M.TECH. THERMAL AND FLUIDS ENGINEERING

DEPARTMENT OF MECHANICAL ENGINEERING

As the energy and process sector in India is in a boom, the need of the hour is engineers with strong background in thermal and fluid sciences capable of carrying out conceptual design. The program is aimed at providing sufficient theoretical, computational and experimental knowledge in the thermal and fluid sciences. It also encapsulates simulation and experimental skills applied to IC engines, power plant, aerospace and gas turbines research. The program is designed to equip students to perform design related to linear and nonlinear steady state/ transient heat transfer, steady and unsteady fluid flow, multiphase flows, fluid structure interactions viz., estimation of thermal and pressure loads and coupled field analysis. The program provides required numerical simulation techniques for design and analysis of equipment like gas turbines and accessories, steam turbines and reactor pipes, heat exchangers, compressors, turbines, pumps, propellers, rotor stator interactions, flow separators, inlet manifolds, volutes, turbo chargers etc. The course also introduces the student to experimental techniques like flow visualization, combustion diagnostics, particle characterization and other recent imaging techniques adopted in the field of thermal research.

Students will be eligible for the post of design engineers in industries related thermal and fluid sciences and also suitable for R&D organizations.

CURRICULUM

First Semester

Course Code	Type	Course	L T P	Credits
MA650	FC	Advanced Engineering Mathematics	3 0 0	3
TF601	FC	Advanced Fluid Dynamics	3 0 0	3
TF602	FC	Advanced Heat Transfer	3 0 0	3
TF603	FC	Advanced Engineering Thermodynamics	3 0 0	3
TF604	FC	Experimental Methods in Thermal & Fluids Engg.	0 0 3	1
TF605	SC	Seminar	0 0 3	1
	E	Elective I	3 0 0	3
HU601	HU	Cultural Education*	0 0 0	P/F
			Credits	**17**

*Non-credit course

Second Semester

Course Code	Type	Course	L T P	Credits
TF606	SC	Fuels&Combustion	30 0	3
TF607	SC	Turbo machines	30 0	3
TF608	SC	Computational Methods in Thermal & Fluids Engg.	3 0 3	4
TF609	SC	Advanced Thermal & Fluids Engg. Lab	0 0 3	1
TF610	SC	Design of heat exchange equipments	3 10	4
	E	Elective II	3 0 0	3
TF611	SC	Project Seminar & Industry familiarisation	0 0 6	2
EN600	HU	Technical Writing	0 0 0	P/F
			Credits	**20**

Third Semester

Course Code	Type	Course	L T P	Credits
TF612	SC	Computational Fluid Dynamics and Heat Transfer	3 0 3	4
	E	Elective III	3 0 0	3
TF799	P	Dissertation – Stage I		8
			Credits	**15**

Fourth Semester

Course Code	Type	Course	L T P	Credits
TF799	P	Dissertation – Stage II		14
Credits	**14**			

Total Credits 66

List of Courses

Foundation Core

Course Code	Course	L T P	Credits
MA650	Advanced Engineering Mathematics	3 0 0	3
TF601	Advanced Fluid Dynamics	3 0 0	3
TF602	Advanced Heat Transfer	3 0 0	3
TF603	Advanced Engineering Thermodynamics	3 0 0	3
TF604	Experimental Methods in Thermal & Fluids Engg.	0 0 3	1

Subject Core

Course Code	Course	L T P	Credits
TF605	Seminar	0 0 3	1
TF606	Fuels& Combustion	3 0 0	3
TF607	Turbo Machines	3 0 0	3
TF608	Computational Methods in Thermal & Fluids Engg.	3 0 3	4
TF609	Advanced Thermal & Fluids Engg. Lab.	0 0 3	1
TF610	Design of Heat Exchanger Equipments	3 1 0	4
TF611	Project Seminar & Industry familiarisation	0 0 6	2
TF612	Computational Fluid Dynamics and Heat Transfer	3 0 3	4

Electives (Elective I, Elective II & Elective III)

Course Code	Course	L T P	Credits
TF701	Boundary Layer Theory	3 0 0	3
TF702	Introduction to Turbulence	3 0 0	3
TF703	Advanced Gas Dynamics	3 0 0	3
TF704	Fluid Structure Interaction	3 0 0	3
TF705	Design of IC Engines and Systems	3 0 0	3
TF706	Chemical Reactor Analysis	3 0 0	3
TF707	Two-phase Flow and Heat Transfer	3 0 0	3
TF708	Gas Turbine Theory and Design	3 0 0	3
TF709	Micro and Nano Scale Thermal and Fluids Engineering	3 0 0	3
TF710	Cryogenics	3 0 0	3
TF711	Renewable Energy	3 0 0	3
TF712	Aerodynamics	3 0 0	3

TF713	Instrumentation and Process Control	3 0 0	3
TF714	Power Plant and Thermal Systems Engineering	3 0 0	3
TF715	Propulsion	3 0 0	3
TF716	Bio-fluid mechanics	3 0 0	3
TF717	IC Engine Combustion and Emissions	3 0 0	3
TF718	Numerical Radiation Heat Transfer	3 0 0	3
TF719	Heat transfer in porous media	3 0 0	3
TF720	Numerical Simulation & Modelling of Turbulent flows	3 0 0	3
TF721	Air-conditioning and Refrigeration Systems	3 0 0	3
TF722	Nuclear Reactor Thermal-Hydraulics and Safety	3 0 0	3

MA650 ADVANCED ENGINEERING MATHEMATICS 3- 0 -0-3

Vector and Tensor Analysis (Cartesian and Curvilinear): Orthogonal coordinate systems, Transformation of coordinate systems; Paths and line integrals, Fundamental theorems of calculus for line integrals, vector fields and gradients; Double and triple integrals, Iterated integrals, Change of variables formula, Applications to area and volume, Green's theorem, Two-dimensional vector fields and gradients; Surface Integrals; Parametric representation of a surface, Fundamental vector product and normal to a surface, Stokes' theorem, Curl and divergence of a vector field, Gauss' divergence theorem; Algebra of Cartesian Tensors, Index notation, Isotropic tensors, Invariants of a tensor.Fourier series, Fourier transforms, Laplace transforms, applications.Review of ODEs;Laplace & Fourier methods, series solutions, and orthogonal polynomials. Sturm-Liouville problem; Review of 1st and 2nd order PDEs. Similarity transformations for converting PDEs to ODEs. Solution of PDEs, Special functions.Linear systems of algebraic equations, Systems of Differential Equations.Review of probability concepts, random variables – one and two dimensional probability distributions and densities. Expectations and Chebychev's theorem, population and sampling distributions, central limits theorem, point and interval estimation, confidence intervals, Calculus of variation.

TEXT BOOKS/REFERENCES:

1. KreyzigE,*Advanced Engineering Mathematics*, New Age International, 1996.
2. SneddonI.N, *Elements of Partial Differential Equations,* McGraw-Hill, 1957.
3. HilderbrandF.B, *Introduction to Numerical Analysis*, Tata McGraw-Hill, 1974.
4. BoyceW.E andDiprimaR.C, *Elementary Differential Equations and Boundary Value Problems,* Wiley, 1977.
5. JainM.K, IyengerS.R.K. and JainR.K, *Computational Methods for Partial Differential Equations,* New Age International, 1994.

TF601 ADVANCED FLUID DYNAMICS 3-0-0-3

Review of Basic Concepts: Concept of continuum, types of fluid.

Differential Fluid Flow Analysis: differential forms of mass, momentum, and energy conservation equations; Potential flow, Navier-Stokes equations and exact solutions, energy equation.Ideal Fluid Flow Analysis: Two dimensional flow in rectangular and polar coordinates; Continuity equation and the stream function; Irrotationality and the velocity potential function; Vorticity and circulation; Plane potential flow and the complex potential function; Sources, sinks, doublets and vortices; Flow over bodies and d'Alembert's paradox; Aerofoil theory and its application.Boundary Layer Theory: Laminar Boundary Layer Equation: Two dimensional equations, displacement and momentum thickness, general properties of the boundary layer equations, skin friction.Turbulent Boundary Layer: Two-dimensional equation, Prandtl's mixing layer Karman's hypothesis universal velocity distribution, RANS models, flow over a flat plate, skin friction drag.Introduction to hydrodynamic theory of lubrication.Introduction to turbo-machinery: pumps, compressors, fans and turbines.Compressible Fluid Flow: One dimensional isentropic flow, Fanno and Rayleigh flows, chocking phenomenon, normal and oblique shocks.

