Master of Technology

in

FLUIDS ENGINEERING

Course Structure, Scheme of Evaluation and Syllabi

(*Effective from July 2017*)

Department of Applied Mechanics

Motilal Nehru National Institute of Technology Allahabad
Allahabad, U.P. -211004, INDIA

Course Structure

I Semester (Total Credits = 20):

Course Code	Subject Name	L	T	P	Credits	Distribution of Marks out of 100		
						TA	Mid Sem. Exam	End Sem. Exam
AM2101	Applied Mathematics & Computation	4	0	0	4	20	20	60
AM2140	Advanced Fluid Mechanics	4	0	0	4	20	20	60
AM2206	Computational Fluid Dynamics	4	0	0	4	20	20	60
AM21XX	**Elective-I**	4	0	0	4	20	20	60
AM21XX	**Elective-II**	4	0	0	4	20	20	60

List of Electives (Semester I):

Elective-I:		**Elective-II:**	
AM2143	Aerodynamics.	**AM2146**	Multiphase Flow.
AM2144	Wind Engineering.	**AM2147**	Design of Experiments.
AM2145	Research Methodology.	**AM2142**	Convective Heat Transfer.
AM2110	Applied Elasticity	**ME2148**	Gas Turbine and Jet Propulsion.
AM2141	Bio-Fluid Dynamics.		

II Semester (Total Credits = 20):

Course Code	Subject Name	L	T	P	Credits	Distribution of Marks out of 100		
						TA	Mid Sem. Exam	End Sem. Exam
AM2240	Turbulence	4	0	0	4	20	20	60
AM2253	Advanced Fluid Mechanics Laboratory	0	0	6	4	20	20	60
AM22XX	**Elective-III**	4	0	0	4	20	20	60
AM22XX	**Elective-IV**	4	0	0	4	20	20	60
AM22XX	**Elective-V**	4	0	0	4	20	20	60

List of Electives (Semester II):

Elective-III:			**Elective-IV:**	**Elective-V:**	
AM2249	Advanced Computational Fluid Dynamics	**ME2243**	Thermo-Fluid Dynamics.	**ME2235**	Advanced Gas Dynamics.
AM2211	Fluid-Structure Interaction.	**AM2243**	Design of Heat Exchangers.	**AM2246**	Industrial Aerodynamics.
AM2241	Boundary Layer Theory.	**AM2244**	Design of Hydraulic Turbines.	**AM2247**	Design of Impeller Pumps.
AM2242	Design of Pipe Networks.	**AM2245**	River Engineering.	**AM2248**	Condition Monitoring, Diagnosis and Predictive Maintenance of Pumps.

III Semester (Total Credits = 20):

S. No.	Subject Name	Credits
AM2395	**Special Study/Term Project/State of the Art/Colloquium Industrial/Research Training**	4
AM2396	**Thesis/Project**	16

IV Semester (Total Credits = 20):

S. No.	Subject Name	Credits
AM2496	**Thesis/Project**	20

Note: The distribution of thesis evaluation marks will be as follows:

1. Supervisor(s) evaluation component: 60%
2. Oral Board evaluation component: 40%

Semester-I

AM2101 Applied Mathematics and Computation		
Designation	:	Compulsory
Pre-requisites	:	Engineering Mathematics and computer programming
Credit and Contact hrs	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment: (Scheme) 20 marks (5 marks for attendance + 15 marks for Assignment submission, Surprise tests, Term paper, Quiz tests, etc.)

Syllabus

Review of Elementary Engineering Mathematics: Solution of homogeneous and non-homogeneous equations; Power series; Laplace transform and its applications; Fourier series and Fourier transform

Linear Algebra: Matrices and Linear Transformations, Operational Fundamentals of Linear Algebra, Systems of Linear Equations, Gauss Elimination Family of Methods, Special Systems and Special Methods, Numerical Aspects in Linear Systems, Eigenvalues and Eigenvectors, Diagonalization and Similarity Transformations, Jacobi and Givens Rotation Methods, Tri-diagonal Matrices, QR Decomposition Method, Eigenvalue Problem of General Matrices, Singular Value Decomposition, Direct and Iterative solvers.

Ordinary Differential Equations: Introduction to ordinary differential equations, homogeneous linear equations of second order, non-homogeneous linear equations of second order, free and forced oscillation problems, problems with variable coefficients, system of equations.

Partial Differential Equations (PDEs): Existence and uniqueness of differential equations, nature of solution, Hyperbolic, Parabolic and Elliptic PDEs, nonlinear PDEs.

Nonlinear Equations: Motivation, Open and braketing method, Bisection, Fixed point, Newton's method, Secant and False position method, Rate of convergence, Merits and demerits of methods.

Numerical Integration: Motivation, Newton-Kotes method, Trapezoidal rule, Simpson's rule, Rhomberg integration, Gauss Quadrature.

Initial Value Problem: Motivation, Euler's method, Modified Euler method, Runge-Kutta methods, Adaptive integrations and multistep methods.

Boundary-value and Eigen-value Problem: Methods and Applications in Mechanics.

References books

1. "Numerical Methods in Engineering", M. Salvadori, Prentice Hall International, 1961.
2. "Applied Numerical Methods", B. Carnahan, Krieger Pub, 1990.
3. "Applied Numerical Analysis", C.F. Gerald and P.O. Wheatley, 5th edition, Addison-Wesley, 1998.
4. "Numerical Mathematics & Computing", W. Cheney and D. Kincaid, 5th edition, Brooks/Cole, 2004.
5. "Applied Partial Differential Equations", Paul DuChateau and David Zachmann.
6. "Partial Differential Equations for Scientists and Engineers", Stanley J. Farlow.
7. "Numerical Methods for Partial Differential Equations", William F. Ames.
8. "Numerical Methods for Elliptic and Parabolic Partial Differential Equations**",** John R Levison, Peter Knabner, Lutz Angermann.

AM2140 Advanced Fluid Mechanics		
Designation	:	Compulsory
Pre-requisites	:	*Engineering Fluid Mechanics, Thermodynamics.*
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme):20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).

Syllabus

Basic Conservation & Governing Laws: Statistical & continuum methods, Eulerian & Lagrangian coordinates, material derivatives, control volumes, Reynolds' transport theorem (RTT), conservation of mass, momentum and energy, constitutive equations, Navier-Stokes equations- differential & intergral approach, energy equations, governing equations for Newtonian fluids, boundary conditions.

Potential Flows: Stokes stream functions, solution of potential equation, flow in a sector, flow around a sharp edge, flow near a blunt nose force and moment on a circular cylinder and sphere, conformal transformations, Joukowski transformations.

Viscous Incompressible Flows: Exact solutions for Couette flow, Poiseuille flow, flow between rotating cylinders, Stokes' first problem, Stokes' second problem, pulsating flow between parallel surfaces, stagnation-point flow, flow in convergent and divergent channels, flow over porous wall. Stokes approximation, rotating sphere in a fluid, uniform flow past a sphere and cylinder, Ossen's approximation, Hele-Shaw flow.

Introduction to Boundary Layer: Derivation of boundary layer equation, How potential flow complements B.L. equation, Integral solution of B.L., Laminar and turbulent boundary layers; transition; B.L. separation and control.

Introduction to Compressible Flow: Velocity of sound and its importance, physical difference between incompressible, subsonic and supersonic flows, Mach number and its significance. Isentropic flow through nozzles, shocks and expansion waves, Rayleigh and Fanno Flow.

References books

1. "Fundamental Mechanics of Fluids", I. G. Currie.
2. "Foundations of Fluid Mechanics", S.W. Yuan, Prentice-Hall India Pvt. Ltd, New Delhi.
3. "Advanced Fluid Mechanics", K. Muralidhar & G. Biswas, Narosa Publishing, 2005.
4. "Boundary Layer Theory", H. Schlichting, 6th Edition, McGraw-Hill Inc., 1986.
5. "Modern Compressible Flow with Historical Perspective", John D. Anderson, McGraw Hill.
7. "Fundamentals of Aerodynamics" (2nd ed), J. D. Anderson, McGraw Hill.
8. "Fundamentals of Fluid Mechanics", B.R. Munson, D.F. Young & T.H. Okiishi, 2nd Ed., John Wiley.
9. "Introduction to Fluid Mechanics", R.W. Fox & A.T. McDonald, 5th Edition, John Wiley,2001.
10. "Viscous Fluid Flow", F. M. White, 2nd Edition, McGraw-Hill, 1991.

