon of flame stabilization in laminar and turbulent flames.
- Analyze the pollution formation mechanisms in combustion of solid, liquid and gaseous fuels.

UNIT – I:
FUELS: Detailed classification – Conventional and Unconventional Solid, Liquid, gaseous fuels and nuclear fuels – Origin of Coal – Analysis of coal.
Coal – Carborisation, Gasification and liquification – Lignite: petroleum based fuels – problems associated with very low calorific value gases: Coal Gas – Blast Furnace Gas Alcohols and Biogas.

UNIT – II :
PRINCIPLES OF COMBUSTION: Chemical composition – Flue gas analysis – dew point of products – Combustion stoichiometry.
Chemical kinetics – Rate of reaction – Reaction order – Molecularity – Zeroth, first, second and third order reactions - complex reactions – chain reactions. Theories of reaction Kinetics – General oxidation behavior of HC's.

UNIT – III:
THERMODYNAMICS OF COMBUSTION: Enthalpy of formation – Heating value of fuel - Adiabatic flame Temperature – Equilibrium composition of gaseous mixtures.

UNIT – IV:
LAMINAR AND TURBULENT FLAMES PROPAGATION AND STRUCTURE: Flame stability – Burning velocity of fuels – Measurement of burning velocity – factors affecting the burning velocity.

Combustion of fuel, droplets and sprays – Combustion systems – Pulverized fuel furnaces – fixed, Entrained and Fluidised Bed Systems.

UNIT – V:

ENVIRONMENTAL CONSIDERATIONS: Air pollution – Effects on Environment, Human Health etc. Principal pollutants – Legislative Measures – Methods of Emission control.

References:

1. Combustion Fundamentals / Roger A Strehlow / Mc Graw Hill
2. Fuels and combustion / Sharma and Chander Mohan/ Tata Mc Graw Hill
3. Combustion Engineering and Fuel Technology / Shaha A.K./ Oxford and IBH.
4. Principles of Combustion / Kanneth K.Kuo/ Wiley and Sons.
5. Combustion / Sarkar / Mc. Graw Hill.
6. An Introduction to Combustion / Stephen R. Turns/ Mc. Graw Hill International Edition.
7. Combustion Engineering / Gary L. Berman & Kenneth W. Ragland/ Mc. Graw Hill International Edition.

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COMPUTATIONAL FLUID DYNAMICS
(Elective-V)

Prerequisites: Fluid Dynamics & Hydraulic Machinery

Course Objectives:
The course is intended to
- Understand the basics of computational fluid dynamics (CFD).
- Differentiate between finite difference and finite volume methods applied in CFD.
- Provide the necessary background in discretization methods, accuracy, stability and convergence aspects of numerical solutions.
- Develop an understanding of the capabilities and limitations of various numerical and mathematical models of fluid flow.
- Introduce some of the models required to compute turbulent and incompressible fluid flow problems
- Apply CFD to heat transfer problems.

Course Outcomes:
At the end of the course, the student will be able to:
- Understand the stepwise procedure to completely solve a fluid dynamics problem using computational methods
- Derive the governing equations and understand the behaviour of the equations
- Analyze the consistency, stability and convergence of various discretization schemes for parabolic, elliptic and hyperbolic partial differential equations.
- Analyze variations of SIMPLE schemes for incompressible flows and variations of Flux Splitting algorithms for compressible flows.
- Analyze various methods of grid generation techniques and application of finite difference and finite volume methods to various thermal problems

UNIT - I:

Introduction to Numerical Methods - Finite Difference, Finite Element and Finite Volume Methods – Classification of Partial Differential Equations – Solution of Linear Algebraic Equations – Direct and Iterative Approaches

Finite difference methods: Taylor's series – FDE formulation for 1D and 2D steady state heat transfer problems – Cartesian, cylindrical and spherical co-ordinate systems – boundary conditions – Un steady state heat conduction – Errors associated with FDE - Explicit Method – Stability criteria – Implicit Method – Crank Nickolson method – 2-D FDE formulation – ADI – ADE

UNIT-II:
Finite Volume Method: Formation of Basic rules for control volume approach using 1D steady heat conduction equation – Interface Thermal Conductivity - Extension of General Nodal Equation to 2D and 3D Steady heat conduction and Unsteady heat conduction

UNIT -III:

FVM to Convection and Diffusion: Concept of Elliptic, Parabolic and Hyperbolic Equations applied to fluid flow – Governing Equations of Flow and Heat transfer – Steady 1D

Convection Diffusion – Discretization Schemes and their assessment – Treatment of Boundary Conditions

UNIT - IV:
Calculation of Flow Field: Vorticity & Stream Function Method - Staggered Grid as Remedy for representation of Flow Field - Pressure and Velocity Corrections – Pressure Velocity Coupling - SIMPLE & SIMPLER (revised algorithm) Algorithm.

UNIT - V:
Turbulent Flows: Direct Numerical Simulation, Large Eddy Simulation and RANS Models

Compressible Flows: Introduction - Pressure, Velocity and Density Coupling.

