KINGS

COLLEGE OF ENGINEERING

DEPARTMENT OF MECHANICAL ENGINEERING

QUESTION BANK

Sub.Code/Name:ME1303Gas Dynamics and Jet Propulsion

Year/Sem:III/V

UNIT-1

COMPRESSIBLE FLOW – FUNDAMENTALS

PART-A (2 Marks)

1) ***State the difference between compressible fluid and incompressible fluid ?***

Compressible flow is that type of flow in which the density of the fluid changes from point to point, i.e., density is not constant for the fluid .

$$\rho \neq constant$$

Examples: Gases, vapor

Incompressible flow is that type of flow in which the density of the fluid constant .

$$\rho = constant$$

Examples: Liquids.

2) ***Define stagnation pressure?***

Stagnation pressure is the pressure of the gases when it is isentropically decelerated to zero velocity at zero elevation.

$$Po/p = \{To/T\}^{\gamma/\gamma-1}$$

$$Po/P = \{1 + \gamma-1/2\ M^2\}^{\gamma/\gamma-1}$$

where

Po - *stagnation pressure*
P - *Static pressure*
M - *Mach number*

3) ***Express the stagnation enthalpy in terms of static enthalpy and velocity of flow?***

Stagnation enthalpy, ho=$h + c2/2$
Where
h- Static enthalpy – j/kg
c- Velocity of fluid – m/s.

4) ***Explain Mach cone and Mach angle?***

Mach cone: Tangents drawn from the source point on the spheres define a conical surface referred to as Mach cone.

Mach angle: The angle between the Mach line and the direction of motion of the body (flow direction) is known as Mach angle.

5) ***Define adiabatic process?***

In an adiabatic process there is no heat transfer between the system and the surrounding, ie.,Q =0

6) ***Define Mach number?***
The Mach number is an index of the ratio between inertia force and elastic force.

M^2 = Inertia force / Elastic force

It is also defined as the ratio of the fluid velocity (c) to the velocity of sound (a).

M = c/a

7) ***Define zone of action and zone of silence ?***

The region inside the Mach cone is called the zone of action and the region outside the Mach cone is termed as the zone of silence.

8) ***Define closed and open system?***

A closed system does not permit any mass transfer, only energy transfer takes place.
In open system both the mass and energy transfer takes place.

9) ***What is the difference between intensive and extensive properties?***

Intensive properties:
These properties are independent on the mass of the system.
Example: Pressure, Temperature, etc

Extensive properties:
These properties are dependent upon the mass of the system.
Example: Total volume, Total energy, etc.

10) ***Distinguish between Mach wave and normal shock?***

Mach Wave: The lines at which the pressure difference is concentrated and which generate cone are called Mach lines or Mach waves.

Normal shock: A shock wave is nothing but a steep finite pressure wave. When the shock wave is right angle to the flow, it is called normal shock.

Unit -2

DUCTS FLOW THROUGH VARIABLE AREA
PART-A (2 Marks)

1) Differentiate Adiabatic and Isentropic process.

Adiabatic process:
In a process there is no heat transfer from the fluid to surroundings or from the surroundings to the fluid.

Isentropic process:
In a isentropic entropy remains constant and it is reversible .During this process there is no heat transfer from the fluid to surroundings or from the surroundings to the fluid. Therefore an isentropic process can be stated as reversible adiabatic process.

S = constant
Q =0

2) ***Differentiate nozzle and diffuser ?***

Nozzle:
It is a device which is used to increase the velocity and decrease the pressure of fluids.

Diffuser:
It is a device which is used to increase the pressure and decrease the velocity of fluids.

3) ***What is Impulse function ?***

The sum of pressure force (pA) and impulse force (ρAc^2) gives Impulse function (F)

$$F = pA + \rho ac^2$$

4) ***Differentiate between adiabatic flow and diabatic flow ?***

Diabatic flow :
Flow in a constant area duct with heat transfer and without friction is known as diabatic flow (Rayleigh flow)

Adiabatic flow:
Flow in a constant area duct with friction and without heat transfer is known as adiabatic flow (Fanno flow).