AM2206 Computational Fluid Dynamics		
Designation	:	Compulsory
Pre-requisites	:	*Engineering Fluid Mechanics, Heat Transfer, Engineering Mathematics, CAD, Computer programming.*
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme):20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).

Syllabus

Basic ideas of CFD: Introduction to CFD, role of CFD and its applications, future of CFD.

Governing equations (GE's) of Fluid dynamics: Modeling of flow, control volume concept, substantial derivative, physical meaning of the divergence of velocity. Continuity equation, momentum equation, energy equation and its conservation form. Equations for viscous flow (Navier-Stokes equations), equations for inviscid flow (Euler equation). Different forms of GE's, initial and boundary conditions.

FVM for Diffusion Problems: FVM for 1D steady state diffusion, 2D steady state diffusion, 3d steady state diffusion. Solution of discretised equations- TDMA scheme for 2D and 3D flows.

FVM for Convection-Diffusion Problems: FVM for 1D steady state convection-diffusion, Central differencing scheme, Conservativeness, Boundedness, Transportiveness, Upward differencing scheme, Hybrid differencing scheme for 2D and 3D convection-diffusion, Power-law scheme, QUICK scheme.

Solution Algorithm for Pressure-velocity Coupling in Steady Flows: Concept of staggered grid, SIMPLE, SIMPLER, SIMPLEC, PISO algorithm.

FVM for Unsteady Flows: 1D unsteady heat conduction (Explicit, Crank-Nicolson, fully implicit schemes), Implicit mecthods for 2D and 3D problems, Discretization of transient convection-diffusion problems, solution procedure for transient unsteady flow calculations (transient SIMPLE, transient PISO algorithms).

Grid Generation: General transformation of the equations. Metices and Jacobians. Types of grids- structured and unstructured grids, grid generation methods- algebraic, differential and hybrid methods. Coordinate stretching, boundary-fitted coordinate systems. Elliptic and hyperbolic grid generation methods, orthogonal grid generation for Navier-Stokes equations, Multi-block grid generation.

Latest development in CFD techniques and newer applications.

References books

1. "An Introduction to Computational Fluid Dynamics: the Finite Volume Method", H.K. Versteeg and W. Malalasekara, 2nd edition, Pearson Education, England, 2007.
2. "Computational Fluid Dynamics for Engineers" B. Andersson & others, 1st edition, Cambridge University Press, U.K., 2012.
3. "Computational Fluid Flow and Heat Transfer" (2nd edition), K. Muralidhar and T. Sundararajan, Narosa Publishing, 2004.
4. "Numerical Heat Transfer and Fluid Flow", S.V. Patankar, McGraw-Hill, New York, 1980.
5. "Principles of Computational Fluid Dynamics", P. Wesseling, Springer-Verlag.
6. "Computational Techniques for Fluid Dynamics Volume I & II" (2nd edition), C.A.J. Fletcher, Springer-Verlag, 1991.
7. "Computational Fluid Mechanics and Heat Transfer" (2nd edition), J.C. Tannehill, D.A. Anderson and R.H. Pletcher, Taylor and Francis, 1997.
8. "Numerical Computation of Internal and External Flows" (Vols. I & II), C. Hirsch, Wiley International, 1988.
9. "Computational Fluid Dynamics for Engineers" (Vols. I & II), K. Hoffmann and S. T. Chiang, Engineering Education System, 1993.

AM2143 Aerodynamics		
Designation	:	Elective
Pre-requisites	:	*Engineering Fluid Mechanics, Thermodynamics.*
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme):20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).

Syllabus

Introduction to Aerodynamics: Hot air balloon and aircrafts, Various types of airplanes, Wings and airfoils, lift and Drag, Centre of pressure and aerodynamic centre, Coefficient of pressure, moment coefficient, Application of potential flow in aerodynamic problems.

Incompressible Flow Theory: Design of airfoils using conformal transformation, Kutta condition, Karman – Trefftz profiles, Thin aerofoil Theory and its applications. Vortex line, Horse shoe vortex, Biot - Savart law, Prandtl lifting line theory, Panel methods.

Compressible Flow Theory: Potential equation for compressible flow, small perturbation theory, Prandtl-Glauert Rule, Linearised supersonic flow, Method of characteristics.

Airfoils, Wings and Airplane configuration in High Speed Flows: Critical Mach number, Drag divergence Mach number, Shock stall, super critical airfoils, Transonic area rule, Swept wings (ASW and FSW), supersonic airfoils, wave drag, delta wings, Design considerations for supersonic airplanes.

Viscous Flow Measurements: Types of wind tunnels – Flow visualization processes – Measurement of force and moments in wind tunnels. Measurement of pressure, velocity and wall shear stress, Flow visualizations.

Latest developments and trends in Aerodynamics: UAV, MAV.

References books

1. L.J. Clancey, Aerodynamics, Indian Edition 2006, Sterling Book House, Mumbai.
2. J.D. Anderson, "Fundamentals of Aerodynamics", McGraw-Hill Book Co., New York, 1985. Rathakrishnan.E., Gas Dynamics, Prentice Hall of India, 1995.
3. Shapiro, A.H., Dynamics & Thermodynamics of Compressible Fluid Flow, Ronald Press, 1982.
4. E.L. Houghton and N.B. Caruthers, Aerodynamics for Engineering Students, Edward Arnold Publishers Ltd., London (First Indian Edition), 1988
5. Zucrow, M.J., and Anderson, J.D., Elements of gas dynamics McGraw-Hill Book Co., New York, 1989.
6. W.H. Rae and A. Pope, "Low speed Wind Tunnel Testing", John Wiley Publications, 1984.

AM2144 Wind Engineering		
Designation	:	Elective
Pre-requisites	:	
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme):20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).

Syllabus

Introduction to Wind engineering: Wind climates and wind-induced phenomena, extreme wind climatology. Atmospheric boundary layer: Governing equations, mean velocity profiles, power law, logarithmic law wind speeds, atmospheric turbulence profiles, general characteristics of atmospheric turbulence, spatio-temporal expressions of wind fluctuations, spatio-temporal scales of fluctuations, spectral density function, length scale of turbulence, roughness parameters.

Bluff body aerodynamics: flow around bluff bodies and pressure distributions, governing equations, boundary layers and flow separations, wake and vortex formation, Strouhal number, Reynolds number, flow separation and reattachments, oscillatory flow patterns, vortex shedding, flow switching– Time varying forces to wind velocity in turbulent flow and its three-dimensional structures. Static wind forces and dynamic wind forces, quasi-steady assumption and fluctuating wind pressures, motion-induced forces and aerodynamic damping, wind force correlation and wind force combination.

Structural dynamics: human comfort and habitability of buildings to vibrations, damping in buildings and sophisticated evaluation techniques, suppression of wind-induced vibrations.

Aeroelastic phenomena: Vortex shedding and lock in phenomena in turbulent flows, across wind galloping, wake galloping - Torsional divergence, along wind galloping of circular cables, cross wind galloping of circular cables, wind loads and their effects on tall structures.

Wind loading: Introduction, analysis and synthesis loading coefficients, local & global coefficients, pressure shear stress coefficients, force and moment coefficients. Assessment methods, quasi steady method, peak factor method, extreme value method.

Wind tunnel and its full-scale testing, simulation techniques in wind tunnels.

Tornado wind and its effects on structures, microburst and its effects on structures, ASCE7 standard provisions.

Aerodynamics of wind turbines, wind-induced cable vibration.

References books

1. Wind Effects on Structures: Fundamentals and Applications to Design" by Simiu and Scanlan, , 3rd Ed. John Wiley and Sons, Inc., 1996.
2. "Building Aerodynamics" by Tom Lawson, Imperial College Press, London, 2001.
3. "Aerodynamics and drag mechanisms of bluff bodies and road vehicles", M.Sovran (Ed), Plenum press, New York, 1978.
4. "Winds forces in engineering" by P. Sachs, Pergamon Press, 1978.
5. "Flow induced vibrations" by R.D. Blevins, Van Nostrand, 1990.
6. "Wind Power Principles" by N.G. Calvent, Charles Griffin & Co., London, 1979.
7. "Car Aerodynamics" by Hucho.
8. "Design Guides to wind loading of buildings structures (Part I & II)" by N J Cook, Butterworths, London, 1985.
9. ASCE/SEI 7-10 Minimum Design Loads for Buildings and Other Structures.
10. IS: 875 (1987) Part III Wind loads, Indian Standards for Building codes.