TEXT BOOKS:

1. Numerical heat transfer and fluid flow – S.V. Patankar (Hemisphere Pub. House)
2. An Introduction to Computational Fluid Dynamics – FVM Method – H.K. Versteeg, W. Malalasekhara (PHI)
3. Computational Fluid Flow and Heat Transfer – Muralidharan & Sundarajan (Narosa Pub)

REFERENCE BOOKS:

1. Computational Fluid Dynamics – Hoffman and Chiang, Engg Education System
2. Computational Fluid Dynamics – Anderson (TMH)
3. Computational Methods for Fluid Dynamics – Ferziger, Peric (Springer)
4. Computational Fluid Dynamics, T.J. Chung, Cambridge University
5. Computaional Fluid Dynamics – A Practical Approach – Tu, Yeoh, Liu (Elsevier)
6. Text Book of Fluid Dynamics, Frank Chorlton, CBS Publishers

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ADVANCED CAD
(Elective-V)

Prerequisites: CAD/CAM

Course Objectives:
The course is intended to
- Learn advanced concepts of feature based modeling and parametric modeling
- Understand the mathematical basis for geometric modeling of curves and surfaces and their relationship with computer graphics.
- Understand the methods of representation of wireframe, surface, and solid modeling systems.
- Consider data associativity concepts of CAD/CAE integration; Be familiar with interoperability and data transfer techniques between design and analysis software systems
- Learn role of CAD in MDO (Multidisciplinary Design Optimization).
- Understand role of PDM/PLM in an engineering enterprise.
- Gain experience in design projects involving multiple CAD systems
- Gain extensive hands-on experience with two commercial CAD systems to gain proficiency in using the systems at advanced levels, migrating and sharing data between systems, and applying the theory covered in this course.

Course Outcomes:
At the end of the course, the student will be able to:
- Understand geometric transformation techniques in CAD.
- Develop mathematical models to represent curves.
- Design surface models for engineering applications.
- Model engineering components using solid modeling techniques.
- Design and analysis of engineering components.

Unit 1
Introduction to CAD: Introduction to CAD, CAD input devices, CAD output devices, CAD Software, Display Visualization Aids, and Requirements of Modeling

Unit 2
2D Transformations of geometry: 2D Translation, 2D Scaling, 2D Reflection, 2D Rotation, Homogeneous representation of transformation, Concatenation of transformations
3D Transformations of geometry and Projections: 3D Translation, 3D Scaling, 3D Reflection, 3D Rotation, Homogeneous representation of transformation, Concatenation of transformations, Perspective, Axonometric projections, Orthographic and Oblique projections.

Unit 3
Design of Curves : Analytic Curves, PC curve, Ferguson, Composite Ferguson, curve Trimming and Blending, Bezier segments, de Castellan's algorithm, Bernstein polynomials, Bezier- subdivision, Degree elevation, Composite Bezier, Splines, Polynomial Splines, B-spline basis functions, Properties of basic functions, Knot Vector generation, NURBS.

Unit 4

Design of Surfaces : Differential geometry, Parametric representation, Curves on surface, Classification of points, Curvatures, Developable surfaces, Surfaces of revolution, Intersection of surfaces, Surface modeling, 16-point form, Coons patch, B-spline surfaces.

Unit 5

Design of Solids: Solid entities, Boolean operations, B-rep of Solid Modeling, CSG approach of solid modeling, advanced modeling methods.

Data Exchange Formats and CAD Applications: Data exchange formats, Finite element analysis, reverse engineering, modeling with point cloud data, Rapid prototyping.

References:

1. Ibrahim Zeid and Sivasubramanian, R., CAD/CAM Theory and Practice, Tata McGraw Hill Publications, New Delhi, 2009.

2. David F. Rogers, J. A. Adams, Mathematical Elements for Computer Graphics, TMH, 2008.

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EXERGY ANALYSIS OF THERMAL SYSTEMS
(Elective-V)

Prerequisites: Thermodynamics

Course Objectives:
To enable the students to understand the exergy method of energy systems.
1. To develop the knowledge of students in applying the exergy approach to solve the problems of thermal power plants.

Course Outcomes:
Student will be able to
1. Design and analysis of energy systems with irreversibility concept.
2. Parametric evaluation of energy systems using second law of thermodynamics.
3. Identify the exergetic destruction in various components of plant.

Unit I : Concept of Exergy
Concept of exergy Available work Exergy loss, Reversibility and irreversibility - exergy for control region physical exergy and chemical exergy closed system analysis Exergy evaluation of solid, liquid and gaseous fuels tables and charts.

Unit II : Thermodynamic Equilibrium
Combustion - Combustion reactions - Enthalpy of formation - Entropy of formation - Reference levels for tables Heat of reaction Adiabatic flame temperature - General product Enthalpies Equilibrium - Chemical equilibrium of ideal gases Effects of Non-reacting gases Equilibrium in multiple reactions - The vont Hoff Equation - The chemical potential and phase equilibrium The Gibbs Phase Rule.

Unit – III : Exergy Analysis - Methodology
Control mass analysis control region analysis pictorial representation of exergy balance exergy based property diagrams thermodynamic feasibility of new thermal plants applications of exergy method Exergy analysis of renewable energy systems.

