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) Stream function is defined for
(a) all three-dimensional flow situation
(b) flow of perfect fluid
(c) irrotational flows only
(d) two-dimensional incompressible flows.

(ii) Simple Couette flow is
(a) purely shear driven flow
(b) purely pressure driven flow
(c) combination of shear and pressure driven flow
(d) constant across the passage.

(iii) Doublet is a special case of
(a) source and uniform flow combination
(b) source and sink combination
(c) sink and uniform flow combination
(d) uniform and vortex flow combination.

(iv) At stagnation point the resultant velocity of combined flow field is
(a) negative (b) infinite (c) zero (d) ½.

(v) Camber of an aerofoil represents
(a) distance between leading and trailing edge
(b) mean profile of aerofoil
(c) ratio of maximum thickness to cord
(d) ratio of span of wing to chord.

(vi) For irrotational flow *Curl V* is equal to
(a) zero (b) positive (c) negative (d) infinite.

(vii) The boundary layer separation takes place if
(a) pressure gradient is zero (b) pressure gradient is positive
(c) pressure gradient is negative (d) both (a) and (c).

(viii) Select the expression that does not give the sonic velocity
(a) $\sqrt{\frac{\gamma P}{\rho}}$ (b) $\sqrt{\frac{\gamma\rho}{P}}$ (c) $\sqrt{\left(\frac{\partial P}{\partial \rho}\right)_S}$ (d) $\sqrt{\gamma RT}$

(ix) Incompressible flow analysis for a compressible gas medium is valid for Mach number
(a) less than 0.3 (b) 0.3 to 0.5
(c) 0.5 to 0.8 (d) 0.8 to 1.2.

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

Group – B

2. (a) Derive Laplace equation for potential flow which is linear, second order and partial differential equation.

(b) (i) Define circulation and vorticity.
(ii) An open circular cylinder of 20cm diameter and 100cm long contains water upto a height of 60cm. The tank is rotated about its vertical axis at 300rpm. Find the depth of the parabola formed at the free surface of water.

4 + (4 + 4) = 12

3. (a) Prove that the stream functions are family of circles for a doublet.

(b) A point source having strength 0.6 m^2/s is located at (-1, 0) and a point sink of strength 1.2 m^2/s is located at (1, 0). Determine the resultant velocity at point (1, 1).

6 + 6 = 12

Group – C

4. (a) Prove that the relationship between the average velocity $(\bar{u})$ and maximum velocity (U_{max}) in case of parallel flow between two fixed parallel plates is $U_{max} = 1.5\bar{u}$.

(b) Oil flows between two parallel plates, one of which is at rest and the other moves with a velocity U. (i) If the pressure is decreasing in the direction of flow at the rate of 5 Pa/m, the dynamic viscosity is 0.05 kg/ms, the spacing of the horizontal plate is 0.04 m and the volumetric flow Q per unit width is 0.02 m^2/s, what is the velocity U? (ii) Calculate U if the pressure is increasing at a rate of 5 Pa/m in the direction of flow.

5 + (4 + 3) = 12

5. (a) For laminar flow between two concentric cylinders of radii R_1 and R_2, which are rotated at constant angular velocity ω_1 and ω_2 respectively, derive the expression of tangential velocity V_θ at any radius r, in terms of R_1, R_2, ω_1 and ω_2. State the necessary assumptions for the derivation.

(b) For Blasius flow over a flat plate, write the Prandtl boundary layer equations, with necessary boundary conditions. What is shooting technique?

8 + 4 = 12

Group – D

6. (a) Prove that a small disturbance propagates through a compressible fluid medium with sonic speed. Hence, find the speed of propagation at 27°C in air. Given, R = 287J/kgK and γ = 1.4 for air.

(b) Write short note on Mach cone.

(7 + 1) + 4 = 12

7. (a) What is meant by 'choking of a duct'?

(b) Air flows isentropically in a duct. Properties at section 1 are V_1 = 250 m/s, T_1 = 350 K. At section 2 downstream, the temperature has dropped to 330 K. Find (i) velocity at section 2, and (ii) Mach number at section 2. Given, c_p = 1000J/kgK, R = 287J/kgK and γ = 1.4 for air.

4 + (5 + 3) = 12

Group – E

8. (a) Derive the expression for drag for flow past a cylinder without circulation.

(b) An aeroplane weighing 39.24 kN is flying in a horizontal direction at 360 km/h. The plane spans 15 m and has a wing surface area of 35 m^2. If drag co-efficient is 0.03 and density of air is 1.22 kg/m^3, determine

(i) Co-efficient of lift

(ii) Power required to drive the plane

(iii) Theoretical value of the boundary layer circulation.

6 + 6 = 12

9. (a) How the position of the stagnation points for flow over a rotating cylinder in a uniform flow is determined?

(b) A 300 mm diameter circular cylinder is rotated about its axis in a stream of water having a uniform velocity of 5 m/s. Estimate the rotational speed when both the stagnation points coincide. Estimate the lift force experienced by the cylinder under such condition. Density of water is assumed to be 1000 kg/m^3.

6 + 6 = 12