5) ***State the expression for dA/A as a function of Mach number ?***

$dA/A = dp/\rho c^2 [\ 1-M^2\ ]$

6) ***Give the expression for T/To and T/T* for isentropic flow through variable area interms of Mach number ?***

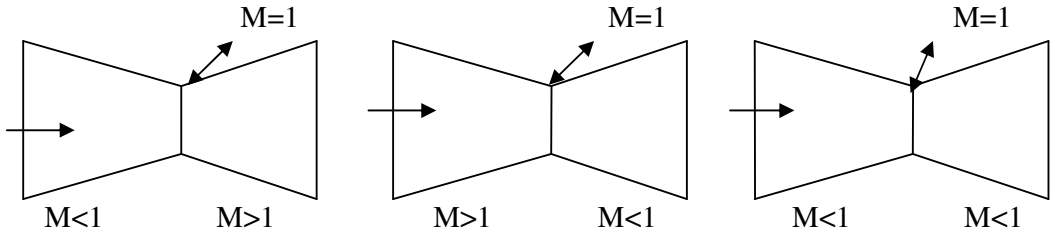
$To/T = 1+[\gamma-1/2]M^2$

$$To/T = \frac{1}{1+[\gamma-1/2]\ M^2}$$

$$T^*/T = 2/\gamma+1 + [\gamma-1/\ \gamma+1]\ M^2$$

$$T/T^* = \frac{1}{2/\ \gamma+1\ + [\gamma-1/\ \gamma+1]\ M^2}$$

7) ***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***



Nozzle ***Diffuser*** ***Venturi***

8) ***What is chocked flow through a nozzle?***

The mass flow rate of nozzle is increased by decreasing the back pressure. The maximum mass flow conditions are reached when the throat pressure ratio achieves critical value. After that there is no further increase in mass flow with decrease in back pressure .This condition is called chocking. At chocking condition M=1.

9) ***What type of nozzle used for sonic flow and supersonic flow?***

Constant area duct nozzle is used for sonic flow and divergent nozzle is used for supersonic flow.

10) ***When does the maximum mass flow occur for an isentropic flow with variable area?***

Mass flow rate will be maximum at throat section where the Mach number is one.

Unit -3

DUCTS FLOW THROUGH CONSTANT AREA

PART-A (2 Marks)

1) ***What are the consumption made for fanno flow?***

- ✓ One dimensional steady flow.
- ✓ Flow takes place in constant sectional area.
- ✓ There is no heat transfer
- ✓ The gas is perfect with constant specific heats.

2) Differentiate Fanno flow and Rayleigh flow?

Rayleigh flow:
Flow in a constant area duct with heat transfer and without friction is known as Rayleighs flow.
Fanno Flow:
Flow in a constant area duct with friction and without heat transfer is known as Fanno flow.

3) Explain chocking in Fanno flow?

In a fanno flow, subsonic flow region, the effect of friction will increase the velocity and Mach number and to decrease the enthalpy and pressure of the gas.
In supersonic flow region, the effect of friction will decrease the velocity and Mach number and to increase the enthalpy and pressure of the gas.
In both cases entropy increases up to limiting state where the Mach number is one(M=1) and it is constant afterwards. At this point flow is said to be chocked flow.

4) Explain the difference between Fanno flow and Isothermal flow?

Fanno flow	*Isothermal flow*
• Flow in a constant area duct with friction and without heat transfer is known as fanno flow. • Static temperature is not constant.	• Flow in a constant area duct with friction and the heat transfer is known as isothermal flow. • Static temperature remains constant.

5) Write down the ratio of velocities between any two sections in terms of their Mach number in a fanno flow ?

$$C2/C1=M1/M2\frac{[1+[\gamma-1/2]\ M1^2]^{1/2}}{[1+[\gamma-1/2]\ M2^2]^{1/2}}$$

6) Write down the ratio of density between any two section in terms of their Mach number in a fanno flow?

$$Þ2/Þ1= M1/M2\ \frac{[1+[\gamma-1/2]\ M1^2]^{1/2}}{[1+[\gamma-1/2]\ M1^2]^{1/2}}$$

7) *What are the three equation governing Fanno flow?*

- Energy equation

- Continuity equation
- Equation of state

8) ***Give the expression to find increase in entropy for Fanno flow?***

$$\frac{S2-S1}{R} = \ell n \, M1/M2 \, \frac{[1+[\gamma-1/2]\, M1^2]^{\gamma+1/2(\gamma-1)}}{[1+[\gamma-1/2]\, M1^2]^{\gamma+1/2(\gamma-1)}}$$

9) Give two practical examples where the Fanno flow occurs?

- Flow in air breathing engines
- Flow in refrigeration and air conditioning
- Flow of fluids in long pipes.

10) What is Rayleigh line and Fanno line?

Rayleigh line:
Flow in a constant duct area with heat transfer and without friction is described by a curve is known as Rayleigh line.

Fanno Line:
Flow in a constant duct area without heat transfer and with friction is described by a curve is known as Fanno line.

Unit-4

NORMAL SHOCK

PART-A (2 Marks)

1) What is mean by shock wave ?