Unit - IV : Exergy Applied to Processes
Expansion process - compression process heat transfer processes mixing and separation processes chemical process and combustion Linde air liquefaction plant CHP plant GT-ST combined cycle plant refrigeration plant heat pump systems fuel cell systems

Unit - V : Thermoeconomic Applications of Exergy
Structural coefficients exergy losses optimization of component geometry thermoeconomic optimization of thermal systems thermoeconomic optimization of heat exchanger in a CHP plant exergy costing in multi product plant.

Text books:
1. Tadeusz Jozef Kotas (1995), The Exergy Method of Thermal Plant Analysis, Krieger Pub.
2. John E. Ahern (1980), The Exergy Method of Energy Systems Analysis, A Wiley-Inter science Publication.

3. □rahim Din禄, Marc A. Rosen (2007), Exergy: Energy, Environment, and Sustainable Development, Elsevier.
4. Adrian Bejan (1997), Advanced Engineering Thermodynamics, Wiley.

Reference Books:

1. Adrian Bejan (1996), Entropy Generation Minimization: The Method of Thermodynamic Optimization of Finite-Size Systems and Finite-Time Processes, CRC Press.
2. J.P.Holman (1968), Thermodynamics, Mc.Graw Hill Publishers
3. Jan Szargut, David R. Morris, Frank R. Steward (1988), Exergy Analysis of Thermal, Chemical, and Metallurgical Processes, Hemisphere Publishers.

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ENERGY CONSERVATION AND MANAGEMENT
(Elective - VI)

Prerequisites: None

Course Objectives:
The course is intended to
- Demonstrate the importance and role of energy management in the functional areas like Manufacturing Industry, Process Industry,. Commerce and Government
- To know the different energy resources
- Understand thermodynamic power cycles and the associated processes and fuels
- Understand the economics of energy conversion
- Enable the students to understand the basic energy conversion and management principles and to identify sources of energy loss and target savings
- Enable students in carrying out budgeting and risk analysis
- Analyze the performance of the wind turbine

Course Outcomes:
At the end of the course, the student will be able to:
- Explain the fundamentals of energy management and its influence on environment
- Describe methods of energy production for improved utilization.
- Apply the principles of thermal engineering and energy management to improve the performance of thermal systems.
- Analyze the methods of energy conservation and energy efficiency for buildings, air conditioning, heat recovery and thermal energy storage systems.
- Assess energy projects on the basis of economic and financial criteria.

UNIT-I
INTRODUCTION: Principles of energy management. Managerial organization, Functional areas for i) manufacturing industry, ii) Process industry, iii) Commerce, iv) Government, Role of Energy manager in each of these organizations. Initiating, Organizing and managing energy management programs

UNIT -II
ENERGY AUDIT: Definition and concepts. Types of energy audits, Basic energy concepts, Resources for plant energy studies. Data gathering, Analytical techniques. Energy Conservation: Technologies for energy conservation, Design for conservation of energy materials, Energy flow networks. Critical assessment of energy usage. Formulation of objectives and constrains, Synthesis of alternative options and technical analysis of options. Process integration.

UNIT-III
ECONOMIC ANALYSIS: Scope, Characterization of an investment project. Types of depreciation, Time value of money. Budget considerations, Risk analysis.

UNIT-IV

METHODS OF EVALUATION OF PROJECTS: Payback, Annualized costs, Investor's rate of return, Present worth, Internal rate of return, Pros and cons of the common method of analysis, Replacement analysis.

UNIT-V

ALTERNATIVE ENERGY SOURCES: SOLAR ENERGY: Types of devices for solar energy collections, Thermal storage system, Control systems. Wind Energy, Availability, Wind Devices, Wind Characteristics, performance of turbines and systems.

References:

1. Energy Management Hand Book / W.C. Turner (Ed)
2. Energy Management Principles / CB Smith/ Pergamon Press
3. Energy Management / W.R.Murthy and G.Mc.Kay / BS Publication
4. Management / H.Koontz and Cyrill Donnel / McGraw Hill
5. Financial Management / S.C.Kuchhal / Chaitanya Publishing House

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CONVECTIVE HEAT TRANSFER
(Elective-VI)

Prerequisites: None

Course objectives:
The course is intended to
- Understand the need of the non-convectional energy sources
- Know the role of non-convectional energy for the environment.
- Understand the energy resources utilization systems.
- Know the source and potential of wind energy and understand the classifications of wind mills.
- Summarize the principles of bio-conversion, ocean energy and geo thermal energy
- Apply the principles of thermo electric generators, fuel cells, and MHD generators.

Course Outcomes:
At the end of the course, the student will be able to:
- Understand the fundamental and advanced principles of forced and natural convection heat transfer processes.
- Formulate and solve convective heat transfer problems
- Apply the principles of convective heat transfer to estimate the heat dissipation from devices.
- Evaluate the energy requirements for operating a flow system with heat transfer.
- Relate to the current challenges in the field of convective heat transfer.

UNIT-I:
Introduction to Forced, free & combined convection – convective heat transfer coefficient – Application of dimensional analysis to convection – Physical interpretation of dimensionless numbers.
Equations of Convective Heat Transfer: Continuity, Navier-Strokes equation & energy equation for steady state flows – similarity – Equations for turbulent convective heat transfer – Boundary layer equations for laminar, turbulent flows – Boundary layer integral equations.

