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) 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) Pressure drag is _____ and chance of flow separation is _____ for a streamlined body.
(a) less, more (b) more, less
(c) less, less (d) more, more.

(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) A low compressibility correction factor results from..... Mach number compressible flow (fill in the blank).
(a) low (b) high (c) negative (d) infinite.

(viii) Mach angle in a Mach cone is

(a) $\sin^{-1}(M)$ (b) $\sin^{-1}(\frac{1}{M})$ (c) $\sin^{-1}(2M)$ (d) $\sin^{-1}(\frac{2}{M})$

(ix) In a compressible flow the stagnation temperature is always

(a) lower than static temperature (b) higher than static temperature
(c) equal to the static temperature (d) both (a) and (c)

(x) Mass flow rate through a duct is maximum when the Mach number at the throat is

(a) 5 (b) 1 (c) 0 (d) ∞.

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 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.

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

6 + (2 + 4) = 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) State the Prandtl's boundary layer equations and show that the velocity profile for a laminar flow past a flat plate has an infinite radius of curvature on the surface of the plate.

(b) For finding the velocity distribution in case of flow between two concentric rotating cylinders, write down the assumptions consider with justification.

9 + 3 = 12

Group – D

6. (a) How the compressibility correction factor affects the accuracy of velocity calculation using a pitot-static tube?

   (b) Explain: (i) supersonic diffuser is convergent shaped duct, and (ii) supersonic nozzle is divergent shaped duct.

6 + (3 + 3) = 12

7. (a) An airplane is capable of flying with a Mach number of 0.8. What can be the maximum speed of the airplane (i) at the sea level where temperature is 27°C, and (ii) at high altitude where the temperature is -43°C? Given, R = 287J/kgK and $\gamma = 1.4$ for air.

   (b) How the stagnation temperature (T_0) is related to the static temperature (T) in isentropic compressible flow?

6 + 6 = 12

Group – E

8. (a) A metallic ball 2 mm diameter and relative density 12 is dropped into fluid of specific gravity 0.95 and viscosity 1.5 kg/ms. Find out the drag force exerted by fluid on metallic ball and calculate the terminal velocity of the ball.

   (b) Derive the expression for lift for flow past a cylinder with circulation.

6 + 6 = 12

9. (a) Explain the terms: (i) Magnus effect (ii) Drag force

   (b) A jet plane which weighs 29430 N and has a wing area of 20 m^2 flies at a velocity of 250 km/hr. When the engine delivers 7357.5 kW. 65% of the power is used to overcome the drag resistance of the wing. Calculate the co-efficient of lift and co-efficient of drag for the wing. Take $\rho_{air} = 1.21 kg/m^3$.

6 + 6 = 12

Department & Section	Submission Link
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