ME6604-GAS DYNAMICS AND JET PROPULSION

Unit I – Basic concepts and Isentropic flows

Part A (2 Marks)

1. State the difference between compressible fluid and incompressible fluid ?
2. Define stagnation pressure?
3. Express the stagnation enthalpy in terms of static enthalpy and velocity of flow?
4. Explain Mach cone and Mach angle?
5. Define adiabatic process?
6. Define Mach number?
7. Define zone of action and zone of silence ?
8. Define closed and open system?
9. What is the difference between intensive and extensive properties?
10. Distinguish between Mach wave and normal shock?

Part B (16 Marks)

1.Air is discharged from a reservoir at po = 6.91 bar and to = 325 C 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. (AU: May 2012, Dec 2009, May 2008)

2.A supersonic diffuser diffuses air in an isentropic flow from a mach number of 3 to a mach number of 1.5. The static conditions of air at inlet are 70 kpa and -7 C. If the mass flow rate of air is 125 kg/s, determine the stagnation conditions, areas at throat and exit, static conditions (pressure, temperature, velocity) of air at exit.
(AU: May 2012)

3.A supersonic nozzle expands air from Po = 25 bar and T0 = 1050 K to an exit pressure of 4.35 bar: the exit are of the nozzle is 100 cm2. Determine i) throat area ii) pressure and temperature at the throat iii) temperature at exit iv) Exit velocity as fraction of the maximum attainable velocity v) mass flow rate.
(AU: May 2011, May 2010)

5.4.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) exit pressure ii) the exit velocity and iii) the force exerted on the diffuser walls assume isentropic flow, γ =1.4, Cp = 1.00 J/Kg K
(AU: May 2011, May 2010, May 2009 Dec 2008, Dec 2007)

6.The pressure, temperature and Mach number at the entry of a flow passage are 2.45 bar, 26.5 C and 1.4 respectively. If the exit mach number is 2.5, determine for adiabatic flow of

a perfect gas (γ = 1.3, R = 0.469 kJ/Kg K). I) Stagnation temperature. ii) Temperature and velocity of gas at exit. Iii) the flow rate per square metre of the inlet cross-section. (AU: May 2010, May 2008)

7.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, 2.058 bar and 260 m/s. The area of cross-section at entry is 500cm2. Assuming adiabatic flow determine i) Stagnation temperature ii) maximum velocity iii) Mass flow rate iv) Area of cross section
at exit. (AU: May 2010, May 2008)

8.In an isentropic flow diffuser the inlet area is 0.15 m2. 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.
(AU: Dec 2009)

9.Air is drawn isentropically from a standard atmosphere at sea level (101.3 KPa and 15 C) through a converging diverging nozzle. The static pressure at two different locations at 80 KPa and 40 KPa respectively. Determine the Mach number at each of these locations. Also determine the velocity at each of these locations.
(AU: May 2009)

10.Air (Cp = 1.05 KJ/Kg-K, γ = 1.38) at P1 = 3 × 105 N/m2 and T1 = 500 k flows with a velocity of 200 m/s in a 0.3 m diameter duct. Calculate: Mass flow rate, Stagnation temperature, Mach number and stagnation pressure values assuming the flow as compressible and incompressible respectively.
(AU: Dec 2008, Dec 2007)

11.Air flowing in a duct has a velocity of 300 m/s, pressure 1.0 bar and temperature 290 k. Taking γ = 1.4 and R = 287 J/Kg K. Determine: i) Stagnation pressure and temperature. ii) Velocity of sound in the dynamic and stagnation conditions. Iii) Stagnation pressure assuming constant density.
(AU: May 2008, Dec 2007)

12.What is the effect of Mach number on compressibility? Prove for γ=1.4, Po –P / ½ P c^2 = 1 +¼ M^2 + 1/40 M 4 + …….
(AU: May 2009, Dec 2007, Dec 2006)

13.Derive area ratio as a function of Mach number for one dimensional isentropic flow
(AU: Dec 2008)

Unit II – 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?

Part B (16 Marks)

1.Air having mach number 3 with total temperature 295 C and static pressure 0.5 bar flows through a constant are duct adiabatically to another section where the mach number is 1.5. Determine the amount of heat transfer and the change in stagnation pressure
(AU: May 2004)

2.Air flow through a constant area duct with inlet temperature of 20 C and inlet Mach number of 0.5. what is the possible exit stagnation temperature? It is desired to transfer heat such that at exit of the duct the stagnation temperature is 1180 K. For this condition what must be the limiting inlet Mach number? Neglect friction. (AU: Dec 2004)

3.Air enters a combustion chamber with certain Mach number. 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. (AU: Dec 2005)

4.A circular duct passes 8.25 kg/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 is 0.005. If the Mach number at entry is 0.15, determine the diameter of the duct, length of the duct, pressure and temperature at the exit, and stagnation pressure loss.
(AU: May 2012, May 2010, May 2009, Dec 2007)

5.The mach number at inlet and exit for a Rayleigh flow are 3 and 1.5 respectively. At inlet static pressure is 50 kPa and stagnation temperature is 295 K. Consider the fluid is air. Find i) the static pressure, temperature and velocity at exit, ii) stagnation pressure at inlet and exit, iii) heat transferred, iv) maximum possible heat transfer, v) change in entropy between the two sections, vi) is it a cooling or heating process?