AM2145 Research Methodology		
Designation	:	Elective
Pre-requisites	:	*Engineering Mathematics & Computer Programming*
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme):20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).

Syllabus

Introduction: A quick glance on research, Conceptualizing a research design Reviewing the literature.

Formulating a Research Problem: Identifying variables, Constructing hypotheses, Establishing the validity and reliability, Constructing an instrument for data collection, Measurement and Scaling Techniques, Sampling Fundamentals, Methods of Data Collection, Defining the Research Problem.

Developing a research plan and writing and presenting a research proposal (Mid-sem Exam).

Experimentation:

Processing data: Analysing Data, Analysis of Variance and Covariance,Testing of Hypotheses, Multivariate Analysis Techniques, Chisquare Test, Displaying data.

Research methodology and practice evaluation.

Writing and presentation of a research report (End Sem Exam).

References books

1. Research Methodology: Methods and Techniques, C R Kothari.

AM2110 Applied Elasticity		
Designation	:	Elective
Pre-requisites	:	Mechanics of Materials
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme):20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).

Syllabus

Analysis of Stress: Concept of Stress, Stress Components, Equilibrium Equations, Stress on a General Plane (Direction Cosines, Axis Transformation, Stress on Oblique Plane through a point, Stress Transformation), Principal Stresses, Stress Invariants, Deviatoric Stresses, Octahedral Stresses, Plane Stress, Stress Boundary Condition Problem.

Analysis of Strain: Deformations (Lagrangian Description, Eulerian Description), Concept of Strain, Strain Components (Geometrical Interpretation), Compatibility Equations, Strain transformation, Principal Strains, Strain Invariants, Deviatoric Strains, Octahedral Strains, Plane Strain, Strain Rates.

Stress-Strain Relations: Introduction, One-Dimensional Stress-Strain Relations (Idealized Time independent and Time–dependent stress-strain laws), Linear Elasticity (Generalized Hooke's Law), Stress-Strain Relationships for Isotropic and Anisotropic Materials (Plane stress and Plane Strain)

Basic Equations of Elasticity for Solids: Introduction, Stresses in Terms of displacements, Equilibrium Equations in terms of displacements, Compatibility equations in Terms of Stresses, Special cases of Elasticity equations (Plane Stress, Plane strain, Polar Co-ordinates), Principle of Superposition, Uniqueness of Solution, Principle of virtual work, Potential and Complementary energy, Variational Principles, St. Venant's Principle, Methods of analysis for Elastic Solutions, Elastic solutions by Displacement and stress Functions, Airy's Stress Function (Plane stress, Plane strain, Polar Co-ordinates).

Torsion: Introduction, Circular shaft, Torsion of non-circular cross-section, St. Venant's theory, Warping function, Prandtl's stress function, Shafts of other cross-sections, Torsion of bars with thin walled sections.

Viscoelasticity: Introduction, Viscoelastic models (Maxwell, Kelvin-Voigt, Generalized Maxwell and Kelvin models), Viscoelastic stress-strain relationships.

References books

1. Mathematical Theory of Elasticity: I. S. Sokolnikoff
2. Advanced Mechanics of Materials: Boresi
3. Theoretical Elasticity: A. E. Green and W. Zerna
4. Theory of Elasticity: Timoshenko and Gere
5. Advanced Strength and Applied Elasticity: A. C. Ugural and S. K. Fenster
6. Applied Elasticity: R.T.Fenner
7. Advanced Strength of Materials: L. S. Srinath

AM2141 Bio-Fluid Dynamics		
Designation	:	Elective
Pre-requisites	:	*Engineering Fluid Mechanics, Elementary Biology*.
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme):20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).

Syllabus

Introduction to Fluid Mechanics: Fluid properties, basic laws governing conservation of mass momentum and energy; Laminar flow, Couette flow and Hagen-Poiseuille equation, turbulent flow.

Bio-fluid Dynamics: Blood system network and physiology, blood rheology, Vessel structure and mechanical properties Lymphatic system; Body fluids and their motions; Flow of Newtonian and non-Newtonian fluids in rigid tubes, flexible tubes and collapsible tubes.

Cardio-vascular system: Heart and pumping process, Blood flow in body, Flow dynamical study of circulatory system, heart and blood vessels, anatomy and physiological considerations; Components and functions of arterial and venous systems: Blood flow through arteries and veins; Kinetic energy, flow, pressure-flow relations in vascular beds; Cardiac cycle; Cardiac valve dysfunctions; Blood pressure, regulation and controlling factors; Coronary circulation, heart failure.

Human Respiratory system: Physiology, Weibel's lung model, realistic lung model, studies of flow behavior in upper and lower human respiratory system during different breathing conditions, studies of wall shear stress and its implications, Dispersion and deposition of aerosols/inhaled particles in respiratory system, critical airways, tumorous airways.

References books

1. "Bio-fluid Mechanics", J.N. Mazumdar, World Scientific, 1992.
2. "Biomechanics: Motion", Flow, Stress, and Growth", Y.C. Fung, Springer-Verlag, 1990.
3. "Cardiovascular Physiology", R.M. Berne, M.N. Levy, 8th Edition, Mosby, 2001.
4. "Bio-fluid Dynamics", C. Klienstreuer, Taylor & Francis.

AM2146 Multiphase Flow		
Designation	:	Elective
Pre-requisites	:	*Engineering Fluid Mechanics, Fluid Machinery.*
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme):20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).

Syllabus

Introduction to Multiphase Flow: Introduction, Estimation of flow patterns, Classification and characteristics of complex Mixture, The Flow Properties of Fluid, Basic concept of flow of Newtonian and Non-Newtonian fluids.

Fundamental Concept of the Flow of Multiphase Mixtures: mechanics of transportation, Description of general two phase systems, Continuity equation, Momentum equation, Mechanical energy equation, Slip and Hold up effect.

Flow of Gas-Liquid and Liquid–Liquid Mixture in Pipes: Flow patterns, Holdup, Empirical overall correlations, Pressure gradient, Bubble flow pattern, Slug flow, Stratified flow, Wave flow and Annular-mist flow.

Flow of Gas-Solid and Liquid–Solid Mixture in Pipes: Flow patterns, Holdup, General correlations.

Freight Pipelines: Slurry transportation System, Pneumatic transportation System, Capsule transportation System, Measurement techniques.

Modeling Multiphase Flows: Introduction, General Multiphase Model, Volume of Fluid (VOF) Model Theory, Mixture Model Theory, Eulerian Model Theory, Wet Steam Model Theory, Modeling Mass Transfer in Multiphase Flows, Modeling Species Transport in Multiphase Flows, Solution Strategies for Multiphase Modeling.

References books

1. "The Flow of Complex Mixtures in Pipes", G.W. Govier & K. Aziz, Van Nostrand Reinhold Co., NY, 1972.
2. "Multiphase Fluid Flow Theory & Practice", F.G. Hammitt, McGraw-Hill Inc., NY, 1980.
3. "Computational Methods for Multiphase Flow" A. Prosperetti, G. Tryggvason, Cambridge University Press, 2009.

AM2147 Design of Experiments		
Designation	:	Elective
Pre-requisites	:	*Engineering Mathematics & Computer Programming*
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme):20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).

Syllabus

Introduction to Design of Experiments: Strategy of Experimentation, applications of Experimental Design, Basic Principles, Guidelines for DoE.

Basic Statistical Methods: Sampling and Sampling Distributions, Randomized Designs, Paired Comparison Designs, Inferences About the mean and Variances of Normal Distributions.

Analysis of Variance: The Analysis of Variance, Analysis of the Fixed Effects Model, Model Adequacy Checking, Practical Interpretation of Results, Determining Sample Size, The Random Effects Model, The Regression Approach to the Analysis of Variance, Nonparametric Methods in the Analysis of Variance.

Experiments with Blocking Factors: The Randomized Complete Block Design, The Latin Square Design, The Graeco-Latin Square Design, Balanced Incomplete Block Designs.

Factorial Experiments: Basic Definitions and Principles, The Advantage of Factorials, The Two-Factor Factorial Design, The General Factorial Design, Fitting Response Curves and Surfaces, Blocking in a Factorial Design.

Two-Level Factorial Designs: The 2^2 Design, The 2^3 Design, The General 2^k Design, A Single Replicate of the 2^k Design, Unreplicated 2^k Design, Addition of Center Points to the 2^k Design.

