Biju Patnaik University of Technology, Orissa Rourkela

M.Tech Syllabus in Thermal Engg. / Heat Power Engg.

Semester I			
Professional core :	3 subjects	12 credits	(4 credits each)
Elective:	2 subjects	6 credits	(3 credits each)
Sessionals/ Laboratory:	1 or 2 nos.	4 credits	
Pre-thesis work and seminar		2 credits	
	Total	**24 credits**	
Semester II			
Professional core :	2 subjects	8 credits	(4 credits each)
Elective:	3 subjects	9 credits	(3 credits each)
Sessionals/ Laboratory :	1 or 2 nos.	4 credits	
Pre-thesis work and seminar		2 credits	
Comprehensive viva voce I		2 credits	
	Total	**25 credits**	
Semester III			
Thesis part I		14 credits	
Open elective		3 credits	
	Total	**17 credits**	
Semester IV			
Thesis part II		20 credits	
Seminar		2 credits	
Comprehensive viva voce II		2 credits	
	Total	**24 credits**	
	Total	**90 credits**	

M.Tech in Thermal Engineering / Heat Power Engineering

Semester 1

Sl. No.	Subject	L – T – P	Credits
HTPC101	Advanced Fluid Mechanics	3 – 1 – 0	4
HTPC102	Advanced Heat Transfer – I (Conduction & Radiation)	3 – 1 – 0	4
HTPC103	Advanced Refrigeration Engineering	3 – 1 – 0	4
	Elective – I (*Any One*):	3 – 0 – 0	3
HTPE101	Internal Combustion Engines		
HTPE102	Energy Conservation and Management		
HTPE103	Gas Dynamics		
HTPE104	Hydel Power and Wind Energy		
	Elective – II(*Any One*):	3 – 0 – 0	3
HTPE105	Solar Energy Technology		
HTPE106	Thermal and Nuclear Power Plants		
HTPE107	Renewable Energy Systems		
HTPE108	Design of Thermal Systems		
Sessionals / Practicals			
HTPR101	Engineering Software Laboratory	0 – 0 – 3	2
HTPR102	Thermal Engineering Laboratory	0 – 0 – 3	2
HTPT101	Pre-thesis work and seminar		2
		Total credit	**24**

Semester 2

Sl. No.	Subject	L – T – P	Credits
Professional Core			
HTPC201	Advanced Engineering Thermodynamics	3 – 1 – 0	4
HTPC202	Advanced Heat Transfer – II (Convective Heat and Mass Transfer)	3 – 1 – 0	4
	Elective – III(*Any One*):	3 – 0 – 0	3
HTPE201	Computational Fluid Dynamics		
HTPE202	Computational Methods in Thermal Engineering		
HTPE203	Experimental Methods in Thermal Engineering		
HTPE204	Heat Exchanger Analysis and Design		
	Elective – IV (*Any One*):	3 – 0 – 0	3
HTPE205	Theory of Combustion and Emission		
HTPE206	Air Conditioning and Ventilation Systems		
HTPE207	Gas Turbine and Jet Propulsion		
HTPE208	Boiling, Condensation and Two-phase Flow		
	Elective – V (*Any One*):	3 – 0 – 0	3
HTPE209	Cryogenic Technology		
HTPE210	Aircraft and Rocket Propulsion		
HTPE211	Power Plant Practice and Control		
HTPE212	Finite Element Methods in Thermal Engineering		
Sessionals			
HTPR201	Advanced Thermal Engg and Measurement Laboratory	0 – 0 – 3	2
	Elective Laboratory	0 – 0 – 3	2
HTPT201	Pre-thesis work and seminar		2
HTCV201	Comprehensive Viva-Voce I		2
		Total credit	**25**

Semester 3

Sl. No.	Subject	Contact Hours L – T – P	Credits
1.	**Open Elective (Any one)** Research Methodology Design of Experiments Project Management and Costing Quality System Design Soft Computing	3 – 0 – 0	3
1.	Thesis Part I		14
			17

Semester 4

Sl. No.	Subject	Contact Hours L – T – P	Credits
HTPT401	Thesis Part II (Presentation and Evaluation)		20
HTCV401	Seminar		2
HTCV402	Comprehensive Viva-Voce II		2
			24

Total Credits: 90

Advanced Fluid Mechanics

Module I

Concept of continuum and definition of a fluid. Body and surface forces, stress tensor, Scalar and vector fields, Eulerian and Lagrangian description of flow. Motion of fluid element - translation, rotation and vorticity; strain rate tensor, continuity equation, stream function and velocity potential.

Module II

Transport theorems, constitutive equations, derivation of Navier Stokes equations for compressible flow. Exact solutions of Navier Stokes equations : plane Poiseuille flow and Couette flow, Hagen-Poiseuille flow, flow between two concentric rotating cylinders, Stoke's first and second problem, Hiemenz flow, flow near a rotating disk, flow in convergent- divergent channels. Slow viscous flow : Stokes and Oseen's approximation,

Module III

Theory of hydrodynamic lubrication. Boundary layer : derivation, exact solutions, Blasius, Falkner Skan, series solution and numerical solutions. Approximate methods. Momentum integral method. Two dimensional and axisymmetric jets. Description of turbulent flow, velocity correlations, Reynold's stresses, Prandtl's Mixing Length Theory, Karman's velocity defect law, universal velocity distribution.