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

UNIT – III:

NATURAL CONVECTION: Boussineq approximation – Governing equations – Similarity – Boundary layer equations for free convective laminar flows – Numerical solution of boundary layer equations.

Free Convective flows through a vertical channel across a rectangular enclosure – Horizontal enclosure – Turbulent natural convection.

UNIT – IV:

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

UNIT - V:

CONVECTIVE HEAT TRANSFER THROUGH POROUS MEDIA: Area weighted velocity – Darcy flow model – energy equation – boundary layer solutions for 2-D forced convection – Fully developed duct flow – Natural convection in porous media – filled enclosures – stability of horizontal porous layers.

References:

1. Convective Heat & Mass Transfer/ Ghiaasiaan / Cambridge
2. Introduction to Convective Heat Transfer Analysis/ Patrick H. Oosthuigen & David Naylor /McGraw Hill
3. Convective Heat & Mass Transfer /Kays & Crawford/TMH
4. Fundamentals of Heat & Mass Transfer – Thirumaleshwar – Pearson
5. Heat Transfer – Gregory Nellis & Sanford Klein - Cambridge

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CRYOGENIC ENGINEERING
(Elective-VI)

Prerequisites: Advanced Heat and Mass Transfer

Course Objectives:
To impart knowledge on properties of cryogenic fluid, cycles and cryogenic refrigerators.

Course Outcomes:
At the end of the course, the student will be able to:
- Understand concepts of cryogenic systems.
- Relate air-liquefaction processes to practical situations.
- Interpret and analyze helium liquefaction techniques.
- Classify cascade refrigeration systems.
- Understand principles of ultra-low temperature systems and their applications.
- Assess storage systems and insulation techniques used in cryogenic applications.

UNIT -I:
INTRODUCTION TO CRYOGENIC SYSTEMS: Mechanical Properties at low temperatures. Properties of Cryogenic Fluids.
Gas Liquefaction: Minimum work for liquefaction. Methods to protect low temperature. Liquefaction systems for gages other than Neon. Hydrogen and Helium.

UNIT II:
LIQUEFACTION SYSTEMS FOR NEON, HYDROGEN AND HELIUM: Components of Liquefaction systems. Heat exchangers. Compressors and expanders. Expansion valve, Losses in real machines.

UNIT-III:
GAS SEPARATION AND PURIFICATION SYSTEMS: Properties of mixtures, Principles of mixtures, Principles of gas separation, Air separation systems.

UNIT-IV:
CRYOGENIC REFRIGERATION SYSTEMS: Working Medium, Solids, Liquids, Gases, Cryogenic fluid storage & transfer, Cryogenic storage systems, Insulation, Fluid transfer mechanisms, Cryostat, Cryo Coolers

UNIT-V:
APPLICATIONS: Space technology, In-Flight air separation and collection of LOX, Gas industry, Biology, Medicine, Electronics.

References:

1. Cryogenic Systems/ R.F.Barren/ Oxford University Press
2. Cryogenic Research and Applications: Marshal Sitting/ Von Nostrand/ Inc. New Jersey
3. Cryogenic Heat Transfer/ R.F.Baron
4. Cryogenic Engineering Edit / B.A. Hands/ Academic Press, 1986
5. Cryogenic Engineering/ R.B.Scottm Vin Nostrand/ Inc. New Jersey, 1959
6. Experimental Techniques in Low Temperature Physics- O.K. White, Oxford Press, 1968
7. Cryogenic Process Engineering/ K.D. Timmerhaus & TM Flynn/ Plenum Press, 1998
8. Hand Book of Cryogenic Engineering – J.G.Weisend –II, Taylor and Francis, 1998

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EQUIPMENT DESIGN FOR THERMAL SYSTEMS
(Elective-VII)

Prerequisites: Advanced Heat and Mass Transfer

Course Objective:
The course is intended to
- Design and analyse the heat exchangers parallel flow, counter flow, multipass and, cross flow heat exchanger
- Design and analyse the Shell and tube heat exchanger
- Enable to carryout the preformance of heat exchanger with the extended surfaces.
- Design and analyse the cooling towers.

Course Outcomes:
At the end of the course, the student will be able to:
- Understand the physics and the mathematical treatment of typical heat exchangers.
- Apply LMTD and Effectiveness methods in the design of heat exchangers and analyze the importance of LMTD approach over AMTD approach.
- Analyze the performance of double-pipe counter flow (hair-pin) heat exchangers.
- Design and analyze the shell and tube heat exchanger.
- Understand the fundamental, physical and mathematical aspects of boiling and condensation.
- Classify cooling towers and explain their technical features.

UNIT -I:
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. Multipass, cross flow heat exchanger design calculations:

UNIT-II:
DOUBLE PIPE HEAT EXCHANGER: Film coefficient for fluids in annulus, fouling factors, Calorific temperature, Average fluid temperature, The calculation of double pipe exchanger, Double pipe exchangers in series parallel arrangements.
Shell & Tube Heat Exchangers: Tube layouts for exchangers, Baffle heat exchangers, Calculation of shell and tube heat exchangers, Shell side film coefficients, Shell side equivalent diameter, The true temperature difference in a 1-2 heat exchanger. Influence of approach temperature on correction factor. Shell side pressure drop, Tube side pressure drop, Analysis of performance of 1-2 heat exchanger and design of shell & tube heat exchangers, Flow arrangements for increased heat recovery, the calculation of 2-4 exchangers.

