Incompressible Flow

Course Contents:

1. Introduction and Basic Concepts - Definition of fluid and concept of continuum; Properties of fluids; Flow field, streamlines, path lines and streak lines; Kinematics of fluid motion; Eulerian and Lagrangian formulations

2. Governing Equations of Fluid Flow - Reynolds transport theorem; Mass and momentum conservation; Navier-Stokes equation; Analytical solutions to simple flows; Couette Flow; Poiseuille flow; Euler and Bernoulli equation

3. Potential Flow - Stream function and velocity potential; Elementary plane flows; Superposition of elementary plane flows; Concept of lift and drag

4. Boundary Layer Theory - Concept of boundary layer; Derivation of boundary layer equations; Boundary layer flow over a flat plate; Boundary layer flow with non-zero pressure gradient; Flow separation and drag; Free shear flow

5. Turbulent flows - Characteristics of turbulent flows; Concept of averaging; Reynolds Averaged Navier Stokes (RANS) equations; Turbulent internal flows; Turbulent external flows; Flow over Wedge ; 2-D laminar Jet

Advanced Heat and Mass Transfer

Course Contents:

Review of Heat Transfer- Derivation of Heat Balance Equation (for low speed flows) in Cartesian Coordinates- Generalization for cylindrical & spherical coordinates- Types of boundary conditions (4 lectures)

Unsteady lumped solution- one dimensional steady conduction solutions in cartesian, cylindrical & spherical geometries- steady/ unsteady conduction solutions by separation of variables technique in cartesian, cylindrical & spherical coordinates, conduction in semi-infinite solid, conduction with phase change (10 lectures)

Velocity and Thermal Boundary layers, similarity approach, Integral technique- laminar and turbulent boundary layers- heat transfer correlations for external flows- high speed boundary layer solution, Natural convective heat transfer from a heated plate (10 lectures)

Developed flow inside ducts and pipes- Thermally developed laminar flow solutions- Nusselt number for constant heat flux and constant wall temperature- turbulent flow in pipes (6 lectures)

Fundamentals of condensation and boiling- pool boiling curve- flow boiling (4 lectures)

Radiation basics- black and gray body radiation- radiation in enclosures- gas radiation- radiation in participating media (8 lectures)

Basics of mass transfer- mass averaged and mole averaged velocities and fluxes- Fick's law of diffusion- Species balance equation- one dimensional mass transfer solutions- mass transfer boundary layer- mass transfer correlations- combined heat and mass transfer (10 lectures)

Text Books:

1. Fundamentals of Heat & Mass Transfer, Theodore L. Bergman, Adrienne S. Lavine, Frank R. Incropera, David P. Dewitt, Incropera& Dewitt, Seventh Edition, John Wiley & Sons, 2011.
2. (ii)Transport Phenomena by R. Byron Bird, Warren E. Stewart, Edwin N. Lightfoot, Second Edition, John Wiley & Sons, 2002.
3. (iii)Convective Heat & Mass Transfer, W.M. Kays, M.E. Crawford, BemhardWeigand, Fourth Edition, McGraw-Hill

Applied Thermodynamics

Course Contents:

Second Law Analysis
Review of entropy; Second law analysis for a control volume; Irreversibility and availability; Exergy balance equation and Exergy analysis

Vapor power cycles
Rankine cycle with superheat, reheat and regeneration; Exergy analysis; Super-critical and ultra super-critical Rankine cycle

Gas power cycles
IC engines – Air standard Otto, Diesel and Dual cycle;Gas turbines; Air standard Brayton cycle; Effect of reheat, regeneration and intercooling; Combined gas and vapor power cycles

Vapor compression refrigeration cycles
Vapor refrigeration systems and their analysis;Commonly used refrigerants and their properties; Supercritical vapor compression refrigeration cycles

Pschyrometry
Introduction to Pschyrometric principles; Application of mass and energy balances to air-conditioning systems; Wet- and dry-bulb temperatures; Pschyrometric chart; Air conditioning processes

Combustion
Combustion reactions – Stoichiometry; First law analysis, Heat calculations, Adiabatic flame temperature

Gas Dynamics
Basic ideas in compressible flow; Normal shocks; Flow of perfect gases through nozzles; Flow of steam and refrigerant through nozzles; Supersaturation, Wilson line and condensation shock

Text Books/References

1. Fundamentals of Engineering Thermodynamics, Michael J. Moran, Howard N. Shapiro, Daisie D. Boettner and Margaret B. Bailey, Wiley, 7th edition
2. Fundamentals of Gas Dynamics, V. Babu, Ane Books, 2nd edition

Measurements in Thermal Engineering

Course Contents:

Introduction to measurements.Measurement categories-primary and derived quantities, intrusive and non-intrusive methods;Analysis of experimental data- types of errors, uncertainty analysis, propagation of uncertainty; Statistical analysis of experimental data- normal error distributions (confidence interval and level of significance, Chauvenet's criterion), Chi-square test of goodness of fit, method of least squares (regression analysis, correlation coefficient), multivariable regression, Students' t-distribution, graphical analysis and curve fitting.

