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) A Thermally Perfect Gas is one in which
(a) change in density is independent of temperature
(b) change in pressure is independent of temperature
(c) intermolecular force of attraction is negligible
(d) intermolecular force of attraction is significant.

(ii) In an atmosphere, the speed of sound is 300 m/s. If a plane travels at 1620 km/hr in this atmosphere, the Mach angle is
(a) 30.5^0 (b) 56.3^0 (c) 10.7^0 (d) 41.8^0.

(iii) For air ($\gamma = 1.4$), the critical temperature ratio (T^*/T_0) for isentropic flow is
(a) 0.833 (b) 0.728 (iii) 0.628 (d) 0.528.

(iv) The speed of sound in air varies as
(a) $\sqrt{T}$ (b) $\sqrt{\rho}$ (c) $\frac{1}{\sqrt{p}}$ (d) p

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

(vi) A normal shock propagated into still air travels with a speed
(a) equal to the speed of sound in the still air
(b) larger than the speed of sound in the still air
(c) smaller than the speed of sound in the still air
(d) all of the above are possible, depending on the air temperature.

(vii) The prime parameter causing change of state in a Fanno flow is
(a) heat transfer (b) area change (c) friction (d) buoyancy.

(viii) The processes in compressor, turbine, diffuser and nozzle as ideal devices are
(a) reversible (b) adiabatic
(c) reversible and adiabatic (d) none of the mentioned.

(ix) The cycle used in turbojet engine is
(a) reversed Brayton Cycle (b) Brayton Cycle
(c) Diesel Cycle (d) Otto Cycle.

(x) What is the typical liquid propellant feed system used in space launch vehicles?
(a) The Gas pressure feed system (b) Pump-fed system
(c) Gravity assisted feed system (d) No feed system is used.

Group - B

2. (a) What is meant by isentropic flow? Find the expression for velocity of sound for an isentropic process. [(CO1)(Remember/LOCQ)]

(b) An airplane travels at 800 km/hr at sea level where the temperature is 15°C. What would be the speed of the airplane flying at the same Mach number at an altitude, where the temperature is (**-** 40°C) (For air, $\gamma = 1.4$ and R = 287 J/kg-K). [(CO1)(Analyse/IOCQ)]

(2 + 4) + 6 = 12

3. (a) Find an expression of critical pressure ratio (p^*/p_0) in terms of adiabatic index γ, for isentropic flow of compressible fluid, through a variable area duct from a large reservoir. [(CO2)(Understand/LOCQ)]

(b) A tank containing air at a pressure of 250 kPa (abs) and temperature 35°C, is discharging it through a convergent nozzle. If the velocity of flow at the nozzle exit is 200 m/s, find whether the flow is subsonic, sonic or supersonic, at that section. (For air, $\gamma = 1.4$ and R = 287 J/kg-K). [(CO2)(Analyse/IOCQ)]

6 + 6 = 12

Group – C

4. (a) A tank contains air at **-**5° C at a pressure of 303 kPa (abs). A convergent-divergent nozzle of exit diameter 5 cm is designed to discharge the air to the ambient which is at a pressure 101 kPa (abs). Calculate the (i) Mach number and temperature of the flow at exit. (ii) mass flow rate at exit. (For air, $\gamma = 1.4$ and R = 287 J/kg-K). [(CO3)(Evaluate/HOCQ)]

(b) With a sketch, describe the pressure distribution in case of isentropic flow along a converging nozzle for different values of back pressure and also mention the condition of chocking. [(CO3)(Understand/LOCQ)]

6 + 6 = 12

5. (a) What are the conditions of Fanno flow? With T-s diagram, mention the difference between Fanno line flow and Rayleigh line flow. [(CO4)(Remember/LOCQ)]

(b) Air at 40°C flows isentropically from a large tank through a converging nozzle of 40mm diameter at nozzle exit. The tank contains air at 150 kPa(abs) and the discharge is to atmosphere of pressure 95 kPa(abs). Calculate the mass flow rate through the nozzle. (For air, $\gamma = 1.4$ and R = 287 J/kg-K).

[(CO3)(Analyse/IOCQ)]

6 + 6 = 12

Group – D

6. (a) The pressure, velocity and temperature just upstream of a normal shock wave in air are 100 kPa (abs), 660 m/s, and -20°C respectively. Calculate the pressure, velocity, and temperature just downstream of the shock wave. (For air, $\gamma = 1.4$ and R = 287 J/kg-K). [(CO3)(Analyse/IOCQ)]

(b) What is meant by strength of a shock? Obtain an expression of shock strength in terms of Mach number. [(CO3)(Understand/LOCQ)]

6 + 6 = 12

7. (a) What is thrust? What is jet propulsion? Give two examples of early and modern jet propulsion devices. [(CO5)(Remember/LOCQ)]

(b) What are the main components of gas turbine engine used for turbojet aircrafts? Show the various processes occurring in the engine on a T-s diagram.

[(CO5)(Evaluate /LOCQ)]

(2 + 2 + 2) + 6= 12

Group - E

8. (a) Describe the working principle of turbojet engine. What is the main advantage of turbojet? [(CO5)(Remember/LOCQ)]

(b) The diameter of an aircraft propeller is 4.0 m. The speed ratio is 0.8 at a flight speed of 450 km/hr. If the ambient conditions of air at the flight altitude are T = 256K and p = 0.54 bar. Determine (i) propulsive efficiency and (ii) thrust.

[(CO5)(Evaluate/HOCQ)]

6 + 6 = 12

9. (a) What is Rocket propulsion? Why is a rocket called a non-air breathing engine?

[(CO6)(Understand /LOCQ)]

(b) A rocket has the following data:
Propellant flow rate = 5.0 Kg/s
Nozzle exit diameter = 10 cm
Nozzle exit pressure = 1.02 bar
Ambient pressure = 1.013 bar
Thrust chamber pressure = 20 bar
Thrust = 7 kN

(i) Determine the effective jet velocity, actual jet velocity, specific impulse.

[(CO6)(Evaluate/HOCQ)]

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