UNIT-III:

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.

UNIT-IV:

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.

UNIT-V:

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.

References:

1. Process Heat Transfer/D.Q.Kern/ TMH
2. Heat Exchanger Design/ A.P.Fraas and M.N.Ozisick/ John Wiely & sons, New York.
3. Cooling Towers / J.D.Gurney and I.A. Cotter/ Maclaren

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REFRIGERATION AND AIR CONDITIONING
(Elective-VII)

Prerequisites: None

Course Objectives:
The course is intended to
- Familiarize students with the terminologies associated with refrigeration & air conditioning
- Cover the basic principles of psychometric and applied psychometrics
- Familiarize students with system analysis
- Familiarize students with load calculations and elementary duct design
- Familiarize students with refrigerants; vapor compression refrigeration and multi-stage vapor compression systems
- Understand the components of vapor compression systems and other types of cooling systems.

COURSE OUTCOMES: At the end of the course, the student will be able to:
- Understand physical and mathematical aspects of refrigeration and air- conditioning systems.
- Apply theoretical and mathematical principles to simple, complex vapour compression and vapour absorption refrigeration systems.
- Understand conventional and alternate refrigerants and their impact on environment.
- Design air-conditioning systems.

UNIT – I
VAPOUR COMPRESSION REFRIGERATION: Performance of Complete vapor compression system. **Components of Vapor Compression System:** The condensing unit – Evaporators – Expansion valve – Refrigerants – Properties – ODP & GWP - Load balancing of vapor compression Unit.
Compound Compression: Flash inter-cooling – flash chamber – Multi-evaporator & Multistage systems.

UNIT – II
PRODUCTION OF LOW TEMPERATURE: Liquefaction system; Cascade System – Applications.– Dry ice system.
Vapor absorption system – Simple and modified aqua – ammonia system – Representation on Enthalpy –Concentration diagram.
Lithium – Bromide system Three fluid system – HCOP.

UNIT – III
AIR REFRIGERATION: Applications – Air Craft Refrigeration -Simple, Bootstrap, Regenerative and Reduced ambient systems – Problems based on different systems.
Steam Jet refrigeration system: Representation on T-s and h-s diagrams – limitations and applications.
Unconventional Refrigeration system – Thermo-electric – Vortex tube & Pulse tube – working principles.

UNIT – IV

AIR –CONDITIONING: Psychometric properties and processes – Construction of Psychometric chart. Requirements of Comfort Air –conditioning – Thermodynamics of human body – Effective temperature and Comfort chart – Parameters influencing the Effective Temperature. Summer, winter and year round air – conditioning systems.
Cooling load Estimation: Occupants, equipments, infiltration, duet heat gain fan load, Fresh air load.

UNIT – V

AIR –CONDITIONING SYSTEMS: All Fresh air , Re-circulated air with and without bypass, with reheat systems – Calculation of Bypass Factor, ADP,RSHF, ESHF and GSHF for different systems. **Components:** Humidification and dehumidification equipment – Systems of Air cleaning – Grills and diffusers – Fans and blowers – Measurement and control of Temperature and Humidity.

REFERENCES:

1. Refrigeration & Air Conditioning /C.P. Arora/TMH
2. Basic Refrigeration & Air Conditioning – P.N. Ananthanarayanan – McGraw Hill
3. Refrigeration and Air Conditioning – Dr. S.S. Thipse - Jaico
4. Principles of Refrigeration/Dossat /Pearson
5. Refrigeration & Air Conditioning /Arora & Domkundwar/ Dhanpat Rai
6. Refrigeration and Air Conditioning /Manohar Prasad/
7. Refrigeration and Air Conditioning /Stoecker /Mc Graw Hill
8. Refrigeration and Air Conditioning /Jordan& Preister /Prentice Hall
9. Refrigeration and Air Conditioning/Dossat /Mc Graw Hill

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COMPUTER SIMULATION OF SI AND CI ENGINES
(Elective-VII)

Prerequisites: Advanced I.C Engines

Course Objective:
The course is intended to
- Understand the C/H/N/O system, flame temperature, the different types of reaction occurring in an engine, while combustion.
- Understand the simulation in an SI engine with fuel air as working medium.
- Know about how the pressure is being getting developed in an engine.
- Understand the simulation of a 2-stroke engine.
- Understand the simulation in an CI engine with fuel air as working medium

Course Outcomes:
At the end of the course, the student will be able to:
- To impart knowledge on simulation of various engine processes used in prime movers and power plants
- To learn the simulation of engine combustion based on first and second law of thermodynamics.

UNIT-I
Computer Simulation and Thermodynamics of Combustion:
Introduction, Heat of reaction, complete combustion in C/H/O/N Systems, Constant volume adiabatic combustion, constant pressure adiabatic combustion. Calculation of adiabatic flame temperature.