Books:

Advanced Fluid Mechanics, Som and Biswas, Tata McGraw Hill

Fluid Mechanics, A.K.Mohanty

Fundamentals of Fluid Mechanics, Schlitching

Introduction to Fluid Mechanics, Shaughnessy, Oxford University Press

Advanced Heat Transfer–I (Conduction & Radiation)

Module I

Conduction; Derivation of generalized conduction equation for anisotropic inhomogeneous solids, conductive tensor, concepts of isotropic and homogeneous conductivity. ; Steady state conduction: Recapitulation of fundamentals analysis and design variable and cross section and circumferential fins. Analysis of heat conduction in 2-D fins, 2-D and 3-D conduction in solids with complex boundary conditions and heat generation. ;

Module II

Transient conduction: Recapitulation of transient conduction in simple systems. Analysis of transient heat conduction with complex boundary. ; Application of Duhamel's theorem and Special topics: Use of lap- lace transformation in linear conduction problems. The use of green function in the solution of the equations of conduction. ; Numerical methods: Fundamentals of discrimination treatment of boundary conditions, on linearity of properties, anisotropy and complex boundaries.

Module III

Radiation ; Recapitulation of fundamentals of radiative heat transfer, radiative properties of surfaces, methods of estimating configuration factors, heat exchange between diffusively emitting and diffusively reflecting surfaces. Radiant energy transfer through absorbing, emitting and scattering media. Combined conduction and radiation systems: fins, Introduction to solar radiation in earth's atmosphere.

Books

V.S Arpaci – *Conduction Heat Transfer*
E.M Sparrow, R.D Cess – *Radiation Heat Transf*
R.Siegal and J.R Howell-*Thermal radiation heat transfer*.
Y.A.Sengel, Heat Transfer, Tata McGrawHill
Krith, Fundamentals of Heat Transfer
Ozisik, Heat Transfer, John Wiley

Advanced Refrigeration Engineering

Module I

Analysis of refrigeration cycle, principles of psychrometry properties and processes, Air washer, Cooling towers, dehumidifiers, wet bulb and dew point temperatures. Multistage cycle and their optimization.

Module II

Thermodynamic Properties of pure and mixed refrigerants. Eco-friendly Refrigerants, vapour absorption cycle and its components. Ejector Refrigeration System, Vortex Tubes, Principle of liquefaction of gases, Dry ice manufacture, Magnetic Refrigeration Sysem

Module III

Analysis and thermal design of Refrigeration compressor, condenser, evaporator and flow control devices; Design, Lubrication, charging and testing of refrigeration plants, defrosting capacity control, system component balancing, Design and construction details of unitary refrigeration equipment.

Books

Refrigeration and Air Conditioning, C.P.Arora, Tata McGraw Hill

Refrigeration and Air Conditioning, Stoecker and Zones, McGraw Hill

Refrigeration and Air Conditioning, Domkundwar and Arora, Dhanpat Rai and Sons

Refrigeration and Air Conditioning, Manohar Prasad, East West Press

Refrigeration and Air Conditioning, P.L.Balaney

Elective - I

Internal Combustion Engines

Module I

Thermodynamic Analysis of I.C.Engine Cycles. Effect of design and operating parameters on cycle efficiency. Modified fuel-air cycle considering heat losses and valve timing. Engine dynamics and torque analysis. Use of Combustion chart . Thermodynamic cycle with supercharging both S.I. and C.I. Engines. Limits of Supercharging. Methods of Supercharging and Superchargers.

Module II

Fuels and combustion in S.I. engines, knocking and fuel rating. Energy balance, volumetric efficiency, measurement of indicated and brake power. Advanced theory of carburetion. Fuel Injection Systems for S.I. and C.I. Engines. Cooling of engine and governing of engine. Ignition system : conventional and electronic.

Module III

Variable compression ratio engine. Theoretical analysis, methods of obtaining variable compression ratio, Wankel rotary combustion engine, Stratified charged engine, Methods of charge stratification, Dual fuel and Multifuel engines, Biofuels, Variable Valve timing engines, Exhaust emissions, its measurement and control. Fault diagnosis of S.I. Engines.

Books

Fundamentals of I.C. Engines by H.B.Heywood, McGraw Hill

I.C.Engine Theory and Practices, Vol.I & II C.F.Taylor, MIT Press

I.C.Engine, Mathur and Sharma, Dhanpat Rai and Sons

Fundamentals of I.C.Engine by Ganeshan, Tata McGraw Hill

Energy Conservation and Management

Module I

Significance and Scope of Energy conservation and Management, Basic principles and total energy concept, First law optimization, availability. Exergy analysis. Second law optimization of thermal systems.

