DHANALAKSHMI COLLEGE OF ENGINEERING

DEPARTMENT OF MECHANICAL ENGINEERING

QUESTION BANK

ME 2351- GAS DYNAMICS AND JET PROPULSION

UNIT -1 BASIC CONCEPTS AND ISENTROPIC FLOWS

PART-A (2 Marks)

1. **Define stagnation pressure?**
2. **Define adiabatic process?**
3. **What is meant by Isentropic process?**
4. **Define Mach number?**
5. **Define stagnation enthalpy?**
6. **Define stagnation temperature?**
7. **Define crocco number?**
8. **A plane travels at a speed of 3200km/h. An atmospheric of 8^{o}c find the Mach angle?**
9. **The static temperature of air is 300^{o}c and velocity is 200 m/s find the maximum possible velocity obtainable by air?**
10. **Give the relationship between M* and M?**
11. **What is the difference between intensive and extensive property?**
12. **Define open and closed system?**
13. **Define zone of action and zone of silence?**
14. **Differentiate Adiabatic and Isentropic process.**
15. **Differentiate nozzle and diffuser ?**
16. **Differentiate between adiabatic flow and diabatic flow ?**
17. **Give the expression for T/To and T/T* for isentropic flow through variable area interms of Mach number ?**
18. **Draw the variation of Mach number along the length of a convergent divergent duct when it acts as a (a) Nozzle (b) Diffuser (c) Venturi**
19. **When does the maximum mass flow occur for an isentropic flow with variable area?**
20. **What is chocked flow through a nozzle?**

PART – B

1) (a) Derive the following relations for one dimensional isentropic flow:

$$\frac{dA}{A}=\frac{dP}{\rho c^{2}}\left(1-M^{2}\right)$$

(b) Derive the relation of effect of Mach Number on Compressibility.

2) **Derive the equation for mass flow rate in terms of area ratio?**

$$\frac{m_{\max}}{A*} X \frac{\sqrt{T_0}}{P_0} = \sqrt{\frac{\gamma}{R}}\left(\frac{2}{\gamma+1}\right)^{\frac{\gamma+1}{2(\gamma-1)}}$$

3) **(a) Derive the equation for various regions of flow and draw a c-a curve?**
(b) Derive the Bernoulli equation for isentropic compressible flow?
(c) Derive the equation of pressure co efficient for compressible flow?

$$\frac{Po - P}{\frac{1}{2}\rho c^{2}} = 1 + \frac{M^{2}}{4} + \frac{M^4}{40} + \cdots,$$

4) **Carbon di oxide expands isentropically through a nozzle from a pressure of 3.2 bar to 1 bar. If the initial temperature is 475 K, determine the final temperature, the enthalpy drop and the change in internal energy.**

5) **Air (γ=1.4, R=287 J/kg.k) at a inlet Mach number of 0.2 enters a straight duct at 400 K and expands isentropically if the exit Mach number is 0.8 determine the following.**

   i. **Stagnation temperature**
   ii. **Critical temperature**
   iii. **Static temperature at exit**
   iv. **Area ratio.**

6) **Draw and explain Mach cone, Mach angle and Mach waves?**

7) **A conical diffuser has entry and exit diameters of 15 cm and 30cm respectively. The pressure temperature and velocity of air at entry are 0.69bar, 340 k and 180 m/s respectively. Determine**

   i. **The exit pressure, (4)**
   ii. **The exit velocity and (6)**
   iii. **The force exerted on the diffuser walls. (6)**

Assume isentropic flow, γ =1.4,Cp =1.005 KJ Kg-K.