UNIT-II
SI Engine Simulation With Fuel-Air as Working Medium: Deviation between actual and air standard cycles of operation- problems, SI engine simulation with adiabatic constant volume combustion with fuel and air being considered, calculation of temperature drop due to fuel vaporization, calculation of mean effective pressure, torque and thermal efficiency at full throttle, part throttle and supercharged conditions.

UNIT-III
Actual Cycle Simulation in SI Engines: Progressive combustion; gas exchange process, heat transfer process, friction. Procedure of validating computer code with experimental data based on performance parameters and pressure crank angle diagram.

UNIT-IV
Simulation of 2-Stroke SI Engine: Simulation of the process, determination of the pressure-crank angle variation, computation of performance parameters.

UNIT-V
Diesel Engine Simulation: Main difference between SI and CI engine simulation, differences between ideal and actual cycles, mathematical combustion model for diesel engine, heat transfer and gas exchange processes.

Reference Books:

1. Ganesan, V. - *Computer Simulation of Spark Ignition Engine Process,* Universities Press (I) Ltd, Hyderabad - 1996.
2. Ganesan. V., *Computer Simulation of Compression Ignition Engine Process,* Universities Press (I) Ltd, Hyderabad - 2000.
3. Ashley Campbel , *Thermodynamic Analysis of Combustion Engine* - John Wiley and Sons, New York - 1986.
4. Benson.R.S., Whitehouse. N.D., - *Internal Combustion Engines*- Pergamon Press, oxford - 1979.
5. Ramoss.A.L., *Modelling of Internal Combusion Engines Processes*- McGraw-Hill Publishing Co., -1992.

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OPTIMIZATION TECHNIQUES AND APPLICATIONS
(Elective-VIII)

Prerequisites: None

Course Objectives:
The course is intended to

- Develop systematic approach to handle problems to design of electrical circuit etc; with a goal of maximizing the profit and minimizing cost.
- Understand the various optimization techniques such as classified optimization, linear programming. One dimensional minimization methods, unconstrained optimization techniques, constrained optimization techniques and dynamic programming.
- Understand the necessary sufficient conditions for finding the solution of the problems in classical optimization.
- Comprehend the numerical methods for finding approximate solution of complicated problems.
- Apply methods like North West corner rule, least count method etc. to solve the transportation problem.

Course Outcomes:
At the end of the course, the student will be able to:

- Explain an overview of modeling of constrained decision making.
- Develop a mathematical model for a given problem.
- Solve practical problems using suitable optimization technique.
- Analyze the sensitivity of a solution to different variables.
- Use and develop optimization simulation software for variety of industrial problems.

UNIT- I*:*
Single Variable Non-Linear Unconstrained Optimization: Elimination methods :Uni-Model function-its importance, Fibonacci method,&Golden section method. Interpolation methods : Quadratic & Cubic interpolation methods.

UNIT- II:
Multi variable non-linear unconstrained optimization: Direct search methods – Univariantmethod , Pattern search methods – Powell's, Hook -Jeeves, Rosenbrock search methods. Gradient methods: Gradient of function& its importance, Steepest descent method, Conjugate direction methods: Fletcher-Reeves method,& variable metric method.

UNIT- III:
Linear Programming – Formulation, Simplex method&Artificial variable optimization techniques: Big M & Two phase methods. Sensitivity analysis: Changes in the objective coefficients, constants& coefficients of the constraints. Addition and deletion of variables, constraints.

Simulation – Introduction – Types- steps – applications: inventory & queuing – Advantages and disadvantages

UNIT- IV:

Integer Programming- Introduction – formulation – Gomory cutting plane algorithm – Zero or one algorithm, branch and bound method

Stochastic Programming:Basic concepts of probability theory, random variables-distributions-mean, variance, correlation, co variance, joint probability distribution. Stochastic linear programming: Chance constrained algorithm.

UNIT- V:

Geometric Programming: Posynomials – Arithmetic - Geometric inequality – unconstrained G.P- constrained G.P(≤ type only)

Non Traditional Optimization Algorithms: Genetics Algorithm-Working Principles, Similarities and Differences between Genetic Algorithm & Traditional Methods. Simulated Annealing- Working Principle-Simple Problems. Introduction to Particle Swarm Optimization(PSO)(very brief)

TEXT BOOKS:

1. Optimization theory & Applications / S.S.Rao / New Age International.
2. Optimization for Engineering Design, Kalyanmoy Deb, PHI

REFERENCE BOOKS:

1) S.D.Sharma / Operations Research
2) Operation Research / H.A.Taha /TMH
3) Optimization in operations research / R.LRardin
4) Optimization Techniques /Benugundu&Chandraputla / Pearson Asia.
5) Optimization Techniques theory and practice / M.C.Joshi, K.M.Moudgalya/ Narosa Publications

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NANO FLUIDS
(Elective-VIII)

Prerequisites: None

Course Objectives:
The course is intended to
- Understanding of superior thermo physical properties of nanofluids
- Understanding of synthesis of nanofluids
- Comparison of heat transfer using nanofluids with conventional fluids
- Understanding of convection and boiling heat transfer
- Research on this new topic to design modern mini and micro channel heat exchangers with nanofluids exhibiting much higher thermal efficiency and saving energy

Course Outcomes:
At the end of the course, the student will be able to:
- To introduce the application of nanotechnology in the area of fluids and thermal engineering

UNIT-I:
Introduction to nanofluids, nanostructure materials, base fluids, dispersion, sonication and stable suspension. Various types of nanofluids-volumetric concentration.Thermophysical properties: Density; principles of measurement and apparatus. Theoretical equations and new empirical correlations to determine the density of different nanofluids. Viscosity: principles of measurement and apparatus. Andrade’s and other theoretical equations and new empirical correlations to determine the viscosity of different nanofluids. Effect of volumetric concentration and temperature. Effect of subzero temperature on nanofluid viscosity.

