BTS (C) – VII – 05 – 066 (C)

B. Tech Degree VII Semester Examination November 2005

ME 701 COMPRESSIBLE FLUID FLOW

(1999 & 2002 Admissions)

Time : 3 Hours | Maximum Marks : 100

I. (a) Explain the following :

(i) Stagnation state (ii) Mach number
(iii) Mach cone (iv) Critical velocity of sound
(v) Impulse function. (10)

(b) Show that for an incompressible flow fractional changes in velocity and area have opposite signs. (10)

OR

II. (a) Show that in adiabatic flow, an increase in velocity is always accompanied by a decrease in temperature. (10)

(b) Consider adiabatic air flow through a variable area duct. At a certain section of the duct the flow area is 0.1 m^2, the pressure is 120 KPa, the temperature is 15°C, and the duct area is changing at a rate of 0.1 m^2/m. Find $\frac{dp}{dx}, \frac{dv}{dx}$ and $\frac{d\rho}{dx}$. Given $C_p = 1.004 \frac{KJ}{KgK}$ & $R = 0.287 \frac{KJ}{KgK}$.

(i) assuming incompressible flow
(ii) taking compressibility into account. (10)

III. (a) Derive for one dimensional isentropic flow $\frac{dA}{A} = \frac{dP}{\rho c^2}\left[1 - m^2\right]$ from fundamental equations. (10)

(b) The pressure, velocity and temperature of air $\left[\chi = 1.4, C_p = 1.0\, KJ/KgK\right]$ at the entry of a nozzle are 2 bar, 145 m/s and 330 K, the exit pressure is 1.5 bar. (a) What is the shape of the nozzle? (b) Determine for isentropic flow (i) the Mach number at entry and exit. (ii) the flow rate and the maximum possible flow rate. (10)

OR

IV. (a) Derive an expression for the variation of the Mach number with the friction factor and the duct length. (10)

(b) Air enters a long circular duct $\left[d = 12.5\, cm, \bar{f} = 0.0045\right]$ at a Mach number of 0.5, pressure 3.0 bar and temperature 312 K. If the flow is isothermal throughout the duct determine (i) the length of the duct required to change the Mach number to 0.7 (ii) pressure and temperature of air at M = 0.7, (iii) the length of the duct required to attain limiting Mach number and (iv) state of air at the limiting Mach number. (10)

(Turn Over)

V. (a) Prove that the dimensionless value of the heat transfer in a Rayleigh process from a Mach number M_1 to M_2 is

$$\frac{Q}{C_p T_1} = \frac{M_2^2 - M_1^2}{2M_1^2\left[1+\chi M_2^2\right]^2}\left[1\left(1-\chi M_1^2 M_2^2\right)+\left(\chi-1\right)\left(M_2^2+M_1^2\right)\right]. \quad (10)$$

(b) Air enters a constant area duct at a pressure of 620 kPa and a temperature of 300°C, the velocity at the inlet being 100 m/s. If the velocity at the exit to the duct is 210 m/s, determine the pressure, temperature, stagnation pressure and stagnation temperature at the exit to the duct. Also find the heat transfer per unit mass in the duct. Assume that the effects of friction are negligible. (10)

OR

VI. (a) Develop the given relation for Rayleigh flow -

$$\frac{S_2 - S_1}{R} = 1_n \frac{M_2}{M_1}\left[\frac{M_2}{M_1} - \frac{1+\chi M_1^2}{1+\chi M_2^2}\right]\frac{\chi+1}{\chi-1}. \quad (10)$$

(b) The data for a combustion chamber employing a hydrocarbon fuel is given below :
Entry : gas velocity = 152 m/s, pressure = 4 bar, temperature = 400 K.
Exit : Mach number = 0.8
Take $\chi = 1.3$, $C_p = 2.144$ kJ/KgK for the products of combustion. Calorific value of the fuel burnt = 43 MJ/Kg. Determine - (i) Entry Mach number (ii) pressure, temperature and velocity of the gas at exit, (iii) stagnation pressure loss and (iv) air fuel ratio required. (10)

VII. (a) Derive the following relation for flow through a normal stock :

$$\frac{Py}{Px} = \frac{2\chi}{\chi+1}Mx^2 - \frac{\chi-1}{\chi+1}. \quad (8)$$

(b) the ratio of the exit to entry area in a subsonic diffuser is 4.0. The Mach number of a jet of air approaching the diffuser at P_o=1.013 bar, T = 290 K is 2.2 There is a standing normal shock wave just outside the diffuser entry. The flow in the diffuser is isentropic. Determine at the exit of the diffuser:
(i) Mach number (ii) temperature and (iii) pressure.
What is the stagnation pressure loss between the initial and final states of the flow? (12)

OR

VIII. (a) Explain why the throat area of the diffuser in a supersonic wind tunnel is larger than the nozzle throat area. Why is it desirable to locate the shock wave at the diffuser throat during the operation of the tunnel? (6)

(b) the stagnation pressure and temperature of air at the entry of a nozzle are 5 bar and 500 K respectively. The exit Mach number is 2.0 where a normal shock occurs. Calculate the following quantities before and after the shock: static and stagnation pressure and temperatures, air velocities and Mach numbers. What are the values of stagnation pressure loss and increase in entropy across the shock? (14)

IX. Explain briefly the working principles of the following with neat sketches :
(i) Hot wire anemometer (any one type). (10)
(ii) Interferometer for determining the density variations. (10)

OR

X. Explain the working principles of the following with neat sketches :
(i) Shock tube (10)
(ii) Schlieren technique. (10)

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