Module II

Energy audits and conservation programme, elements of energy accounting. Plant energy studies : concepts, resources, procedures and implementation. Energy accounting indices, energy budget and variance analysis- statistical and engineering models. Economic aspects, payback. Waste Heat recovery; high, medium and low temperature applications, Methods of energy conservation in domestic and industrial sectors; case studies

Module III

Energy sources, Classification and characterization of fuels (fossil and bio-fuel), conversion and utilization, environmental and economic issues, optimum use of energy resources, Thermodynamic cycles, Principles of thermal energy conversion in boilers, internal combustion engines and gas turbines, cogeneration and combined cycle power generation, fuel cells and MHD technology, solar, wind and nuclear power, utilization of industrial heat, Energy management in industry, Environmental and economic evaluation advanced pollution control technology.

Book

R. Gold Stick and A. Thumann, Principles of Waste Heat Recovery, PHI, 1986.

D. Y. Goswami, F. Kreith, Energy Conversion- CRC Press, 2007

V. Kadambi, and M. Prasad, Introduction to energy conversion turbo machinery: Energy conversion cycle- Wiley Eastern, New Delhi, 1974,

Gas Dynamics

Module I:
Fundamental Aspects of Gas Dynamics: Introduction, Isentropic flow in a stream tube, speed of sound, Mach waves; One dimensional Isentropic Flow: Governing equations, stagnation conditions, critical conditions, maximum discharge velocity, isentropic relations ; Normal Shock Waves: Shock waves, stationary normal shock waves, normal shock wave relations in terms of Mach number;

Module II:
Oblique Shock Waves: Oblique shock wave relations, reflection of oblique shock waves, interaction of oblique shock waves, conical shock waves; Expansion Waves: Prandtl-Meyer flow, reflection and interaction of expansion waves, flow over bodies involving shock and expansion waves ; Variable Area Flow: Equations for variable area flow, operating characteristics of nozzles, convergent-divergent supersonic diffusers ; Adaiabatic Flow in a Duct with Friction: Flow in a constant area duct, friction factor variations, the Fanno line ;

Module III:
Flow with Heat addition or removal: One-dimensional flow in a constant area duct neglecting viscosity, variable area flow with heat addition, one-dimensional constant area flow with both heat exchanger and friction ; Generalized Quasi-One-Dimensional Flow: Governing equations and influence coefficients, solution procedure for generalized flow with and without sonic point ; Two-Dimensional Compressible Flow: Governing equations, vorticity considerations, the velocity potential, linearized solutions, linearized subsonic flow, linearized supersonic flow, method of characteristics.

Text Books
L. D. Landau and E. M. Lifshitz, Fluid Mechanics. 2nd ed., Butterworth-Heinemann, 1995.
H. W. Liepmann, and A. Roshko, Elements of Gas Dynamics, Dover Pub, 2001.

References
P. H. Oosthuizen and W. E. Carscallen. Compressible Fluid Flow. NY, McGraw-Hill, 1997.
M. A. Saad, Compressible Fluid Flow. 2nd ed. Upper Saddle River, NJ: Prentice-Hall, 1993.
F. M. White, Viscous Fluid Flow. 2nd ed. New York: McGraw-Hill, 1991.
A. H. Shapiro, Compressible Fluid Flow 1 and 2. Hoboken NJ: John Wiley.

Hydel Power and Wind Energy

Module I:
Elements of hydropower scheme, hydropower development in India. Power house structures and Layout. Hydropower plants classification: Surface and underground power stations, Low- medium-high head plants-layout and components, pumped storage plants. Load and power studies: load curve, load factor, load duration curve, firm capacity, reservoir capacity, capacity factor

Module II:
Hydraulic turbines and types and classification, constructional features, selection, characteristic curves, governing of turbine, drafts tubes-types, hydraulic principles. Gates and valves types. Penstock and surge tanks.
Wind machine types, classification, parameters. Wind measurements, data presentation, power in the wind. Wind turbine aerodynamics, momentum theories, basic aerodynamics, airfoils and their characteristics

Module III:
Horizontal Axis Wind Turbine (HAWT) - Blade Element Theory, wake analysis, Vertical Axis Wind Turbine (VAWT) aerodynamics.
HAWT rotor design considerations, number of blades, blade profile, 2/3 blades and teetering, coning, power regulation, yaw system, tower.
Wind turbine loads, aerodynamic loads in steady operation, wind turbulence, static - dynamic - fatigue analysis, yawed operation and tower shadow, WECS control system, requirements and strategies.
Wind Energy Conversion System (WECS) siting, rotor selection, Annual Energy Output (AEO).
Synchronous and asynchronous generators and loads, integration of wind energy converters to electrical networks, inverters. Testing of WECS.

Text Books

Water Power Engineering: M.M.Desmukh, Dhanpat rai and Sons
Wind Energy Conversion Systems, Freris L.L., Prentice Hall 1990.

Reference Books

Water power Development : Mosonyi
Hydroelectric hand book: Creagar, W.P. and Justin, J.D., John Wiley & Sons,New York.
Davis' Handbook of applied hydraulics : Zipparro, V. J. and Hasen H., Mc-GrawHill, Inc.,
Hydropower structures : R.S.Varshiray, Nem Chand and Bros. Roorkee
Water Power Engineering: M.M.Dandekar and K.N.Sharma, Vikas Pub
Spera D.A., Wind Turbine Technology: Fundamental Concepts of Wind Turbine Engineering, ASME Press, NY 1994.
Johnson, G.L., Wind Energy Systems, Prentice Hall, 1985.

