GAS DYNAMICS AND JET PROPULSION
(MECH 4243)

Time Allotted : 3 hrs **Full Marks : 70**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A
(Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) An isentropic flow is one which is
(a) adiabatic (b) isothermal
(c) adiabatic and reversible (d) irreversible.

(ii) Fluid is flowing through a duct with a Mach number equal to 1.6. An increase in cross-sectional area in the downstream will cause an.
(a) decrease in velocity (b) increase in velocity
(c) increase in static pressure (d) choked flow situation.

(iii) For air ($\gamma = 1.4$) the critical pressure ratio (p^*/p_0) for isentropic flow is
(a) 0.833 (b) 0.728 (iii) 0.628 (d) 0.528.

(iv) The fluid property that remains unchanged across a normal shock wave is
(a) stagnation enthalpy (b) stagnation pressure
(c) static pressure (d) mass density.

(v) When heat is added to a compressible flow
(a) the flow temperature will always increase
(b) the Mach number will always increase
(c) the entropy may decrease
(d) the flow stagnation temperature will always increase.

(vi) In a normal shock in a gas
(a) the upstream flow is supersonic
(b) the upstream flow is subsonic
(c) the downstream flow is sonic
(d) the downstream flow as well as the upstream flow is supersonic.

(vii) The conditions across a normal shock
(a) lie at the intersection of the Fanno and Rayleigh lines for the flow
(b) have the same stagnation temperature
(c) both (a) and (b) are true
(d) both (a) and (b) are false.

(viii) Which one is the air breathing engine in jet propulsion
(a) atmospheric jet & rocket engines (b) rocket Engines
(c) atmospheric jet engines (d) none of the above.

(ix) The performance of Ram Jet engine is best at
(a) low speed (b) medium speed
(c) high speed (d) none of the above.

(x) A rocket engine uses
(a) gaseous and solid propellants (b) gases and liquid propellants
(c) solid and liquid propellants (d) none of the above.

Group- B

2. (a) Define Mach number. What is the significance of Mach number in compressible fluid flow? [(CO1)(Remember/LOCQ)]
(b) A rocket is found to have a speed of 250 km/hr in air at a temperature of (-40^{0}C). Calculate the Mach number and the Mach angle. (For air, γ = 1.4 and R = 287 J/kg-K). [(CO1)(Analyse/IOCQ)]
(3 + 3) + 6 = 12

3. (a) Find an expression of area-velocity relationship for a compressible fluid flow in terms of Mach number. [(CO2)(Understand/LOCQ)]
(b) Air at an absolute pressure 60 kPa and temperature 27^{0}C, enters a passage at 486 m/s. The cross sectional area at entrance is 0.02 m^2. At Section 2, further downstream, the pressure is 78.8 kPa (abs). Assuming isentropic flow, calculate the Mach number at Section 2. [(CO2)(Analyse/IOCQ)]
6 + 6 = 12

Group – C

4. (a) Air flows steadily and isentropically in a converging nozzle and finally discharges to the atmosphere. At any section, where the absolute pressure is 179 kPa, the temperature is 39^{0}C and the air velocity is 177 m/s. Determine the nozzle throat pressure. [(CO3)(Evaluate/HOCQ)]
(b) With a sketch, describe the pressure distribution in case of isentropic flow along a converging-divergent nozzle for different values of back pressure. [(CO3)(Understand/LOCQ)]
6 + 6 = 12

5. (a) With T-s diagram, briefly explain the Fanno line Flow in a constant area duct. [(CO4)(Remember/LOCQ)]

(b) Air flows from a large tank (p= 650 kPa abs, T= 550^0C) through a converging nozzle, with a throat area of 600mm^2, and discharges to the atmosphere. Determine the rate of mass flow, under isentropic condition in the nozzle. [(CO3)(Analyse/IOCQ)]

6 + 6 = 12

Group – D

6. (a) Derive the equations of Rankine-Hugoniot normal shock wave relation. [(CO 3)(Understand/LOCQ)]

(b) A normal shock wave takes place during the flow of air at a Mach number 1.8. The static pressure and temperature of the air upstream of the shock were 100 kPa (abs) and 15^0C. Determine the Mach number, pressure and temperature downstream of the shock. (For air, γ = 1.4 and R = 287 J/kg-K). [(CO3)(Analyse/IOCQ)]

6 + 6 = 12

7. (a) State the basic principle of jet propulsion. Give two examples of early and modern jet propulsion devices. [(CO5)(Remember/LOCQ)]

(b) The diameter of the propeller of an aircraft is 2.5 m. It flies at a speed of 500 km/hr at an altitude of 8000 m. For a flight to jet speed ratio of 0.75, determine (i) the flow rate of air through propeller, (ii) thrust produced, and (iii) the thrust power. [(CO5)(Evaluate/HOCQ)]

6 + 6 = 12

Group - E

8. (a) Describe the working principle of Scramjet engine. What is its main advantage over Ramjet? [(CO6)(Remember/LOCQ)]

(b) A turbojet engine propels an aircraft at a Mach number of 0.8 in level flight at an altitude of 10 km. The data for the engine is given below:
Stagnation temperature at the turbine inlet = 1200 K
Stagnation temperature rise through the compressor = 175 K
Calorific value of the fuel = 43 MJ/kg
Compressor efficiency = 0.75
Combustion chamber efficiency =0.975
Turbine efficiency = 0.81
Mechanical efficiency of the power transmission between turbine and compressor = 0.98
Exhaust nozzle efficiency = 0.97
Specific impulse = 25 sec
Assuming the same properties for air and combustion gases, calculate
(i) Fuel air ratio

(ii) Compressor pressure ratio.

[(CO6)(Evaluate/HOCQ)]

6 + 6 = 12

9. (a) Write down the advantages of liquid propellant rockets over solid propellant rockets? [(CO 6) (Remember /LOCQ)]

(b) Draw a neat line diagram of liquid propellant rocket system and explain it. [(CO6) (Understand/LOCQ)]

6 + 6 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	56.25	25	18.75

Course Outcome (CO):

After the completion of the course students will be able to

CO 1 Relate the fundamental equations of one dimensional compressible fluid flow with basic concepts of gas dynamics

CO 2 Interpret one dimensional compressible flow through variable area duct.

CO 3 Describe steady one-dimensional isentropic flow and normal shock flow.

CO 4 Formulate compressible flow parameters in flow through constant area duct with friction and heat transfer

CO 5 Use theory of jet propulsion in performance analysis of various jet propulsion engines.

CO 6 Value the basic concepts of rocket propulsion.

*LOCQ: Lower Order Cognitive Question; IOCQ: Intermediate Order Cognitive Question; HOCQ: Higher Order Cognitive Question