TEXT BOOKS/REFERENCES:

1. MunsonB. R., Young, D. F., and Okiishi, T. H., *Fundamentals of Fluid Mechanics*. 6th Ed., John Wiley & Sons.2009.
2. Cengel, Y. A. and Cimbala, J.M. *Fluid Mechanics – Fundamentals and applications*, Tata McGraw Hill, 2008.
3. White, F. M., *Viscous Fluid Flow*, 3rd Ed., McGraw Hill.2006.
4. White, F. M., *Fluid Mechanics*, 5th Ed., McGraw Hill.2003.
5. Kundu, P. K., and Cohen, I. M., *Fluid Mechanics*, 4th Ed., Academic Press. 2008

TF602 ADVANCED HEATTRANSFER 3-0- 0-3

Fourier's law, thermal conductivity of matter, heat diffusion equation for isotropic and anisotropic media, boundary and initial conditions. One-dimensional steady-state conduction through plane wall, cylinder and sphere.Conduction with thermal energy generation, heat transfer from extended surfaces, radial fins and fin optimization; Multidimensional- steady-state heat conduction; Transient conduction – lumped capacitance method and its validity, plane wall and radial systems, semi-infinite solid, anisotropic conduction, numerical solution of conduction problems: FDM and FEM methods.

Review of viscous flow. Hydrodynamic and thermal boundary layers, Laminar flow heat transfer to developed and developing flow, laminar forced convection in pipe and ducts with different boundary conditions,external flows. Laminar Natural Convection, natural convection in Enclosures, heat transfer correlations.Turbulence modelling, Heat transfer in turbulent boundary layers, Eddy diffusity of heat and momentum, turbulent flow through circular tubes and parallel plates with heat transfer,analogies between heat and momentum transfer,Turbulent free convection from vertical surface,turbulent heat transfer correlation. Boiling and condensation heat transfer – correlation and applications.

Radiation heat transfer, blackbody radiation,Plank distribution, Wien's displacement law, Stefan –Boltzmann law, surface emission,surface emission, surface absorption, reflection, and transmission, Kirchoff's law, graysurface;Radiation intensity and its relation to emission, irradiation and radiosity, View factors and Radiation exchange between surfaces.

TEXT BOOKS/REFERENCES:

1. Bergman T. L., Lavine A. S, Incropera F. P, DeWitt D. P., *Fundamentals of Heat and Mass Transfer*, John Wiley & Sons, 2011.
2. Kreith, F. and Bohn, M. S., *Principles of Heat Transfer*, 6th Ed.,Thomson Learning. 2007.

3. Burmeister, L. C., *Convective Heat Transfer*, 2e, John Wiley, 1993.
4. Modest M F, *Radiative Heat Transfer*, McGraw-Hill, 1993.
5. Kays, W. M. and Crawford, M. E., *Convective Heat and Mass Transfer*, Tata McGraw Hill, 2005.
6. Welty, J. R., Wicks, C. E. , Wilson, R. E. and Rorrer, G. L., *Fundamentals of Momentum, Heat and Mass Transfer*, 5th Ed., John Wiley & Sons and Sons, 2007

TF603 ADVANCED ENGINEERING THERMODYNAMICS 3-0-0-3

Review of I and II Laws of Thermodynamics: Maxwell equations, Joule-Thompson experiment, irreversibility and availability, Transient flow analysis, entropy balance, entropy generation.

Exergy Analysis: Concepts, exergy balance, exergy transfer, exergetic efficiency, exergy analysis of power and refrigeration cycles.

Real Gases and Mixtures: Thermodynamic cycles and cycle efficiency.

Thermodynamic Properties of Homogeneous Mixtures: Partial molal properties, chemical potential, fugacity and fugacity coefficient, fugacity relations for real gas mixtures, ideal solutions, phase equilibrium.

Kinetic theory of gases, basic assumption, molecular flux, equation of state for an ideal gas, collisions with a moving wall, principle of equipartition of energy, classical theory of specific heat capacity, Equations of state, thermodynamic property relations, residual property functions, properties of saturation states.

TEXTBOOKS/REFERENCES:

1. Wylen and Sontag, *Fundamentals of Classical Thermodynamics,* Wiley Eastern Limited, New Delhi.
2. Michel A Saad, *Thermodynamics: Principles and Practices*, Prentice Hall, 1997.
3. CengelYunus A. and Boles Michael, *Thermodynamics: An Engineering Approach,* 7^{th}Edn, McGraw Hill, 2011.
4. Wark, K., *Advanced Thermodynamics for Engineers*, John Wiley & Sons.1995
5. Bejan, A., *Advanced Engineering Thermodynamics*, 3rd Ed., John Wiley & Sons.2006

TF604 EXPERIMENTAL METHODS IN THERMAL AND FLUIDS ENGINEERING 0-0-3-1

1. a) Pipe friction apparatus & b) Reynolds apparatus
2. a) Thermal conductivity of solids & b) Heat transfer through pin fin
3. a) Notch apparatus & b) Pelton wheel test rig
4. a) Forced convection heat transfer & b) Natural convection heat transfer
5. a) Verification of Bernoulli equation & b) Centrifugal pump test rig
6. a) Parallel & counter flow heat exchanger & b) Shell and tube heat exchanger

7. a) Meta-centre apparatus & b) Venturi and orifice meter test rig
8. a) Stephan-Boltzmann apparatus & b) Emissivity apparatus
9. a) Francis turbine test rig & b) Hele-shaw flow apparatus
10. R&AC test rig.

TEXT BOOKS/REFERENCES:

1. Goldstein, R. J., *Fluid Mechanics Measurement*, 2nd Ed., CRC Press. 1996.
2. Eckert, R. G. and Goldstein, R. J., *Measurements in Heat Transfer*, 2nd Ed., Springer. 1986.

TF605 SEMINAR 0- 0- 3- 1

The student will be given some advanced topics in the field of fluid flow and heat transfer. He/she shall extensively refer literature (min. 3hrs in a week) and prepare a properly formatted seminar report. He/she need to present the work at the end of the semester. The valuation will be based on viva-voce during the presentation and content and organization of the report.

TF606 FUELS AND COMBUSTION 3-0-0-3

Fuels, Importance of combustion, combustion equipment, Thermodynamics of reacting systems; conservation of mass and energy in a chemical reaction; Enthalpy of formation, enthalpy of reaction, adiabatic flame and equilibrium temperature, second law aspects of chemical reactions. Essentials of chemical Kinetics; molarity and order of chemical reaction, general equation for rate of reaction, equation of Arrhenius, activation energy.Structure and propagation of flames in homogeneous gas mixtures, simplified Rankine-Hugoniot relations, properties of Hugoniot curve, analysis of deflagration and detonation branches, properties of Chapman Jouguet wave; Unstable combustion.Laminar flame structure, theories of flame propagation and calculation of flame speeds, flame speed measurements, stability limits of laminar flames, flammability limits and quenching distance. Burner design; Mechanisms of flame stabilization in laminar and turbulent flows; Flame quenching, diffusion flames, comparison of diffusion with premixed flame, combustion of gaseous fuel jets, Burke and Shumann development.Burning of Condensed Phase: General mass burning considerations, combustion of fuel droplet in a quiescent and convective environment. Introduction to combustion of fuel sprays.Ignition: Concepts of ignition, chain ignition, thermal spontaneous ignition, forced ignition.Essential features of combustion process in engines, flame structure and speed, spray structure, auto-ignition.Combustion Generated Pollution and its Control, Introduction to CAE code (Ch. Eqbm. Analysis).

TEXT BOOKS/REFERENCES:

1. Glassman I., *Combustion*, 4th Ed., Academic Press. 2008.

2. Warnatz, J., Mass, U., and Dirbble, R. W.,*Combustion: Physical and Chemical Fundamentals, Modeling and Simulation, Experiments, Pollutant Formation*, 4th Ed., Springer-Verlag. 2006.
3. Turns Stephen R., *An Introduction to Combustion - Concepts and Applications*, Second Edition, McGraw Hill, 2000.
4. Mukunda H. S., *Understanding Combustion*, Orient Blackswan, Second Edition, 2009
5. Kenneth K. Kuo, *Principles of combustion*, Wiley-Interscience; Second edition, 2005.

