B.E. MECHANICAL ENGINEERING SECOND YEAR FIRST SEMESTER – 2023

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) What do you mean by the entrance length for the laminar flow through a duct?

(b) 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. Find also the expressions for shear stress and average velocity for the flow. Write all pertinent assumptions.

(5+15)

2. (a) Employing the order of magnitude analysis, derive the dimensionless form of Prandtl's boundary layer equations with the respective boundary conditions for the flow over a flat plate.

(b) Air at 300 K flows over a flat plate at a speed of 2 m/s. Calculate the boundary layer thickness at distances 0.1 m and 0.3 m from the leading edge of the plate. Also calculate the mass flow rate within the boundary layer at 0.1 m and 0.3 m, if the dimensionless velocity distribution, $\frac{u}{U_\infty} = \frac{3}{2}\left(\frac{y}{\delta}\right) - \frac{1}{2}\left(\frac{y}{\delta}\right)^3$. Here, δ is the boundary layer thickness, and U_∞ is the free stream velocity. Take the density and viscosity of the air as $\rho = 1.17\ kg/m^3$, and $\mu = 1.85 \times 10^{-5}\ kg/m.s$, respectively.

(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, show that one may obtain the 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 $Re_x = \frac{U_\infty x}{\vartheta}$, ϑ being the kinematic viscosity of the fluid.

(10+10)

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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)Draw the pressure distribution in a convergent-divergent nozzle for different conditions of the back pressure – ranging from no flow to shock at the nozzle exit. In the figure indicate the condition of chocked nozzle, the subsonic zones and supersonic (if any) zones. What will be ratio of the throat pressure to stagnation pressure under chocking condition?

(b) A large reservoir at 600 K supplies airflow through a converging-diverging nozzle with a throat area of 2 cm^2. A normal shock wave forms at a section of area 6 cm^2. Just downstream of the shock, the pressure is 150 kPa. Calculate (a) the pressure in the throat, (b) the mass flow, and (c) the pressure in the reservoir.

(10+10)

6. Using the Buckingham's π-theorem, show that the discharge (Q) of liquid through a rotodynamic pump having an impeller of diameter D and width b running at a speed N, when producing a pressure head H, can be expressed in the form:

$$Q = (ND^3)\,\phi\left[\frac{D}{b},\ \frac{N^2D^2}{gH},\ \frac{\rho N D^2}{\mu}\right]$$

Here, ρ is the fluid density, μ is the fluid viscosity, and g is the acceleration due to gravity.

[Take D, N and ρ as repeating variables.]

(20)

7. Write short notes on: (a) Boundary layer separation. (b) Drag and Lift. (c) Magnus effect. (d) Mach cone.

(5+5+5+5)

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