Static and dynamic characteristics; System response- first and second order systems and analysis, Measurement of temperature- thermoelectric thermometry, resistance thermometry, pyrometry, liquid in glass, bimetallic and liquid crystal thermometer, temperature sensors for measurement of transient temperature; Measurement of pressure-U-tube manometer, Bourdon gage, pressure transducers, measurement of transient and vacuum pressures.Measurement of volume flow rate-variable area type flow meter-orifice plate meter, flow nozzle, venture meter, rotameter. Measurement of velocity-Pitot static and impact probes, velocity measurement based on thermal effect, Doppler velocimeter, Time of flight velocimeter.

Text Books:

1. S P Venkateshan, Mechanical Measurements, Anne Books Pvt. Ltd., 2015.
2. J P Holman, Experimental Methods for Engineers, McGraw-Hill, 2011.

References:

1. J R Taylor, An Introduction to Error Analysis: The Study of Uncertainties in Physical Measurements, University Science Books, 1997
2. Doebelin, Measurement System, Tata McGraw-Hill Education, 1984
3. Beckwith, Mechanical Measurements, Pearson Education India, 2007

Numerical Methods in Thermal Engineering

1. Solution of Linear Algebraic Equations
    1.1. Gaussian elimination
    1.2. LU decomposition
    1.3. Pivoting strategies
    1.4. Operation Count
    1.5. Matrix inversion
    1.6. Special cases
        1.6.1. Tridiagonal and block tridiagonal systems
    1.7. Well conditioned and Ill conditioned system
    1.8. Matrix and Vector norms
    1.9. Condition Number and its implications

2. Solution of Non-linear Algebraic Equations
    2.1. Bisection, Newton-Raphson and Secant method
    2.2. System of non-linear equations

3. Basics of finite difference method
    3.1. Discretization of spatial and time derivatives using Taylor's series
    3.2. Truncation error and order of discretization
    3.3. Fourier (von Neumann) stability analysis

4. Solution of Ordinary Differential Equations
    4.1. Initial Value problems
        4.1.1. Euler explicit and implicit methods
        4.1.2. Runge-Kutta method
        4.1.3. Predictor-Corrector methods
    4.2. Boundary value problem
        4.2.1. Shooting method
        4.2.2. Finite difference method applied to pin fin heat dissipation
    4.3. Stiff problems
        4.3.1. Meaning of stiffness
        4.3.2. Further insights into stiffness by the application of Euler explicit and implicit method to a stiff problem
        4.3.3. Solution of stiff problem
        4.3.4. Example - Chemical kinetics

5. Solution of Elliptic Partial Differential Equations
    5.1. Physical problems governed by elliptic PDE's
    5.2. Five-point and nine-point discretizations of Poisson's equation
    5.3. Iterative methods
        5.3.1. Point Iterative methods - Jacobi, Gauss-Seidel, and SOR
        5.3.2. Detailed theory of the convergence of iterative methods
        5.3.3. Global Iterative methods - Steepest Descent and Conjugate Gradient

6. Classification of PDEs and characteristics of a PDE

7. Solution of Parabolic Partial Differential Equations
    7.1. Physical problems governed by parabolic PDE's
    7.2. Operator splitting and ADI methods

Suggested Textbooks

1. Numerical Mathematics and Computing, by Ward Cheney and David Kincaid, International Thomson Publishing Company
2. Applied Numerical Analysis, by Curtis Gerald and Patrick Wheatley, Addison-Wesley
3. Analysis of Numerical Methods, by E. Isaacson & H. B. Keller, John Wiley & Sons
4. Numerical Solution of Partial Differential Equations : Finite Difference Methods, by G. D. Smith, Oxford University Press, 1985
5. Matrix Computations, by G. H. Golub, Johns Hopkins University Press
6. Numerical Recipes, by W. H. Press et al

ME6290- Advanced Energy Conversion
(Course Content)

1. **Fossil and Biofuels (Classification & Characterization)**

- Solid, liquid and gaseous fuels and their properties; I law for reacting systems, Heat of combustion and HCV, LCV; Adiabatic flame temperature, bond energy and heat of formation; dissociation, free energy change, chemical equilibrium and equilibrium products.