A shock wave nothing but a steep finite pressure wave.The shock wave may be described as a compression wave front in a subsonic flow field across which there is abrupt change in flow properties.

2) What is mean by Normal shock?

When the shock wave at right angle to the flow it is called normal shock.

3) What is oblique shock?

When the shock wave is inclined at an angle to the flow it is called oblique shock.

4) Define strength of shock wave?

It is defined as the ratio of the difference in downstream and upstream shock pressure (py-px) to upstream shock pressure (px)it is denoted by £

$$£ = py - px / px$$

5) What are applications of moving shock wave ?

It is used in

- Jet engines
- Shock tubes
- Supersonic wind tunnel
- Practical admission turbines

6) Shock waves cannot develop in subsonic flow? Why?

In subsonic flow the velocity of fluid is less than the velocity of sound .Due to this reason, deceleration is not possible in subsonic flow so shock waves cannot develop in subsonic flow.

7) Define compression and rarefaction shock? Is the latter possible?

A shock wave which is at a higher pressure than the fluid into which it is moving is called a compression wave.
The shock wave which is at a lower pressure than the fluid into which it is moving is called a expansion shock wave or rarefaction shock wave.
It is not possible.

8) State the necessary conditions for a normal shock to occur in compressible flow?

- The compression wave is to be at right angle to the compression flow
- Flow should be supersonic

9) Give the difference between normal and oblique shock?

Normal shock	Oblique shock
• Shock wave is right angle to the flow • One dimensional flow	• Shock wave is inclined at an angle to the flow. • Two dimensional flow.

10) what are the properties change across a normal shock ?

- stagnation pressure decreases
- stagnation temperature remains const
- static pressure and temperature increases

Unit -5

PROPULSION

PART-A (2 Marks)

1) Differentiate jet propulsion and rocket propulsion (or) differentiate between air breating and rocket propulsion?

Sno	Jet propulsion	Rocket propulsion
1.	Oxygen required for combustion purpose is taken from the atmosphere.	Oxygen is filled in a tank in the rocket engine itself and used for combustion purpose
2.	Altitude limitation	No altitude limitation
3.	Flight speed always less than jet velocity.	Flight speed can be greater than jet velocity.
4.	Reasonable efficiency	Low efficiency expect at extremely high flight speed
5.	Trust decreases with altitude	Trust improves slightly with altitude

2) What is monopropellant? Give one example for that?

The liquid propellant both the fuel and oxidizer in a single chemical is known as a monopropellant .It is stable at normal ambient conditions and liberates thermal chemical energy on heating.

Example:

- Nitroglycerine
- Nitro methane

3) What is bipropellant?

If the fuel and oxidizer are different from each other in its chemical nature , the propellant is called the bipropellant.

Example:

- Liquid oxygen –gasoline.
- Hydrogen peroxide – hydrazine

4) Classify the rocket engines based on sources of energy employed?

On the basis of source of energy employed rocket engine is classified as:

- ❖ Chemical rocket engines
- ❖ Solar rocket engines
- ❖ Nuclear rocket engines
- ❖ Electrical rocket engines

5) What is specify impulse of rocket?

The thrust developed by unit weight flow rate of the propellant is known as specific impulse.

Isp =F/Wp

6) Define specific consumption?

The propellant consumption rate per unit thrust is known as specific propellant consumption.

SPC =Wp/F

7) What is weight flow co-efficient?

It is the ratio of propellant flow rate to the throat force

Cw =Wp/poA*

8) What is IWR?

IWR (impulse to weight ratio) is the ratio of total impulse of the rocket to the total weight of the rocket.

IWR = **I** total/**W**total

9) What is thrust co-efficient?

It is the ratio of the thrust to the thrust force

Cf = F/po A*

10) Define propulsive efficiency?

It is ratio of the propulsive power to the power output of the engine

0p =propulsive power/power output of the engine.

Unit -1

COMPRESSIBLE FLOW – FUNDAMENTALS

Part - B (16 Marks)

1) Derive the energy equation b

$$a^2/\gamma - 1 + \tfrac{1}{2} c^2 = \tfrac{1}{2} c^2 max = ao^2/\gamma - 1 = ho$$

Stating the assumptions used.An air jet (γ =1.4, R=287 J/Kg K) at 400K has sonic velocity .Determine:

1. ***velocity of sound at 400 K (2)***
2. ***Velocity of sound at the stagnation conditions.(4)***
3. ***Maximum velocity of the jet.(4)***
4. ***Staganation enthalpy. (4)***
5. ***crocco number. (2)***

2) ***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 perfect gas (γ =1.3, R=0.469 KJ/Kg K).***

3) 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,500cm² . Assuming adiabatic flow determines:

1. ***stagnation temperature, (4)***
2. ***maximum velocity, (4)***
3. ***mass flow rate, and, (4)***
4. ***area of cross-section at exit. (4)***

4) An aircraft flies at 800 Km/hr at an altitude of 10,000 meters (T=223.15 K,P=0.264 bar). The air is reversibly compressed in an inlet diffuser. If the Mach number at the exit of the diffuser is 0.36 determine (a) entry Mach number and (b) velocity, pressure and temperature of air at diffuser exit.

