ADVANCED FLUID MECHANICS
(MECH 3233)

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) The velocity potential and stream function are mutually
(a) parallel (b) perpendicular
(c) inclined at 60° (d) inclined at 30°.

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

(iii) For a plane Poiseuille flow, the nature of shear stress distribution between the plates is
(a) linear (b) parabolic (c) hyperbolic (d) logarithmic

(iv) The magnitude of Vorticity is equal to
(a) circulation (b) circulation per unit area
(c) circulation multiplied by area (d) circulation multiplied by curve length

(v) The dimension of stream function is
(a) LT^{-1} (b) L^2T^{-1} (c) L^3T^2 (d) L^2T^{-2}

(vi) The tangential velocity component of ideal fluid flow on the surface of a cylinder is given by
(a) U sinθ (b) 2U sinθ (c) 3U sinθ (d) 4U sinθ

(vii) For an fully incompressible fluid the value of Mach number is always
(a) greater than 1 (b) less than 1
(c) tends to infinity (d) equal to zero.

(viii) The speed of sound in air varies as
(a) $\sqrt{T}$ (b) $\sqrt{\rho}$ (c) $\frac{1}{\sqrt{p}}$ (d) p

(ix) When compared to a streamlined body, a bluff body will have
(a) more pressure drag but less friction drag
(b) more pressure drag and more friction drag
(c) less pressure drag and less friction drag
(d) less pressure drag but more friction drag.

(x) If we reverse the direction of velocities of a sink flow, it becomes
(a) counter sink flow (b) source flow
(c) a free vortex (d) a forced vortex.

Group – B

2. (a) The velocity components in a two-dimensional flow are
$u = \frac{y^3}{3} + 2x - x^2 y$ *and* $v = xy^2 - 2y - \frac{x^3}{3}$.
(i) Prove that it is a case of possible steady incompressible flow.
(ii) Show that the flow is irrotational.

(b) What is the difference between free and forced vortex?

(4 + 4) + 4 = 12

3. (a) A cylindrical vessel closed at both ends is 14 cm in diameter and 100 cm high contains water up to a depth of 64 cm. Determine the height of paraboloid formed, if it is rotated about its vertical axis at a speed of 240 rpm. Also find the speed of rotation of the vessel, when the axial depth of water is zero.

(b) Check whether the stream function $\psi = 5xy$ is irrotational and if so, determine the corresponding potential function ϕ.

6 + 6 = 12

Group – C

4. (a) Show that in case of Couette flow, the shear stress at the horizontal mid-plane of the channel is independent of the pressure gradient imposed on the flow.

(b) Water at 15°C flows between parallel plates with gap width b = 2.5 mm. The upper plate moves with speed U = 0.25 m/s in the positive x direction. The pressure gradient is $\frac{\partial p}{\partial x} = -175 \text{Pa/m}$. Locate the point of maximum velocity and determine its magnitude (let y = 0 at the bottom plate).

6 + (4 + 2) = 12

5. (a) Velocity profile of laminar boundary layer is given by $\frac{u}{U_\infty} = \frac{3}{2}\frac{y}{\delta} - \frac{1}{2}\left(\frac{y}{\delta}\right)^3$. Determine the expressions for boundary layer thickness (δ), shear stress (τ_0), skin friction coefficient (C_f) and coefficient of drag (C_D) in terms of Reynolds number.

(b) Find out the relationship between the average velocity and maximum velocity in case of parallel flow between two fixed parallel plates.

8 + 4 = 12

Group – D

6. (a) Air at 40°C flows isentropically from a large tank through a converging nozzle of 40 mm diameter at nozzle exit. The tank contains air at 150 kPa(abs) and the discharge is to atmosphere of pressure 95 kPa(abs). Calculate the mass flow rate through the nozzle. (For air, $\gamma = 1.4$ and R = 287 J/kg-K)

(b) A rocket is found to have a speed of 260 km/hr in air at a temperature of (-40°C). Calculate the Mach number and the Mach angle. (For air, $\gamma = 1.4$ and R = 287 J/kg-K).

8 + (2 + 2) = 12

7. (a) An air plane is moving in an atmosphere with pressure p = 44 kPa (abs) and density $\rho = 0.63$ kg/m^3. A Pitot tube on the plane records the stagnation pressure as 70 kPa (abs). Estimate the speed of the airplane and the stagnation temperature. (For air, $\gamma = 1.4$ and R = 287 J/kg-K).

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

(3 + 3) + 6 = 12

Group – E

8. (a) A man descends to the ground from an aeroplane with the help of a parachute against the resistance of air with a uniform velocity of 10m/s. The shape of the parachute is hemispherical of 5 m diameter. Find the weight of the man. Assume $C_d = 0.5$ and $\rho_{air} = 1.25$ kg/m^3.

(b) What do you mean by superimposed flow? Explain how the contour of a half body is obtained.

6 + (2 + 4) = 12

9. (a) Flow over a plane half body is studied by superimposing a uniform flow at 6m/s on a source at the origin. If a body has maximum width of 2.4 m, then determine (i) the coordinate of the stagnation point, (ii) width of the body at the origin and (iii) velocity at a point $(0.5, \pi/2)$.

(b) A point P (3, 1) is situated in the flow field of a doublet of strength 6 m^2/s. calculate the velocity at this point and also the value of the stream function.

6 + 6 = 12

Department & Section	Submission Link
ME	https://classroom.google.com/c/NTYzMTYzODM5MDZa/a/MzY0NjEyNDc5MTMz/details