2. **Clean Energy Technologies (Fluidized Bed Boilers, Gasification and Gasifiers; Integrated Gasifier, Combined Cycle Technology)**

- Principle of Fluidization, minimum fluidization velocity, categorization of fluidized beds based on Archimedes number; coal combustion and gasification reactions; PC boilers, FBC boilers, FBC gasifiers; IGCC and its cycle efficiency.

3. **Supercritical Boilers; Cogeneration and Combined Cycle Power Generation**

- Modern thermal power plants; Rankine cycle analysis for performance improvement by reheat, regeneration and superheating, once-through boiler in supercritical power plants; Analysis of cogeneration systems; Performance analysis of combined cycle power system; Binary cycle power systems.

4. **Fuel Cells & MHD Technology**

- Comparison fuel cell with battery and IC engine; thermodynamic analysis of PEM fuel cell; voltage – current characteristics of fuel cells and over-potentials; types of fuel cells.
- MHD conversion, energy balance for MHD, efficiency of MHD converter.

5. **Solar and Wind Power Plants**

- Solar Thermal Power Generation. Concentrating solar power (CSP) technologies-stand alone and grid connected systems
- Wind Energy Conversion Systems; Sources and Potential, Types of wind turbines and their characteristics, Wind Characteristics, Theory of horizontal-axis and vertical axis wind turbines, Introduction to off-shore wind energy conversion

6. **Advanced Nuclear Power**

- Three stage nuclear conversion and closing of nuclear conversion cycle; thermal reactors, working principle of BWR, PWR, APWR; fast breeder reactor

7. **Advanced Pollution Control Technology**

- Introduction to Air pollution control devices, control of particulate matter and gaseous pollutants from thermal power plants

Syllabus for Engineering Mathematics (Thermal Engineering Stream)

Section 1: Linear Algebra

Algebra of matrices; Inverse and rank of a matrix; System of linear equations; Symmetric, skew-symmetric and orthogonal matrices; Determinants; Eigenvalues and eigenvectors; Diagonalisation of matrices; Cayley-Hamilton Theorem.

Section 2: Calculus

Functions of single variable: Limit, continuity and differentiability; Mean value theorems; Indeterminate forms and L'Hospital's rule; Maxima and minima; Taylor's theorem; Fundamental theorem and mean value-theorems of integral calculus; Evaluation of definite and improper integrals; Applications of definite integrals to evaluate areas and volumes. Functions of two variables: Limit, continuity and partial derivatives; Directional derivative; Total derivative; Tangent plane and normal line; Maxima, minima and saddle points; Method of Lagrange multipliers; Double and triple integrals, and their applications. Sequence and series: Convergence of sequence and series; Tests for convergence; Power series; Taylor's series; Fourier Series; Half range sine and cosine series.

Section 3: Vector Calculus

Gradient, divergence and curl; Line and surface integrals; Green's theorem, Stokes theorem and Gauss divergence theorem (without proofs).

Section 3: Complex variables

Analytic functions; Cauchy-Riemann equations; Line integral, Cauchy's integral theorem and integral formula (without proof); Taylor's series and Laurent series; Residue theorem (without proof) and its applications.

Section 4: Ordinary Differential Equations

First order equations (linear and nonlinear); Higher order linear differential equations with constant coefficients; Second order linear differential equations with variable coefficients; Method of variation of parameters; Cauchy-Euler equation; Power series solutions; Legendre polynomials, Bessel functions of the first kind and their properties.

Section 5: Partial Differential Equations

Classification of second order linear partial differential equations; Method of separation of variables; Laplace equation; Solutions of one dimensional heat and wave equations.

Section 6: Probability and Statistics

Axioms of probability; Conditional probability; Bayes' Theorem; Discrete and continuous random variables: Binomial, Poisson and normal distributions; Correlation and linear regression.

Section 7: Numerical Methods

Solution of systems of linear equations using LU decomposition, Gauss elimination and Gauss-Seidel methods; Lagrange and Newton's interpolations, Solution of polynomial and transcendental equations by Newton-Raphson method; Numerical integration by trapezoidal rule, Simpson's rule and Gaussian quadrature rule; Numerical solutions of first order differential equations by Euler's method and 4th order Runge-Kutta method.