UNIT-II:
Thermal conductivity: principles of measurement and apparatus. Hamilton-Crosser and other theoretical equations and new empirical correlations to determine the thermalconductivity of different nanofluids. Effect of volumetric concentration and temperature. Effect of Brownian motion on enhancing the thermal conductivity. Specific heat: principles of measurement and apparatus. Buongeorno’s thermal equilibrium equation and other theoretical equationsand new empirical correlations to determine the specific heat of different nanofluids. Effect of volumetric concentration and temperature.

UNIT-III:
Combined effects of thermophysical properties of nanofluids on the thermal diffusivity, the Prandtl number, the Reynolds number and the Nusselt number. Basic understanding of their effects on frictional loss and Heat transfer. Convective heat transfer: Single-phase fluid equations, laminar flow, entry length and fully developed friction factor and heat transfer coefficient. Graetz number effect in the entry region. Correlations for friction factor and Nusselt number for nanofluids. Turbulent flow: Single phase fluid fully developed flow Dittus-Boelter and Glienilski equations. Blasius and other turbulent friction factor correlations.Their comparison with nanofluidsdata. New correlations for turbulent friction factor and Nusselt number for nanofluids.

UNIT-IV:

Principles of measurement and apparatus for the nanofluid convective heat transfer coefficient. Recent empirical relations for convection coefficient of various types of nanofluids. Effect of particle Peclet number. Effect of volumetric concentration. Application of nanofluids to various types of industrial heat exchangers. Heating capacity, mass flow, heat exchanger surface area, LMTD and pumping power for nanofluids versus conventional heat transfer fluids.

UNIT-V:

Application to building heating and cooling Comparison of nanofluids performance with glycol solution in hydronic coils.Application to automobile radiators. Comparison of the performance of nanofluids under arctic and sub-arctic temperatures with glycol solutions. Introduction to electronic cooling in microchannels with nanofluids.

Reference Books:

1. Microscale and Nanoscale Heat Transfer by C. Sobhan and G. Peterson, First edition, CRC Press
2. Fluid Mechanics by F. M. White, 5th Edition, McGraw-Hill
3. Heat Transfer by A. Bejan 2nd Edition, John Wiley
4. Handbook of Nanostructured Materials and Nanotechnology Vol. I and II - H.S.Nalwa, I edition, American Scientific Publishers
5. Springer Handbook of Nanotechnology by Bharat Bhushan, 1st edition, Springer-Verlag Publication

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ADVANCED MATERIALS FOR THERMAL SYSTEMS
(Elective-VIII)

Prerequisites:
Undergraduate in materials science or mechanical engineering, or instructor approval

Course objectives:
The course is intended to

- to identify, design and develop new materials and composites for compact thermal energy storage,
- to develop measuring and testing procedures to characterize new storage materials reliably and reproducibly
- to improve the performance, stability, and cost-effectiveness of new storage materials,
- to develop multi-scale numerical models, describing and predicting the performance of new materials in thermal storage systems,
- to develop and demonstrate novel compact thermal energy storage systems employing the advanced materials
- to assess the impact of new materials on the performance of thermal energy storage in the different applications considered, and
- to disseminate the knowledge and experience acquired in this task

Course Outcomes:
At the end of the course, the student will be able to:

- Successfully apply advanced concepts of materials engineering to the analysis, design and development of materials, devices, systems, and processes to meet desired needs of society professionally and ethically.
- Be continuously aware of contemporary issues and research opportunities/challenges in the field of materials engineering as related to energy and sustainability and engage in life-long learning in the field and in the fundamentals of other related disciplines.
- Use advanced materials characterization techniques, skills, and modern scientific and engineering tools.
- Communicate effectively in written and oral form, both, individually and as a member of a multidisciplinary team.