5) Air (Cp =1.05 KJ/Kg K,γ =1.38) at p1 =3*10 ^5 N/m² and T1 =500 k flows with a velocity of 200 m/s in a 30 cm diameter duct. Calculate mass flow rate,stagnation temperature,Mach number, and,Stagnation pressure values assuming the flow as compressible and incompressible.

7) (a) What is the effect of Mach number on compressibility prove for γ=1.4

$$\frac{p_0 - p}{\frac{1}{2} p c^2} = 1 + \frac{1}{4} M^2 + 1/40\, M^4 + \ldots\ldots \quad (8)$$

(b) Show that for sonic flow the deviation between the compressible and incompressible flow values of the pressure coefficient of a percent gas (γ =1.4) is about 27.5 per cent.(8)

Unit -2

DUCTS FLOW THROUGH VARIABLE AREA

Part - B (16 Marks)

1) *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 =287J/Kg K determine:*
    1) *Stagnation pressure and temperature, (4)*
    2) *Velocity of sound in the dynamic and stagnation conditions, (6)*
    3) *Stagnation pressure assuming constant density. (6)*
2) *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*
    1) *The exit pressure, (4)*
    2) *The exit velocity and (6)*
    3) *The force exerted on the diffuser walls. (6)*

    Assume isentropic flow, γ =1.4,Cp =1.00 KJ Kg-K.

3) *A nozzle in a wind tunnel gives a test –section Mach number of 2.0 .Air enters the nozzle from 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:*
    1) *Pressures,temperature and velocities at the throat and test sections, (4)*
    2) *Area of cross- sectional of the test section , (4)*
    3) *Mass flow rate, (4)*
    4) *Power rate required to drive the compressor. (4)*
4) *Air is discharged from a reservoir at Po =6.91bar and To =325˚c through a nozzle to an exit pressure of 0.98 bar .If the flow rate is 3600Kg/hr determine for isentropic flow:*
    1) *Throat area, pressure,and velocity, (4)*
    2) *Exit area,Mach number ,and (6)*
    3) *Maximum velocity. (6)*
5) *A super sonic wind tunnel settling chamber expands air or Freon-21 through a nozzle from a nozzle from a pressure of 10 bar to 4bar in the test section . calculate the stagnation temperature to the maintained in the setting chamber to obtain a velocity of 500 m/s in the test section for,*
    1) *Air ,Cp =1.025 KJ/Kg K, Cv =0.735 KJ/Kg K*
    2) *Freon -21 ,Cp =0.785 KJ/Kg K ,Cv= 0.675 KJ/Kg K.*

    What is the test section Mach number is each case ?
6) *Derive the following relations for one dimensional isentropic flow:*
    - *$dA/A = dP/\rho c^2(1 - M^2)$*
    - *$p^*/p = (2/\gamma+1 + \gamma-1/\gamma+1M^2)$*

unit -3

DUCTS FLOW THROUGH CONSTANT AREA

Part - B (16 Marks)

Flow in constant area ducts with friction (Fanno flow)

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 p1 =1bar, T1 =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:

1) ***Lengths of the duct upstream and downstream of the shock wave, (6)***
2) ***Mass flow rate of the gas and (4)***
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 3.0bar 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 lengthof 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.

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 ?

Flow in constant area ducts with heat transfer(Rayleigh flow)

7) 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

8) 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

9) 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)

10) 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} = ρ² c ²

Unit -4

NORMAL SHOCK

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:
Mx =2.5, px= 2bar ,Tx =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.

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.

a) Mach number , (4)
b) Temperature, and (4)
c) Pressure (4)
What is the stagnation pressure loss between the initial and final states of the flow ? (4)

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

5) 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.

6) Starting from the energy equation for flow through a normal shock obtain the following relations (or) prandtl – meyer relation
Cx Cy =a*²
M*x M*y =1

Flow with oblique shock waves:

7) Air approaches a symmetrical wedge (δ =15˚) at a Mach number of 2.0.Determine for the strong and weak waves (a) wave angle (b) pressure ratio (c) density ratio,(d) temperature ratio and (e)downstream Mach number
Verify these values using Gas tables for normal shocks.