TF607 TURBO MACHINES 3-0-0-3

Classification- Specific work- Representation of specific work in T-S and H-S diagrams-Internal and external losses – Euler's equation of Turbo machinery-Ideal and actual velocity triangles-Slip and it's estimation-Impulse and reaction type machines-Degree of reaction-Effect of outlet blade angle on blade shape-Model laws, Specific speed and Shape number-Special features of hydro, steam and gas turbines-Performance characteristics of turbo-machines- Thin aerofoil theory-Cascade mechanics.

Pumps, compressors, blowers and fans – Design and off-design Characteristics (Cavitation, Surge and Stall)

TEXT BOOKS/REFERENCES:

1. SayersA.T, *Hydraulic and Compressible flow Turbomachines*, McGrawHill Book Co. Ltd., 1990.
2. Naixing Chen, Aerothermodynamics of Turbomachinery: Analysis and design, John Wiley & Sons Pte- Ltd, Singapore, 2010.
3. BaljeO.E, Turbomachines: a guide to design, selection and theory, John Wiley & Sons Pte- Ltd, New York, 1981.
4. Dixon S.L. and Hall C.A, Fluid Mechanics and Thermodynanmics of turbomachinery, Elsevier Buterworth-Heinmann, USA, 2010.
5. YahyaS.M., Turbines, Compressors and Fans, Tata McGraw Hill, New Delhi, 1983.

TF608 COMPUTATIONAL METHODS IN THERMAL AND FLUIDS ENGINEERING 3-0-3-4

Taylor series expansion, root finding, interpolation, extrapolation; Numerical solution of systems of nonlinear algebraic equations; Newton-Raphson method.

Solution of linear algebraic systems, determinant, inverse, norms and condition number.Elementary Matrix Computation, Eigenvalue Problems and singular Value Decomposition.Systems of Linear Equations, Solution using various iterative methods, matrix inversion methods. Conjugate gradient, BiCGStab, GMRES.

Numerical Differentiation, Numerical integration: Newton-Cotes methods, error estimates, Gaussian quadrature.

Numerical integration of ODEs: Boundary Value Problems, Differential Algebraic Equations, Euler, Adams, Runge-Kutta methods, and predictor-corrector procedures; stability of solutions; solution of stiff equations.Finite difference (FD) method. Forward, Backward and Central schemes. Solution of ODE by FD method. Introduction to stability, numerical errors and accuracy.

Application of finite difference method to thermal engineering problems. Solution of hydrodynamic and thermal boundary layer equations by FD method. Stream function-vorticity formulation, Solution of 2-D flows in complex geometries. Application to transient heat transfer by FD method. FD method used for 2D and 3D problems.

TEXT BOOKS/REFERENCES:

1. Hoffman, J.D., *Numerical Methods for Engineers and Scientists*, Marcel Dekker, 2001.
2. Mathews, J. H., *Numerical Methods*, Prentice Hall, 1994.
3. HilderbrandF.B., *Introduction to Numerical Analysis*, Tata McGraw-Hill, 1988.
4. Boyce W.E. andDiprimaR.C., *Elementary Differential Equations and Boundary Value Problems*, Wiley, 1977.
5. JainM.K., IyengerS.R.K. and JainR.K., *Computational Methods for Partial Differential Equations,* New Age International, 1994.

TF609 ADVANCED THERMAL & FLUIDS ENGG. LAB 0-0-3-1

Dynamic similarity and scaling; Types of measurement devices & techniques; Errors in Measurement and its Analysis: Causes and types of experimental errors, systematic and random errors; Uncertainty analysis, computation of overall uncertainty, calibration.

Experiments in Wind Tunnel: Surface pressure distribution on circular cylinder, symmetric and cambered aero-foils-estimation lift and drag, smoke flow visualization. Laminar-turbulent transition for various geometries.

Experiments in Water Channel: Visualization of flow over streamline and bluff bodies-vortex shedding from bluff bodies (like circular cylinder)-study of vortex streets.

2-D laminar flow over bluff bodies (Hele-Shaw flow)-construction of flow net (velocity potential lines and streamlines).Numerical visualization of flow over bluff bodies using Ansys/Algor Software-comparison of numerical flow patterns with experimental ones.

Performance characteristics of Centrifugal compressor and axial flow fan.

Free Convection Heat Transfer-Forced Convection Heat Transfer-Measuring instruments for R&A/C applications-measurement of very low temperature-Measurement of density and viscosity of oils-measurement of gas flow rate through pipelines.

Steady state and transient convective heat transfer

Radiation Heat Transfer-Boiling Heat Transfer-Performance evaluation of vapour compression refrigeration-performance evaluation of thermoelectric refrigerator and heat pump-Measurement and analysis of combustion parameters in I.C. Engines-Evaluation of the calorific value of gaseous and liquid fuels.

TEXT BOOKS/REFERENCES:

1. Goldstein, R. J., *Fluid Mechanics Measurement*, 2nd Ed., CRC Press. 1996.
2. Doeblin, E. O., *Measurements System Application and Design*, 5th Ed., McGraw Hill, 2004
3. Marangoni R D and Lienhard J H, *Mechanical Measurements* by Beckwith T G, 6th Ed., Prentice Hall. 2006
4. Eckert, R. G. and Goldstein, R. J., *Measurements in Heat Transfer*, 2nd Ed., Springer. 1986.
5. Barlow Jewel B., Rae William H., Pope Alan, *Low speed wind tunnel testing*, 3e, Wiley, 1999.

TF610 DESIGN OF HEAT EXCHANGER EQUIPMENTS 3-1-0-4

Introduction: classification, Design of heat exchangers: engineering design- steps for designing, designee a workable system, optimum systems, economics, probabilistic approach to design, sizing and rating problems; LMTD and ε-NTU approach of design.
Design of shell and tube heat exchanger – basic design procedure and theory, overall heat-transfer coefficient, fouling factors, shell and tube exchangers: construction details, general design considerations: Fluid allocation, Shell and tube fluid velocities, Pressure drop**,** tube-side and shell side heat-transfer coefficient and pressure drop, (single phase), Kern's method, design problems.
Design of Condenser; Heat-transfer fundamentals, Condensation outside horizontal tubes, inside and outside vertical tubes, inside horizontal tubes, Condensation of steam, Mean temperature difference, De-superheating and sub-cooling, Pressure drop in condensers, design problems.
Design of Compact heat exchanger: introduction, design producer of compact heat exchanger, fins, fin effectiveness and fin efficiency, pressure drop analysis of plate fin heat exchanger, problems.
Plate heat exchanger: Gasketed plate heat exchangers, Welded plate, advantages and disadvantages over the other heat exchangers, design procedure, heat transfer coefficient and pressure drop calculation on both the sides of exchanger, problems on plate exchanger.
Heat pipe: introduction, working principle, working fluids, wick structure and material, classification of heat pipe, pressure variation along the heat pipe, limitations of a heat pipe, problems on heat pipe.
Thermal design of heat exchanger such as Regenerative heat exchanger, Super heater, Air pre-heaters, analysis and design of cooling towers.
Optimum design: criteria for optimization of heat exchanger constraints, feasible and optimum design, and optimization based on volume, weight, cont entropy generation and thermo economics. Performance Behaviour: Design vs. simulation, steady state performance-effectiveness, transient performance, non uniformities in temperature and flow; Three fluid/ multi fluid heat exchanger behaviour.
Introduction to Design codes (ASME, TEMA, HTRIetc)

TEXT BOOKS/REFERENCES:

1. Coulson & Richardson's series, Sinnott R. K., *Chemical Engineering Design*, Elsevier, 2005
2. Serth. R. W, *Process Heat Transfer-Principles and Applications*, Elsevier, 2007.
3. Kern D, Q, *Process Heat Transfer*, McGraw-Hill, 1965.
4. Shah R K and Sekulic D P, *Fundamentals of Heat Exchanger Design*, John Wiley and Sons, 2002.
5. Kays W M and London A L, *Compact Heat Exchanger*, Krieger Publishing Company, 1998.

