Applied Mechanics Department

AML 711/713, Advanced/Applied Fluid Mechanics

Date: Dec, 1, 2006

I Sem, 2006-07.

MAJOR TEST

Max. Marks: 80

Time: 1-3pm.

NOTE: Answer ALL Questions.

(1) (a). Consider the Isentropic, Steady, one dimensional flow of a Compressible perfect gas through a Variable area duct. Derive the relation to demonstrate how Mach no affects the relation between dA/dx, $d\rho/dx$ and dp/dx. (6)

(b). A purely converging nozzle is supplied compressed air at a constant pressure p_0 from a reservoir. The pressure in the down stream reservoir is p_B and exit pressure at the nozzle is p_e. Explain through figures how mass flux ($\dot{m}$) and (p_e/p_0) Varies as p_B is reduced gradually from its initial Value of p_0. (6).

(2) Consider the flow of water ($\rho = 10^3$ kg/m³, $\mu = 1$ cP) through a circular pipe of 100 mm diameter at an average Velocity of 1.5 m/s. What is the maximum roughness height allowable (in mm) so that the pipe can be considered as hydraulically smooth (Use $f = 0.32/Re^{1/4}$) (10).

(3) Assume that the Velocity profile in the Laminar Boundary layer over a flat plate is given by

$$u/U_\infty = y/\delta \text{ for } 0 \le y/\delta \le 1. \text{ and } u/U_\infty = 1 \text{ for } y/\delta > 1.$$

For this profile calculate δ^*/δ and θ/δ. Starting from Von Karman's Momentum Integral Equation, using this Velocity profile derive the expression for $\delta(x)$ and Coeff. of drag (C_D). Using the above result calculate the drag force and Boundary layer thickness at the downstream edge of a flat plate (2 m wide and ~~2 m~~ 1.0 m long) over which water ($\rho = 10^3$ kg/m³ and $\mu = 1$ cP) flows at a Velocity of 0.3 m/s. Assume that only one face of the plate is wetted (12)

(4) Define Prandtl's mixing length and explain its physical significance How is ~~its~~ it related to eddy Viscosity? Using this hypothesis, show that the Velocity profile in the fully turbulent layer near the wall is given by,

$$\phi = A \ln \eta + D \quad \text{where } \phi = \bar{u}/v_0^*, \quad \eta = (y v_0^*/\nu)$$

A and D are constants. State all assumptions made (10).

(5) Briefly describe the following.

(a) Orr-Sommerfeld Equation and Neutral Stability curve.

(b) Coefft friction in a hydrodynamically lubricated Bearing.

(c) Effect of surface tension on gravity surface waves. (12)

(6) Consider laminar Boundary layer over a flat plate. Using Reynolds Analogy, show that when Pr = 1 and Viscous dissipation is neglected, Nusselt Number (Nu) is given by

$$Nu = \tfrac{1}{2}\, Re\, C_D.$$

(8)

$$Nu = \frac{Ql}{k(T_w - T_\infty)bl}; \quad Re = \frac{\rho U_\infty l}{\mu}, \quad C_D = F_D \Big/ \tfrac{1}{2}\rho U_\infty^2 bl.$$

(7) A Vertical take off and landing aircraft takes in air horizontally at the rate of 80 kg/s and discharges Vertically downwards at a Velocity of 700 m/s relative to the aircraft at an exit pressure of 0.5 kgf/cm² (gauge). It consumes fuel at the rate of 3 kg/s and weight of the aircraft is 3000 kgf. The exit area of the Vertical exhaust is 0.5 m². Use Integral analysis to calculate the initial Vertical acceleration of the aircraft (8).

(8) Consider laminar and Turbulent Boundary layer over a flat plate. Compare their following properties

(a) growth rate of B.L

(b) Drag force on the plate.

(c) Velocity profile in the B.L. (8)