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^{o}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^{0}C 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 Υ=1.4 and C_p=1.2kJ/kgK. (10)

10 Air enters a constant area pipe with velocity 150m/s, temperature 60^{0}C 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 Υ=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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APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

SEVENTH SEMESTER B.TECH DEGREE EXAMINATION(S), MAY 2019

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 a) What is Mach angle? Derive an expression for Mach angle in terms of Mach number. (4)

b) A perfect gas having C_p = 1017.4 J/kg and molecular weight 28.97 flows adiabatically in a converging passage with a mass flow rate if 29.18kg/s. At a particular location, M = 0.6, T = 550K and p = 0.2 MPa. Calculate the area of cross section of the duct at the location. (6)

2 Derive the expression for sonic velocity in terms of the difference of specific heats and the ratio of specific heats of the medium. (10)

3 Derive an expression for mass flux in terms of Mach number for an isentropic flow. From the expression for mass flux determine the condition for maximum mass flux. (10)

4 A supersonic nozzle expands air from p_o = 25 bar and T_o = 1050 K to an exit pressure of 4.35 bar; the exit area of the nozzle is 100 cm^2. Determine (a) throat area (b) pressure and temperature at the throat (c) temperature at exit (d) exit velocity as fraction of the maximum attainable velocity and (e) mass flow rate (10)

PART B

Answer any three full questions, each carries 10 marks.

5 a) What do you meant by shock strength? (3)

b) Explain why shock is impossible in subsonic flow. (3)

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

6 A convergent divergent nozzle has an exit to throat area ratio of 3.0. The stagnation properties of air at inlet are 700 kN/m^2 and 90 ^oC. The throat area is 10 cm^2. Due to its operation at off design condition a plane normal shock is seen to stand at the section where M = 2. Determine the Mach number, static pressure and static temperature at the exit of the nozzle. Assume isentropic flow before (10)

and after the shock.

7 a) Explain the phenomenon of frictional chocking. (3)

b) A convergent-divergent nozzle is provided with a pipe of constant cross section at its exit. The exit diameter of nozzle and that of pipe is 40 cm. The mean coefficient of friction for the pipe is 0.0025. Stagnation pressure and temperature of air at the nozzle entry are 12 bar and 600 K. The flow is isentropic in the nozzle and adiabatic in the pipe. The Mach number at the entry and exit of the pipe are 1.8 and 1.0 respectively. Determine i) length of pipe, ii) diameter of the nozzle throat and iii) pressure and temperature at the pipe exit. (7)

8 a) Differentiate between Fanno flow and Isothermal flow. What is the limit for continuous subsonic isothermal flow through a constant area duct. (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^{o}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)

PART C

Answer any four full questions, each carries 10 marks.

9 A combustion chamber in a gas-turbine plant receives air at 300 K, 55 kPa and 60 m/s. The fuel air ratio is 29 and the calorific value of the fuel is 42MJ/kg. Assuming Υ=1.4, R=0.287 kJ/kg K for the gas, determine *(i)* Mach numbers at inlet and exit. *(ii)* pressure, temperature and velocity of the gas at exit of combustion chamber. *(iii)* percentage loss in stagnation pressure. (10)

10 Air-fuel mixture enters a combustion chamber with a initial velocity of 150m/s, pressure of 4 bar and temperature of 410K. The mach number at the exit of the combustion chamber is 0.8. Taking Υ=1.3, C_p=1.144kJ/kgK and calorific value of fuel = 43 MJ/kg, find *(i)* entry Mach no. *(ii)* exit temperature and pressure *(iii)*stagnation pressure loss and *(iv)* air-fuel ratio required. (10)

11 Derive an expression for the maximum possible Heat addition (Q_{max}) in terms of Mach number, gamma and temperature for a Rayleigh flow. Explain the phenomenon of thermal choking. (10)

12 a) With the help of neat sketch explain the working of a shock tube. (4)

b) With a neat sketch show the working of a Open type and Closed type wind tunnel clearly labelling the different parts (6)

13 a) Draw the bridge circuit of a constant current hot wire anemometer and explain the working principle. (4)

b) With a neat sketch show the working principle of Shadowgraph and Schlieren techniques (6)

14 a) Draw the bridge circuit of a constant temperature hot wire anemometer and explain the working principle. (4)

b) What is the advantage of using a Kiel probe over a Pitot tube. How is the yaw sensitivity of the Kiel probe compared to the Pitot tube. (6)

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APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

SEVENTH SEMESTER B.TECH DEGREE EXAMINATION(R&S), DECEMBER 2019

Course Code: ME409

Course Name: COMPRESSIBLE FLUID FLOW

Max. Marks: 100 Duration: 3 Hours

Use of Gas Tables permitted. Assume suitable values for missing data.