8) 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.

9) 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.

10) Derive the Rankine –Hugoniot relation for an oblique shock

$$\frac{\rho_2}{\rho_1} = \frac{\gamma+1}{\gamma-1}\frac{p_2}{p_1} \Big/ \left[1 + \frac{\gamma+1}{\gamma-1}\frac{p_2}{p_1}\right]$$

Compare graphically the variation of density ratio with the intial Mach number in isentropic flow and flow with oblique shock.

11) 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 are2.5 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

12) The conditions of a gas in a combuster 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 1172.5KJ/Kg.
Take Cp=1.005KJ/kg, γ =1.4.

13) 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)***

14) 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} r = $\rho^2 c^2$

Unit -5

PROPULSION

Part - B (16 Marks)

1) A turboprop engine operates at an altitude of 3000 meters above mean sea level and an aircraft speed of 525 Kmph. The data for the engine is given below
Inlet diffuser efficience =0.875
Compressor efficieny =0.790
Velocity of air at compressor entry =90m/s
Properties of air : γ =1.4, Cp =1.005 KJ/kg K

2) The diameter of the propeller of an aircraft is 2.5m; It flies at a speed of 500Kmph at an altitude of 8000m. For a flight to jet speed ratio of 0.75 determine (a) the flow rate of air through the propeller, (b) thrust produced (c) specific thrust, (d) specific impulse and (e) the thrust power.

3) 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

4) 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

- ✓ ***Fuel –air ratio, (2)***
- ✓ ***Compressor pressure ratio, (4)***
- ✓ ***Turbine pressure ratio, (4)***
- ✓ ***Exhaust nozzles pressure ratio ,and (4)***
- ✓ ***Mach number of exhaust jet (2)***

5) A ramjet engine operates at M=1.5 at an altitude of 6500m.The diameter of the inlet diffuser at entry is 50cm and the stagnation temperature at the nozzle entry is 1600K.The calorific value of the fuel used is 40MJ/Kg .The properties of the combustion gases are same as those of air (γ =1.4, R=287J/Kg K). The velocity of air at the diffuser exit is negligible
Calculate (a) the efficiency of the ideal cycle, (b) flight speed (c) air flow rate (d) diffuser pressure ratio (e) fuel –ratio (f)nozzle pressure ratio (g) nozzle jet Mach number (h) propulsive efficiency (i) and thrust. Assume the following values: η_D =0.90, η_B =0.98, η_j= 0.96.Stagnation pressure loss in the combustion chamber =0.002Po2.

6) A rocket flies at 10,080 Kmph with an effective exhaust jet velocity of 1400m/s and propellant flow rate of 5.0Kg/s .If the heat of reaction of the propellants is 6500KJ/Kg of the propellat mixture determine;

- ***a) Propulsion efficiency and propulsion power, (6)***
- ***b) Engine output and thermal efficiency ,and (6)***
- ***c) Overall efficiency. (4)***

7) Determine the maximum velocity of a rocket and the altitude attained from the following data:
Mass ratio =0.15

Burn out 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 .

8) A missile has a maximum flight speed to jet speed ratio of 0.2105 and specific impulse equal to 203.88 seconds .Determine for a burn out time of 8 seconds

- ***a) Effective jet velocity (4)***
- ***b) Mass ratio and propellant mass function (4)***
- ***c) Maximum flight speed, and (4)***
- ***d) Altitude gain during powered and coasting flights (4)***

9) 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/s²

10) With a neat sketches the principle of operation of:
1. ***turbo fan engine and (8)***
2. ***ram jet engine (8)***

11) Explain the construction and operation of a ramjet engine and derive an expression for the ideal efficiency.

12) Explain the construction and operation of a solid propellant rocket engine. Also name any four solid propellants.and state its advantages and disadvantages.

13) What are the advantages and disadvantages of liquid propellants compared to solid propellants.

14) Dicuss in detail the various propellants used in solid fuel rockets and liquid fuel system .Also sketch the propellant feed-system for a liquid propellant rocket motor.

15) Briefly explain the construction and working of :

- ***A. Rocket engine (6)***
- ***B. Ramjet engine (6)***
- ***C. Pulsejet engine (4)***

16) With the help of a neat sketch describe the working of a ramjet engine. Depict the various thermodynamic process occurring in it on h-s diagram. What is the effect of flight Mach number on its efficiency?

17) Explain with a neat sketch the working of a turbo-pump feed system used in a liquid propellant rocket?

<u>End</u>