Blocking and Confounding Systems for Two-Level Factorials: Blocking a Replicated 2^k Factorial Design, Confounding in the 2^k Factorial Design, Confounding the 2^k, Factorial Design in Two Blocks.

Two-Level Fractional Factorial Designs: The One-Half Fraction of the 2^k Design, The One-Quarter Fraction of the 2^k Design, The General 2^{k-p} Fractional Factorial Design.

Regression Modeling: Linear Regression Models, Estimation of the Parameters in Linear Regression Models, Hypothesis Testing in Multiple Regression, Confidence Intervals in Multiple Regression, Prediction of New Response Observations, Regression Model Diagnostics, Testing for Lack of Fit.

Response Surface Methodology: Introduction to Response Surface Methodology, The Method of Steepest Ascent, Analysis of a Second-Order Response Surface, Experimental Designs for Fitting Response Surfaces, Experiments with Computer Models.

Random Effects Models: Random Effects Models, The Two-Factor Factorial with Random Factors, The Two-Factor Mixed Model, Sample Size Determination with Random Effects, Rules for Expected Mean Squares, Approximate *F* Tests.

Other Topics: Non-normal Responses and Transformations, Unbalanced Data in a Factorial Design, The Analysis of Covariance, Repeated Measures.

References books

1. Design and Analysis of Experiments, Douglas C. Montgomery, 8th Edition, Wiley.
2. Design and Analysis of Experiments (Springer Texts in Statistics), Angela M. Dean, Daniel Voss.
3. Experiments: Planning, Analysis, and Optimization (Wiley Series in Probability and Statistics) C. F. Jeff Wu, Michael S. Hamada.
4. Statistical Design and Analysis of Experiments, with Applications to Engineering and Science, Robert L. Mason, Richard F. Gunst, James L. Hess.
5. Statistical Design and Analysis of Experiments (Classics in Applied Mathematics No 22.) Peter W. M. John.
6. Statistics for Experimenters: Design, Innovation, and Discovery , George Box.
7. Designing Experiments and Analyzing Data: A Model Comparison Perspective, Second Edition by Maxwell and Delaney.
8. The Design of Experiments Sir Ronald Aylmer Fisher.
9. Design of Experiments for Engineers and Scientists, Jiju Antony.

AM2142 Convective Heat Transfer		
Designation	:	Elective
Pre-requisites	:	*Engineering Heat Transfer, Fluid Mechanics, Thermodynamics.*
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme):20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).

Syllabus

Introduction: Physical origins and rate equations, Governing equations, units and dimensions, concepts of thermal boundary layer, displacement thickness, momentum thickness and energy thickness.

Laminar External flow and heat transfer: Blasius Solution, Temperature distribution over a flat plate boundary layer, Falkner-Skan and Eckert solutions, flow with transpiration, solutions for flow over an isothermal flat plate, flat plate with constant heat flux and with varying surface temperature, flows with pressure gradient.

Laminar internal flow and heat transfer: Exact solutions to Navier–Stokes Equations, Fully developed forced convection in pipes, Forced convection in the thermal entrance region of ducts and channels, heat transfer in the combined entrance region, Integral method for internal flows with different wall boundary conditions.

Natural Convection heat transfer: Governing equations for natural convection, Boussinesq approximation, Dimensional Analysis, Similarity solutions for Laminar flow past a vertical, Integral method for natural convection flow past vertical plate, effects of inclination, Natural convection in enclosures, mixed convection heat transfer past vertical plate and in enclosures.

Turbulent convection: Governing equations, Turbulence Models, Turbulent flow and heat transfer across flat plate and circular tube, Turbulent natural convection heat transfer, Empirical correlations for different configurations.

Latest development and state-of-art in convective heat transfer and its applications.

References books

1. Incropera F P and Dewitt D, “Fundamentals of Heat and Mass Transfer”, John Wiley.
2. Kays W M and Crawford M E, "Convective Heat and Mass Transfer",McGraw Hill.
3. Bejan A, “Convection Heat Transfer”, John Wiley
4. Schlichting H., " Boundary Layer Theory ", Sixth edition, McGraw Hill.

ME2148 Gas Turbines and Jet Propulsion		
Designation	:	Elective
Pre-requisites	:	*Engineering Fluid Mechanics, Thermodynamics.*
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme):20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).

Syllabus

Review of Gas Dynamics: Physical difference between incompressible, subsonic and supersonic flows, three reference speeds, dimensionless velocity, concepts of static and stagnation parameters. Pressure waves, finite, shock and detonation waves, compound waves, Analysis of piston excited waves, shock tubes, one-dimensional isentropic flow, normal shocks, Rayleigh flow, Fanno flow.

Gas Turbine Outline: Review of Thermodynamic principles, Gas turbine cycles, main components of Gas turbine power plants, performance characteristics, typical Gas Turbine Plants**.** Methods of improving efficiency and power output of gas turbine plants**.**

Design considerations of Centrifugal and axial flow compressors**.**

Types of Gas turbine plants and their theory of operation, design consideration of gas turbine plants**.** Detailed study of main systems of gas turbine plants**.**

Selection of materials of Gas turbine components**.** Trouble shooting, maintenance and actual performance evaluation of gas turbine plants**.** Recent development of gas turbine plants**.**

Jet Propulsion Outline: Basic theory of Jet & rocket propulsion devices and historical development**.** Types of various jet propulsion plants like air screw, turboprop, turbojet, Ram jet, pulse jet, rocket propulsion, etc. and their comparative study**.**

Performance study of various jet propulsion devices from ideal and practical consideration**.**

Study and design considerations of main components of jet propulsion plants. Thrust augmentation devices and their thermodynamic analysis**.**

Combustion performance, products of combustion and their properties**.** Recent advances in jet propulsion and Rocket propulsion devices**.**

Latest trends and advancement in Gas Turbine and Jet Propulsion.

References books

1. "Gas Dynamics", E. Rathakrishnan, Prentice-Hall of India, New Delhi, 2002.
2. "Compressible Fluid Flow", M.A. Saad, Prentice-Hall, New Jersey, 1985.
3. "The Dynamics and Thermodynamics of Compressible Fluid Flow" (2 volumes), A. H. Shapiro, The Ronald Press, New York, 1953.
4. "Gas Turbine Fundamentals", Cohen, Rogers and Saravanamutto, Pearson Education.
5. "Jet Propulsion", Jack D. Mattingly, McGraw Hill Inc.
6. "Gas Turbines", V. Ganeshan, Tata-McGraw-Hill, New Delhi.
7. "Gas Turbines", R. Yadav.

Semester-II

AM2240 Turbulence		
Designation	:	Compulsory
Pre-requisites	:	*Engineering Fluid Mechanics, Thermodynamics, Engineering mathematics, Statistical methods.*
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme):20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).

Syllabus

Introduction: Flow instability and transition to turbulence, Nature of Turbulence, Indicial notation for tensors, Fourier transforms and Parseval's theorem.

Governing Equations of Turbulence:

Eulerian, Lagrangian and Fourier descriptions of turbulence:

Statistical description of turbulence: Reynolds Averaged Navier-Stokes equations, Reynolds stress evolution equations.

Kolmogorov's Hypothesis: Diffusivity of turbulence and turbulence length scale.

Filtered Description of Turbulence: Bridging methods and large eddy simulation (LES).

Turbulent Free Shear Flows: Free Shear Flows- jet flows including heat transfer- 2D flows, wall jet and plane jets, its structure; turbulent jets, turbulent mixing layer and buoyancy effects- its structure; turbulent wake flows, wake of self propelled bodies; wall-bounded shear flows- its structure; boundary layer flows; thermal plume.

Wall Bounded Turbulent Flows: Turbulent flows in pipes, channels and boundary layers, Law-of-the-wall, Effects of surface roughness on turbulence.

Development of Turbulent closure models: Boussinesq approximation, Reynolds stress evolution closures.

Rapid Distortion Theory (RDT) of Turbulence:

Dynamics of Turbulence: Linear Instability Theory, Nonlinear Stability Analysis, Dynamical Systems, Introduction to Chaos. Vorticity dynamics- Reynolds stress and vorticity, vortex stretching, mean vorticity equation, kinetics energy and mean flow, kinetic energy of fluctuations, energy cascade, dissipation, material element deformation, mixing Navier-Stoke's equation for turbulent flow, turbulent energy dissipation equation.