UNIT – I:
Review of MECHANICAL PROPERTIES: FUNDAMENTALS AND TENSILE, HARDNESS, AND IMPACT TESTING: The Tensile Test: Use of the Stress – Strain Diagram, True Stress and True Strain, The Bend Test for Brittle Materials, Hardness of Materials, Strian Rate effects and Impact Behaviour Heat Treatment of Steels and Cast Irons: Designations and Classification of Steels, Simple Heat treatments, Isothermal Heat treatments, Quench and Temper Heat treatments, Surface treatments, Weldability of Steel. FRACTURE MECHANICS, FATIGUE, AND CREEP BEHAVIOUR: Fracture Mechanics, The Importance of Fracture Mechanics, Microstructural Features of Fracture in Metallic Materials., Microstructural Features of Fracture in Ceramics, Glasses, and Composites, Fatugue, Result of the Fatigue test, Application of Fatigue test, Creep, Stress Ruptur, and Stress Corrosion, Evaluation of creep Behaviour

UNIT-II:

Nuclear Power Plant and Their Materials:Nuclear reactor, pressurised reactor, breeder reactor. Materials for fuel, control rods, coolant, moderator, shielding.Effects of Radiation on Materials Properties: Effects of α,β, γ rays on creep, fatigue, tensile, and other properties of metals, alloys, ceramics, polymers, rubbers etc. Effects on electrical, electronic and magnetic behaviour of materials, Effects on crystal structure, grain size etc.

UNIT-III:

Materials in Fuel cells and Solar Cells Electrocatalyst materials for low temperature fuel cells, Conductive membranes for low-temperature fuel cells, Materials for high temperature fuel cells, silicon, quantum dots for solar energy, nanomaterials for solar thermal energy and photovoltaic.

UNIT-IV:

Materials in Thermal Power Generation Superalloys, steels, ceramics, TBC, hydrogen membrane materials, sensor and sensor materials, biomass, coal, flyash,etc.

UNIT-V:

Energy storage-Artificial photosynthesis/solar to fuels, CO2 separation and utilization, Safer nuclear waste disposal, biofuels production, biological fuel cell technologies, reduction of energy use in manufacturing processes, Improved grid technologies, sustainable energy economy

Reference Books:

1. Introduction to Nuclear Science, Bryan, J. C., CRC Press.
2. Fundamentals of Radiation Materials Science, G.S. Was, Springer
3. Nuclear Reactor Materials and Applications, B.M. Ma, Van Nostrand Reinhold Company.
4. Nuclear Reactor Materials, C.O. Smith, Addison-Wesley Publishing Company.
5. Fundamentals Aspects of Nuclear Fuel Elements, D.R. Olander,
6. Structural Materials in Nuclear Power Systems, J. T. A. Roberts, Plenum Press.
7. Handbook of Fuel Cells, Wolf Vielstich, Arnold Lamm, Hubert A. Gasteiger, and Harumi Yokokawa, John Wiley and Sons, Inc.
8. Advanced power plant materials, design and technology, Edited by D Roddy, Woodhead Publishing Series in Energy No. 5 and CRC Press.

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COMPUTATIONAL METHODS LABORATARY

Prerequisites: None

Course Objectives:
The lab is mainly intended to
- Familiarize the usage of CFD software package
- Reduce the time for solving different fluid flow problems.
- Model the heat transfer problems where fluid flow is present in CFD software package such as ansys and gambit.
- Analyze the different thermal systems for variable fluid flow properties such as mass flow rate, Reynolds number etc
- Analyze the thermal systems under different flow conditions such as turbulent flow etc
- Correlating the results obtained using different software with theoretical knowledge.
- Identify the critical situation where the fluid flow can affect the thermal system.

Course Outcomes:
At the end of the course, the student will be able to:
- Formulate problems in fluid flow and heat transfer.
- Develop codes for numerical methods to solve 1D and 2D heat conduction and convection problems.
- Use commercial software ANSYS for solving real life engineering problems.

C programming for problem solving.

Solving Thermal Engineering problems using available packages such as T K Solver, ANSYS, CFX, STARCD, MATLAB, FLUENT etc…

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SEMINAR

Prerequisites: None

Course Objectives: None

Course Outcomes:
At the end of the course, the student will be able to:
- Identify and compare technical and practical issues related to the area of course specialization.
- Outline annotated bibliography of research demonstrating scholarly skills.
- Prepare a well organized report employing elements of technical writing and critical thinking
- Demonstrate the ability to describe, interpret and analyze technical issues and develop competence in presenting.

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COMPREHENSIVE VIVA – VOCE

Prerequisites: None

Course Objectives: None

Course Outcomes:
- Comprehend the knowledge gained in the course work
- Infer principles of working of thermal energy systems
- Demonstrate the ability in problem solving and to communicate effectively

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PROJECT PHASE-I

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Prerequisites: None

COURSE OBJECTIVES:
- To Get adequate knowledge about research concepts
- To describe mathematical modeling and simulation
- To understand experimental modeling
- To get knowledge about the interpretation of result

Course Outcomes:
- Identify a topic in advanced areas of thermal engineering
- Review literature to identify gaps and define objectives & scope of the work
- Employ the ideas from literature and develop research methodology
- Develop a model, experimental set-up and / or computational techniques necessary to meet the objectives.

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PROJECT PHASE-II & DISSERTATION

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Prerequisites: None

COURSE OBJECTIVES:

- To describe research concepts.
- To Get adequate knowledge about mathematical modeling
- To describe experimental modeling
- To understand analysis of results.
- To know about report writing

Course Outcomes:

- Identify methods and materials to carry out experiments/develop code
- Reorganize the procedures with a concern for society, environment and ethics
- Analyze and discuss the results to draw valid conclusions
- Prepare a report as per the recommended format and defend the work.
- Explore the possibility of publishing papers in peer reviewed journals/conference proceedings.