TF611 PROJECTSEMINAR & INDUSTRY FAMILIARISATION 0-0-6-2

Students will be assigned an M.Tech project by the end of the first semester. He/she shall extensively study (min. 6hrs in a week) the research already carried out in the in the field of their thesis work. The student shall bring out the current status of the problem, clearly indicating the shortcomings and gaps in understanding. He/she shall prepare a properly formatted seminar report giving all of the above details. He/she need to present the work carried out at the end of the semester. Credits will be awarded based on the viva-voce during the presentation and the content and organization of the report.

The students shall visit industrial units connected with their curriculum and present reports about the plant design, equipment, instrumentation etc.

TF612 COMPUTATIONAL FLUID DYNAMICS AND HEAT TRANSFER 3-0-3-4

Review of Conservation equations for mass, momentum and energy; coordinate systems; Eulerian and Lagrangian approach, Conservative and non-conservative forms of the equations, rotating co-ordinates.

Classification of system of PDEs: parabolic elliptic and hyperbolic; Boundary and initial conditions; Overview of numerical methods;

Review of Finite Difference Method, Introduction to integral method, method of weighted residuals, finite elements finite volume method & least square method.

Numerical Grid Generation: Basic ideas, transformation and mapping, unstructured grid generation, moving grids, unmatched meshes.

Finite Volume Method: Basic methodology, finite volume discretization, approximation of surface and volume integrals, interpolation methods - central, upwind and hybrid formulations and comparison for convection-diffusion problem; Basic computational methods for compressible flows.

Advanced Finite Volume methods: FV discretization in two and three dimensions, SIMPLE algorithm and flow field calculations, variants of SIMPLE, Turbulence and turbulence modelling, illustrative flow computations, Introduction to turbulence modelling, CFD methods for compressible flows.

Commercial software FLUENT and CFX – grid generation, flow prediction and post-processing.Validation methods for CFD analysis.

TEXT BOOKS/REFERENCES:

1. Anderson D A, Tannehill J C, and Pletcher R H, *Computational Fluid Mechanics and Heat Transfer,* 2nd ed, Taylor & Francis, 1997.
2. Hirsch, *Analysis of Internal and external flows*, vols 1, 2.
3. PatankarS V, *Computational Fluid Mechanics and Heat Transfer*, Hemisphere, 1980.
4. Jaluria, Y., and Torrance, K.E., *Computational Heat Transfer*, Taylor & Francis. 2002
5. Ferziger, J. H. and Peric, M., *Computational Methods for Fluid Dynamics*, 3rd Ed., Springer. 2003
6. Versteeg, H. and Malalasekra, M., *An Introduction to Computational Fluid Dynamics: The Finite Volume Method*, 2nd Ed., Prentice Hall. 2007.

ELECTIVES

TF701 BOUNDARY LAYER THEORY 3-0-0-3

Introduction: Ideal and real fluids, the concept of boundary layer, Navier- Stokes equations, the limiting cases of large and small Reynolds number, energy equation.

Laminar Boundary Layer Equation: Two dimensional equations, displacement and momentum thickness, general properties of the boundary layer equations, skin friction.

Similarity Solutions: Wedge flow and its particular cases, flow past a cylinder, two dimensional inlet flows in straight channel.

Approximate Methods: Karman-Polhausen methods, numerical methods.

Symmetrical Boundary Layers: Circular jet, body of revolution, Manglers transfixion.

Boundary Layer Control: Different methods of boundary layer control, flow over a flat plate with uniform suction.

Turbulent Boundary Layer: Two-dimensional equation, Prandtl's mixing layer Karman's hypothesis universal velocity distribution, flow over a flat plate, skin friction drag.

Thermal Boundary Layers: Two-dimensional equations forced flow over flat plate at zero in advances, natural flow over a vertical plate.

TEXT BOOKS/REFERENCES:

1. Schlichting, H. and Gersten, K., *Boundary Layer Theory*, Springer-Verlag, 2004
2. White, F. M., *Viscous Flow*, 3rd Ed., McGraw Hill. 2005
3. Cebeci, T. and Cousteix, J., *Modeling and Computation of Boundary-Layer Flows*, 2nd Ed., Springer-Verlag. 2005
4. Rozenhead, L., *Laminar Boundary Layers*, Dover Publications, 1988
5. Kays, W. M., Crawford, M. E., and Weigand, B., *Convective Heat and Mass Transfer*, 4th Ed., McGraw Hill. 2004

TF702 INTRODUCTION TO TURBULENCE 3-0-0-3

Origin, examples and character of turbulence, Reynolds stress, energy relations, closure problem, phenomenology, eddy viscosity. Statistics. spectra, space-time correlations, macro

&micro scales, statistical theory of turbulence, locally isotropic turbulence, Kolmogorov's hypothesis, correlation method, spectral method, turbulence diffusion. Numerical Turbulence modelling, one-, two- and multiple equations for turbulence modelling, Reynolds and Favre averaging, RSM, Large eddy and DNS methods.

Experimental techniques: Hot Wire Anemometer, Laser Doppler Anemometer, Flow visualisation techniques, laminar-turbulent transition.

TEXT BOOKS/REFERENCES:

1. Tennekes H. and Lumley J.L., *A first course in Turbulence*, MIT Press, USA, 1972.
2. W.D, Comb Mc, *the Physics of Fluid Turbulence*, Oxford University Press Inc, New York, 1990.
3. Stephen.B.Pope, *Turbulent Flows*, Cambridge University Press, UK, 2000.
4. Davidson P.A., *Turbulence: An introduction for Scientists and Engineers*, Oxford University Press Inc, New York, 2004.
5. BatchelorG.K., *The Theory of homogeneous turbulence*, Cambridge University Press, UK, 1993.

TF703 ADVANCED GAS DYNAMICS 3-0-0-3

Basic equations of gas dynamics: Introduction, Isentropic flow ina streamtube, speed of sound, Mach wavesand Mach cone, Effect of Mach number on compressibility.

One dimensional Isentropic Flow: Governing equations, stagnation conditions, critical conditions, maximum discharge velocity, isentropic relations.

Shock Waves: Normal Shock waves, stationary normal shock waves, normal shock wave relations in terms of Mach number, Hugoniot Equations; 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; Linearized twodimensionalsubsonic flows; Prandtl-Glaurt/ Goethert transformation,Linearizedsupersonic flow; Ackeret's theory.

Variable Area Flow: Equations for variable area flow, operating characteristics of nozzles, convergent-divergent supersonic diffusers, flow separation, contour optimization, bell nozzle, new nozzle concepts.

Adiabatic Flow in a Duct with Friction: Flow in a constant area duct, friction factor variations, the Fano line.

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.

Unsteady wave motions:Moving normal shockwaves, Reflected shock waves, Physical features ofwave propagation, Elements of acoustic theory,Incident and reflected waves, Shock tube relations,Piston analogy, Incident and reflected expansionwaves, Finite compression waves, Shock tuberelations.

3D flow: Cones at angle of attack, Blunt-nosed bodies at angle of attack.

Introduction to experimental facilities:Subsonicwind tunnels, Supersonic wind tunnels, Shock tunnels,Free-piston shock tunnel, Detonation-driven shocktunnels, and Expansion tubes.

TEXT BOOKS/REFERENCES:

1. Zucker, R. D. and Biblarz, O., *Fundamentals of Gas Dynamics*, 2nd Ed., John Wiley & Sons. 2002
2. Anderson, J. D. *Modern Compressible Flow*, McGraw Hill. 2004
3. Liepmann, H.W. and Roshko, A., *Elements of Gas Dynamics*, Dover Publication.2002
4. Rathakrishnan, E., *Applied Gas Dynamics*, John Wiley & Sons, 2012
5. Hoffmann, J. D., *Gas Dynamics*, Vol 1&2, 1985.
6. Shapiro,A.H. *The Dynamics and Thermodynamics of Compressible Fluid Flow,Vol. I& II*,The Ronald Press Co, New York.
7. Oosthuizen, P.H., and Carscallen, W.E., Compressible Fluid Flow McGraw-Hillinternational editions, McGraw-Hill Companies, Inc.,Singapore.
8. Babu V. Fundamentals of Gas Dynamics Ane Books India, Chennai.
9. Chapman A.J. and Walker W.F. Introductory Gas Dynamics Holt, Reinhart andWinston, Inc. NY, USA.
10. Sutton George.P &Biblarz Oscar, *Rocket Propulsion Elements*, John Wiley & Sons Inc., 2001

TF704 FLUID STRUCTURE INTERACTION 3-0-0-3

Introduction: Vibration, Mode Shapes; Flow around bluff bodies- Vortex shedding and induced vibrations- Fluid Elastic excitations and instabilities- Galloping, ovalling and turbulence induced vibrations- Interference effects- Jet switching- Vibrations of fluid conveying conduits and flexible tubes- Wave induced vibrations-Wake structures associated with flow-induced vibrations.