Turbulence modeling: General comments on turbulence models; Method of solving turbulent equations- Direct numerical simulation (DNS), Large-eddy simulation (LES), Reynolds averaged Navier-Stokes equation (RANS), k-ε models. Turbulence models: Eddy viscosity models -zero equation models (constant eddy viscosity and mixing length models), one equation models, two equation models; Reynolds stress transport models (RSM). Wall treatments.

References books

1. "Turbulent Flows", S.B. Pope, Cambridge University Press, 2000.
2. "Turbulence Modeling for CFD" David C. Wilcox, DCW Industries, 3rd Edition, 2006.
3. "Viscous Fluid Flow", F.M. White, Tata McGraw Hill, 2011.
4. "A First Course in Turbulence", H. Tennekes and J.L. Lumley, The MIT Press, 1972.
5. "Turbulence", O. Hinze, McGraw Hill Inc.
6. "Turbulent Flow: Analysis, measurement and Prediction", Bernard, P.S., A.D. Wallace, J.M., John Wiley & Sons Inc., New Jersey, 2002.
7. "Turbulent Flows", Biswas, G. and Eswaran, V. Narosa Publishing, 2002.
8. "Turbulent Flows" (3rd ed.), Garde, New Age International, New Delhi.

AM2253 Advanced Fluid Mechanics Laboratory		
Designation	:	Compulsory
Pre-requisites	:	*Basic knowledge of Fluid Mechanics and Engineering Mathematics, Computer Programming, CFD.*
Credit and Contact hours	:	0(L) - 0(T) – 6(P) – 4(Cr)
Assessment Methods	:	**Practical Examination: (Scheme)** End-Semester Exam: 50 marks.
		Internal Assessment: (Scheme) 50 marks (10 marks for attendance + 40 marks for sessional assessment and/or Term paper based on regular performance on Practical and Experimentation, Demonstration of knowledge and skill development through Surprise / Quiz Tests, Viva etc. and Assignments & Report Writing..

Syllabus

Experiment 1: Study of the pressure distribution over smooth and rough cylinder.
Experiment 2: Study of the Pressure distribution over symmetric airfoil.
Experiment 3: Study of the Pressure distribution over cambered airfoil& thin airfoils.
Experiment 4:Study of the characteristics of three dimensional airfoils involving measurement of lift, drag, pitching moment.
Experiment 5: Performance of an aerofoil with flap, influence of flap angle on lift, drag and stall.
Experiment 6: Flow visualization studies in low speed flow over airfoil with different angle of Incidence.
Experiment 7: Pressure distribution around a two- dimensional model in supersonic flow conditions, at different angles of attack.
Experiment 8: Lift coefficient for aerodynamic models in supersonic flow.
Experiment 9: Shock waves and expansion patterns around a two-dimensional model in supersonic flow conditions. (Flow visualization with Schlieren Apparatus.)
Experiment 10: Measurement of the Velocity profile in laminar and turbulent boundary layers.
Experiment 11: Measurement of the Velocity profile in the boundary layer at on rough and smooth plates.
Experiment 12: Measurement of the Velocity profile in the boundary layer at various distances from the leading edge of the plate.
Experiment 13: Measurement of Performance of a Centrifugal Pump and its Vibration Analysis.

References books

1. "Instrumentation, Measurements & Experiments Fluids", E. Rathakrishnan, CRC Press, NY, 2007.
2. "Low-Speed Wind Tunnel Testing", A. Pope and J.J. Harper, John Wiley & Sons Inc., NY, 1966.
3. "Experimental Methods for Engineers", J.P. Holman, McGraw-Hill Inc., NY, 2001.
4. "Design & Analysis of Experiments", D.C. Montgomery, Wiley, 7th ed., 2009.

AM2249 Advanced Computational Fluid Dynamics		
Designation	:	Elective
Pre-requisites	:	*Computational Fluid Dynamics*..
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme):20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).

Syllabus

Multiphase Flow Modeling: Volume of Fluid (VoF) Method for Multiphase flow: Volume fraction equation, Advection of volume fraction, Geometrical Interface Reconstruction methods: Piecewise Line Interface Calculation (PLIC). Moment of Fluid (MOF), High Resolution Differencing schemes - Compressive Interface Capturing Scheme for Arbitrary Meshes (CICSAM) and Coupling with N-S solver. Level Set Method for Multi-Phase Flow. Level Set based Immersed Boundary Method for Moving Boundary Problems. Mixture model, Eulerian model, Wet steam model.

Finite Volume Method for Complex Geometry: Body-fitted coordinate grids for complex geometries, Cartesian vs. curvilinear grids, difficulties of curvilinear grids, Block-structured grids, unstructured grids and its discretization, discretization of diffusion and convective terms, treatment of source terms, assembly of discretized equations, Pressure-velocity coupling in unstructured meshes, staggered vs. co-located grid arrangements, extension of face velocity interpolation method to unstructured meshes.

Particle based simulation techniques: Molecular Dynamics (MD), Direct Simulation Monte Carlo (DSMC), Lattice Boltzmann Method (LBM). Application to LBM to bluff-body wake, microflow, and other fluid flow problems.

Introduction and basics of OpenFOAM: solver structure, setting up and running different examples, data visualization and analysis. Intermediate and Advance concepts in OpenFOAM: Programming in OpenFOAM, implementing a new solver and new boundary conditions.

Computer Architecture and Parallelization in CFD: Introduction to HPC and HPC Concepts. Parallel Programming: OpenMP, MPI and GPGPU programming.

References books

1. "An Introduction to Computational Fluid Dynamics: the Finite Volume Method", H.K. Versteeg and W. Malalasekara, 2nd edition, Pearson Education, England, 2007.
2. "Computational Fluid Dynamics for Engineers" B. Andersson & others, 1st edition, Cambridge University Press, U.K., 2012.
3. "Computational Fluid Flow and Heat Transfer" (2nd edition), K. Muralidhar and T. Sundararajan, Narosa Publishing, 2004.
4. "Numerical Heat Transfer and Fluid Flow", S.V. Patankar, McGraw-Hill, New York, 1980.
5. "Principles of Computational Fluid Dynamics", P. Wesseling, Springer-Verlag.
6. "Computational Techniques for Fluid Dynamics Volume I & II" (2nd edition), C.A.J. Fletcher, Springer-Verlag, 1991.
7. "Computational Fluid Mechanics and Heat Transfer" (2nd edition), J.C. Tannehill, D.A. Anderson and R.H. Pletcher, Taylor and Francis, 1997.
8. "Numerical Computation of Internal and External Flows" (Vols. I & II), C. Hirsch, Wiley International, 1988.
9. "Computational Fluid Dynamics for Engineers" (Vols. I & II), K. Hoffmann and S. T. Chiang, Engineering Education System, 1993.

AM2211 Fluid-Structure Interaction		
Designation	:	Elective
Pre-requisites	:	*Engineering Fluid Mechanics, Strength of materials.*
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme):20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).

Syllabus

Introduction to Fluid-structure interaction: Concept of fluid-structure interaction, brief history of fluid-structure interaction, dimensional analysis, concept of the hydrodynamic mass (added mass), hydrodynamic mass matrix.

Mathematical formulation of a simple fluid-structure interaction problem: Fluid domains, solid domains, coupling of the equations for fluid and structure.

Analysis Methods for Fluid-structure interaction problems: One-way separate analysis method (Hydrodynamics mass and damping method), Two-way coupled analysis method.

Vortex induced Vibration: Vortex wake of a stationery cylinder, Strouhal number, effects of cylinder motion on wake, analysis of vortex-induced vibration and its reduction.

Galloping and Flutter: Introduction to galloping, galloping instability, galloping response, vortex shedding, turbulence and galloping, flutter, prevention of galloping and flutter.

Instability of tube and cylinder arrays: Description of elastic instability, theory of fluid elastic instability, vibration of pairs of cylinders.

Vibration induced by Oscillatory flow: Inline forces and their maximum, inline motion, fluid force coefficients, transverse force and response, reduction of vibration induced by oscillating flow, ship motion in a seaway.

Vibration induced by turbulence and sound: Elements of the theory of random vibrations, sound and turbulence-induced vibration of panels, turbulence-induced vibration of tubes and rods, wind-induced vibration, response of aircraft to gusts, reduction of vibration induced by turbulence.

Fluid Coupling: Concentric cylinders with open ends of fluid filled annular gap, concentric cylinders with closed ends of fluid annular gap.

