ME8096 GAS DYNAMICS AND JET PROPULATION

IMPORTANT QUESTIONS AND QUESTION BANK

UNIT-I BASIC CONCEPTS AND ISENTROPIC FLOWS

2-Marks

1. How is the static temperature of the low related to total temperature?
2. Distinguish between nozzle and diffuser?
3. What do you understand by compressibility effect?
4. What is subsonic, sonic and supersonic flow with respect to mach number?
5. How the area and velocity vary in supersonic flow of nozzle and diffuser?
6. "Higher the velocity of supersonic flow, smaller the angle of cone". Comment on validity of this statement?
7. A plane travels at a speed of 2400km/h. in an atmosphere of 5°C. Find the Mach angle?
8. List the condition for choking in CD nozzle?
9. The wave front caused by firing a bullet gave a Mach angle of 35˚. Find the velocity of the bullet if the static temperature of atmosphere is 276K?
10. Draw the Mach cone and indicate various zones?

Part-B

1. Derive the relation of effect of Mach number on Compressibility?
2. Nitrogen is expanded is entropically in a nozzle from a pressure of 2000 kPa, at a temperature of 1000 K, to a pressure of 101 kPa. If the velocity of the nitrogen entering the nozzle is negligible, determine the exit nozzle area required for a nitrogen flow of 0.5 kg/s. Assume the nitrogen to behave as a perfect gas with constant specific heats, mean molecular mass of 28.0, and $\gamma = 1.4$.?
3. Derive the Bernoulli equation for isentropic compressible Carbon dioxide expands is entropically through a nozzle from a pressure of 3.2bar to 1bar. If the initial temperature is 475 K, determine the final temperature, the enthalpy drop and the change in internal energy flow?
4. Draw and explain Mach cone, Mach angle and Mach waves?
5. An air craft is flying at an altitude of 11000 meters, at 800 Km/hr. 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 Entry Mach number, Velocity, pressure and temperature of air at the diffuser exit?
6. A supersonic diffuser, diffuses air in an isentropic flow from a Mach number of 1.5, the static conditions of air at inlet are 70 kPa and -7oC. if the mass flow rate of air is 125kg/s, determine 1. Stagnation conditions 2. Area at throat and exit 3. Static conditions of air at exit?
7. Air flow in a duct with a velocity of 215 m/s. The temperature of air measured at a point along the duct is 30ºC and the air pressure is 5 bar. Determine a) Stagnation Pressure, b) Mach number at that point?
8. Air is discharged from a reservoir at P_o = 6.91 bar and To = 325ºC

through a nozzle to an exit pressure of 0.98 bar. If the flow rate is 3600 Kg/hr, determine throat area, pressure and velocity at the throat, exit area, exit Mach number and maximum velocity. Consider flow is isentropic?

9. A conical diffuser has entry and exit diameters of 15 cm and 30 cm respectively. The pressure, temperature and velocity of air at entry are 0.69 bar, 340 K and 180 m/s respectively. Determine: (i) The exit pressure, (ii) The exit velocity (iii) The force exerted on the diffuser walls Assume isentropic flow, γ= 1.4, C_p = 1.00 kJ/kg K?
10. In an isentropic flow diffuser the inlet area is 0.15 m^2. At the inlet velocity 240m/s, static temperature = 300 k and static pressure 0.7 bar. Air leaves he diffuser with a velocity of 120 m/s. Calculate at the exit the mass flow rate, stagnation pressure, stagnation temperature, area and entropy change across the diffuser?
11. Derive area ratio as a function of Mach number for one dimensional isentropic flow?
12. Air (γ =1.4, R=287.43 J/Kg K) enters a straight axis symmetric duct at 300 K, 3.45 bar and 150 m/s and leaves it at 277 K, 500 cm^2. Assuming adiabatic flow determines (i) Stagnation temperature (ii) Maximum velocity, (iii) Mass flow rate and (iv) Area of cross-section at exit?
13. A supersonic diffuser, diffuses air in an isentropic flow from a Mach number of 1.5, the static conditions of air at inlet are 70 kPa and -7oC. if the mass flow rate of air is 125kg/s, determine 1. Stagnation conditions 2. Area at throat and exit 3. Static conditions of air at exit?
14. Helium flows at Mach 0.5 in a channel with cross sectional area of 0.16m^2 The stagnation pressure of the flow is 1MPa, and stagnation temperature is 1000 K. Calculate the mass flow rate through the channel, with γ = 5/3?

