GAS DYNAMICS AND JET PROPULSION
(MECH 4243)

Time Allotted : 2½ hrs **Full Marks : 60**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 4 (four) from Group B to E, taking one from each group.

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

Group – A

1. Answer any twelve: **12 × 1 = 12**

Choose the correct alternative for the following

(i) Mach number is the ratio of
(a) fluid velocity and sonic velocity (b) sonic velocity and fluid velocity
(c) fluid velocity and object velocity (d) sonic velocity and object velocity.

(ii) For air ($\gamma = 1.4$) the critical density ratio (ρ^*/ρ_0) for isentropic flow is
(a) 0.833 (b) 0.728 (c) 0.528 (d) 0.634.

(iii) If air ($\gamma = 1.4$ and $R = 287$ J/kg-K) at 19^0C is expanded isentropically, the maximum velocity that can be achieved is
(a) 342.5 m/s (b) 766 m/s (c) 1000 m/s (d) 518 m/s.

(iv) Fanno line flow is a flow in constant area duct
(a) with friction but without heat transfer
(b) without friction but with heat transfer
(c) with both friction and heat transfer
(d) either without friction or without heat transfer.

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

(vi) For supersonic flow, if the area of flow increases then
(a) velocity decreases
(b) velocity increases
(c) velocity remains constant
(d) velocity may increase or decrease or remain constant.

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

(ix) In air-breathing jet engine, the jet is formed by expanding
(a) highly heated atmospheric air (b) solid
(c) liquid (d) plasma.

(x) Only rocket engines can be propelled to space because
(a) they can generate very high thrust
(b) they have high propulsion efficiency
(c) these engines can work on several fuels
(d) they are not air-breathing engines.

Fill in the blanks with the correct word

(xi) For a supersonic flow, the relationship between Mach angle and Mach number is given by _____.

(xii) For air ($\gamma = 1.4$) the critical temperature ratio (T^*/T_0) for isentropic flow is _____.

(xiii) For air ($\gamma = 1.4$), in case of Rayleigh Line flow, the value of Mach number, at the point of maximum temperature is _____.

(xiv) Propulsive efficiency is defined as the ratio of _____ and _____.

(xv) A jet engine works on the principle of conservation of_____.

Group - B

2. (a) Classify different types of fluid flow, based on Mach number. State the basic equations (continuity, momentum, energy) for one-dimensional compressible flow. *[(CO1)(Remember/LOCQ)]*

(b) An object is immersed in an air flow with a static pressure of 200 kPa (abs), temperature of 20^0C and velocity of 200 m/s. Find the pressure and temperature at the stagnation point. *[(CO1)(Analyse/IOCQ)]*

6 + 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 27^0C, 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)(Apply/IOCQ)]*

6 + 6 = 12

Group - C

4. (a) For compressible, isentropic flow through a converging duct, find the value of Mach number for maximum discharge. *[(CO2)(Understand/LOCQ)]*

(b) A nozzle is designed to expand air isentropically to atmospheric pressure 101 kPa (abs) from a large tank in which properties are held constant at temperature 5^0C and pressure 304 kPa (abs). The desired flow rate is 1 kg/s. Determine the exit area of the nozzle. *[(CO3)(Evaluate/HOCQ)]*

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 steadily and adiabatically from a large tank through a converging nozzle, connected to a constant area duct. The nozzle is considered frictionless. Air in the tank is at p = 1MPa (abs), T = 125^0C. The absolute pressure at the nozzle exit (duct inlet) is 784 kPa. Determine the pressure at the end of the duct length L, if the temperature there is 65^0C. *[(CO3)(Evaluate/HOCQ)]*

6 + 6 = 12

Group - D

6. (a) Derive the equations of Rankine-Hugoniot normal shock wave relation. *[(CO3)(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)(Evaluate/HOCQ)]*

6 + 6 = 12

7. (a) How is forward motion of an aircraft achieved by propeller actions? How does the aircraft lift-off the ground? Explain with the help of illustrative sketches. *[(CO5)(Remember/LOCQ)]*

(b) An aircraft equipped with turbo-jet is flying at a speed of 1000 km/hr at 10 km altitude. The propulsive efficiency = 0.6 and overall efficiency = 0.2. If the drag of the aircraft is 6.5 kN, find (i) jet exit velocity and (ii) volume handled by the compressor per second. (Take C.V. of fuel used = 40MJ/kg, $\rho_{air} = 0.175 kg/m^3$). *[(CO5)(Analyse/IOCQ)]*

6 + 6 = 12

Group - E

8. (a) Describe the working principle of ramjet engine. Depict the various thermodynamic processes occurring in it on *h-s* diagram. *[(CO5)(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
Temperature and velocity of sound at the engine entry at 10 km altitude are 223.15 K and 299.6 m/s, respectively
Assuming the same properties for air and combustion gases, calculate:
(i) Fuel air ratio
(ii) Compressor pressure ratio
(iii) Turbine pressure ratio. *[(CO5)(Evaluate/HOCQ)]*

6 + 6 = 12

9. (a) Write down the advantages and disadvantages of solid propellant rockets. *[(CO6)(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	18.75	25

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.*