Some practical problems: Tube bundle vibrations in heat exchangers and nuclear reactors-Vibrations of stacks and other tall structures, transmission line vibrations- Methods of suppressing flow-induced vibrations. Bio-fluid mechanics.

TEXT BOOKS/REFERENCES:

1. Robert D. Blevins, *Flow-Induced Vibration*, 2nd Edition, Van Nostrand Reinhold, New York, USA, 1990.

2. E. Naudascher, and D. Rockwell, *Flow-Induced Vibrations: An Engineering Guide,* Dover publishers, USA, 2005.
3. M.M. Zdravkovich, *Flow around circular cylinders, Vol.1: Fundamentals*, Oxford University Press, Oxford, England.1997.
4. Thomson, W.T and Dahleh, M.D., *Theory of vibrations with Applications*, Printice Hall, 1997.
5. Rao, S.S., *Mechanical Vibrations*, Pearson Education, 2004.

TF705 DESIGN OF IC ENGINES AND SYSTEMS 3-0-0-3

Constructional features of different types of internal combustion engines: Number, size and arrangement of cylinders; Fluid motion in IC engines: Swirl, Squish and Tumble; Effect of various design parameters on combustion and emission from IC engines; Heat transfer and energy flow in IC engines; Design of cooling systems in IC engines; Design procedure for important components like cylinder, piston, piston rings, intake and exhaust manifolds and poppet valves; Design procedure for inlet and exhaust ports of two-stroke engines; Design of silencer and air filter.

TEXT BOOKS/REFERENCES:

1. John B. Heywood, *Internal Combustion Engine Fundamentals*, McGraw Hill International Edition, 1989.
2. FergusonC.R., KirkpatrickA. T., *Internal. Combustion Engines:AppliedThermosciences,* 2nd Edition, John Wiley & Sons, 2001.
3. Willard W. Pulkrabek, *Engineering Fundamentals of the Internal Combustion Engine,* Pearson Prentice-Hall, 2004.
4. Charles Fayette Taylor, *The Internal Combustion Engine in Theory and Practice: Combustion, Fuels, Materials, Design, Vol. 1 & 2*, MIT Press, 1985.
5. GuptaH.N., *Fundamentals of Internal Combustion Engines*, PHI Learning Pvt. Ltd., 2006.

TF706 CHEMICAL REACTOR ANALYSIS 3-0-0-3

Review of design of ideal isothermal homogeneous reactors for single and multiple reactions.

Residence time distribution (RTD) of ideal reactors, interpretation of RTD data, flow models for non-ideal reactors – axial dispersion, N tanks in series, and multi-parameter models, diagnosing the ills of reactors, influence of RTD and micro-mixing on conversion.

Adiabatic and non-adiabatic operations in batch and flow reactors, optimal temperature progression, hot spot in tubular reactor, autothermal operation and steady state multiplicity in continuously stirred tank reactor (CSTR) and tubular reactors, introduction to bifurcation theory.

Introduction to multiphase catalytic reactors, effectiveness factor, selectivity, catalyst deactivation, use of pseudo-homogeneous models for design of heterogeneous catalytic reactors (fixed and fluidized beds).

Gas-liquid-solid reactors, hydrodynamics and design of bubble column, slurry and trickle-bed reactors.

TEXT BOOKS/REFERENCES:

1. FoglerH.S., *Elements of Chemical Reaction Engineering*, 4th Ed., Prentice-Hall. 2006
2. Levenspiel O., *Chemical Reaction Engineering*, 3rd Ed., Wiley. 1999
3. FromentG.F. and Bischoff K.B., *Chemical Reactor Analysis and Design*, 2nd Ed., Wiley. 1990
4. DoraiswamyL.K. and Sharma M.M., *Heterogeneous Reactions Analysis*. Vols. 1&2, Wiley.1984

TF707 TWO-PHASE FLOW AND HEAT TRANSFER 3-0-0-3

Introduction: Review of one-dimensional conservation equations in single phase flows, Types of flow, volumetric concentration, void fraction, volumetric flux, relative velocity, drift velocity, flow regimes, flow pattern maps, analytical models.
Homogeneous Flow: One dimensional steady homogeneous equilibrium flow, homogeneous friction factor, turbulent flow friction factor.
Separated Flow: Slip, Lockhart-Martinelli method for pressure drop calculation, pressure drop for flow with boiling, flow with phase change.
Drift Flow Model: General theory, gravity flows with no wall shear, correction to simple theory, Armond or Bankoff flow parameters.
Compressible multi-fluid formulations.
Boiling: Thermodynamics of boiling, Regimes of boiling, nucleation, gas nucleation in bulk liquid, growth of bubbles, motion at a heating surface, heat transfer rates in pool boiling, forced convection boiling, heat transfer correlations, maximum heat flux or burnout, boiling of metals.
Condensation: Nusselt theory, Film and drop-wise condensation, boundary layer treatment of laminar film condensation, condensation in vertical and horizontal tubes, condensation inside a horizontal tube.

TEXT BOOKS/REFERENCES:

1. Ishii, M. and Hibiki, T., *Thermo-fluid Dynamics of Two-Phase Flow*, Springer. 2009.
2. Brennen, C. E., *Fundamentals of Multiphase Flow*, Cambridge University Press. 2009.
3. Collier, J. G. and Thome, J. R., *Convective Boiling and Condensation*, Oxford University Press, 1996.
4. Rohsenow, W.M., Hartnett, J.P. and Ganic, E.N. (Ed.), *Handbook of Heat Transfer*, McGraw Hill. 1998.
5. Tong, L.S. and Tang, Y. S., *Boiling Heat Transfer and Two-phase Flow*, 2nd Ed., CRC Press. 1997.

TF708 GAS TURBINE THEORY AND DESIGN 3-0-0-3

General Considerations of Turbomachinery: Classification; Euler's Equation for Turbomachinery; Velocity triangle; Cascade analysis & nomenclature. Shaft Power & Aircraft Propulsion Cycles. Centrifugal Compressors: Workdone and pressure rise; Slip; Compressibility effects; Compressor characteristics. Axial Flow Compressors: Stage pressure rise; Blockage in compressor annulus; Degree of reaction; 3-D flow; Stage performance; h-s diagram & efficiency; off-design performance; Performance characteristics; Design process. Combustion System. Axial Flow Turbines: Stage performance; Degree of reaction; h-s diagram & efficiency; Vortex theory; Overall turbine performance; Performance characteristics; Blade cooling; Design process. Prediction of performance of simple gas turbines; Off Design performance; Gas turbine blade materials; matching procedure.

TEXT BOOKS/REFERENCES:

1. Cohen H., *Gas Turbine Theory*, 4th Edition, Longman, 1998.
2. Jack D. Mattingly, *Elements of Gas Turbine Propulsion*, McGraw-Hill, Inc., 1996.
3. Lakshminarayana B., *Fluid Dynamics & Heat Transfer of Turbo machinery*, John Wiley & Sons, 1996.
4. Lefebvre Arthur Henry,*GAS Turbine Combustion*, Second Edition, Taylor & Francis Group, 1999.
5. Farokhi Saeed,*Aircraft Propulsion* , Wiley, 2008.
6. Hill Philip, Peterson Carl, *Mechanics and Thermodynamics of Propulsion*, Addison-Wesley Pub. Co, 1992.