UNIT-2 FLOW THROUGH DUCTS

2-Marks

1. In Rayleigh flow what is the Mach number at which the total enthalpy is maximum?
2. How do you specify equivalent diameter for noncircular cross section?
3. List some flow properties?
4. Label the limiting Mach number in isothermal flow?
5. State the assumptions made to derive the equations of isothermal flow?
6. Explain at what conditions the assumption of Rayleigh flow is not valid in heat exchanger?
7. Define Rayleigh line and state its application?
8. Define critical condition in Fanno flow?
9. State the assumptions made for Isothermal flow?
10. Write down the expression for pressure ratio of two sections in terms of Mach number in Rayleigh flow?

Part -B

1. Air enters a combustion chamber with certain Mach sufficient heat is added to obtain a stagnation temperature ratio of 3 and a final Mach number of 0.8. Determine the Mach number at entry and the percentage loss in static pressure. Take γ = 1.4 and Cp =1.005 kJ/kg-K?
2. 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 is 2.5 bar and 1000°C respectively, determine (a) Mach number, pressure and temperature of the gas at entry (b) heat supplied per kg of the gas and (c) the maximum heat that can be supplied. Take γ = 1.3, Cp= 1.218 KJ/Kg K?
3. The conditions of a gas in a combustor at entry are: P1 = 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 1172.5 KJ/Kg. Take Cp=1.005 KJ/Kg
4. 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 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 b) Final pressure, temperature and velocity of the gas c) Percent stagnation pressure loss in the combustion chamber and d) The maximum stagnation temperature attainable?
5. A supersonic nozzle is provided with a constant diameter circular duct at exit. The duct diameter is same as the nozzle exit diameter. Nozzle exit cross-section is three times that of its throat. The entry conditions of the gas (γ=1.4, R=0.287 kJ/Kg K) are P0 =10 bar, T0= 600 K .Calculate the static pressure, Mach number and the velocity of the gas in the duct?
6. Air flows out of a pipe with a diameter of 0.3 m at a rate of 1000 m3/ 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?
7. In an isentropic flow diffuser the inlet area is 0.15 m^2. At the inlet velocity 240 m/s, static temperature = 300 K and static pressure 0.7 bar. Air leaves the diffuser with a velocity of 120 m/s. calculate the exit the mass flow rate, stagnation pressure, stagnation temperature, area and entropy change across the diffuser?
8. At an inlet temperature of 60oC flows with subsonic velocity through an insulated pipe having inside diameter of 50 mm and a length of 5 m. the pressure at the exit of the pipe is 101 KPa and the flow is chocked at the end of the pipe. If the friction factor 4f = 0.005, determine the inlet Mach number, the mass flow rate and the exit temperature?

9. _Air (γ = 1.4) flows into a constant area insulated duct with a Mach number of 0.20. For a duct diameter of 1 cm and friction coefficient of 0.02, determine the duct length required to reach Mach 0.60. Determine the length required to attain Mach 1. Finally, if an additional 75cm is added to duct length needed to reach Mach 1, while the initial stagnation conditions are maintained, determine the reduction in flow rate that would occur?
10. Air flows through a pipe of 25 mm diameter and 51 m length. The conditions at the pipe exit are M2= 0.8, P2=1 atm and T2= 270 K. Assuming adiabatic one-dimensional flow, calculate M1, P1,T1 at the pipe entrance. Take the local friction co efficient to be 0.0005?
11. Air enters a long circular duct (d =12.5 cm, 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?
12. 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?
13. Air having Mach number 3 with total temperature 295°C and static pressure 0.5 bar flows through a constant is duct adiabatically to another section where the Mach number is 1.5. Determine the amount of heat transfer and the change in stagnation pressure?
14. The stagnation temperature of air in a combustion chamber is increased to 3.5 times its initial value. If the air at entry is at 5 bar, 105°C and a Mach number of 0.25 determine: i) the Mach number, pressure and temperature at exit. ii) Stagnation pressure loss and iii) the heat supplied per kg of air?
15. Atmospheric air at pressure 1.01325 x 10^5 N/m^2 and temperature 300 K is drawn through a frictionless bell mouth entrance into a 3 m long tube having a 0.05 m diameter. The average friction coefficient f = 0.005, for the tube. The system is perfectly insulated(i)Find the maximum mass flow rate and the range of back pressures that will produce this flow(ii) What is the exit pressure required to produce 90% of the maximum flow rate, and what will be the stagnation pressure and the velocity at the exit for that mass flow rate?