(AU: May 2012)

6.Air at Po = 10 bar, To = 400 K is supplied to a 50 mm diameter pipe. The friction factor for the pipe surface is 0.002. If the Mach number changes from 3.0 at the entry to 1.0 at the exit determine i) the length of the pipe and ii) the mass flow rate.
(AU: May 2011)

7.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 41.87MJ/Kg. Taking γ = 1.4 and R= 0.287 KJ/Kg K for the gas determine: I) the initial and final mach numbers ii) final pressure, temperature and velocity of the gas. Iii) percent stagnation pressure loss in the combustion chamber and iv) the maximum stagnation temperature attainable.
(AU: May 2011, Dec 2007)

8.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.
(AU: May 2010, May 2008)

9.Air enters a constant area duct at M1 = 3, P1 = 1 atm and T1 = 300 K. inside the duct the heat added per unit mass is q = 3 × 105 J/Kg. Calculate the flow properties M2, P2, T2, ρ2, To2 and Po2 at the exit. (AU: Dec 2009)

10.Air at an inlet temperature of 60 C 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 choked 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.
(AU: Dec 2009)

11.Air flows with negligible friction in a constant are duct. At section one, the flow properties are T1 = 60.4 C, P1 = 135 kPa absolute and velocity 732 m/s. Heat is added to the flow between section one and section two, where the mach number is 1.2. Determine the flow properties at section two, the heat transfer per unit mass and the entropy change. (AU: May 2009)

12.A long pipe of 0.0254 m diameter has a mean coefficient of friction of 0.003. Air enters the pipe at a mach number of 2.5, stagnation temperature 310 K and static pressure 0.507 bar. Determine for a section at which the mach number reaches 1.2: i) Static pressure and temperature, ii) Stagnation pressure and temperature, iii) Velocity of air, iv) Distance of this section from the inlet and v) mass flow rate of air.
(AU: Dec 2008, May 2008)

13.The mach number at the exit of a combustion chamber is 0.9. the ratio of stagnation temperatures at exit and entry is 3.74. If the pressure and temperature of the gas at exit are 2.5 bar and 1273 K respectively, determine: i) Mach number, pressure and temperature of the gas at entry ii) the heat supplied per Kg of the gas and iii) the maximum heat that can be supplied.(AU: Dec 2008)

Unit-III 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 ?

Part B (16 Marks)

1.Derive the equation for Mach number in the downstream of the normal shock wave
(AU: May 2012)

2.The velocity of a normal shock wave moving into stagnant air (P = 1.0 bar, T = 17 C) is 500m/s. if the area of cross section of the duct is constant, determine pressure, temperature, velocity of air, stagnation temperature and Mach number imparted upstream of the wave front.
(AU: May 2012)

3.Air approaches a symmetrical wedge (angle of deflection δ= 15') at a Mach number of 2. Consider strong waves conditions. Determine the wave angle, pressure ratio, density ratio, temperature ratio and downstream Mach number.
(AU: May 2012)

4.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 Po = 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, I) Mach number ii) Temperature and pressure iii) What is the stagnation pressure loss between the initial and final stages of the flow
(AU: May 2011, May 2010, Dec 2008, Dec 2007, May 2007)

5.Derive the equation for static pressure ratio across the shock waves (AU: May 2012)

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 i) Deflection angle ii) Final Mach number and iii) the temperature of the gas (AU: May 2011, May 2008)

7.A supersonic nozzle is provided with a constant diameter circular duct at its 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 = 0.287kJ/kg-k) are Po = 10 bar, To = 600 K. Calculate the static pressure, Mach number and the velocity of the gas in the duct: i) when the nozzle operates at this design condition ii) when a normal shock occurs at this design condition. ii) when a normal shock occurs at its exit.
(AU: May 2010, May 2008)

8.A convergent-divergent nozzle is designed to expand air from a reservoir in which the pressure is 800 kpa and temperature is 40 C to give a mach number at exit of 2.5. the throat area is 25 cm2. Find i) mass flow rate, ii) exit area and iii) when a normal shock appears at a section where the area is 40 cm2 determine the pressure and temperature at exit.
(AU: Dec 2009)

9.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 300 C, calculate the static temperature and total pressure upstream and downstream of the tube. (AU: Dec 2009)

10.A convergent-divergent nozzle has an exit area to throat area ratio of 2. Air enters this nozzle with a stagnation pressure of 1000 kPa and a stagnation temperature of 360 K. the throat area is 500 mm2. The divergent section of the nozzle acts as a supersonic nozzle. Assume that a normal shock stands at a point M = 1.5. Determine the exit plane of the nozzle, the static pressure and temperature and Mach number.(AU: May 2009)