8) **A nozzle in a wind tunnel gives a test –section Mach number of 2.0 .Air enters the nozzlefrom a large reservoir at 0.69 bar and 310 k .The cross –sectional area of the throat is 1000cm^2.Determine the following quantites for the tunnel for one dimensional isentropic flow**

   i. **Pressures,temperature and velocities at the throat and test sections, (4)**
   ii. **Area of cross- sectional of the test section , (4)**
   iii. **Mass flow rate, (4)**
   iv. **Power rate required to drive the compressor. (4)**

9) (a) Ambient air (P_o = 1 bar, T_o = 285K) is sucked by a blower through a convergent nozzle. The throat diameter is 12 cm. if the velocity at throat reaches the sonic value. Determine

i) Pressure and temperature at the throat
ii) Maximum mass flow rate

(b) A supersonic wind tunnel settling chamber expands air of Freon-21 through a nozzle from a pressure of 10 bar to 4 bar in the test section. Calculate the stagnation temperature to be maintained in the settling chamber to obtain a velocity at 500 m/s. in the test section for

i) Air (C_p = 1.025 KJ/Kg.K C_v = 0.735 KJ/Kg.K)
ii) Freon-21 (C_p = 0.785 KJ/Kg.K C_v = 0.675 KJ/Kg.K)

What is the test section Mach number for each case?

10) An air craft is flying at an altitude of 11000 meters, at 800kmph the air is reversibly compressed in an inlet diffuser the inlet temperature is 216.65 K and pressure is 0.226 bar. If the Mach number at the exit of the diffuser is 0.35. Calculate the following

1. Entry Mach number
2. Velocity, pressure and temperature of air at the diffuser exit.

UNIT – 2 FLOW THROUGH DUCTS

PART-A (2 Marks)

1) What are the consumption made for fanno flow?
2) Differentiate Fanno flow and Rayleigh flow?
3) Explain chocking in Fanno flow?
4) Explain the difference between Fanno flow and Isothermal flow?
5) Write down the ratio of velocities between any two sections in terms of their Mach number in a fanno flow ?
6) Write down the ratio of density between any two section in terms of their Mach number in a fanno flow?
7) What are the three equation governing Fanno flow?
8) Give the expression to find increase in entropy for Fanno flow?
9) Give two practical examples where the Fanno flow occurs?
10) What is Rayleigh line and Fanno line?
11) What is the value of Mach number of air at the maximum point in Rayleigh heating process?
12) What are the assumptions made for Rayleigh flow?
13) What is fanno flow?
14) Define Rayleigh flow?

15) **Define fanning's coefficient of skin friction?**
16) **Write down the expression for the pressure ratio of two sections interms of Mach number in Rayleigh flow?**
17) **Under what conditions the assumption of Rayleigh flow is not valid in a heat exchanger?**
18) **Define Fanno line?**
19) **Write down the expression for the length of duct in terms of the two Mach numbers M1 and M2 for a flow constant area duct with the influence of friction.**
20) **State the assumptions made to derive the equations for isothermal flow.**

PART B (16MARKS)

1. A circular duct passes 8.25Kg/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 coefficient of friction 0.005.If the Mach number at entry is 0.15, determine :

- i) **The diameter of the duct , (2)**
- ii) **Length of the duct, (4)**
- iii) **Pressure and temperature at the exit, (4)**
- iv) **Stagnation pressure loss, and (4)**
- v) **Verify the exit Mach number through exit velocity and temperature. (2)**

2. A gas (γ =1.3,R=0.287 KJ/KgK) at P_1 =1bar, T_1 =400 k enters a 30cm diameter duct at a Mach number of 2.0.A normal shock occurs at a Mach number of 1.5 and the exit Mach number is1.0, If the mean value of the friction factor is 0.003 determine:

- i) **1)Lengths of the duct upstream and downstream of the shock wave, (6)**
- ii) **2)Mass flow rate of the gas and (4)**
- iii) **3)Change of entropy upstream and downstream of the shock, across the shock and downstream of the shock. (6)**

3. Air enters a long circular duct (d =12.5cm, f=0.0045) at a Mach number 0.5, pressure 3.0 bar and temperature 312 K. If the flow is isothermal throughout the duct determine (a) the length of the duct required to change the Mach number to 0.7, (b) pressure and temperature of air at M =0.7 (c) the length of the duct required to attain limiting Mach number, and (d) state of air at the limiting Mach number. Compare these values with those obtained in adiabatic flow. (16)