UNIT III NORMAL AND OBLIQUE SHOCKS

2-Marks

1. What is the response of change fluid stagnation states across a normal rock?

2. Mention the useful application of shock wave?
3. What is the use of Pitot tube in supersonic flow?
4. State the reasons the shock waves cannot be developed in subsonic flow?
5. State the necessary conditions for a normal shock to occur in compressible flow?
6. Prepare the list the situations where shocks are undesirable?
7. Explain how the pilot tube and could be used to measure the Mach number in supersonic flow?
8. Complete the Prandtl-Meyer relation for normal shock?
9. Write the changes across normal shock for Mach number and static pressure?
10. Give two useful applications of the shock waves?

Part-B

1. Helium at 35°C is flowing at a Mach number of 1.5. Find the velocity and determine the local Mach angle. Determine the velocity of air at 40°C to produce a Mach angle of 38°?
2. The ratio of the 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 2. Temperature 3. Pressure 4. What is the stagnation pressure loss between the initial and final states?
3. 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?
4. 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) Calculate the test section Mach number and the diffuser throat area if a normal shock is located in the test section?
5. A gas (γ =1.3) at p1 =345 Mbar, T1= 350 K and M_1=1.5 is to be is entropically expanded to 138 Mbar. Evaluate (a) the deflection angle, (b) final Mach number and (c) the temperature of the gas?
6. An oblique shock wave at an angle of 35° occurs at the leading edge a symmetrical wedge. Air has a Mach number of 2.0 upstream temperature of 310 K and upstream pressure of 10 bar. Determine the following Downstream pressure Downstream temperature Wedge angle Downstream Mach number?
7. An air jet at a Mach number of 2.1 is is entropically deflected by 10° in the clockwise direction. The initial pressure is 100 kN/$m^2$and initial temperature is 98°C. Determine the final state of air after expansion?
8. A jet of air at a 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?

9. A supersonic stream of air at M=3.0 is deflected inwards by 15 degrees. This generates strong and weak oblique shock waves. Calculate the following quantities for these waves: Wave angle, Downstream Mach number, Temperature ratio, static and stagnation pressure ratios?
10. A uniform supersonic air flow at Mach 2.0 passes over a wedge. An oblique shock, making an angle of 40 ° with the flow direction, is attached to the wedge. If the static pressure and temperature in the freestream are 0.5 x 105 N/m2 and 0°C, determine the static pressure and temperature behind the wave, the Mach number of the flow passing over the wedge and the wedge angle?
11. A jet of air at 270K and 0.7 bar has an initial mach number of 1.9. If it passes through a normal shockwave, determine the following for downstream of the shock. (1) Mach number (2) Pressure (3) Temperature (4) Speed of sound (5) Jet of velocity (6) Density?
12. Derive an expression for the Mach number downstream of a normal shock in terms of upstream Mach number?
13. For an oblique shock wave with a wave angle of 33° and upstream Mach number 2.4, calculate the flow deflection angle, the pressure and temperature ratios across the shock wave and the Mach number behind the wave?
14. A pilot tube kept in a supersonic wind tunnel forms a bow shock ahead of it. The static pressure upstream of the shock is 16 kPa and the pressure at the mouth is 70 kPa. Estimate the mach number of the tunnel. If the stagnation temperature is 300ºC, calculate the static temperature and total pressure upstream and downstream

UNIT IV JET PROPULSION

2-Marks

1. Rewrite thrust power and propulsive efficiency of aircraft engine?
2. Why a ram jet engine does not require a compressor and turbine?
3. Name three commonly used aircraft engines?
4. Define specific consumption?
5. What is meant by By-Pass ratio of turbofan engine?
6. What are the benefits of thrust augmentation in a turbojet engine?
7. List out the main parts of a Ram jet engine?
8. What is weight flow co-efficient?
9. What is scram jet?
10. Write an expression for thrust of a jet propulsion?