Elective II

Solar Energy Technology

Module I

Current alternate energy sources-thermodynamic view point and conversion methods. Components of solar energy systems, collector performance. Radiation and meteorological data processing, long term conversion factors. System configurations and system performance prediction.

Module II

Simulations, design methods. System design and optimizations. Solar thermal systems applications to power generation, heating and cooling.

Module III

Solar passive devices solar stills, ponds, greenhouse, dryers. Trombe wall, overhangs and winged walls. Wind energy conversion systems. Economics of solar and wind energy systems.

Text Books

S. P. Sukhatme, Solar Energy - Principles of thermal collection and storage, second edition, Tata McGraw-Hill, New Delhi, 1996

J. A. Duffie and W. A. Beckman, Solar Engineering of Thermal Processes, second edition, John Wiley, New York, 1991

References

D. Y. Goswami, F. Kreith and J. F. Kreider, Principles of Solar Engineering, Taylor and Francis, Philadelphia, 2000

D. D. Hall and R. P. Grover, Biomass Regenerable Energy, John Wiley, New York, 1987.

J. Twidell and T. Weir, Renewable Energy Resources, E & F N Spon Ltd, London, 1986.

Thermal and Nuclear Power Plants

Module I :
Energy scenario. Overview of steam power plant. Analysis of steam cycles. Feedwater heaters. Deaerator and drain cooler. Optimization of cycle parameters, reheat and regeneration. Analysis of multi-fluid coupled cycles. Cogeneration of powerand process heat. Combined cycle power generation. Fuels. Combustion mechanisms. Draft systems. Combustion control. Furnaces for burning coal in fluidized beds and in pulverized form. Coal handling installation.

Moddule II :
Different types of boilers and their specific uses. Boiler mountings and accessories. Feedwater treatment. Boiler maintenance. Circulation theory. Downcomers and risers. Drum and its internals. Economiser. Convective and radiant super heaters. Superheat temperature control. Recuperative and regenerative air preheaters. Dust and ash removal systems. Environmental aspects of power generation

Module III :
Basic concepts of reactor physics, radioactivity. Neutron Scattering. Thermal and fast reactors. Nuclear cross-sections. Neutron flux and reaction rates. Moderator criteria. Reactor core design. Conversion and breeding. Types of reactors. Characteristics of boiling water, pressurized water, pressurized heavy water, gas cooled and liquid metal cooled reactors. Future trends in reactor design and operation. Thermal-hydraulics of reactors. Heavy water management. Containment system for nuclear reactor. Reactor safety radiation shields. Waste management. Indian nuclear power programme.

Text Book:

M.M.EI. Wakil., ‗*Nuclear Power Engineering'*, McGraw Hill Book Company, New York, 1987.

2. S. Glasstone and A. Setonske., ‗*Nuclear Reactors, Engineering*', 3rd Ed., CBS Publishers and Distributors, 1992.

Reference

Loftness, ‗*Nuclear Power Plants'*, D. Van Nostrand Company Inc, Princeton, 1964.

S. Sarg et al., ‗*Physics of Nuclear Reactors'*, Tata McGraw Hill Publishing Company Ltd., 1985.

T. J. Connoly., ‗*Fundamentals of Nuclear Energy'*, John Wiley, 1978.

Renewable Energy Systems

Module I

Energy scenario and renewable energy sources : global and Indian situation. Potential of non-conventional energy sources, economics. Solar Radiation: Solar thermal process, heat transfer devices, solar radiation measurement, estimation of average solar radiation. Solar energy storage: stratified storage, well mixed storage, comparison.

Module II

Hot water system, practical consideration, solar ponds, Non-convective solar pond, extraction of thermal energy and application of solar ponds. Wind energy: The nature of wind. Wind energy resources and modeling. Geothermal energy: Origin and types of geothermal energy and utilization.

Module III

OTEC: Ocean temperature differences. OTEC systems. Recent OTEC developments. Wave energy: Fundamentals. Availability Wave-energy conversion systems. Tidal energy: Fundamentals. Availability Tidal-energy conversion systems. ; Energy from biomass: Photosynthesis; Biomass resource; Utilisation of biomass.

Books

S.P.Sukhatme, ‗Solar Energy Principle of Thermal Collection and Storage', Tata McGraw Hill, 1990.
G.L. Johnson, Wind energy systems, Prentice Hall Inc. New Jersey.
J.M.Kriender, ‗Principles of Solar Engineering', McGraw Hill, 1987.

Reference

V.S. Mangal, ‗Solar Engineering', Tata McGraw Hill, 1992.
N.K.Bansal, ‗Renewable Energy Source and Conversion Technology', Tata McGraw Hill, 1989.
P.J. Lunde., ‗Solar Thermal Engineering', John Willey & Sons, New York, 1988.
J.A. Duffie, and W.A. Beckman, ‗Solar Engineering of Thermal Processes', Wiley & Sons, 1990.