4. A convergent –divergent nozzle is provided with a pipe of constant cross-section at its exit the exit diameter of the nozzle and that of the pipe is 40cm. 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 600k. The flow is isentropic in the nozzle and adiabatic in the pipe. The Mach numbers at the entry and exit of the pipe are 1.8 and 1.0 respectively. Determine

a) The length of the pipe , (4)
b) Diameter of the nozzle throat, and (6)
c) Pressure and temperature at the pipe exit. (6)

5. Show that the upper and lower branches of a Fanno curve represent subsonic and supersonic flows respectively . prove that at the maximum entropy point Mach number is unity and all processes approach this point .How would the state of a gas in a flow change from the supersonic to subsonic branch ? (16)

6. The Mach number at the exit of a combustion chamber is 0.9. The ratio of stagnation temperature at exit and entry is 3.74. If the pressure and temperature of the gas at exit are 2.5 bar and 1000°C respectively determine (a) Mach number ,pressure and temperature of the gas at entry ,(b) the heat supplied per kg of the gas and (c) the maximum heat that can be supplied. Take γ= 1.3, Cp= 1.218 KJ/KgK (16)

7. The conditions of a gas in a combuster at entry are: P1=0.343bar ,T1 = 310K ,C1= 60m/s. Detemine the Mach number ,pressure ,temperature and velocity at the exit if the increase in stagnation enthalpy of the gas between entry and exit is 1172.5KJ/Kg. Take Cp=1.005KJ/KgK, γ =1.4 (16)

8. A combustion chamber in a gas turbine plant receives air at 350 K ,0.55bar and 75 m/s .The air – fuel ratio is 29 and the calorific value of the fuel is 41.87 MJ/Kg .Taking γ=1.4 and R =0.287 KJ/kg K for the gas determine.

a) The initial and final Mach numbers, (4)
b) Final pressure ,temperature and velocity of the gas, (4)
c) Percent stagnation pressure loss in the combustion chamber , and (4)
d) The maximum stagnation temperature attainable. (4)

9. Obtain an equation representing the Rayleigh line . Draw Rayleigh lines on the h-s and p-v planes for two different values of the mass flux. Show that the slope of the Rayleigh line on the p-v plane is {dp/dv} = $\dot{\rho}^2 c^2$ (16)

10. Air flows out of a pipe with a diameter of 0.3m at a rate of 1000 m^3/ min at a pressure and temperature of 150 kPa and 293 K respectively. If the pipe is 50 m long, and assuming that friction coefficient f = 0.005, find the Mach number at exit, the inlet pressure and the inlet temperature.

UNIT – 3 NORMAL AND OBLIQUE SHOCKS

PART-A (2 Marks)

1) What is mean by shock wave ?
2) What is mean by Normal shock?
3) What is oblique shock?
4) Define strength of shock wave?
5) What are applications of moving shock wave ?
6) Shock waves cannot develop in subsonic flow? Why?
7) Define compression and rarefaction shock? Is the latter possible?
8) State the necessary conditions for a normal shock to occur in compressible flow?
9) Give the difference between normal and oblique shock?
10) what are the properties change across a normal shock ?
11) What is meant by normal shock as applied to compressible flow?
12) Explain oblique shock where it occurs?
13) What is prandtl meyer relation? What its significance?
14) How can you define strong shock wave mathematically?
15) Define supersonic wind tunnels?
16) Give the difference between Normal shock and Oblique shock?
17) What is meant by normal shock as applied compressible flow?
18) Calculate the strength of shock wave when normal shock appears at M = 2.
19) Shown a normal shock in h-s diagram with the help of Rayleigh line and Fanno line.
20) Define Fanno line?