Damping of structures: Elements of damping, Definitions of damping coefficient and damping ratio, total damping, fluid (hydrodynamic) damping, structural (or support) damping, damping of bridges, towers, buildings, piping and aircraft structures.

Sound induced by Vortex shedding: Sound from single and vibrating cylinders, sound from multiple tubes and heat exchangers, sound from flow over cavities.

Examples of Fluid-structure interaction analyses: One-way separate analysis of fluid-induced vibration of steam generator tubes, two-way coupled analysis of flow-induced vibration of two tubes. Latest development in Fluid-Structure interaction.

References books

1. Robert D. Belvins (2001), Flow-induced Vibration, 2nd ed., 477 pp., Krieger Publishing Company, Malabar, Florida, USA.
2. J. Ballmann (ed.) (2003), Flow Modulation and Fluid-Structure Interaction at Airplane Wings, Springer.
3. N.G. Barton and J. Periaux (eds.) (2003), Coupling of Fluids, Structures and Waves in Aeronautics, Springer.

AM2241 Boundary Layer Theory		
Designation	:	Elective
Pre-requisites	:	*Engineering Fluid Mechanics, Heat Transfer.*
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme):20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).

Syllabus

Incompressible Laminar Boundary Layers: Exact solutions of the Navier-Stokes equation exhibiting boundary layer at low viscosity. The boundary-layer equations in the spirit of Prandtl. Scaling, non-dimensionalisation and Reynolds number. Limitations of potential flow past a cylinder. Prandtl's boundary-layer equations in two dimensions deduced by order-of-magnitude arguments. Blasius solution: displacement thickness, skin friction, drag.

Transition and Incompressible Turbulent Boundary Layers: Concept of stability; basis of boundary layer stability analysis; physics of transition to turbulence. Reynolds stresses, mean velocity and shear stress in a turbulent boundary layer; the log law and power law profiles. Turbulent boundary layers in zero and non-zero pressure gradients. Separation in adverse pressure gradients. Concept of and occurrence in steady flows, and at rear stagnation point of impulsively started cylinder.

Boundary Layer Separation & Flow Control: Causes of boundary layer separation and its consequences, active and passive flow control, various different flow control techniques and their applications.

Introduction to Perturbation Theory: Regular and singular perturbations. Examples from algebraic equations and ordinary differential equations. The classical boundary-layer equations of Prandtl as the leading term in a matched asymptotic expansion. Exact solutions of the classical boundary-layer equations like Flow past a wedge: Falkner Skan. Far wake of a flat plate. Two-dimensional jet. Lock's mixing layer. Prandtl transformation. Prandtl-Glauert law for subsonic flow; Ackeret's law and applications. Axisymmetric flows: Mangler's transformation. Split disc Ekman layer problems: Stewartson layers. Glauert wall jet.

Thermal Boundary Layer: Introduction to thermal boundary layer, heat transfer in boundary layer, convective heat transfer, importance of non dimensional numbers, Prandtl number, Nusselt number, Lewis number etc.

References books

1. "Boundary Layer Theory", Schlichting, H., McGraw Hill Inc.
2. "The Laminar Boundary-Layer Equations", Curle, N., Oxford University Press.
3. "Laminar Boundary Layers", Rosenhead, L. (Edited), Oxford University Press.
4. "An Introduction to Fluid Mechanics", Batchelor, G. K., Oxford University Press.
5. "Separation of Flow", C.T. Chung, McGraw Hill Inc.

AM2242 Design of Pipe Networks		
Designation	:	Elective
Pre-requisites	:	*Engineering Fluid Mechanics, Computer Programming*
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme):20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).

Syllabus

Introduction: uses, requirements, flow and pressure, Layout, PIPE GRAPHICS, Main sizing, Storage and pumping, Pipe valve fittings, Water meter, installation and testing

Basic Principles of Pipe Flow, Head Loss Equations.

Pipe Network Analysis Methods, Loop flow correction method, linear method. **Cost Considerations.**

General Principles of Pipe Network Synthesis: Water Transmission Lines, Water Distribution Mains, Single Input Source Branched Systems, Single Input Source Looped Systems,

Multi Input Source Branched Systems, Multi Input Source Looped Systems, Decomposition of a Large Water System and Optimal Zone Size, Reorganization of Water Distribution Systems.

Optimal design of branched pipe networks by linear programming problems (LPP): Dynamic and nonlinear programming for looped networks.

Reliability of distribution system

Fluid transients: water hammer: theory, boundary conditions, water column separation unsteady flow analysis by rigid column method graphical water hammer analysis air in pipeline .

Operation and maintenance of Pipe networks.

Term Paper: Development of program for Analysis and optimization of pipe network.

References books

1. Introduction to Urban Water Distribution: Unesco-IHE Lecture Note Series: by NemanjaT rifunovic.
2. Pipe Network Analysis, Eds. Lambert M Surhone, Mariam T Tennoe, Susan F Henssonow
3. Liquid Pipeline Hydraulics, E. ShashiMenon
4. Water distribution systems: simulation and sizing, Thomas M. Walski, Johannes Gessler, John W. Sjostrom
5. Analysis of flow in pipe networks, Roland W. Jeppson
6. Water distribution modeling, Volume 1, Thomas M. Walski, Donald V. Chase, DraganSavic
7. Analysis of Water Distribution Systems, Thomas M. Walski
8. Modeling, analysis, and design of water distribution systems, Lee Cesario, American Water Works Association
9. Advanced water distribution modeling and management, Volume 1, Thomas M. Walski
10. Simulation and analysis of gas networks, AndrzejOsiadacz
11. Hydraulic analysis of unsteady flow in pipe networks, J. A. Fox
12. Solving the Pipe Network Analysis Problem Using Optimization Techniques, School of Engineering and Applied Science, Southern Methodist University Nonlinear programs
13. Optimal design of water distribution networks, P.R. Bhave
14. Reliability analysis of water distribution systems, Larry W. May.
15. Performance in water distribution: a systems approach, SérgioTeixeira Coelho
16. Improving Efficiency and Reliability in Water Distribution Systems, Enrique Cabrera, Antonio F. Vela
17. Computer modeling of water distribution systems, American Water Works Association
18. Computer Applications in Water Supply: Systems optimization and control, Bryan Coulbeck
19. Integrated computer applications in water supply: Applications and implementations for systems operation and management. Vol. 2
20. Water transmission and distribution, American Water Works Association

AM2243 Thermo-Fluid Dynamics		
Designation	:	Elective
Pre-requisites	:	*Engineering Mathematics & Computer Programming*
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme):20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).

Syllabus

Thermodynamic State Equations*:* Perfect and real gases, state equation of perfect gas, Amagat's isothermals, Detailed study of Van der Waal, Dieterio, Berthelot, Redlich and Kwong and other state equations for real gases, compressibility factor and compressibility chart, generalized chart.

Review of Thermodynamic Laws and Entropy*:* Reversibility and irreversibility, statements of second law and their discussion Equivalence of Kelvin-Planck and Clausius statements, Carnot engine and Carnot refrigeration, Thermodynamic temperature scale and absolute zero temperature, Clausius theorem and Clausius inequality, concept and characteristics of entropy Principle of increase of entropy and entropy of universe.

Availability and Irreversibility*:* Available energy lost work and degradation of energy, Maximum work, Availability – in a closed system and in a steady flow system, Gibbs function, Helmholtz function, Irreversibility and its measurement.

General Thermodynamic Relations: General relations from energy equations, specific heat relations, relations for internal energy, enthalpy and entropy, Joule-Thomson coefficient, Applications of general thermodynamic relations to ideal gas, Van der Waal and other state equations.

Review of Basic Equations and Steady State Conduction*:* General three-dimensional heat conduction equation, Steady one-dimensional heat conduction through simple and composite planes, cylindrical and spherical walls without heat generation, Effect of variable thermal conductivity, Critical thickness of insulation. Steady one-dimensional heat conduction through plane wall, hollow cylinder, solid cylinder and solid sphere with uniform heat generation, Heat transfer from finned surfaces, general equation, efficiency and effectiveness of fins, conduction in cooling of turbine balding, optimum dimensions, comparison of fin materials. Two-dimensional steady state heat conduction, Numerical and graphical methods, Analogical solution.

Unsteady State Heat Conduction*:* Heating and Cooling with negligible internal resistance, Temperature-time response of thermocouple, Heating and cooling with negligible surface resistance, Transient heat conduction in semi-infinite solids, Laplace's equation, Separation of Variables, Lumped capacitance methods, Heating and Cooling of infinite plate with finite internal and surface resistance, Numerical and graphical analysis.