TF709 MICRO AND NANO SCALE THERMAL & FLUIDS ENGINEERING 3-0-0-3

Microscale Energy Transport in Solids: Microstructure of solids, crystal vibrations and phonons, photon interactions, particle transport theories, non-equilibrium energy transfer.
Molecular Clusters: Clusters and clustering, thermo-physical properties of clusters, control of clusters and condensation.
Molecular Forces and Phase Change in Thin Liquid Films: Thermodynamics of thin films, interfacial meniscus properties, interfacial mass flux.
Heat Transfer and Pressure Drops in Microchannels: Single phase and two phase flow, flow boiling, dryout, bubble behavior, flow pattern
Micro Heat Pipes: Fundamental operating principles, steady state and transient modeling and construction techniques.
Microscale Heat Transfer in Biological Systems at Low Temperature: Life above and below the freezing temperature of water, freezing of cells and tissues, mechanism of freeze survival.
Microscale Thermal Sensors and Actuators: MEMS technology, flow sensors, infrared radiation detectors, thermal conductivity sensor, thermal expansion actuators and micro-steam engine.
Nanofluids: Preparation of nano-fluids, sputtering, characterization of nano-fluids, thermal properties of nano-fluids, single phase convective and boiling heat transfer processes.

TEXT BOOKS/REFERENCES:

1. Tien, C. L ., Majumdar, A. and Gerner, F. M., *Microscale Energy Transport*, Taylor & Francis, 2003.
2. Zhang, Z., *Nano/Microscale Heat Transfer*, McGraw Hill, 2007.
3. Volz, S., *Microscale and Nanoscale Heat Transfer*, Springer-Verlag, 2007.

4. Celate, G. P., *Heat Transfer and Transport Phenomena in Microscale*, Begell House, 2000.
5. Kakac, S., Vasiliev, L. L., Bayazitoglu, Y., Yener, Y., *Microscale Heat Transfer: Fundamentals and Applications*, Springer-Verlag, 2005.

TF710 CRYOGENICS 3-0-0-3

Methods of producing cold: thermodynamic basis, first and second law analysis.

Review of Solid and fluid properties at low and cryogenic temperatures- Liquefaction systems: Open and Closed cycles; Effect of component efficiencies as performance of different liquefaction cycles- Cryogenic refrigerators; Recuperative and Regenerative cycles - Effect of irreversibilities on system performance; Micro-miniature and miniature cryo-coolers for space and defence applications. Thermal stratification in cryo tanks, cryo tank insulation.

TEXT BOOKS/REFERENCES:

1. Willaim.E.Bryson, *Cryogenics*, Hanser Gardner Publications, 1999.
2. JhaA.R., *Cryogenic Technology and Applications*, Elsevier Butterworth- Heinemann, USA, 2006.
3. Thomas.M.Flynn, *Cryogenic Engineering*, Marcel Dekker Inc, 2005.
4. Randell.F.Barron, *Cryogenic Systems*, Oxford University Press, New York, 1985.
5. Stoecker W.F. and Jones J W, *Refrigeration and Air Conditioning*, 2nd Ed., McGraw-Hill International Editions, 1982.

TF711 RENEWABLE ENERGY 3-0-0-3

Renewable energy sources in India-potential sites, availability. Solar Energy: measurement and collection, flat plate collectors, concentrating collectors, solar ponds, photovoltaic conversion, Thermal energy storage. Ocean Energy: Principles of OTEC (Ocean Thermal Energy Conversion)- wave energy, tidal energy, energy conversion systems. Wind Energy: Principle, potential and status; Wind characteristics; National Wind Atlas; Theory of wind turbine blades; types of wind turbines and their characteristics. Bio-fuels: Sources and potential, properties and characterization; Biogas generation through aerobic and anaerobic digestion; Thermo-chemical methods of bio-fuel utilization: Combustion and gasification; Status of bio-fuel technology. Geo-thermal Energy-nature, types and utilization.

Recent trends in renewable energy- Flow Induced Vibration as a source of energy. Applications: Applications of renewable energy sources-typical examples. Energy audit.

TEXT BOOKS/REFERENCES:

1. Boyle, G., *renewable Energy: Power for a sustainable future*, 2nd Edition, Oxford University Press, New York, 2004.
2. Aldo V Rosa.,*Fundamentals of Renewable Energy Processes*, 2nd Edition, Elsevier Inc, USA, 2009.
3. Boyle, G., Evertt, B and Ramage, J., *Energy Systems and sustainability; power for a sustainable future*, Oxford University Inc., New York, 2003.
4. Craddock, D., *Renewable Energy Made Easy: Free Energy from Solar, Wind, Hydro power and other alternative energy sources*, Atlantic Publishing Group Inc., 2008.
5. Wengenmayr, R., Buhrke, T., *Renewable Energy: Sustainable Energy Concepts for the future*, Wiley-VCHVerlag GmbH & Co, Germany, 2008.

TF712 AERODYNAMICS 3-0-0-3

Basics equations of Fluid Mechanics, Inviscid flows, Steam function, Velocity potential, Two-dimensional incompressible flows: laplace's equation, its solutions, Flows over aerofoils: Conformal transformation, thin airfoil theory. Introduction to finite wings: Prandtl's lifting line theory. Effect of boundary layer separation on flow over airfoils.
Introduction to bluff body aerodynamics: flow over circular cylinders, effect of geometry, dynamic effects, unsteady aerodynamics.

TEXT BOOKS/REFERENCES:

1. Anderson J.D. *Aircraft Performance and Design*, WCB McGraw Hill, 1999.
2. McCormick B.K.*Aerodynamics, Aeronautics and Flight Mechanics*, John Wiley and Son Inc., 1994.
3. Warren.F.Phillips, *Mechanics of Flight*, John Wiley & Sons Inc, New Jersey, 2010.
4. Zdravkovich, M.M., 1997. *Flow Around Circular Cylinders*, Vol. 1: Fundamentals. Oxford University Press, Oxford, England.
5. Zdravkovich, M.M., 2003. *Flow Around Circular Cylinders*, Vol. 2: Applications. Oxford University Press, Oxford, England.

TF713 INSTRUMENTATION AND PROCESS CONTROL 3-0-0-3

Instrumentation

Introduction: Measurement and its classification by physical characteristics, direct and inferential measurement, on- and off- line measurement.
Static Characteristics of Instruments: Error, accuracy, repeatability, drift, threshold, backlash, hysteresis, zero-stability, static, coulomb and viscous friction, live zero, suppressed zero, working bind.
Sensor and Transducers: Classification, principles and applications, interpretation of performance specification of transducers.
Building Blocks of an Instrument : Transducer, amplifier, signal conditioner, signal isolation, signal transmitter, display, data acquisition modules, I/O devices, interfaces.

Process Instrumentation: Working principles of transducers/instruments employed for the measurement of flow, level, pressure, temperature, density, viscosity, etc. and their merits and demerits.
Data Acquisition and Signal Processing: Systems for data acquisition and processing, modules and computerized data system, digitization rate, time and frequency domain representation of signals, and Nyquist criterion; A brief description of elements of mechatronics, modular approach to mechatronics and engineering design. Introduction to LabView and Matlab for data capture and analysis.

Process Control

Introduction: The concept of process dynamics and control, review of Laplace transform methods, Laplace transform of disturbances and building functions, dynamic model building of simple systems.
Linear Open Loop System: Physical examples of first order systems and their response for step, impulse and sinusoidal inputs, linearization of non linear models, response of first order system in series, examples of second order systems and their response.
Linear Closed Loop System: The control system and its elements, closed loop transfer functions, transient response of simple control systems, concept of stability and use of Routh-Hurwitz test for stability.
Controllers: Modes of control action, control system and its closed-loop transfer function.
Root Locus Method : Root locus treatment, response from root locus and its application to control system design.
Frequency Response: Introduction to frequency response, Bode diagrams of simple systems, Bode stability criterion, control system design by frequency response, use of gain and phase margins.

TEXT BOOKS/REFERENCES:

1. Nakra B. C. and Chaudhry K. K., *Instrumentation, Measurement and Analysis*, 2nd Ed., Tata-McGraw Hill. 2004
2. Andrew W. G., *Applied Instrumentation in the Process Industries*, Vol. I, II and III 3rd Ed., Gulf Publication. 1993
3. Coughanowr D. R. and LeBlanc S., *Process System Analysis and Control*, 3rd Ed., McGraw Hill. 2008
4. Bequette B. W., Process Control – *Modeling, Design and Simulation*, Prentice-Hall of India. 2003
5. Doeblin, E. O., *Measurements System Application and Design*, 5th Ed., McGraw Hill, 2004

TF714 POWER PLANT AND THERMAL SYSTEMS ENGINEERING 3-0-0-3

Energy scenario, Overview power plants, Types of power stations, Economy and thermal schemes of power stations.