Part - B (16 Marks)

Flow with normal shock

1)The state of a gas (γ=1.3,R =0.469 KJ/Kg K) upstream of a normal shock is given by the following data: M_x =2.5 , p_x= 2bar ,T_x =275K calculate the Mach number , pressure, temperature and velocity of the gas downstream of the shock; check the calculated values with those give in the gas tables. (16)

2) The ratio of th exit to entry area in a subsonic diffuser is 4.0 .The Mach number of a jet of air approaching the diffuser at p0=1.013 bar, T =290 K is 2.2 .There is a standing normal shock wave just outside the diffuser entry. The flow in the diffuser is isentropic . Determine at the exit of the diffuser.

1. Mach number , (4)
2. Temperature, and (4)
3. Pressure (4)
4. What is the stagnation pressure loss between the initial and final states of the flow (4)

3) a) The velocity of a normal shock wave moving into stagnant air (P =1.0 bar, T=17°C) is 500 m/s If the area of cross- section of the duct is constant determine (a) pressure (b) temperature (c) velocity of air (d) stagnation temperature and (e) the mach number imparted upstream of the wave front.

b) The following data refers to a supersonic wind tunnel:

Nozzle throat area =200cm² Test section cross- section =337.5cm²

Working fluid ;air (γ=1.4, Cp =0.287 KJ/Kg K)

Determine the test section Mach number and the diffuser throat area if a normal shock is located in the test section.

4) A supersonic diffuser for air (γ=1.4) has an area ratio of 0.416 with an inlet Mach number of 2.4 (design value). Determine the exit Mach number and the design value of the pressure ratio across the diffuser for isentropic flow. At an off- design value of the inlet Mach number (2.7) a normal shock occurs inside the diffuser .Determine the upstream Mach number and area ratio at the section where the shock occurs, diffuser efficiency and the pressure ratio across the diffuser. Depict graphically the static pressure distribution at off design. (16)

5) Starting from the energy equation for flow through a normal shock obtain the following relations (or) prandtl – meyer relation (16)

$$C_x \times C_y = a^{*2}$$
$$M_x^* \times M_y^* = 1$$

<u>Flow with oblique shock waves</u>

6) A gas (γ =1.3) at p1 =345 Mbar, T1= 350 K and M1=1.5 is to be isentropically expanded to 138 Mbar. Determine (a) the deflection angle , (b) final Mach number and (c) the temperature of the gas. (16)

7) a) A jet of air at Mach number of 2.5 is deflected inwards at the corner of a curved wall..The wave angle at the corner is 60°.Determine the deflection angle of the wall, pressure and temperature ratios and final Mach number.

b) Derive the Rankine –Hugoniot relation for an oblique shock Compare graphically the variation of density ratio with the intial Mach number in isentropic flow and flow with oblique shock.

8) The Mach number at the exit of a combustion chamber is 0.9. The ratio of stagnation temperature at exit and entry is 3.74.If the pressure and temperature of a gas at exit are 2.5 bar and 1000°C respectively determine (a) Mach number ,pressure and temperature of the gas at entry,(b) the heat supplied per Kg of the gas and (c) the maximum heat that can be supplied.

Take γ=1.3 and Cp =1.218 KJ/Kg K (16)

9) The conditions of a gas in a combustor at entry are: P_1 = 0.343 bar,T1= 310K ,C1 = 60m/s Determine the Mach number, pressure, temperature and velocity at the exit if the increase in stagnation enthalpy of the gas between entry and exit is 1172.5KJ/Kg. Take Cp=1.005KJ/kg, γ =1.4. (16)

10) A combustion chamber in a gas turbine plant receives air at 350 K , 0.55 bar and 75m/s. The air –fuel ratio is 29 and the calorific value of the fuel is 41.87 MJ/Kg. Taking γ =1.4 and R =0.287 KJ/Kg K for the gas determine :

a) The initial and final Mach number, (4)
b) Final pressure,temperature and velocity of the gas, (4)
c) Percent stagnation pressure loss in the combustion chamber and (4),
d) The maximum stagnation temperature attainable. (4)