Convection*:* Laminar and turbulent flow, hydrodynamic and thermal boundary layer. Dimensional analysis and dimensionless numbers for free and forced convection. Empirical relations and practical solution of free and forced convection in pipes, over plates and across cylinders and spheres, combined free and forced convection, combined free convection and radiation heat transfer.

References books

1. Introduction to Thermodynamics, Classical and Statistical, Third Edition, Sonntag, R.E., and Van Wylen, G, John Wiley and Sons, 1991.
2. Advanced Engineering Thermodynamics, Bejan, A., John Wiley and Sons, 1988.
3. Advanced Thermodynamics for Engineers, Kenneth Wark Jr., McGraw-Hill Inc., 1995.
4. Fundamentals of Heat & Mass Transfer, Incropera F.P. and DeWitt. D.P., John Wiley & Sons, 1996.
5. Analysis of Heat and Mass Transfer, Ozisik. M.N., McGraw Hill Co., 1980.
6. Heat Transfer - Basic Approach, Eckert. E.R.G., and Drake.R.M., McGraw-Hill Co., 1985.
7. Convection Heat Transfer, Bejan. A., John Wiley and Sons, 1984.

AM2243 Design of Heat Exchangers		
Designation	:	Elective
Pre-requisites	:	*Engineering Mathematics & Computer Programming*
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme):20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).

Syllabus

Introduction, classification and selection; heat exchanger thermo-hydraulic fundamentals;
heat exchanger design; compact heat exchangers; shell and tube heat exchanger design; regenerators; plate heat exchangers and spiral plate heat exchangers; Boilers, Re-boilers, condensers, Air cooled Heat exchangers,
Heat exchanger network design, Targeting and super targeting, Pinch design method, Network optimization, heat-transfer augmentation; fouling; corrosion;
flow-induced vibration of shell and tube heat exchangers; mechanical design of shell and tube heat exchangers; material selection and fabrication; quality control and quality assurance and nondestructive testing.
Latest advancement in Heat exchangers.

References books

1. Process Heat Transfer by DQ Kern.
2. Heat exchangers: Thermal-hydraulic fundamentals and design SadıkKakaç, A. E. Bergles, F. Mayinger.
3. Heat Exchanger Design Handbook Series:Dekker Mechanical Engineering, 2000, CRC Press.

AM2244 Design of Hydraulic Turbines		
Designation	:	Elective
Pre-requisites	:	*Engineering Fluid Mechanics, Thermodynamics and Fluid Machineries.*
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme):20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).

Syllabus

Hydropower plants: Types, main components. Plant load factor, load duration curve, installed capacity, firm power, secondary power, and load prediction.

Penstocks and Water Hammer: Types of penstocks and their design criteria, Economical diameter of penstock, Valves, Bends, Manifolds, Effect of Water-hammer in penstock, Surge tanks.

Introduction to Hydraulic Turbines: Definition of head, discharge, power and efficiency of hydraulic turbines and hydro-unit. Classification based on head, specific speed, degree of reaction and direction of flow. Energy losses in turbines. Euler's energy equation, blade surface equation.

Impulse Turbines: Energy conversion in Pelton turbine, design parameters, design of turbine runner, nozzle, spear.

Reaction(Francis)Turbines: Classification, flow in runner, design parameters, determination of meridional flow, one-dimensional method of designing runner blades, relationship between the shape of blades and two-dimensional flow within runners. Blade designing in potential and rotational meridional flow. Draft tube- design and application. Deriaz turbine.

Reaction (Axial Flow) Turbines: Major definitions and relations concerning the flow within a runner, design parameters, flow upstream and downstream of the runner, determination of velocity triangles at inlet and outlet of the runner. Airfoil method of blade designing –cascade analysis and its performance, loss mechanism, blade profiles, forces acting on blades.

Cavitation in Hydraulic Turbine: Condition, types, consequences, remedy. Turbine cavitation coefficient, NPSH. Similarity laws in cavitating flows. Method of cavitation investigation in hydraulic turbines at laboratories and hydropower plants.

Turbine Performance Characteristics: Main characteristics and operating characteristics, iso-efficiency characteristics, Determination of major prototype turbine parameters on the basis of model characteristic curves. Derivation of the complete characteristics of prototype turbine. Distorted model, scale effect and efficiency.

Latest Trends and Development in Hydraulic Turbines: State-of-art for last few decades, latest design trends, newer applications in micro and pico-hydel power stations.

References books

1. "Water Power Engineering", H.K. Barrows, McGraw-Hill Book Co., New York.
2. "Hydropower Structures", R.S. Varshney, Nemchand & Brothers, Roorkee (U.P.), 1992.
3. "Hydraulic Turbines" (Volume I and II), V. V. Barlit, MACT- Bhapal, 1969.
4. "Hydraulic Machines", Jagdish Lal, Metropolitan Book Co., Delhi.
5. "Fluid Mechanics and Thermodynamics of Turbomachinery", 4th Edition,, S.L.Dixon, Butterworth and Heinemann, 1998.
6. "Hydraulic Turbine", M. Nechleba, McGraw-Hill Inc., New York, 1957.

AM2245 River Engineering		
Designation	:	Elective
Pre-requisites	:	*Engineering Fluid Mechanics, Mathematics.*
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme):20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).

Syllabus

Characteristics of River.
Classification of flow, uniform flow, Gradually varied flow, Rapidly varied flow, unsteady flow.
Channelization, sediment transport, canalization and flood routing.
Interlinking of Rivers, River confluences and river network.
Bank erosion, River restoration, draught and flood management.
Latest advancement in river engineering and development of new techniques.

References books

1. River Mechanics. P Y Julien
2. Principles of river engineering: the non-tidal alluvial river. editorial board, P. Ph. Jansen.
3. Fluvial Processes in River Engineering: Howard H. Chang
4. Open-Channel Flow: M. Hanif Chaudhry.

ME2235 Advanced Gas Dynamics		
Designation	:	Elective
Pre-requisites	:	Fluid Mechanics, Thermodynamics
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
	:	**Internal Assessment (Scheme):**20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).

Syllabus

Introduction: Glimpses of classical thermodynamics, statistical thermodynamics; Non-dimensionalization of Navier-Stokes and Energy equation with role of Mach number highlighted; stagnation quantities.

Normal Shocks: Governing equations, Rankine – Huguenot, Prandtl and other relations, weak shocks, thickness of shocks, normal shocks in ducts, performance of convergent-divergent nozzle with shocks, moving shock waves, shock problems in one dimensional supersonic diffuser, supersonic pitot tube.

Flow in Constant Area Duct with Friction: Governing equations, working formulas and tables, choking due to friction, performance of long ducts, Isothermal flow in long ducts.

Flow in Constant Area Duct with Heating and Cooling: Governing equations, working formula and tables, choice of end states, choking effects, shock waves with changes in stagnation temperature.

Generalized One-Dimensional Flow: Working equations, general method of solution, example of combined friction and area change, Example of combined friction and heat transfer.

Oblique shock: governing physical equations and general relations, shock polar diagram and auxiliary diagrams, strong and weak shocks, detached shock, interaction and reflection of shocks.

Method of characteristics: general principle of integration using method of characteristics, application to one dimensional isentropic progressive waves, application to steady two dimensional irrotational isentropic supersonic flows, Prandtl-Meyer expansion.

Boundary layer flow with Prandtl number unity and arbitrary Prandtl number, Integral equations of Laminar boundary layer, Differential and integral equations of Boundary layer, flow past a flat plate with turbulent Prandtl number of Unity. Elementary idea of boundary layer in tubes and in the presence of shock waves. Study of various flow visualization techniques. Study of different types of wind tunnels, their design criteria.

References books

1. "Gas Dynamics", E. Rathakrishnan, Prentice-Hall of India, New Delhi, 2002.
2. "Compressible Fluid Flow", M.A. Saad, Prentice-Hall, New Jersey, 1985.
3. "The Dynamics and Thermodynamics of Compressible Fluid Flow" (2 volumes), A. H. Shapiro, The Ronald Press, New York, 1953.
4. "Low-Speed Wind Tunnel Testing", A. Pope and J.J. Harper, John Wiley & Sons Inc., NY, 1966.
5. "Viscous Flow", F.M. White.

