ADVANCED FLUID DYNAMICS

I-Semester

Course Code: 19ME2201	**L**	**P**	**C**
	3	0	3

Prerequisites: Fluid Mechanics

Course Outcomes: At the end of the course the student shall be able to

CO1. Analyze and apply the concepts of turbulent flow to solve the fluid flow problems.
CO2. Explain the concepts of boundary layer.
CO3. Classify the compressible fluid flows and discuss stagnation properties.
CO4. Solve nozzle, diffuser and shock wave problems of compressible fluids.
CO5. Apply Prandtl, Rankine-Hugniot equations to solve oblique shock waves and discuss the Fanno curves.

UNIT-I **10 Lectures**

Characteristics of turbulent flow - Reynolds equations of motion - turbulence modelling – Boussinesq Eddy viscosity concept – Prandtl‘s mixing length concept –Vonkaman similarity concept – Prandtl‘s universal velocity distribution-Karman – Prandtl velocity distribution power law for velocity in smooth pipes – Friction factor for smooth and rough pipes-Charts for friction factor in pipe flow.

Learning outcomes: At the end of this unit, the student will be able to

1. Explain the concepts of Boussinesq's eddy viscosity, Prandtl's mixing length and Vonkarman similarity concept. (L2)
2. Apply Prandtl's universal distribution equation to solve turbulent flow problems in pipes. (L3)
3. Use friction factor charts in pipe flows. (L3)

UNIT-II **10 Lectures**

Navier – Stokes Equations of motion – boundary layer over a flat plate – thickness of boundary layer –Prandtl‘s boundary layer equation – Vonkarmann momentum equation – shear stress and drag force – laminar boundary layer – turbulent boundary layer –pressure distribution in the boundary layer –boundary layer separation – drag and lift force – lift on an airfoil.

Learning outcomes: At the end of this unit, the student will be able to

1. Explain the concepts of boundary layer formation on a flat plate (L2)
2. Apply Von karman momentum equation to solve boundary layer problems (L3)
3. Discuss the methods of controlling boundary layer separation (L2)

UNIT-III **10 Lectures**

Propagation of sound waves – Mach number – Mach angle – equation of sound wave. Energy equation – energy equation for non-flow and flow processes – adiabatic energy equation –

stagnation enthalpy - stagnation temperature - stagnation pressure – stagnation velocity of sound – reference velocities – Bernoulli‘s equation – effect of Mach number on compressibility.

Learning outcomes: At the end of this unit, the student will be able to

1. Explain the propagation of sound waves in compressible fluid flow (L2)
2. Summarize the stagnation properties in compressible fluid flows(L2)
3. Discuss the effect of Mach number on compressibility (L2)

UNIT-I V **10 Lectures**

Comparison of isentropic and adiabatic processes – Mach Number variation - expansion in nozzles – compression in diffusers – stagnation and critical states – area ratio as a function of mach number – impulse function - mass flow rate, flow through nozzles - convergent nozzles – convergent-divergent nozzles – flow through diffusers. Development of a shock wave – rarefaction wave – governing equations, Prandtl-Meyer relation – Mach number downstream of the shock wave – static pressure ratio across the shock - temperature ratio across the shock – density ratio across the shock - stagnation pressure ratio across the shock

Learning outcomes: At the end of this unit, the student will be able to

1. Explain the expansion or compression of fluid flow through nozzle and diffusers (L2)
2. Describe the conditions for the development of shock waves (L2)
3. Derive Prandtl- Meyer relation of shock waves (L6)

UNIT-V **10 Lectures**

Nature of flow through oblique shock waves – fundamental relations - Prandtl‘s equation – Rankine-Hugoniot equation. The Fanno curves – Fanno flow equations – variation of flow parameters.

Learning outcomes: At the end of this unit, the student will be able to

1. Explain the formation of oblique shock waves (L2)
2. Derive Prandtl and Rankine Hugoniot equations for oblique shock waves (L6)
3. Illustrate the Fanno flow curves (L4)

TEXT BOOKS:

1. P. Balachandran, *Engineering Fluid Mechanics*, First Edition, PHI Learning Private Limited, New Delhi, 2012.
2. S.M. Yahya, *Fundamentals of Compressible Flow With Aircraft and Rocket Propulsion (SI UNITs)*, Fifth Edition, New Age International Publishers, NewDelhi, 2016.

REFERENCE BOOKS:

1. Yunus A. Cengel and John M. Cimbala, *Introduction to Fluid Mechanics*, Second Edition, Tata McGraw-Hill, 2010.
2. S.W. Yuan, *Foundations of Fluid Mechanics*, Prentice-Hall, 1970.

3. Patrick H. Oosthuizen and William E. Carscallen, *Compressible Fluid Flow*, First Edition, McGraw-Hill Companies, Inc., New York, 1997.