UNIT- 4 JET PROPULSION

PART-A

1) **What is meant by jet propulsion?**
2) **Define propulsive efficiency?**
3) **How will you classify propulsive Engine?**
4) **Differenciate shaft propulsion and Jet propulsion?**
5) **List out the different types of jet engines?**
6) **Define the principle of Ramjet engine?**
7) **List out the components of a Ram jet engine?**
8) **Give the difference between Ramjet engine and Pulse jet engine?**
9) **Give the difference between Ramjet engine and Turbo jet engine?**
10) **Give the difference between a Turbo jet engine and Turbo prop engine?**
11) **What is Ram effect?**
12) **What is weight flow co-efficient?**
13) **What is IWR?**
14) **What is thrust co-efficient?**
15) **What is specific Impulse?**
16) **Write the formulae for propulsive efficiency and define the same?**
17) **Explain specific thrust as applied to jet engines?**
18) **Differentiate between pressure thrust and momentum thrust?**
19) **What is after burning in turbo jet engine?**
20) **Define thrust for a rocket engine and how it is produced?**

PART-B

1. **Explain the principle of operation of a turbojet engine and state its advantages and disadvantages**

2. (i) Explain the working principle of turbofan engine with a neat sketch. (6)

(ii) A turbojet engine, on the test bed, receives air at 1 bar and 300 K and it is compressed through a compression ratio of 8, with an isentropic efficiency of 85%. Fuel with heating value of 40 MJ/kg is used to raise the temperature to 1100 K before entering the turbine with isentropic efficiency of 95%. The mechanical transmission efficiency is 95%. The expansion in the nozzle is complete. Determine the jet velocity, specific impulse and specific fuel consumption.

3. i) Explain the working principle of Ramjet engine with a neat sketch. (6)

(ii) A turbojet engine, flying at an altitude, receives air at 0.6 bar and 255 K and it is compressed through a compression ratio of 8, with an isentropic efficiency of 80%. Fuel with heating value of 40 MJ/kg is used to raise the temperature to 1200 K before entering the turbine with isentropic efficiency of 95%. The mechanical transmission efficiency is 97%. A convergent nozzle with an exit area of 0.5 m2 is used to produce a gas jet. Determine the jet velocity, thrust, and specific fuel consumption. (10)

4. An aircraft flies at 960Kmph. One of its turbojet engines takes in 40 kg/s of air and expands the gases to the ambient pressure .The air –fuel ratio is 50 and the lower calorific value of the fuel is 43 MJ/Kg .For maximum thrust power determine (a)jet velocity (b) thrust (c) specific thrust (d) thrust power (e) propulsive, thermal and overall efficiencies and (f) TSFC (16)

5. A turbo jet 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 =1200K
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 seconds

Assuming the same properties for air and combustion gases calculate

- **i) Fuel –air ratio, (2)**
- **ii) Compressor pressure ratio, (4)**
- **iii) Turbine pressure ratio, (4)**
- **iv) Exhaust nozzles pressure ratio ,and (4)**
- **v) Mach number of exhaust jet (2)**

6. A turbojet aircraft flies at 875 kmph at an attitude of 10,000 m above mean sea level. Calculate (i) air flow rate through the engine (ii) thrust (iii) specific thrust (iv) specific impulse (v) thrust power and (vi) TSFC from the following data :

diameter of the air at inlet section = 0.75 m
diameter of jet pipe at exit = 0.5 m

velocity of the gases at the exit of the jet pipe = 500 m/s
pressure at the exit of the jet pipe = 0.30 bar
air to fuel ratio = 40.

7. (i) Derive the thrust equation for rocket engine

(ii) 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 : The flow rate of air through the propeller, Thrust produced, specific thrust, specific impulse and thrust power.