Design of Thermal Systems

Module I
Modeling of Thermal Systems: types of models, mathematical modeling, curve fitting, linear algebraic systems, numerical model for a system, system simulation, methods for numerical simulation;

Module II
Acceptable Design of a Thermal System: initial design, design strategies, design of systems from different application areas, additional considerations for large practical systems; Economic Considerations: calculation of interest, worth of money as a function of time, series of payments, raising capital, taxes, economic factor in design, application to thermal systems;

Module III
Problem Formulation for Optimization: optimization methods, optimization of thermal systems, practical aspects in optimal design, Lagrange multipliers, optimization of constrained and unconstrained problems, applicability to thermal systems; search methods: single-variable problem, multivariable constrained optimization, examples of thermal systems; geometric, linear, and dynamic programming and other methods for optimization, knowledge-based design and additional considerations, professional ethics.

Text Books

W.F. Stoecker, Design of Thermal Systems - McGraw-Hill, 1971

References

Y. Jaluria, Design and Optimization of Thermal Systems –CRC Press, 2007.

Bejan, G. Tsatsaronis, M.J. Moran, Thermal Design and Optimization - Wiley, 1996.

R. F. Boehm, Developments in the Design of Thermal Systems - Cambridge University Press, 1997.

N.V. Suryanarayana, Design & Simulation of Thermal Systems - MGH, 2002.

2nd Semester

Advanced Thermodynamics

Review of Basics: First law and Second law analysis – concept of entropy – principle of increase of entropy – entropy generation – Availability – concept of exergy – exergy analysis of combustion processes. Helm Holtz function – Gibb‘s function – OnSagar reciprocity relation. Thermodynamic relations, Maxwell‘s relations, T-ds equations – specific heat relations – energy equation – Joule Thomson effect – Clausius Claperyon Equation. Criteria for Equilibrium – Gibb‘s phase rule – Conditions for stability. Compressibility factor, fugacity and activity, computation from the generalized charts, dependence of fugacity and activity on pressure and temperature, chemical – equilibrium. Phase rule – ideal and real solution of gases, liquids, equilibrium system. Statistical Thermodynamics: Thermodynamics probability, Maxwell statistics, Fermi Dirac and Bose – Einstein statistics, Entropy and probability, Degeneracy of energy levels, Partition functions. Kinetic Theory of Gases: Perfect gas model, Distribution of translational velocities distribution function, molecular collisions and mean free path, equipartition of energy.

Essential Readings:

1. A.S. Michael, *‘Thermodynamic for Engineers’*, Prentice Hall, 1972.
2. P.K. Nag., *‘Engineering Thermodynamics’*, II Ed., McGraw Hill, 1995.

Supplementary Reading:

1. G.J. Van Wylen & R.E. Sonntag., *‘Fundamentals of Classical Thermodynamics’*, Willy Eastern Ltd. 1989 (Unit I, II & III)
2. J.P. Holman., *‘Thermodynamics’*, 4th Ed., McGraw Hill, 1988.
3. J. Hsieg, *‘Principles of Thermodynamics’*, McGraw Hill, 1978.
4. Lee and Sears, *‘Statistical Thermodynamics’*, Addition Wesley, 1976.
5. V. Nastrand, S. Glasstne., *‗Thermodynamics for Chemists’*, 1974.
6. M.D. Burghardt, *‘Engineering Thermodynamics for Engineers’*, Harper and Row, NY, 1987.
7. K. Wark, *‘Advanced Thermodynamics for Engineers’*, McGraw Hill, NY, 1987.
8. K. Smith, H.C. Van Ness, *Introduction to Chemical Engineering Thermodynamics*. McGraw Hill, 1987.

Advanced Heat Transfer-II (Convective Heat & Mass Transfer)

Convection: Energy equation – thermal boundary layer. Forced convection – Practical correlations –flow over surfaces – internal flow. Natural convection, combined forced and free convection combined convection and radiation in flows. ; Boiling and Condensation: Boiling – Pool and flow boiling, correlations. Condensation – modes and mechanisms – correlations and problems. Heat Exchangers: Heat Exchanger and Mass Transfer -Heat exchanger: types – LMTD method and the effectiveness – NTU method. Mass Transfer: types – Fick's law of diffusion – mass diffusion equation, Equimolar counter diffusion – convective mass transfer. Evaporation of water into air.

Essential Readings:

1. J.P. Holman., *'Heat and Mass Transfer'*, Tata McGraw Hill, 8th Ed., 1989.
2. D.D. Kern, *'Extended Surface Heat Transfer'*, New Age International Ltd., 1985.

Supplementary Reading:

1. F.P. Incropera and D. P. Dewit, ‗*Fundamentals of Heat and Mass Transfer'*, 4th Ed., John
2. Wiley & Sons, 1998.
3. C.P. Kothandaraman., ‗*Fundamentals of Heat and Mass Transfer'*, 2nd Ed., New Age International, 1997.
4. E.R.D Eckert and R.M. Drake, ‗*Analysis of Heat and Mass Transfer'*, McGraw Hill, 1980.
5. Kays, W.M. and Crawford W., ‗*Convective Heat and Mass Transfer'*, McGraw Hill Inc., 1993.
6. Burmister L.C., *'Convective Heat Transfer'*, John Willey and Sons, 1983.