Review of various ideal cycles–Rankine and Brayton–and fuel-air cycles. Thermodynamics optimization of design parameters. Real cycle effects–internal and external irreversibilitites, pressure drops, heat loss, condenser air leakage, fouling of heat transfer surfaces, combustion losses–and their impact on the thermodynamic cycle. Optimization ofreal and double reheat cycles. Analysis of off-design performance.

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 power and process heat. Thermal power plant equipment, Combustion mechanisms, Furnaces, Combustion control, boilers (coal based, RDF based), economizers, Feedwater treatment. feed water heater, Boiler maintenance. Down-comers and risers. Drum and its internals. Convective and radiant super heaters. Superheat temperature control, condensers, combustion chamber and gas loops, elements of gas turbines theory, cooling towers, Dust and ash removal systems. Combined cycle power plants, Internal combustion engine plants for peak load standby and start up, Elements of hydropower generation and wind turbine, Elements of nuclear power plants, nuclear reactors and fuels, Recent advances in power plants, Renewable energy: solar, geothermal, wind, biomass, ocean, fuel cells, Environmental aspects of power generation, sustainability and future scenarios.

TEXT BOOKS/REFERENCES:

1. Suryanarayana, N.V., and Arici, O., *Design and Simulation of Thermal Systems*, McGraw Hill. 2001
2. Jaluria, Y., *Design and Optimization of Thermal Systems*, 2nd Ed., CRC Press. 2007
3. Bejan, A., Tsatsaronic, G., and Moran, M., *Thermal Design and Optimization*, John Wiley & Sons. 1995
4. Saravanamuttoo, H.I.H., Rogers, G.F.C., Cohen, H. and Straznicky, P.V., *Gas Turbine Theory*, 6th Ed., Pearson Prentice Hall. 2008.
5. H. Cohen, Gas Turbine Theory, 4th Edition, Longman, 1998.

TF715 PROPULSION 3-0-0-3

Principles of propulsion: Thermodynamic cycle analysis and efficiencies of propulsive devices.

Introduction to Aerospace propulsion, various propulsive devices used for aerospace applications. Launch vehicle dynamics, Classifications of rockets: Electric, Nuclear and Chemical rockets, cryogenic and semi-cryogenic engines, Applications of rockets.

Nozzle design: Flow through nozzle, Real nozzle, Equilibrium and frozen flow, Adaptive and non-adaptive nozzles. Thrust vector controls, Rocket performance parameters. Solid propellant rockets, Grain compositions. Design of grain. Liquid propellant rockets, Injector design, cooling systems, Feed Systems: Pressure feed and turbo-pump feed system. Heat transfer problems in rocket engines.

Introduction to various aircraft propulsive devices: Piston-prop, Turbo-prop,Turbojet, Turbofan, Turbo shaft, Ramjet,Vectored- thrust, Lift engines. Gas Turbine Cycles and cycle based performance analysis; 1-D and 2-D analysis of flow through gas turbine components - Intake, Compressors, Turbines, Combustion Chamber, Afterburner, and Nozzle. Compressor and Turbine blade shapes; cascade theory; radial equilibrium theory; matching of compressor and Turbine. Turbine cooling. Single spool and Multi- spool engines. Power plant performance with varying speed and altitude. Thermo-acoustic instability.

TEXT BOOKS/REFERENCES:

1. Oates G.C (Ed.) *Aerothermodynamics of Aircraft Engine Components*,AIAA, 1988.
2. Hill, P. G. and Peterson, C.R., *Mechanics and Thermodynamics of Propulsion*, 2^{nd}Ed., Prentice Hall, 1991.
3. Sutton George P., Biblarz Oscar,*Rocket Propulsion Elements*, John Wiley & Sons, 2010.
4. Turner Martin J. L., *Rocket and Spacecraft Propulsion : Principles, Practice and New Developments*, 3rd ed. Springer, 2009
5. Mukunda H. S., *Understanding Aerospace Chemical Propulsion*, Interline Publishing Pvt. Ltd., 2004.

TF716 BIO-FLUID MECHANICS 3-0-0-3

Physiological characteristics of cardiovascular system- Newtonian and non-Newtonian fluids-Flow properties of blood and its various constituents- Steady and pulsatile flows in rigid and elastic tubes and their application to arterial system- Flow and material exchange in capillary network- Flow through bends, constrictions and branches- Flow through distensible tubes and its application to venous system.

TEXT BOOKS/REFERENCES:

1. RossEthier C. and Craigg A. *Simmons, Introductory Biomechanics*, Cambridgetexts in Biomedical Engineering, 2007.
2. Kleinstreuer C., *Biofluid Dynamics: Principles and Applications*, CRC Press,Taylor&Francis Group, 2006.
3. Zamir.C, *The Physics of pulsatile flow*, Springer-Verlag NY, 2000.
4. Mazumdar J. N., *Biofluid Mechanics*, World Scientific, 2004.
5. Waite.L, *Applied Biofluid Mechanics*, McGraw Hill, 2007

TF717 IC ENGINE COMBUSTION AND EMISSIONS3-0-0-3

Introduction to Combustion; Thermo-chemistry and thermodynamics of combustion; Laminar and turbulent premixed flames, Premixed engine combustion; Spray formation and atomization, Direct injection and CI engine combustion; Combustion systems and management. Introduction to air pollutants and pollution; Genesis and formation of engine emissions, NO kinetics, Soot formation and oxidation, NOx-Soot tradeoff. Different emission standards and measurement techniques; Control of emissions in SI and CI engines, Impact of engine design parameters on emissions, exhaust after treatment, lean de-NOx catalysts, DISC and HCCI engines; Alternative propulsion systems e.g., HEV, FCV etc.; Engine fuel impacts on emissions, alternative fuels e.g., CNG, alcohols, biodiesel, hydrogen, GTL.

TEXT BOOKS/REFERENCES:

1. John B. Heywood, *Internal Combustion Engine Fundamentals*, McGraw Hill International Edition, 1989.
2. Pundir B. P., *Engine Emissions: Pollutant Formation and Advances in Control Technology*, Narosa Publishing House, New Delhi, 2007.
3. Ferguson C.R., Kirkpatrick A. T., *Internal. Combustion Engines : Applied Thermosciences*, 2nd Edition, John Wiley & Sons, 2001.
4. Willard W. Pulkrabek, *Engineering Fundamentals of the Internal Combustion Engine*, Pearson Prentice-Hall, 2004.
5. Charles Fayette Taylor, *The Internal Combustion Engine in Theory and Practice: Combustion, Fuels, Materials*, Design, Vol. 2, MIT Press, 1985.

TF718 NUMERICAL RADIATION HEAT TRANSFER 3-0-0-3

Fundamentals of thermal radiation; Radiative transfer without participating media; Radiative transfer with participating media; Governing equations in radiative transfer analysis with participating media; Radiative properties of molecular gases and particulate media; Exact solutions of one-dimensional gray media; Approximate solution methods for one-dimensional media Methods for solving radiative transfer problems - analytic method, Monte Carlo method, zonal method, flux method, P-N approximation, discrete ordinate method, finite element method, discrete transfer method, finite volumet method, collapsed dimension method. Application of numerical methods for solving conjugate radiation, conduction and/or convection problems in 1-D and 2-D Cartesian and axi-symmetric geometry.

TEXT BOOKS/REFERENCES:

1. Siegel R and Howell J. R., *Thermal Radiation Heat Transfer*, 3rd edition, Taylorand Francis, 1992.
2. Modest M. F., *Radiative Heat Transfer*, McGraw-Hill, 1993.
3. Ozisik M. N., *Radiative Transfer and Interactions with Conduction and Convection*, John Wiley & Sons, 1973.
4. ArunnNarasimhan,*Elements of heat and fluid flow in porous media,* CRC Press, Taylor & Francis Group, 2012.

