Ref. No.: Ex/ME(M2)/PC/B/T/213/2024

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

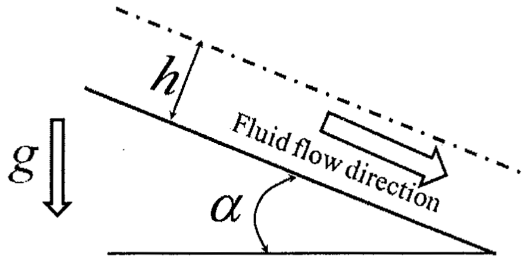
Subject: FLUID MECHANICS - II   Time: 3 Hrs.   Full Marks: 100

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

All the symbols carry usual meanings.

1. (a) Starting from the reduced form of the governing Navier-Stokes equations with appropriate boundary conditions for pressure driven **steady** laminar flow of an **incompressible** fluid between horizontal **stationary** flat parallel plates, obtain the dimensionless velocity distribution across the plates. Sketch the corresponding velocity profiles and obtain the expression for the average velocity of the flow, shear stress, and skin-friction coefficient. Write all pertinent assumptions. (10)

   (b) A viscous fluid flows down an inclined plate of angle α, as shown. The viscosity of the fluid is μ and density is ρ. g is the acceleration due to gravity. Assume negligible viscous force due to air and pressure on a free surface is constant. Determine the velocity profile and flow rate. Write all pertinent assumptions. (10)



2. (a) Derive Prandtl's boundary layer equations with boundary conditions for the flow of viscous fluid over a flat plate. Write all assumptions. (10)

   (b) A pillar of square cross-section 15cm×15cm and length 8m is immersed in a water flow of 1.5 m/s. Estimate the bending moment exerted by the flow at the bottom of the pillar if the drag coefficient of a square cylinder is 2.1. Take the density and kinematic viscosity of the water as $\rho = 1000\ kg/m^3$, and $\nu = 1.02 \times 10^{-6}\ m^2/s$, respectively. (10)

3. (a) Explain the phenomenon of the boundary layer separation in detail. Show different velocity profiles for the favourable, zero, and adverse pressure gradients. (10)

   (b) A general sinusoidal velocity profile for laminar boundary-layer flow over a flat plate may be expressed as $\frac{u(y)}{U_0} = a_0 \sin(a_1\eta) + a_2$, where $\eta = \frac{y}{\delta}$. Using suitable boundary conditions, find the constants a_0, a_1, and a_2. Also obtain the expressions for the momentum and displacement thicknesses for such a flow. (10)

[Turn over

4. (a) Show that in a flow field streamlines and equipotential lines are normal to one another. (5)

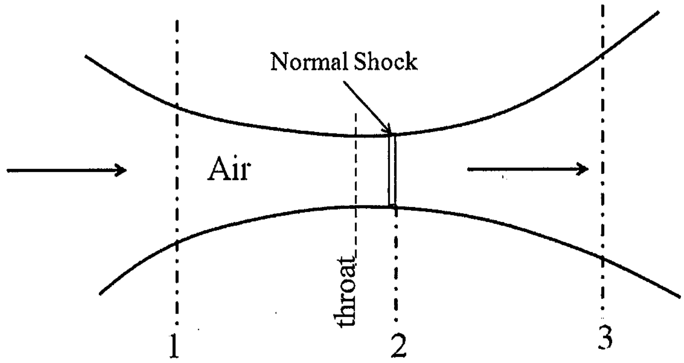
(b) Show that combinations of rectilinear flow parallel to x-axis and a doublet may form a streamline pattern similar to flow past a circular cylinder. Find locations of stagnation points for such a flow and draw the variation of pressure coefficient along its circumference. Furthermore, obtain the expressions for the horizontal and vertical force components acting on the circular cylinder. (15)

5. (a) For the isentropic flows with area changes, show that $\frac{du}{u} = \left(\frac{1}{M^2-1}\right)\frac{dA}{A} = -\frac{dp}{\rho u^2}$. Here, M is the Mach number, u is the flow velocity, A is the area, p is pressure, and ρ is fluid density. Explain different cases for subsonic and supersonic flows when $dA > 0$ and $dA < 0$. (10)

(b) Air flows adiabatically through a duct. At point 1 the velocity is 250 m/s, with $T_1 = 320\,K$ and $p_1 = 170\,kPa$. Compute (a) T_{01}, (b) p_{01}, (c) ρ_{01}, (d) M_1, (e) u_{max1}, and (f) u^*. At point 2 further downstream u_2 = 290 m/s and $p_2 = 135$ kPa. (g) What is the stagnation pressure p_{02}. (10)

6. (a) Deduce an expression connecting upstream and downstream Mach number of a normal shock. (10)

(b) Air flows through a duct as shown, 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, the (a) mass flow, (b) Mach number at section 3, and (c) stagnation pressure at section 3. Given: : M_1 = 2.5; p_1 = 40kPa; T_1 = 303K. Write all pertinent assumptions. Use $R = 287$ J/kg.K (10)



7. For turbulent, incompressible flow through a straight pipe of diameter "D", the head loss (h_f) in a length L of the pipe depends on (i) the mean velocity of flow (V), (ii) fluid density (ρ), (iii) fluid viscosity (μ), (iv) height of roughness elements (ε), (v) acceleration due to gravity (g), (vi) length (L) of pipe, and (vii) diameter (D) of the pipe. Using the Buckingham's π-theorem, show that one may express a functional relationship (if the Reynolds number $\mathrm{Re} = \rho VD/\mu$)

$$\frac{h_f}{L} = \phi\left(\mathrm{Re}, \frac{\varepsilon}{D}, \frac{V^2}{gD}\right) \tag{20}$$