Electives –III (Any One)

Computational Fluid Dynamics

Introduction: Basic tools of CFD, Numerical Vs experimental tools. ; Mathematical Behavior of PDEs: Parabolic, Hyperbolic and Elliptic PDEs. ; Methodology of CFDHT: Discrete representation of flow and heat transfer domain: Grid generation, Governing equations and boundary conditions based on FVM/FDM, Solution of resulting set of linear algebraic equations, Graphical representation and analysis of qualitative results, Error analysis in discretization using FVM/FDM. ; Solution of 1-D/2-D steady/unsteady: Diffusion problems, Convection problems, Convection-diffusion problems, source term linearization. ; Explicit and Implicit Approach: Explicit and implicit formulation of unsteady problems, Stability analysis. ; Solution of Navier-Stokes Equations for Incompressible Flows: Staggered and collocated grid system, SIMPLE and SIMPLER algorithms. ; Special Topics in CFDHT: Numerical Methodology for Complex Geometry, Multi-block structured grid system, Solution of phase change Problems.

Essential Reading:

1. S.V. Patankar, *Numerical Heat Transfer and Fluid Flow*, Taylor and Francis, ISBN-10: 0891165223.

Supplementary Reading:

1. H. K. Versteeg and W. Malalasekra, *Introduction to Computational Fluid Dynamics: The Finite Volume Method,* Prentice Hall (2nd Edition), ISBN-10: 0131274988.
2. Jr. D. A. Anderson, *Computational Fluid Mechanics and Heat Transfer* by McGraw-Hill Education
3. M. N. Ozisik, *Finite Difference Method,* CRC (1st Edition).

Computational Methods in Thermal Engineering

Introduction: Concepts of consistency, stability, and convergence of numerical schemes. Various finite difference and finite element methods and their applications to fundamental partial differential equations in engineering and applied sciences. Case studies selected from fluid mechanics and heat transfer. ; Finite Difference Method: Classification, Initial and Boundary conditions, Forward, Backward difference, Uniform and non-uniform Grids, Grid Independence Test. Basic finite difference schemes. Boundary treatments. Fourth order RK methods and Predictor-corrector methods and Nachsheim-Swigert iteration with applications to flow and heat transfer. ; Parabolic and hyperbolic problems: Model problems and stability estimates. Examples of the methods of lines. The Lax-Richtmyer equivalence theorem. Stability analysis. Discrete Fourier series. Von- Neumann stability analysis. Consistency, convergence and error estimates. Keller Box and Smith‘s method with applications to thermal boundary layers. ; Convection dominated problems: The failure of standard discretization, Upwinding and Higher order methods.

Supplementary Reading(s):

1. K.Muralidhar and T.Sundararajan, "*Computational Fluid Flow and Heat Transfer*", Narosa Publishing House ,New Delhi1995.
2. P.S., Ghoshdasdidar, *"Computer Simulation of flow and heat transfer"* TMH Ltd., 1998.
3. S.V. Patankar, "*Numerical heat transfer fluid flow*", Hemisphere Publishing Co, 1980.
4. D.A. Anderson, I.I. Tannehill, and R.H. Pletcher, *Computational Fluid Mechanics and Heat Transfer*, Hemishphere Publishing Corporation, New York, USA, 1984.
5. C.A.J. Fletcher, ,"*Computational Techniques for Fluid Dynamics*
6. *Fundamental and General Techniques*, Springer-Verlag,1987.
7. T.K. Bose, "*Numerical Fluid Dynamics*" Narosa Publishing House, 1997.
8. T.K. Sengupta, *Fundamentals of Fluid Dynamics*, University Press, Hyderabad.

Heat Exchange Analysis & Design

Constructional Details: Types, Fluid flow arrangements, parallel, counter and cross flow, shell and tube heat exchanger, Regenerators and recuperator. Condensers – Industrial applications. ; Heat Transfer: Modes of Heat Transfer, Overall heat transfer coefficient, Thermal resistance, Efficiency. Temperature Distribution and its implications, LMTD, effectiveness ; Flow Distribution: Effect of Turbulence, Friction Factor, Pressure Loss, Orifice, Flow nozzle, Diffusers, Bends, Baffles, Effect of Channei Divergence, Manifolds. ; Stress in tubes, Headers sets and Pressure vessels: Differential Thermal Expansion, Thermal stresses, Shear stresses, Thermal sleeves, Vibration, Noise, types of failures. ; Design Aspects: Heat transfer and pressure loss flow configuration effect of baffles. Effect of deviations from ideality. Design of typical liquid-liquid, gas-gas-liquid heat exchangers. Design of cooling towers.

Essential Reading:

1. W.M. Kays and A.L. London., ‗*Compact Heat Exchangers'*, 3rd Ed., TMH,1984.
2. A.P. Frass and M.N.Ozisik, *Heat Exchanger Design'*,John Wiley & Sons Inc, 1965.
3. G.Wlker, ‗*Industrial Heat Exchangers'*, A basic guide, TMH V Book Co., 1980.