TF719 HEAT TRANSFER IN POROUS MEDIA 3-0-0-3

Introduction; Fluid mechanics – Darcy momentum equation; Porosity; Pore structure; Permeability; High Reynolds number flows; Brinkman superposition of bulk and boundary effects; Local volume-averaging method; Homogenization method; Semiheuristic momentum equations; Significance of macroscopic forces; Porous plain media interfacial boundary conditions; Variation of porosity near bounding impermeable surfaces. Conduction heat transfer Local thermal equilibrium; Local volume averaging for periodic structures; Particle concentrations from dilute to point contact; Areal contact between particles caused by compressive force; Statistical analysis: A variational formulation; A thermodynamic analogy. Convection heat transfer – Dispersion in a tube: Hydrodynamic dispersion; Dispersion in porous media; Local volume averaging for periodic structures; Three dimensional periodic structures; Dispersion in disordered structures: Simplified hydrodynamics, particle hydrodynamics; Properties of dispersion tensor; Experimental determination of D; Dispersion adjacent to bounding surfaces. Radiation heat transfer – Continuum treatment; Radiative properties of single particle; Radiative properties: Dependent and Independent; Volume averaging for independent scattering; Experimental determination of radiative properties; Boundary conditions; Solution methods for equation of radiative transfer; Scaling in radiative heat transfer; Noncontinuum treatment: Monte Carlo simulation; Radiant conductivity; Modeling dependent scattering; Recent developments in the analysis of heat transfer in porous media. Applications: Heat pipes, Fuel cells.

TEXT BOOKS/REFERENCES:
Books

1. Kaviany M., *Principles of Heat T ransfer in Porous Media*, Springer-Verlag, New York, 1991.
2. Carbonell R. G. and Whitaker S., *Heat and Mass Transfer in Porous Media, in Fundamentals of Transport Phenomena in Porous Media*, Bear and Corapcioglu, eds., MartinusNijhoff Publishers. 1984.

Journals

1. Transport in Porous Media
2. International Journal of Heat and Mass Transfer
3. Numerical Heat Transfer, Part A and Part B
4. Journal of Heat Transfer, Trans. ASME.
5. Journal of Thermo physics and Heat Transfer
6. Journal of Fluid Mechanics, Trans. ASME.

TF720 NUMERICAL SIMULATIONS AND MODELLING OF TURBULENT FLOWS 3-0-0-3

Introduction: Physical description and significance of turbulent flows. Transition and onset of turbulence; Turbulent free shear and wall-bounded flows; Challenges and complexities. Direct Numerical Simulation (DNS): Introduction; Governing Equations; Computational cost; Examples of DNS of channel and free-shear flows. Large Eddy Simulation (LES): Introduction; Filtering; Filtered conservation equations; Smagorinsky's model; Appraisal and perspective. Reynolds Averaged Equations: Reynolds averaging; Reynolds averaged equations; Closure problem. Turbulent Viscosity Models: Turbulent viscosity hypothesis; Algebraic models; Turbulent-kinetic-energy models; Exact and modelled equations for turbulent-kinetic-energy and its dissipation; Modifications for wall effects and buoyancy-driven flows. Reynolds-Stress Models: Introduction; Closure relations; Examples; Limitations.

TEXT BOOKS/REFERENCES:

1. Tennekes, H., and Lumley, J.L., 1972, *A First Course in Turbulence*, MIT Press, Cambridge, Massachusetts, USA.
2. Pope, S.B., 2000, *Turbulent Flows*, Cambridge University Press.
3. Ferziger, J.H., and Peric, M., 2002, *Computational Methods for Fluid Dynamics*, Springer.
4. Schlichting, H., and Gersten, K., 2000, Boundary Layer Theory, Springer.
5. Wilcox, D.C., 2010, *Turbulence Modelling for CFD*, DCW Industries, California, USA.

TF721 REFRIGERATION AND AIR-CONDITIONING SYSTEMS 3-0-0-3

Goff and Gratach method of calculation of moist air properties, mass transfer and evaporation of water into moist air, theory of psychrometer, correlation of w.b.t. with temperature of adiabatic saturation, Lewis number, construction of h.w. psychrometric chart. Review of refrigeration and air conditioning load calculations.Two phase flow, flow regimes, maps, two-phase pressure drop in evaporator and condensers.

Vapour compression, multiple evaporator and compound compression system with and without inter cooling, dual compressors, cascade systems, vapour absorption system-analysis, solid carbon dioxide, principle of production, three stage system with water and flash inter-cooler, pressure snow chambers, regenerative liquid, binary system.

Performance characteristics and capacity control of reciprocating, rotary and centrifugal compressors, screw compressors, hermetically sealed units, analysis of centrifugal compressors.

Direct contact transfer equipment, simple air washer and indirect evaporative cooling, contact mixture principle, enthalpy potential, basic equation for direct contact transfer equipment, graphical and analytical methods for heat and mass transfer analysis of air-washers with heated and chilled water sprays, cooling towers.

Water cooled and air-cooled condensers, performance and heat transfer processes in evaporative condenser, flooded and dry expansion type evaporators, liquid chiller, overall performance of evaporators, capillary tubes, system design factors, pressure and temperature distribution, ASHRAE simplified calculation procedure, expansion valves, operation and performance calculation of thermostatic expansion valve, application of constant pressure expansion valve.

Ice manufacture, design of refrigerated cars and warehouses.

TEXT BOOKS/REFERENCES:

1. Stoecker, W. F. and Jones, J. W., 1983, *Refrigeration and Air-conditioning*, McGraw Hill.
2. *ASHRAE Handbook*, 2009, American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE).
3. Whitman, B., Johnson, B., Tomczyk, J. and Silberstein, E., 2008, *Refrigeration and Air Conditioning Technology*, 6th Ed., Delmar Cengage Learning.
4. Hundy, G. H., Trott, A. R. and Welch, T. C., 2008, *Refrigeration and Air-Conditioning*, 4th Ed., Butterworth-Heinemann.
5. Arora, C. P., 2008, *Refrigeration and Airconditioning*, 3rd Ed., Tata-McGrawHill.
6. Kuehn, T. H., Ramsey, J. W. and Threlkeld J. L., 1998, *Thermal Environmental Engineering*, 3rd Ed., Prentice Hall.

TF722 NUCLEAR REACTOR THERMAL-HYDRAULICS AND SAFETY 3-0-0-3

Basic concepts of reactor physics, radioactivity. Neutron Scattering. Thermal and fast reactors. Overview of nuclear reactor systems.Sources and distribution of thermal loads in nuclear power reactors.

Flow Regimes in Two-Phase Flow, Two-phase flow models: Homogeneous Equilibrium Model, Separated and Slip Flow Model, Void Fraction Correlations,Stratified Flow Analysis and Flow Pattern transition, Pool Boiling & Flow Boiling Heat Transfer, Critical Flow, Nuclear Applications of Fluid Mechanics and Heat Transfer.

Heat generation in reactors, Nuclear Heat Transport, steadyandunsteady conduction in reactor elements, Hydraulics of reactor system loops, Hydraulics of heated channels,

Safety philosophy, Thermal Design Principles, Single Channel Analysis, Sub-channel analysis, LOCA and LOFA Modelling, modelling of containment loading. Waste management. Indian nuclear power programme.

Review of Thermal-Hydraulics Codes Used for Reactor Accident Analysis, Advanced Safety Concepts and Upcoming Reactor Safety Methods and next generation reactors.

Thermal-Hydraulics Uncertainty Analysis, Probabilistic safety assessment, regulatory procedure and licensing.

TEXT BOOKS/REFERENCES:

1. Todreas, Neil E., and Mujid S. Kazimi. *Nuclear Systems: Thermal Hydraulic Fundamentals. Vol. 1*. New York, NY: Taylor & Francis Inc., 1990.
2. Glasstone, S. and Sesonske, A., *Nuclear Reactor Engineering,* Springer, 1994.
3. LewisE. E., *Nuclear reactor Safety*, Wiley Interscience, 1977.
4. TongL.S. and TangY.S., *Boiling heat transfer and Two-phase Flow,* Taylor and Francis, 1997.
5. CollierJ.B. and ThomeJ.R., *Convective boiling and condensation,* Oxford Science Publications, 1994.
6. WallisG.B., *One dimensional two-phase flow,* McGraw Hill, 1969.

7. Richard T. Lahey and Frederick J. Moody, *The Thermal-Hydraulics of Boiling Water Reactors*, Second Edition, American Nuclear Society, 1993
8. JonesO.C., ed., *Nuclear Reactor Safety Heat Transfer*, Hemisphere, 1981.
9. M. M. El-WakilNuclear Heat Transport, 1978.