8. An aircraft flies at 960 kmph. One of its turbojet engines takes in 40 kg/sec of air and expands the gases to the ambient pressure. The air fuel ratio is 50 and the calorific value of the fuel is 43 MJ/kg. For maximum thrust power determine

(i) Jet velocity (ii) Thrust (iii) Specific thrust (iv) Thrust power (v) Propulsive, thermal and overall efficiencies and (vi) TSFC

9. A turbo propels an aircraft at a speed of 900 km/hour, while taking 3000 kg of air per minute. The isentripic enthalpy drop in the nozzle is 200 kJ/kg and nozzle efficiency is 90%. The air-fuel ratio is 85 and the combustion efficiency is 95%. The calorific value of the fuel is 42000kJ/kg. calculate

(i) The propulsive power (ii) Thrust power (iii) Thermal efficiency and (iv) Propulsive efficiency

10. A turbojet engine is traveling at 850Km/h at standard sea level conditions (101.32 Kpa and 15^{o}C) .The compressor ratio is 4:1.The turbine inlet temperature is 1000^{o}C.Calculate

(i) Specific Thrust

(ii)Thrust S A C

(iii) Propulsive efficiency

Assume γ = 1.4, C_p = 1.005 kJ/kg. K

UNIT-V SPACE PROPULSION

PART- A

1) **What is monopropellant? Give one example for that?**
2) **What is bipropellant?**
3) **Compare solid propellant and liquid propellant rockets.**
4) **Give two liquid propellants?**
5) **What are the types of liquid propellant rocket engines?**
6) **Name some oxidizers used in rocket engines?**
7) **Name few advantages of liquid propellant rockets over solid propellant rockets?**
8) **What are inhibitors?**
9) **Give the important requirements of rocket engine fuels?**
10) **What is meant by restricted burning in rockets?**

11) **Differentiate jet propulsion and rocket propulsion (or) differentiate between air breathing and rocket propulsion?**
12) **What is meant by hypergollic propellants?**
13) **What is a bypass engine and define bypass ratio?**
14) **Name some propellants for space application?**
15) **What is terminal velocity?**
16) **Write an expression for thrust of jet propulsion?**
17) **Define “Thrust augmentation”?**
18) **Why a rocket is called a non breathing engine?**
19) **Define staging?**
20) **List out the application of space flights?**

PART-B

1`(i) Explain the working of Multi-stage rocket with their merits and demerits. (8)

(ii) Describe the importance of characteristic velocity. A weather satellite is to be launched at an altitude of 500 km above the earth's surface. Determine the required orbital velocity and derive the equation used.

2. Determine the maximum velocity of a rocket and the altitude attained from the following data:

Mass ratio =0.15
Burnout time =75s
Effective jet velocity =2500m/s

What are the values of the velocity and altitude losses due to gravity?Ignore drag and Assume vertical trajectory. (16)

3. What are the advantages and disadvantages of liquid propellants compared to solid propellants. (16)

4.Explain with a neat sketch the working of a gas pressure feed system used in liquid propellant rocket engines.

5. Describe the important properties of liquid and solid propellants desired for rocket propulsion.

6.A Rocket has the following data:

Propellant flow rate : 203 kg/s
Thrust Chamber Pressure : 47 bar
Thrust Chamber temperature : 3020 K
Nozzle exit diameter : 650 mm
Ambient pressure : 1.013 bar
Thrust produced : 420 kN

Calculate effective jet velocity ,actual velocity ,specific impulse and specific propellant consumption.

Recalculate the values of thrust and specific impulse for an altitude of 20000m

7. A rocket nozzle has an exit area ratio 3:1 with isentropic expansion. What will be the thrust per unit area of exit and specific impulse if the combustion chamber temperature is 2973 K and pressure is 20 bar.

Assume atm pressure is 1 bar and R=0.287kJ/kg k and γ =1.3.

8. Draw the sketch of a pulse jet engine. Write down its main advantages and disadvantages.

9. Discuss in detail the various propellants used in solid fuel rockets and the liquid fuel system. Also sketch the propellant feed-system for a liquid propellant rocket motor. (16)

10. Calculate the orbital and escape velocities of a rocket at mean sea level and an altitude of 300km from the following data:

Radius of earth at mean sea level =6341.6Km

Acceleration due to gravity at mean sea level =9.809 m/s^2 (16)

****