ADVANCED FLUID MECHANICS
(MECH 3253)

Time Allotted : 3 hrs **Full Marks : 70**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A
(Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) At any instant of time the value of the stream function ψ remains unchanged along
(a) stream line (b) path line
(c) streak line (d) both (b) and (c).

(ii) Vorticity $\vec{\Omega}$ is equal to
(a) $curl\vec{V}$ (b) $\frac{1}{2}curl\vec{V}$
(c) $\frac{3}{2}curl\vec{V}$ (d) $\frac{1}{3}curl\vec{V}$

(iii) General Couette flow is
(a) purely shear driven flow
(b) purely pressure driven flow
(c) combination of shear and pressure driven flow
(d) none of these.

(iv) In laminar flow between two fixed parallel plates, the shear stress is
(a) constant across the passage
(b) maximum at centre and zero at the boundary
(c) zero all through the passage
(d) maximum at the boundary and zero at the centre.

(v) At the point of flow separation over curved surface
(a) velocity is infinite (b) shear stress is zero
(c) shear stress is maximum (d) pressure gradient is zero.

(vi) Compressible flow analysis for gas medium is suitable for Mach number greater than
(a) 0.3 (b) 0.6 (c) 0.9 (d) 1.

(vii) From Stokes law, the drag coefficient C_D for flow around a sphere having Reynolds Number Re is
(a) $\frac{6}{Re}$ (b) $\frac{12}{Re}$ (c) $\frac{24}{Re}$ (d) independent of Re.

(viii) The Mach angle for a point source moving in compressible medium at sonic speed is
(a) 30° (b) 60° (c) 90° (d) 120°.

(ix) The compressible flow upstream of a shock is always
(a) supersonic (b) subsonic
(c) sonic (d) stagnant.

(x) The shape of a supersonic diffuser is
(a) converging along the flow direction
(b) diverging along the flow direction
(c) both (a) and (b)
(d) straight along the flow direction.

Group – B

2. (a) Explain potential flow.

(b) The velocity potential function ϕ is given by $\phi = x^2 - y^2$.
Find (i) the velocity component in x and y direction. (ii) Also show that ϕ represents a possible case of fluid flow.

(c) Write the difference between free and forced vortex flow with examples.

2 + (2 + 4) + 4 = 12

3. (a) An open circular cylinder of 20 cm diameter and 100 cm long contains water up to a height of 80 cm. It is rotated about its vertical axis. Find the speed of rotation when (i) no water spills, (ii) axial depth is zero.

(b) In a free cylindrical vortex flow of water, at a point a radius of 150mm, the velocity and pressure are 5 m/s and 14.715 N/cm². Find the pressure at radius of 300mm.

(4 + 3) + 5 = 12

Group – C

4. (a) A horizontal circular pipe of outer radius R_1, is placed concentrically inside another circular pipe of inner radius R_2. Considering fully developed laminar flow in the annular space between pipes show that the maximum velocity occurs at a radius R_0 given by $R_0 = \sqrt{\frac{R_2^2 - R_1^2}{2\ln(R_2/R_1)}}$.

(b) In a laminar flow occurring between two parallel plates where one of the plates is in motion and also under the presence of pressure gradient, in such a way that the net forward discharge across any section is zero. Find out the point where minimum velocity occurs and its magnitude.

6 + 6 = 12

5. (a) Using scale analysis describe Prandtl concept of boundary layer.

(b) Oil of viscosity 0.03 Ns/m^2 is flowing between two stationary plates which are parallel and are at 10 mm apart. Width of plates is 2 m. The velocity midway between the plates is 2.0 m/s.
Calculate (i) the pressure gradient along the flow (ii) the average velocity and (iii) the discharge for oil.

6 + (2 + 2 + 2) = 12

Group – D

6. (a) Air flows isentropically through a duct. The velocity at section-1 is V_1 = 220 m/s, with static temperature T_1 = 310 K and static pressure P_1 = 160 kPa. Compute: (i) Stagnation temperature T_0, (ii) Stagnation pressure P_0, (iii) Stagnation density ρ_0, (iv) Static pressure P_2 at section-2 where velocity is 280 m/s. R = 287 J/kgK and γ = 1.4 for air.

(b) Define Mach wave and Mach number.

(2 + 2 + 2 + 2) + (2 + 2) = 12

7. (a) Describe the compressible flow structure in a convergent-divergent nozzle.

(b) Show that the Mach number is 1 at the throat of a converging duct for maximum discharge.

5 + 7 = 12

Group – E

8. (a) State the assumptions of the Stokes law for falling sphere.

(b) Show the nomenclatures of an airfoil with a suitable sketch.

(c) A man descends to the ground using a parachute from an aeroplane with a uniform velocity of 10 m/s. The parachute is hemispherical in shape having diameter of 5m. Find the weight of the man if drag coefficient C_D=0.5. Density of air is 1.2 kg/m^3.

2 + 4 + 6 = 12

9. (a) Explain (i) drag force (ii) streamlined body (iii) bluff body.

(b) A cylinder rotates at 150 rpm and its axis is perpendicular in an air stream which is having uniform velocity of 25 m/s. The cylinder is 1.5 m in diameter and 10 m long. Assuming ideal fluid theory find (i) the circulation, (ii) lift force and (iii) the position of stagnation points. Take density of air as 1.25 kg/m^3.

(2 + 2 + 2) + 6 = 12