Part-B

1. Explain the principle of operation of a turbojet engine and state its advantages and disadvantages?
2. An aircraft flies at 960 Km/hr. 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?

3. A turbojet aircraft flies at 875 km/hr. 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?
4. 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
5. Derive the thrust equation for rocket engine?
6. Differentiate turbojet and turbo prop propulsion engines with suitable diagrams?
7. Describe the working of supersonic ramjet engine with a neat sketch. List out its advantages and disadvantages?
8. Explain with sketches the working of the by-pass engine competitors?
9. How thrust equation is derived for bypass engine? What are the merits and demerits of such engines over its fights?
10. A turbojet has a speed of 750 km/hr while flying at an altitude of 10000m. The propulsive efficiency of the jet is 50% and the overall efficiency of the turbine plant is 16%. The density of the air at 10000 m altitude is 0.173 kg/m^3. The drag on the plane is 6250 N. calorific value of the fuel is 48000 kJ/Kg. Calculate a. Absolute velocity of the jet b. Diameter of the jet c. Power output of the unit in kW?
11. Deduce the equation of Jet thrust and Propeller Thrust?
12. 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?
13. A turbojet engine operates at an altitude of 11km and a inlet Mach number of 0.82. The data for a engine is given below: Stagnation temperature at the turbine inlet = 1220K, Stagnation temperature rise through the Compressor = 170K, CV of the fuel = 42 MJ/kg, Compressor efficiency = 0.75, Combustor efficiency = 0.97, Turbine efficiency = 0.83. Determine (i) Air fuel ratio, (ii) Compressor pressure ratio,(iii) Turbine pressure ratio,(iv)Velocity of aircraft?
14. A turbojet engine operating at a Mach number of 0.8 and the altitude is 10Km has the following data. Calorific value of the fuel is 42,899 kJ/Kg. thrust force is 50 kN, mass flow rate of air is 45 kg/s, mass flow rate of fuel is 2.65 kg/s. etermine the specific thrust, thrust specific fuel consumption, jet velocity, thermal efficiency, propulsion efficiency and overall efficiency Assuming the exit pressure is equal to ambient pressure?

UNIT V SPACE PROPULSION

2-Marks

1. Why rocket is called as non-breathing engine? Can rocket work at vacuum?
2. Explain the applications of inhibitors in solid propellants?
3. Rewrite the mono-propellants. Give examples?
4. Give the important requirements of rocket engine fuels?
5. Prepare any four specific application of rocket?
6. A rocket flies at 10080 km/hr. with an effective exhaust jet velocity of 1400 m/s and the propellant flow rate of 5kg/s. Find the propulsion efficiency and propulsion power of the rocket?
7. Compare the merits and demerits of bio propellants with mono propellants?
8. What is meant by hypergolic propellant?
9. What is bypass engine and define bypass ratio?
10. Briefly explain thrust augmentation and any two methods of achieving it?

Part-B

1. A space craft engine ejects mass at a rate of 30kg/s with an exhaust velocity of 3100m/s. the pressure at the nozzle exit is 5kPa and the exit area is 0.7m^2. What is the thrust of the engine in a vacuum?
2. Explain the working of Multi-stage rocket with their merits and demerits?
3. 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?
4. What are the advantages and disadvantages of liquid propellants compared to solid propellants?
5. Explain with a neat sketch the working of a gas pressure feed system used in liquid propellant rocket engines?
6. Describe the important properties of liquid and solid propellants desired for rocket propulsion?
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?
10. Deduce expressions for propulsive efficiency specific impulse and overall efficiency of a rocket engine?
11. 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. Determine the effective jet velocity, actual jet velocity, specific impulse and the specific

propellant consumption?

12. What are the properties of good propellants? Write short notes about Escape velocity?
13. Draw and explain various types of burning configuration soild propellant?
14. A rocket engine has the following data: Effective jet velocity = 1200m/s. Flight to jet speed ratio = 0.82. Oxidizer flow rate = 3.4 kg/s. Fuel flow rate = 1.2 kg/s. Heat of reaction per kg of the exhaust gases =2520 kJ/kg. Calculate the following: (1). Thrust (2). Specific impulse (3). Propulsive efficiency (4). Thermal efficiency (5) overall efficiency?