PART A

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

1		Derive the conservation of mass equation for compressible flow through a control volume.	(10)
2	(a)	Derive an expression for stagnation temperature in terms of Mach number for compressible fluid flow.	(4)
	(b)	A supersonic fighter plane flies at an altitude of 5000 m. The Mach number of the fighter plane is 3.0. Estimate the time taken by an observer on the ground to hear the sonic boom after the plane passes directly over his head. Take the average temperature at 5000 m altitude as 10°C. Also determine the speed of the aircraft.	(6)
3	a)	Derive an expression for area ratio in terms of Mach number for isentropic flow. Explain graphically the variation of area ratio with Mach number.	(6)
	b)	Derive the condition at which flow become choked in isentropic flow?	(4)
4		An air nozzle is to be designed for an exit Mach number of 2.5. Conditions of the air available in the reservoir are 800 kPa, 523 K. Estimate i) pressure ii) temperature iii) velocity of flow iv) area, at throat and exit of the nozzle. Mass flow rate through the nozzle is 12000 kg/hr.	(10)

PART B

Answer any three full questions, each carries 10 marks.

5	a)	Define shock strength.	(2)
	b)	Derive an expression for Mach number downstream of a normal shock.	(8)
6		The ratio of exit to entry area in a subsonic diffuser is 3.5. The Mach number of a jet of air approaching the diffuser is 2.18. Stagnation pressure of the jet is 1 bar and its static temperature is 300 K. There is a standing normal shock wave just outside the diffuser entry. The flow in the diffuser is isentropic. Determine pressure, temperature and Mach number at the exit of the diffuser. Also find the	(10)

loss in stagnation pressure of the jet as it passes through the diffuser.

7 a) Explain the phenomenon of choking in Fanno flow. (3)

b) Prove that M = 1.0 is the limiting condition for Fanno flow. (5)

c) Explain the significance of critical length in Fanno flow (2)

8 Air at pressure 1 bar and 400 K enters a 30 cm diameter duct with a Mach number of 2.0. A normal shock occurs at a Mach number of 1.5 and the exit Mach number is 1.0. If the mean value of friction factor is 0.003, determine (10)

i) length of the duct upstream and downstream of the shock wave

ii) mass flow rate of air

iii) entropy change across the shock and downstream of the shock.

PART C

Answer any four full questions, each carries 10 marks.

9 Data for entry of air at a constant area duct are p_1 = 0.345 bar, T_1 = 314 K, c_1 = 64 m/s. If 627 kJ/kg if heat is added to the gas in the duct between entry and exit sections, determine at the exit a) pressure b) temperature c) Mach number d) velocity of gas. How much heat is required to accelerate air from initial condition to sonic condition? (10)

10 The stagnation temperature of air in a combustion chamber is increased 3.5 times its initial value. If the air at entry is at 5 bar and 105 °C and a Mach number of 0.25, determine i) Mach number, pressure and temperature at exit (10)

ii) stagnation pressure loss iii) heat supplied per kg of air

11 Prove that the Mach numbers at the maximum enthalpy and maximum entropy points on the Rayleigh line are $1/\sqrt{\gamma}$ and 1.0 repectively. (10)

12 a) Explain the working of a constant current hot wire anemometer used for flow velocity measurement. (4)

b) Explain Schlieren method of flow visualisation used in compressible flow. (6)

13 a) Explain in detail the working of a closed type wind tunnel with the help of a sketch. (6)

b) Explain with the help of sketches how yaw angle is eliminated in a Kiel probe. (4)

14 a) With a neat sketch explain the working of stagnation temperature probe. (6)

b) Explain how Prandtl Pitot probe simultaneously measure static and stagnation pressure. (4)