Supplementary Reading:

1. *'Standards of the Turbular Exchanger Manufacturer Association'*, 6th Ed., Tubular Exchanger Manufacturers Association, New York, 1978.
2. D. Q Kern, ‗*Process Heat Transfer'*, McGraw Hill Book Co., 1984.
3. E.A.D. Saunders., ‗*Heat Exchangers'*, Longman Scientific and Technical, New York, 1988.

Electives –IV (Any One)

Theory of Combustion & Emission

UNIT 1.CYCLE ANALYSIS ; Gas, steam and combined power cycles, refrigeration and air conditioning cycles, second law analysis.

UNIT 2.COMBUSTION THEORY ; Fuels and types, combustion process, combustion mechanism, adiabatic flame temperature, flame propagation, stability, kinetics, combustion aerodynamics, gaseous detonations, flame ignition and extinction and condensed phase combustion, combustion in SI and CI engines, ignition and burning rate analysis.

UNIT 3.COMBUSTION SYSTEMS ; Solid burning equipments, stokers, pulverized coal burning systems, cyclone combustors, emissions, types of fluidized beds, fluidized bed combustion, fundamentals bubbling bed, gas and liquid burners types, gas turbine combustion systems, combustion modeling

UNIT 4.DESIGN OF COMBUSTION SYSTEMS ; Design of combustion systems for boilers, furnaces, gas turbines and internal combustion engines, combustion chamber performance.

UNIT 5.PROPELLANT SYSTEMS; Types, theory of combustion, energy balance calculations

Supplementary Reading(s):

1. C.R. Ferguson and A.T. Kirk Patrick, —*Internal Combustion Engines* , John Wiley & Sons. Inc. 2001.
2. Stephen R Turns, —*Introduction to Combustion: Concepts and Applications* , McGraw Hill, 2000
3. G.L. Borman and K.N. Ragland, —*Combustion Engineering* , McGraw Hill, 1998.
4. D.Winterbone, —Advanced Thermodynamics for Engineers , Elsevier, 1996

Air Conditioning & Ventilation Systems

Psychrometry: simple psychometrics processes, use of psychometrics chart. ; Summer Air –conditioning, Winter Air-Conditioning, Comfort and industrial air conditioning ; Design Conditions, ventilation loads, Comfort air-Conditioning, Physiological factors. Comfort index. Load Estimation, Applied Psychrometrics Air conditioning systems: Spray systems, chilled water and DE Coils, absorption and adsorption systems. Humidifiers. ; Principles of ventilation. Air filtration, Air conveying Fans, ducts and air diffusion equipment. Estimation of air conditioning load, determination of supply state. Design and constructional details of Unitary air conditioning equipment. ; Noise level and acoustic control. Automatic controls in air conditioning.

Supplementary Reading(s):

1. W.F. Stoecker, and J.W. Jones, *Refrigeration and Air Conditioning*, 2nd Edition, Tata McGraw Hill, New Delhi 1982.
2. *ASHRAE Handbook- Fundamentals, American Society of Heating, Refrigerating and Air-Conditioning Engineers Inc*., Atlanta, USA, 1997.
3. W.R Haines and C.L Wilson, *HVAC Systems Design Handbook*, McGraw Hill, 2nd Ed., New Delhi, 1994.
4. R.C Legg, *Air Conditioning Systems - Design, Commissioning and maintenance*, Batsford Ltd, London 1991.

Gas Turbine & Jet Propulsion

Introduction, application, shaft power gas dynamics – Compressibility effect, steady one dimensional compressible flow of a perfect gas in a duct, isentropic flow in a constant area duct with friction, normal shock waves, oblique shock wave, isentropic two dimensional, supersonic expansion and compression. ; Centrifugal fans Blowers and Compressors: Principle of operations, work done and pressure rise, slip factor, diffusers, compressibility effects, non dimensional qualities for plotting compressor characteristics. Bray ton cycle, regeneration and reheating cycle analysis ; Axial flow fans and compressors: Elementary theory, degree of reaction, three dimensional flow, simple design methods, blade design, calculation of stage performance, overall performance, and compressibility effects. Performance characteristics. ; Combustion system: Form of combustion, important factors affecting combustion chamber design, combustion processes, combustion chamber performance, practical problem. ; Axial flow turbines: elementary theory, vortex theory, choice of blade profile, pitch and chord ; estimation of stage performance, he cooled turbine. ; Prediction of performance of simple gas turbines: component characteristic, off design shaft gas turbine, equilibrium running gas generators, off design o free turbine and jet engine, methods of displacing the equilibrium, running line, incorporation of variable pressure losses, methods of improving part load performance, matching procedure for twin spool engines, behavior of gas turbine .Gas turbine rotors and stresses.