11.A convergent divergent nozzle operates at off design condition while conducting air from a high pressure tank to a large container. A normal shock occurs in the divergent part of the nozzle at a section where the cross section area is 18.75 cm2. The stagnation pressure and stagnation temperature at the inlet of the nozzle are 0.21 Mpa and 36 C respectively. The throat area is 12.5 cm2 and the exit area is 25 cm2. Estimate the exit mach number, exit pressure, loss in stagnation pressure and entropy increase during the flow between the tanks.(AU: May 2009)

12.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 on the wall, pressure and temperature ratios and final Mach number.(AU: Dec 2007)

Unit IV- Jet propulsion

Part A (2 Marks)

1. What is thrust (or) drag?
2. What is Thrust Specific Fuel Consumption (TSFC)?
3. Define Specific impulse
4. What are the various types of air breathing engine?
5. What is scram jet?
6. How is turbofan engine different from turbo prop engine?
7. What is thrust augmentation?
8. Give the difference between Ramjet and Turbojet engine
9. What is the difference between turboprop and turbojet engine
10. What type of compressor used in turbojet? Why?

Part B (16 Marks)

1. Differentiate turbojet and turboprop propulsion engines with suitable diagrams (AU: May2012)

2. Write the equations to calculate propulsion efficiency and thermal efficiency of an aircraft. (AU: May 2012)

3. 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. determine 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.
(AU: May 2012)

4. Explain the principle of operation of a turbojet engine and state its advantages and disadvantage(AU: May 2011)

5. 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 TSFC from the following data: Diameter of the air at inlet section = 0.75m Diameter of jet pipe at exit = 0.5m Velocity of the gases at the exit of the jet pipe = 500m/s Pressure at the exit of the jet pipe = 0.30 bar Air to fuel ratio = 40
(AU: May 2011, May 2007)

6. Explain with a neat sketch the principle of operation of a ramjet engine and state its advantages and disadvantages. (AU: May 2010, May 2009).

7. A turbojet propels an aircraft at a speed of 900 km/hr, while taking 3000 kg of air per minute. The isentropic enthalpy drop in the nozzle is 200 kJ/kg and the nozzle efficiency is 90%.

The air-fuel ratio is 85 and the combustion efficiency is 95%. The calorific value of the fuel is 42,000 kJ/Kg. Calculate: i) The propulsion power, ii) Thrust power, iii) Thermal efficiency and iv) Propulsion efficiency.(AU: Dec 2009)

8. Describe the working of supersonic ramjet engine with a neat sketch. List out its advantages and disadvantages. (AU: May 2009)

9. The diameter of the propeller of an aircraft is 2.5m; 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. (AU: Dec 2008)

10. Explain with a neat sketch the principle of operation of a turbojet engine and state its advantages and disadvantages. (AU: May 2008)

Unit V- Space propulsion

Part A (2 Marks)

1. Differentiate jet propulsion and Rocket propulsion.
2. What is mono propellant
3. What is bi propellant
4. Classify the rocket engines based on source of energy employed
5. What is specific impulse of a rocket?
6. Define thrust
7. What is IWR?
8. What is thrust coefficient?
9. Define propulsion efficiency
10. What is weight flow coefficient?

Part-B (16 Marks)

1.A rocket engine has the following data. Combustion chamber pressure is 38 bar, combustion chamber temperature is 3500 K, oxidizer flow rate is 41.67 Kg/s, mixture ratio is 5, and the properties of exhaust gases are Cp/Cv = 1.3 and R = 0.287 kJ/KgK. The expansion takes place to the ambient pressure of 0.0582 bar. Calculate the nozzle throat area, thrust, thrust coefficient, exit velocity of the exhaust and maximum possible exhaust velocity.
(AU: May 2012)

2.Explain briefly about the propellant feed system of a liquid propellant rocket engine with suitable schematic sketches. (AU: May 2012)

3.A rocket has the following data: propellant flow rate = 5 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. Recalculate the values of thrust and specific impulse for an altitude where the ambient pressure is 10 m bar.
(AU: May 2012, Dec 2009)

4. Explain with a neat sketch the working of a gas pressure feed system used in liquid propellant rocket engines (AU: May 2011)

5. Describe the important properties of liquid and solid propellants desired for rocket propulsion. (AU: May 2011, May 2010, May 2008)

6. Explain the working of a turbo-pump feed system used in a liquid propellant rocket
(AU: May 2010, Dec 2007)

7.Deduce expressions for propulsion efficiency specific impulse and overall efficiency of a rocket engine. (AU: Dec 2009)

8. Explain the principle of operation of liquid propellant and solid propellant engines with neat sketch. (AU: May 2009)

9. List down the advantages of liquid propellant rockets. (AU: May 2009)

10. The effective jet velocity from a rocket is 2700 m/s. The forwared flight velocity is 1350 m/s and the propellant consumption is 78.6 kg/s. Calculate: thrust, Thrust power and propulsion efficiency.(AU: Dec 2008)

11. Derive the thrust equation for rocket engines. (AU: Dec 2015)