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Reg No.:_____ Name:_____

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

Seventh Semester B.Tech Degree (S, FE) Examination January 2023 (2015 Scheme)

Course Code: ME409

Course Name: COMPRESSIBLE FLUID FLOW

Max. Marks: 100 Duration: 3 Hours

Use of Gas table is permitted. Assume suitable value for missing data

PART A

Answer any three full questions, each carries 10 marks. Marks

1 a) Derive the general momentum equation for a control volume in integral form. (4)

b) Draw and explain the wave propagation for Mach numbers of 0.5, 1 and 2. Mark zone of silence and zone of disturbance in each case. (6)

2 a) Define stagnation pressure and stagnation temperature. Derive a relation between stagnation pressure, static pressure and Mach number. (4)

b) An aircraft is flying at an altitude of 12,000 m at a Mach number of 0.8. The cross sectional area of the inlet diffuser before the LP compressor stage is 0.4 m^2. Determine (6)

i) the speed of the aircraft

ii) the mass of air entering the compressor per second.

iii) the stagnation pressure and temperature of air at the diffuser entry.

3 a) Explain the phenomenon of chocking in isentropic flow. (2)

b) Explain the flow through a convergent-divergent nozzle at different back pressures. Draw and explain the following graphs (8)

i) $\frac{p_e}{p_o}$ Vs $\frac{p_b}{p_o}$ ii) $\frac{p_t}{p_o}$ Vs $\frac{p_b}{p_o}$ iii) $\frac{m\sqrt{T_o}}{A^* p_o}$ Vs $\frac{p_b}{p_o}$

4 The pressure, velocity and temperature of air at the entry of a nozzle are 2 bar, 145 m/s and 330 K, the exit pressure is 1.5 bar. Determine for isentropic flow (10)

i) the Mach number at entry and exit

ii) the specific flow rate at exit of nozzle

iii) maximum possible specific flow rate

PART B

Answer any three full questions, each carries 10 marks.

5 Derive Prandtl-Meyer relations for a normal shock wave from basic laws with suitable assumptions. (10)

6 a) What is an oblique shock wave? Give two practical situations where the oblique shock waves are produced. (4)

b) An aircraft flies at a Mach number of 1.2 at an altitude of 16 km. The compression in its engine is partly achieved by a normal shock wave standing at the entry of its diffuser. Determine (6)

i) Mach number, pressure, temperature and density immediately downstream of the shock

ii) the increase in entropy due to the normal shock wave

7 a) What is Fanno flow? Explain it with one practical example. (3)

b) What are the assumptions made in deriving equation for Fanno flow? Derive an equation describing a Fanno curve. Show three curves on the temperature-entropy coordinates at three mass flow densities. (4)

c) What is meant by frictional chocking? (3)

8 A long pipe of 25.4 mm diameter has a mean coefficient of friction of 0.003. Air enters the pipe at a Mach number of 2.5, stagnation temperature 310 K and the static pressure 0.507 bar. Determine for a section at which Mach number reaches 1.2 (10)

i) static pressure and temperature

ii) stagnation pressure and temperature

iii) velocity of air

iv) distance of this section from the inlet

v) mass flow rate of air

PART C

Answer any four full questions, each carries 10 marks.

9 a) Explain chocking in Rayleigh flow. (4)

b) Prove that for Rayleigh flow, at maximum entropy point the Mach number is unity. (6)

10 A gaseous mixture of air and fuel enters a ramjet combustion chamber with a velocity of 73.15 m/s at a static temperature and pressure of 333.3 K and 0.5516 bar. The heat of reaction of the fuel air mixture is 1395.5 kJ/kg. Assuming that the working fluid has the same thermodynamic properties as air before and after combustion, that the friction is negligible and that the cross sectional area of the combustion chamber is constant. Calculate (10)

i) the stagnation temperature after combustion

ii) the Mach number after combustion

iii) the final velocity of combustion mixture

iv) the loss in stagnation pressure due to heat addition

v) the maximum heat reaction for which flow with the specified initial conditions can be maintained.

11 Heat rejected from the air flowing in a constant area duct. At the duct entrance the air is moving at 200 m/s and possess static conditions of 300 K and 100 kPa. If 50 kJ/kg is rejected along the duct, find (10)

i) the exit Mach number

ii) the stagnation temperature change

iii) the stagnation pressure change.

12 a) What are the three different optical instruments employed in compressible flow to study density variation in the flow field? What is the basic principle involved in the above instruments? (4)

b) With the help of a neat sketch explain the working of a Schlieren apparatus. (6)

13 Describe the working principles of the following devices with neat sketches: (10)

i) constant temperature hot-wire anemometer for velocity measurement

ii) constant current hot-wire anemometer for velocity measurement

14 a) Describe with the aid of a schematic diagram the working of an open circuit supersonic wind tunnel. (7)

b) In what way does the Kiel probe different from an ordinary pitot tube? (3)

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