Supplementary Reading:

1. J.E Lee, *Theory and design of stream and gas turbine*.
2. Cohen & Rogers, *Gas Turbines*

Cryogenic Technology

Introduction: Cryogenic heat transfer applications, Material Properties at cryogenic temperatures, specific heats and thermal conductivity of solid, liquid and gases, Cryogenic insulations, gas-filled and evacuated powders and fibrous materials, microsphere and multi-layer insulations. ; Conduction: One-dimensional steady-state and transient conduction, conduction in composite materials, thermal contact resistance, cool-down in coated surfaces and fluid-storage vessels. ; Convection: Free and forced convection over external surfaces and tubes, Heat transfer in nearcritical region and its correlations, Kapitza conductance. ; Two-Phase Heat Transfer: Flow regimes, pressure drop, Lockhart-Martinelli correlation, pool boiling, forced convection boiling. ; Radiation: Radiation from LNG fires, free-molecular flow and heat transfer, free-molecular heat transfer in enclosures. ; Heat Exchanger: Cryogenic heat exchanger types, NTU-effectiveness design method, Giauque- Hampson design, Plate-fin and perforated-plate heat exchanger design, effect of variable specific heat, effect of longitudinal heat conduction, effect of heat transfer from ambient, Regenerators, Regenerator design.

Essential Reading:

1. R.F. Barron, ‗*Cryogenic Systems’*, McGraw Hill, 1985.
2. R.B. Scott, ‗*Cryogenics Engineering’*, Van Nostrand & Co., 1962.

Supplementary Reading:

1. H. Weinstock, ‗*Cryogenic Technology’*, 1969.
2. K. D. Timmerhaus and T. M. Flynn., ‗*Cryogenic Process Engineering’*, Plenum Press, New York, 1989.
3. R. W. Vance., ‗*Cryogenic Technology’*, John Wiley & Sons Inc., New York, London, 1971.
4. Sengapatha, A. Bose, ‗*Cryogenics – Progress and Applications’*, Tata McGraw Hill, 1987.

Aircraft & Rocket Propulsion

Introduction, Rocket system and aerodynamics of rockets, Fundamentals of gas turbine engines, Illustration of working principles of gas turbine engine, Propulsion system and operating principle, Thermodynamics of propulsion system, Engine performance parameters, The ramjet cycle, Working principles of ideal ramjet cycle, The turbojet cycle, Working principles of turbojet cycle, Non-ideal turbojet cycle, Axial flow fans and compressors, Polytrophic efficiency of compression, Calculation of stage performance and overall performance, Working principles of turbofan cycle, Rocket performance, Introduction and working principles of multistage rocket, Solid propellant rockets, Liquid propellant rockets ,Thrust control in liquid rockets Cooling in liquid rockets, Hybrid rockets, Limitations of hybrid rockets, Relative advantages of liquid rockets over solid rockets

Supplementary Reading:

1. G.C. Oates, *Aerothermodynamics of Aircraft Engine Components*, AIAA Education Series, New York, 1985.
2. W.W. Bathie*, Fundamentals of Gas Turbines*- John Wiley & Sons, 1984.
3. M.L. Mathur, and R.P. Sharma, *Gas Turbine Jet and Rocket Propulsion*, Standard Publishers and Distributors, Delhi, 1988.
4. P.G. Hill, *Mechanics and Thermodynamics of Propulsion*- Addison Wesley, 1970.
5. S.M. Yahya, *Fundamentals of Compressible Flow* - John Wiley, New York, 1982.
6. A.K. Mohanty, *Fluid Mechanics* - Prentice Hall, New Delhi, 2003.

HTPE211 **POWER PLANT PRACTICE AND CONTROL**

Overview of the Indian power sector, Thermodynamic analysis of conventional power plants. Advanced cycles, (combined cycles), IGCC, AFBC/PFBC, Overview of Nuclear power plants, Radio activity, Cross section, Fission process, reaction rates, diffusion theory, elastic scattering and showing down, criticality calculations, critical heat flux, power reactors, nuclear safety. Steam Turbine- superheater, reheater and partial condenser vacuum. Combined feed heating and Reheating Regenerative Heat Exchangers, Reheaters and Intercoolers in Gas turbine power plants. Hydro power plants – turbine characteristic. Auxiliaries – water treatment systems, Electrostatic precipitator, Flue gas desulphurisation –coal crushing /preparation – Ball mills/ pulverisers, ID/FD fans, Chimney cooling Towers, Power plants control systems-Review of control principles, combustion control, pulveriser control, control of air flow, furnace pressure and feed water, steam temperature control, safety provision/Interlocks. Analysis of system load curve- plant load factor, Energy Auditing, Methodology

Environmental impacts of energy use-Air pollution –SOX, NOX, CO, particulates solid and water pollution formation of pollutants measurement and controls; sources of emission effect of operating and design parameters on emission ,control method, exhaust emission test, procedure standards and legislation; environmental audits; emission factors ad inventories Global warming, CO_2 emission, impacts, mitigation sustainability, externalities, future energy Systems.

BOOKS:

1. Power Plant Technology, M.M.Wakill, Tata McGraw Hill
2. Power Plant Engineering, P. K. Nag Tata McGraw Hill
3. Boiler Control Systems, Lindsay, McGrawHill International, Lodon
4. Power Generation Operation and Control, A.J.Wood and B.F.Woolenberg, John Wiley, New York