Reg No.:_____ Name:_____

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

SEVENTH SEMESTER B.TECH DEGREE EXAMINATION, DECEMBER 2018

Course Code: ME409

Course Name: COMPRESSIBLE FLUID FLOW

Max. Marks: 100 Duration: 3 Hours

Use of Gas Tables Permitted, Assume suitable value for missing data

PART A

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

1 Derive momentum equation for compressible flow through a control volume. (10)

2 a) Derive adiabatic steady flow elliptic energy equation. Represent various flow regimes on steady flow adiabatic ellipse. (4)

b) An air jet (γ = 1.4, R = 287 J/ kg K) at 400 K has sonic velocity. Determine: (6)

i. Velocity of sound at 400 K

ii.Velocity of sound at stagnation condition

iii. Reference Mach number

iv. Maximum velocity of jet

v. Stagnation enthalpy

3 a) Describe the behaviour of flow in a convergent-divergent nozzle when it is operated at (i) design pressure ratio and (ii) pressure ratio lower than design value (4)

b) Air flows isentropically through a duct. At a particular section in the passage, the cross-sectional area is 400 mm^2 and M = 0.4. At another section area is 300 mm^2. What is the Mach number at the second section? What would be the area at the section where M = 1? (6)

4 a) Explain the phenomenon of choking in isentropic flow. (4)

b) Air enters a nozzle having a throat area of 930 cm^2 and attains a Mach number of 2.5 at the exit. The supply of air is at a pressure of 1.05 bar and a temperature of 21°C and is having negligible velocity. Find the mass flow rate, area, pressure, temperature and velocity at the exit of the nozzle. (6)

PART B

Answer any three full questions, each carries 10 marks.

5 a) What is an expansion fan? How does it occur in supersonic flow? (4)

b) Derive Prandtl-Meyer relation for normal shocks. (6)

6 A supersonic nozzle draws air from a high temperature air source and supplies to a constant cross section duct. The diameter of the duct is same as the nozzle exit diameter which is $\sqrt{3}$ times the throat diameter of the nozzle. The source contains air at a pressure and temperature of 1.0 MPa and 600 K. Calculate the Mach number, velocity and pressure of air in the duct, if the nozzle operates at design condition. Also calculate the condition of air in the duct if a normal shock occurs at a section where the diameter is $\sqrt{2}$ times the throat diameter. (10)

7 a) For an isothermal flow, prove that the critical Mach number is $\frac{1}{\sqrt{\gamma}}$ (4)

b) A circular duct passes 8.25 kg/s of air at an exit Mach number of 0.5. The entry pressure and temperature are 3.45 bar and 38°C respectively and the mean coefficient of friction 0.005. If the Mach number at the entry is 0.15, determine i) diameter of the duct, ii) length of duct, iii) pressure and temperature at exit and iv) stagnation pressure loss. (6)

8 a) Prove that Mach number is unity at the maximum entropy point on a Fanno curve. (3)

b) A convergent-divergent nozzle having a throat diameter of 7.5 mm supplies air to an insulated duct of diameter 15 mm. The stagnation properties of air at entry to the nozzle are 7.5 bar and 300 K. The flow trough nozzle is isentropic. The mean coefficient of friction for the duct is 0.005. Calculate the maximum length of the duct that can be provided without discontinuity in the nozzle or duct. Find the condition of air at the exit, for the duct length. (7)

PART C

Answer any four full questions, each carries 10 marks.

9 The ratio of stagnation temperature at the exit and entry of the combustion chamber is 3.75. If the pressure, temperature and flow Mach number at the exit are 2.5 bar, 1000^0C and 0.9 respectively, determine *(i)* Mach number, pressure and temperature of the gas at entry *(ii)* total heat supplied per kg of gas *(iii)* Maximum heat that can be supplied. Take γ=1.4 and C_p=1.2kJ/kgK. (10)

10 Air enters a constant area pipe with velocity 150m/s, temperature 60^0C and pressure 0.5 MN/m^2. If 180 kJ/kg of heat is added to the pipe find *(i)* the final Mach no. *(ii)* the final pressure *(iii)* change in stagnation pressure and *(iv)* change in entropy. Take γ=1.4, R=0.287 kJ/kgK (10)

11 a) Prove that the maximum entropy point in a Rayleigh line is the point where Mach no is unity. (4)

b) Air at Mach No. 1.5, pressure 300kPa and temperature 288K is brought to sonic velocity in a frictionless constant area duct through heat transfer occurs. Determine the final pressure, temperature and heat added during the process. (6)

12 a) Suggest an optical visualisation method for quantitatively calculating the density variation in a flow field. (4)

b) Write short notes on Adiabatic recovery factor(R) and Stagnation temperature correction factor(K) (6)

13 a) With a neat sketch discuss the working of an Interferometer. (4)

b) Discuss the two different ways of using a hot wire anemometer. Which one could be used to measure velocity in a turbulent flow field. (6)

14 a) Explain the working of a Prandtl Pitot static probe with a neat sketch. (4)

b) Discuss the advantages and disadvantages of an open type and closed type wind tunnel. (6)

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