Ref. No. : Ex/ME(M2)/PC/B/T/213/2025

B.E. MECHANICAL ENGINEERING SECOND YEAR FIRST SEMESTER – 2025

Subject: FLUID MECHANICS - II Time: 3 Hrs. Full Marks: 100

Instructions: Answer any five questions. Write all pertinent assumptions. Assume any missing data.

1. (a) Consider a parallel flow of viscous fluid between two plates, where one plate is at rest and another is moving relative to the other at a velocity U_∞. Starting from the governing equations for the fluid flow, obtain the dimensionless velocity distribution across the plates for various values of dimensionless adverse, zero, and favourable pressure gradients. Sketch the corresponding velocity profiles and obtain the expression for the maximum velocity. Write all pertinent assumptions.

(b) A wide moving belt passes through a container of a viscous liquid of viscosity μ (see **Fig. 1**). The belt moves vertically upward with a constant velocity V_∞. Because of the viscous forces, the belt picks up a film of fluid of thickness t. Assume laminar, steady, fully developed, incompressible, Newtonian flow, obtain an expression for the average velocity of the fluid film as it is dragged up the belt.

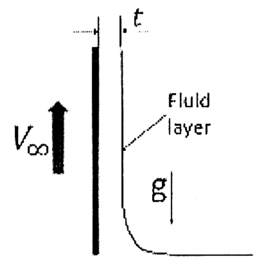

Fig. 1

(10+10)

2. (a) Draw a neat sketch showing the development of boundary layer over a flat plate. Sketch the velocity profile and indicate the boundary layer thickness. Employing the order of magnitude analysis, derive the Prandtl's boundary equations with the respective boundary conditions for the flow over a flat plate.

(b) A general sinusoidal velocity profile for laminar boundary layer flow over a flat plate can be given by $u(y) = C\sin(Dy) + E$. Show that one can obtain an expression for this velocity profile as $\frac{u(y)}{U_\infty} = \sin\left(\frac{\pi}{2}\frac{y}{\delta}\right)$. Here, U_∞ is the free stream velocity, and δ is the boundary layer thickness. (10+10)

3. (a) Derive the von Kármán momentum integral equation for the flow over a flat plate.

(b) The velocity profile within the boundary layer for the flow over a flat plate may be expressed as: $\frac{u}{U_\infty} = a + b\left(\frac{y}{\delta}\right) + c\left(\frac{y}{\delta}\right)^2 + d\left(\frac{y}{\delta}\right)^3$, where δ is the boundary layer thickness, U_∞ is the free stream velocity, and a, b, c, d are constants. Using the von Kármán momentum integral equation and suitable boundary conditions, show that one may obtain an approximate solution, $\frac{\delta}{x} = \frac{4.64}{\sqrt{Re_x}}$ and $C_f = \frac{0.646}{\sqrt{Re_x}}$. Here, C_f is the skin friction factor and the local Reynolds number from the leading edge of the plate $Re_x = \frac{U_\infty x}{\nu}$, ν being the kinematic viscosity of the fluid. (10+10)

4. Show that the combinations of rectilinear flow parallel to the x-axis, a doublet, and an irrotational vortex may form a streamline which is a flow past a rotating circular cylinder. Find the stagnation point for such a flow and draw corresponding possibilities of stagnation point locations for different circulation strengths. Furthermore, obtain the expressions for the horizontal and vertical force components acting on the rotating circular cylinder. (20)

5. (a) Derive the condition of choking for the flow of compressible fluid through a convergent nozzle.

   (b) Air flows isentropically through a duct. At point 1 the velocity is 300 m/s with T_1=350 K and p_1=200 kPa. Compute (a) T_{01}, (b) p_{01}, (c) ρ_{01}, (d) Ma, (e) V_{max}, and (f) V^*. At point 2 further downstream, V_2=350 m/s and p_2 =250 kPa, (g) what is the stagnation pressure p_{02}. All the symbols carry usual meanings from the perspective of compressible fluid flows. (10+10)

6. Air flows through a duct as shown in **Fig. 2**, where, A_1 =24 cm^2, A_2 =18 cm^2, and A_3 =32 cm^2. A normal shock stands at section 2. Compute (a) the mass flow rate, (b) the Mach number, and (c) the stagnation pressure at section 3. It is given that Ma_1 =2.5, p_1 =40 kPa, and T_1 =30^0 C. (20)

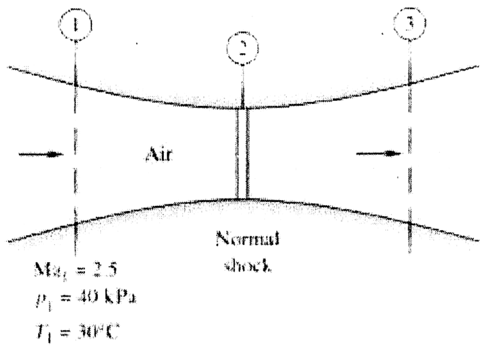

Fig. 2

7. Write short notes on: (a) Operations of a convergent-divergent nozzle at different back pressures. (b) Turbulent boundary layer. (c) Boundary layer separation.

(10+5+5)