GUJARAT TECHNOLOGICAL UNIVERSITY

ADVANCED FLUID MECHANICS
SUBJECT CODE: 2711103
M.E. 1st SEMESTER

Type of course: Core course

Prerequisite: Nil

Rationale: The course is prepared to provide the detailed understanding of fluid mechanics and gas dynamics principles

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks						Total Marks
L	T	P	C	Theory Marks		Practical Marks				
				ESE (E)	PA (M)	PA (V)		PA (I)		
						ESE	OEP	PA	RP	
3	2#	2	5	70	30	20	10	10	10	150

Content:

Sr. No.	Topics	Teaching Hrs.	Module Weightage
	Fluid Mechanics		
1	**Review of Basic Concepts and Fluid Properties:** Basic law of Fluid Motion, Internal stresses and external forces on fluid elements, Review of Concepts of Kinematics of fluid motion, vorticity, circulation, velocity potential and stream function, irrotational flow.	4	10
2	**Governing Equations of Fluid Flow in Differential Form:** Navier – Stokes Equation and exact solutions, Energy equation and solution of fluid flow with thermal effects.	3	6
3	**Dynamics of Ideal Fluid Motion:** Applications, Integrations of Euler's Equation of Motion, Generalized form of Bernoulli Equation, Potential flows, Principle of Superposition.	4	10
4	**Low Reynolds number Approximation of Navier – Stokes Equation:** Creeping flow over sphere, Stokes and Oseen approximation, Hydrodynamic Theory of Lubrication.	3	6
5	**High Reynolds number Approximation:** Prandtl's Boundary Layer Equations, Laminar Boundary Layer over a flat plat, Blausius solution, Falkner – Skan solution, Approximation method for solution of Boundary Layer Equation, Momentum Integral methods, Holstein and Bohlen method, Thermal Boundary Layer, Reynolds Analogy.	5	12
6	**Transition to Turbulence:** Introduction to Theory of Hydrodynamic Stability, Orr-Sommerfeld equation, Results from transition studies, factor affecting transition and its control.	4	10

7	**Fundamental of Turbulent flows:** Reynolds stress tensor, Phenomenological theories of turbulence, Prandtl's Mixing Length and Eddy Viscosity concepts, Universal Velocity distribution, Laws of the Wall and the Wake.	5	12
	Gas Dynamics		
8	**One Dimensional Isentropic Flow:** General features, Working equations, Choking in Isentropic flow, Operation of nozzle, diffuser under varying pressure ratio, performance of real nozzles, applications of isentropic flow.	5	12
9	**Normal Shocks:** Introductory remarks, Governing equations, Rankine Hugoniot, Prandtl and other relations, weak shocks, thickness of shocks, normal shocks in ducts, performance of convergent divergent nozzle with shocks, moving shock waves, shocks problems in one dimensional supersonic diffuser, supersonic pilot tube.	5	12
10	**Flow in constant area duct with friction:** Governing equations, Working Formulas and tables, Choking due to friction, Performance of long duct, Isothermal flow in long duct and flow in constant area duct with heating and cooling.	4	10

Reference Books:

1. Yunus Cengel and John Cimbala, Fluid Mechanics, McGraw Hill Publishing Co. Ltd.
2. F M White, Viscous Fluid Flow, McGraw Hill Publishing Co. Ltd.
3. H Schlichting, Boundary Layer Theory, McGraw Hill Publishing Co. Ltd.
4. F M White, Fluid Mechanics, McGraw Hill Publishing Co. Ltd.
5. Fox, Pritchard and McDonald, Introduction to Fluid Mechanics, John Wiley & Sons
6. Zucker & Biblarz, Fundamentals of Gas Dynamics, John Wiley & Sons, Inc.
7. James John and Theo Keith, Gas Dynamics, Pearson Prentice Hall
8. S M Yahya, Fundamentals of Compressible Flow, New Age International Publishers
9. J D Anderson, Computational Fluid Dynamics, McGraw Hill Publishing Co. Ltd

Course Outcome:

After learning the course the students should be able to

1. Apply the fundamentals of kinematics and conservation laws of fluid flow systems.
2. Apply the principles of high and low Reynolds number flows to fluid flow systems.
3. Review the concepts of boundary layer and flow in transition.
4. Analyse and apply the fundamentals of turbulent flow to various fluid flow systems.
5. Apply the fundamentals of one dimensional isentropic flow to variable area duct.
6. Analyse the principles of normal shock formation and its effects.
7. Apply the principles of compressible flow to constant area duct subjected to friction or heat transfer

List of Experiments:

1. To study the effect of angle of attack on Lift and Drag force
2. To study the loss of energy in wake region behind various models (car, jeep, bus etc.) in the wind tunnel
3. To draw profile of NACA Aerofoils
4. To Investigate on Recent development and advances in rarefied gas dynamics

5. To visualize and plot the pattern of flow around an object in a fluid stream using Hale-Shaw apparatus
6. To develop temperature distribution in thermal boundary layer for the flow over a flat plate.
7. To develop a Gas Table (Isentropic flow, Normal shocks, Fanno flow, Rayleigh flow) for different γ values.
8. A case study: Performance of real nozzle.
9. Derive the solution $u(y,z)$ for flow through an elliptical duct, by solving equation

$$\frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2} = \frac{1}{\mu}\frac{d\hat{p}}{dx} = const$$

Begin with a guessed quadratic solution, $u = A + By^2 + Cz^2$, and work your way through to the exact solution. Where 'a' is major axis radius & 'b' is minor axis radius

Open Ended Problems:

1. To study viscous supersonic flow including compressible boundary layer and compressible turbulent mixing.
2. Measurements of boundary layer thickness using numerical & analytical solution.
3. To determine fin efficiency using numerical and analytical solution