AM2246 Industrial Aerodynamics		
Designation	:	Elective
Pre-requisites	:	*Engineering Fluid Mechanics, Aerodynamics.*
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme):20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).

Syllabus

Atmosphere: Types of winds, Causes of variation of winds, Atmospheric boundary layer, Effect of terrain on gradient height, Structure of turbulent flows.

Wind energy collectors: Horizontal axis and vertical axis machines, power coefficient, Betz coefficient by momentum theory.

Vehicle Aerodynamics: Power requirements and drag coefficients of automobiles, effects of cut back angle, aerodynamics of road vehicles, trains and hovercraft.

Building Aerodynamics: Pressure distribution on low rise buildings, wind forces on buildings. Environmental winds in city blocks, special problems of tall buildings. Building codes, building ventilation and architectural aerodynamics.

Flow induced vibrations: Effects of Reynolds number on wake formation of bluff shapes, vortex induced vibrations. Galloping and stall flutter.

References books

1. "Wind Effects on Structures: Fundamentals and Applications to Design" by Simiu and Scanlan, , 3rd Ed. John Wiley and Sons, Inc., 1996.
2. "Building Aerodynamics" by Tom Lawson, Imperial College Press, London, 2001.
3. "Aerodynamics and drag mechanisms of bluff bodies and road vehicles", M.Sovran (Ed), Plenum press, New York, 1978.
4. "Winds forces in engineering", P. Sachs, Pergamon Press, 1978.
5. "Car Aerodynamics", Hucho,
6. "Design Guides to wind loading of buildings structures (Part I & II)" by N J Cook, Butterworths, London, 1985.
7. ASCE/SEI 7-10 Minimum Design Loads for Buildings and Other Structures.
8. IS: 875 (1987) Part III Wind loads, Indian Standards for Building codes.

AM2247 Design of Impeller Pumps		
Designation	:	Elective
Pre-requisites	:	*Engineering Fluid Mechanics, Fluid machinery.*
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme):20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).

Syllabus

Introduction: Classification of pumps, layout of rotodynamic pumps, head, discharge, power and efficiencies. Dimensional analysis, non-dimensional parameters, condition of similarity, specific speed and its significance. Elements of pumps- impeller, casings, diffusers etc.

Centrifugal Pumps: Classification, single stage and multi-stage pumps, components, priming, pressure rise in pumps, cavitation, NPSH, Thomas cavitation factor, axial thrust.

Flow through Impeller: Euler's fundamental equations, theoretical head for an infinite number of blades, influence of a finite number of blades, pressure and velocity distribution in impeller passages, influence of circulation in impeller passages, influence of pre-whirl on head, choice of blade outlet angle, stalling and surging.

Axial & Mixed Flow Pumps: Geometry of the axial flow impeller vanes, experimental design factors- impeller hub ratio, chord spacing ratio, number of vanes, vane curvature and thickness. Airfoil theory of vanes. Helical pumps and diagonal pumps.

Impeller Design: Geometrical velocity fields, evolution of impeller shapes, impellers with blades of single and double curvature, design calculation of the impeller- principal dimensions. Blade design- blade surface area, blade shape and blade angles, method of determining blade angle for centrifugal and axial impellers. Relation between overall efficiency and specific speed.

Pump Casing: Flow at the outlet of the impeller, volute casing, volute design for optimum efficiency, circular volutes. Crossover, diffusion casing and diffusion rings, axial diffusers.

Pump Characteristics: Classification of characteristics, non-dimensional characteristics, pump operation at off-design conditions, affinity of characteristic curves, iso-efficiency curves, flow conditions corresponding to the optimum efficiency, influence of flow conditions on pump operation,. Pump in series and parallel. Matching of pumps to system characteristics; multi-stage pumps. Losses in pumps, total head-discharge curves.

Pump for special duties: Deepwell pump– submersible pump and vertical turbine pump. Storage pump, turbine pump, boiler-feed pump, circulating pump, condensate pump, non-clog pump, marine pump, self-priming pump.

References books

1. "Impeller Pumps", Stephen Lazarkiewicz and A.T. Troskolanski, Pergamon Press, Warsaw, 1965.
2. "Centrifugal and Axial Flow Pumps- Theory, Design and Applications", A. J. Stepanoff, John-Wiley & Sons, 1967.
3. "Pumps, Fans and Compressors", A. de Kovats and G. Desmur, Blackie & Son Ltd., Glasgow, 1958.
4. "Rotodynamic Pump Design" by R.K. Turton,
5. Centrigfugal Pumps & Blowers" by A. Church and Jagdish Lal, Metropolitan Book Co., Delhi.
6. "Pump Handbook", I.J. Karassic, Tata McGraw Hills Ltd. New Delhi.
7. "Critical Aspects in Rotodynamic Pumps and systems", R.K. Srivastava, Techo Economic Research Institution, New Delhi.
8. "Fluid Mechanics and Thermodynamics of Turbomachinery", 4th Edition, S.L.Dixon, Butterworth and Heinemann, 1998.

AM2248 Condition Monitoring, Diagnosis and Predictive Maintenance of Pumps		
Designation	:	Elective
Pre-requisites	:	*Engineering Fluid Mechanics, Fluid machinery.*
Credit and Contact hours	:	4(L) - 0(T) – 0(P) – 4(Cr)
Assessment Methods	:	**Theory Examination: (Scheme)** End Semester Exam: 60 marks Mid Semester Exam: 20 marks
		Internal Assessment (Scheme):20 marks (5 marks for attendance + 15 marks for Take-home assignments, Surprise / Quiz Test and Class Tutorials).

Syllabus

Introduction: Diagnosis of machine condition and faults, Need and benefits of Condition Monitoring, Machine life cycle, Maintenance Management in Industry, Condition Monitoring and diagnostics of Hydraulic and Electro-pneumatic systems.

Performance analysis and testing of pumps for condition monitoring: Visual Inspection, Measurement of Temperature, Pressure, Flow, Speed and Power. Head Power Characteristics, Shutoff Head method, Balance leak-off flow method for monitoring of pumps.

Acoustic and Vibration Monitoring: Setting band levels for monitoring, Measurement of vibration, General severity assessment, Analyzing and Using the vibration spectrum, Vibration phase angle, Resonance, Specific vibration severity standards for pumps, advanced methods of vibration analysis of pumps, Control of vibration.

Wear Monitoring: Rate of wear, Effects of internal wear on pump performance and its efficiency.

Other monitoring: Corrosion Monitoring, Condition monitoring of shaft seals, Monitoring of seal-less pumps, Non-Destructive Testing, Analysis of wear debris in lubricants.

Monitoring of Positive displacement pumps: Performance characteristics, Condition monitoring by vibration analysis, Condition monitoring by performance analysis, Condition monitoring by analysis of wear particles in liquid pumped.

Performance Improvement Program and Predictive Maintenance: Basic types of maintenance, Application and Benefits of Cost Effective Maintenance, Performance analysis and its application to optimize time for overhaul using shut-off head test results, Knowledge Based Systems for Maintenance Management, Reliability centric maintenance, Modern Maintenance Management Systems.

Expert System: Application of Genetic Algorithm, Artificial Neural Networks and Fuzzy logic for Condition Monitoring, diagnosis and prediction of service life and maintenance management.

Standards, Patents and current research relevant to Condition Monitoring, Diagnosis and Maintenance Management.

Case studies and Term Paper: in detected performance shortfall and in condition monitoring of pumps.

References books

1. Predictive maintenance of pumps using condition monitoring: Ray S. Beebe
2. An Introduction to Predictive Maintenance: R. Keith Mobley
3. Engineering condition monitoring: practice, methods and applications: Ron Barron
4. Handbook of condition monitoring: BKN Rao
5. Handbook of Condition Monitoring: Techniques and Methodology: A. Davies
6. Pump User's Handbook: Life Extension, Heinz P. Bloch, Allan R. Budris
7. Intelligent condition monitoring and diagnosis systems: a computational intelligence approach: Kesheng Wang
8. CMS 110 R – Condition Monitoring Standards– Pump Vacuum Nash
9. CMS 111 R – Condition Monitoring Standards– Pump – Vertical –Multistage
10. CMS 153 R - Condition Monitoring Standards– Pump – Progressive Cavity
11. Modern Pumps: A Comprehensive Survey of Modern Pumping Equipment and Practice, Edward Mollo
12. Know and Understand Centrifugal Pumps L. Bachus, A Custodio.