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Reg No.:_______________ Name:__________________________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

Seventh semester B.Tech examinations (S), September 2020

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 an expression for sonic velocity in medium in terms of the ratio of specific heats and difference of specific heats of the medium. (4)

b) Show that for air at sonic flow condition, the deviation between the compressible and incompressible flow values of the pressure coefficient of a perfect gas is about 27.5 percent. (6)

2 a) A Schlieren photograph showing a wave front by a bullet moving in air gave a Mach angle of 40^0. Find the speed of the bullet if the pressure and temperature of atmosphere are 0.95 bar and 2^0C. (4)

b) Derive steady flow adiabatic ellipse equation. Represent various flow regimes on steady flow adiabatic ellipse. (6)

3 a) Find the maximum value of mass flow parameter $\frac{m\sqrt{T_o}}{A^* p_o}$ for (i) air (ii) carbon dioxide at 273 K. (4)

b) Derive the relation for one-dimensional isentropic flow $\frac{dA}{A} = \frac{dp}{\rho c^2}\left(1 - M^2\right)$ (6)

4 A gas is isentropically expanded from a pressure of 10 bar and temperature of 525 ^{0}C in a nozzle to a pressure of 7.6 bar. If the rate of flow of the gas is 1.5 kg/s determine (10)

i) pressure, temperature and velocity at the nozzle throat and exit

ii) maximum possible velocity attainable by the gas

iii) throat area

Take $\gamma = 1.3$ and R = 0.464 kJ/kgK

PART B

Answer any three full questions, each carries 10 marks.

5 a) Explain two situations where a normal shock wave is formed. (4)

b) Prove that a normal shock wave formation is impossible in subsonic region of a flow. (6)

6 a) Explain the formation of oblique shock wave in a concave corner and expansion fan in convex corner. (4)

b) A stationary normal shock occurs in an air stream when the pressure, temperature and Mach number are 80 kPa, 100 ^{0}C and 1.8 respectively. Determine its density after the shock. Compare this value in an isentropic compression through the same pressure ratio. (6)

7 a) Differentiate between Fanno flow and isothermal flow. Give one practical example for Fanno flow and isothermal flow. (4)

b) Derive the equation of a Fanno curve. Prove that at the maximum entropy point Mach number is unity. (6)

8 a) Air enters, a long circular duct of diameter 12.5 cm and mean coefficient of friction 0.0045, at a Mach number of 0.5, pressure 3 bar and temperature 312 K. If the flow is adiabatic throughout the duct, determine (10)

i) the length of the pipe required to change the Mach number to 0.7

ii) pressure and temperature of air at M=0.7

iii) the length of the pipe required to attain limiting Mach number

iv) pressure, temperature and Mach number at the limiting condition

PART C

Answer any four full questions, each carries 10 marks.

9 a) What is Rayleigh flow? Explain Rayleigh flow with one practical case. (3)

b) What are the assumptions made in deriving equation for Rayleigh flow? Derive an equation describing a Rayleigh curve. Show that at maximum entropy point the flow is sonic. (6)

10 A combustion chamber in a gas turbine plant receives air at 350 K, 0.55 bar and 75 m/s. The air-fuel ratio is 29 and the calorific value of fuel is 41.87 MJ/kg. Determine i) initial and final Mach numbers (10)

ii) final pressure, temperature and velocity of gas

iii) percentage of stagnation pressure loss in the combustion chamber

iv) maximum stagnation temperature attainable

11 The data at inlet to a ramjet engine combustion chamber employing a (10)

hydrocarbon fuel are as follows: velocity of air-fuel mixture = 73 m/s, static temperature = 333 K, static pressure = 0.55 bar. The heat of reaction of the fuel-air mixture is 1400 kJ/kg. Assuming that the working fluid has the same thermodynamic properties as air before and after combustion, calculate

i) the lost in stagnation pressure due to heat addition

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

12 a) When does a shadowgraph preferred over a Schlieren system in studying density effects? Mention the difference in principle of the two instruments. (4)

b) With the help of a neat sketch explain the working of an interferometer. (6)

13 Explain the working of a shock tube with neat sketch. (10)

14 Describe with the aid of a schematic diagram the working of a closed circuit supersonic wind tunnel. (10)

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