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PART-A

UNIT-I BASIC CONCEPTS & ISENTROPIC FLOWS

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 .
Examples: Gases, vapour
Incompressible flow is that type of flow in which the density of the fluid constant . Examples: Liquids

2. What do you understand by adiabatic energy equations? Give the equations.
The adiabatic energy equation is the equation derived from the energy equation for a flow process with q = 0. The heat transfer during the process such as expansion in gases and vapours in turbines are negligibly small.

$h_1 + \frac{1}{2} c_1^2 = h_2 + \frac{1}{2} c_2^2$

3. 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

4. Derive the maximum fluid velocity.
The fluid velocity (c_{max}) corresponding the condition of h = o, C = C_{max}, is the maximum velocity that would be achieved by the fluid when it is accelerated to absolute zero temperature.

5. 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

6. Define the critical velocity of sound and prove that $c^* = \{2 C_p (T_o - T^*)^{1/2}$
The critical velocity of a fluid is its velocity at a Mach number of unity.

Mcritical = c*/a*; c* = a* = 1

7. Why is it more convenient to use M^* instead of M ?

It is convenient since at high fluid velocities M approaches unity and M is not proportional to the fluid velocity alone

8. Define nozzle

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

9.Define Diffuser:

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

10. 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.

UNIT II FLOW THROUGH DUCTS

1. What are the assumptions that are considered for the derivation of the equation of the fanno flow?

a. Free from work and heat transfer.
b. Free from area change
c. Free from gravitational effects

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. 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

5. What is Rayleigh ?

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

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

7. Define fanning's coefficient of skin friction
It is the ratio between wall shear stress and dynamic head it is denoted by 'f'

8. What are the three equation governing Fanno flow?
- Energy equation
- Continuity equation
- Equation of state

9. Give two practical examples for the Rayleigh flow.

Subsonic and supersonic heating process for air through the control volume

10. Under what conditions the assumption of Rayleigh flow is not valid in a heat exchanger.

Under stagnation conditions, the assumption of Rayleigh flow is not valid in a heat exchanger.

UNIT III NORMAL & OBLIQUE SHOCKS

1. What is the normal shock?
When the shock waves are right angles to the direction of flow and the rise in pressure is abrupt are called normal shock waves.

2.What is meant by normal shock as applied to compressible flow?
Compression wave front being normal to the direction of compressible fluid flow. It occurs when the flow is decelerating from supersonic flow. The fluid properties jump across the normal shock.

3.Shock waves cannot develop in subsonic flow? State the reason.
Shocks are introduced to increase the pressure and hence it is a deceleration process. Therefore, shocks are possible only when the fluid velocity is maximum. In a subsonic flow, the velocity of fluid is less then the critical velocity and hence deceleration is not possible. Thus, shock waves cannot develop in subsonic flow.

4.Define oblique shock where it occurs.
The shock wave which is inclined at an angle to the two dimensional flow direction is

called as oblique shock. When the flow is supersonic, the oblique shock occurs at the corner due to the turning of supersonic flow.

5.Give the difference between normal and oblique shock.
NORMAL SHOCK OBLIQUE SHOCK
(a) The shock waves are right angles to the direction of flow.
(b) May be treated as one dimensional analysis.
(a) The shock waves are inclined at an angle to the direction of flow.
(b) Oblique shock is two dimensional analysis.

6.What is Prandtl-Meyer relation? What its significance?
The fundamental relation between gas velocities before and after the normal shock and the critical velocity of sound is known as Prandtl-Meyer relation.
i.e., (i) c_x x $c_y = a^{*2}$
and (ii) M^*_x x M^* y = 1
it signifies the velocities (before and after the shock) with the critical velocity of sound and the product of mach numbers before and after the shock is unity.

7.How can you define strong shocks mathematically?
Shock strength is proportional to (M_x^2 – 1), strong shocks are a result of very high values of the upstream Mach number.

8.How can you determine the mach number of supersonic flows?
By having a pitot tube along with a wall lapping can be used to determine the Mach number of a supersonic stream. The introduction of the pitot tube produces a curved shock a little distance upstream of its mouth.

9. Define supersonic wind tunnels.
A supersonic wind tunnel consists of a nozzle, test section and the diffuser. Normal shocks have applications in supersonic wind tunnels where the diffusion of the supersonic flow after the test section takes place through a shock wave.

10.What do you understand by Oblique shock wave?

When the direction of flow is inclined at an oblique angle to the shock wave it is known as “oblique Shock Wave”.

UNIT-IV ROCKET PROPULSION

1.What is meant by a jet propulsion system?
It is the propulsion of a jet aircraft (or)other missiles by the reaction of jet coming out with high velocity. The jet propulsion in used when the oxygen is obtained from the surrounding atmosphere.

2.How will you classify propulsive engines?
The jet propulsion engines are classified into
i. Air breathing engines and
ii. Rocket engines which do not use atmospheric air.

3.What is the difference between shaft propulsion and jet propulsion?

SHAFT PROPULSION	**JET PROPULSION**
The power to the propeller is transmitted through a reduction gear	There is no reduction gear.
b) At higher altitude, the performance is poor. Hence it is suitable for lower altitudes.	b) Suitable for higher altitudes.
c) With increasing speeds and size of the aircrafts, the shaft propulsion engine becomes too complicated.	c) Construction is simpler.
d) Propulsive efficiency is less.	d) More.

4. List the different types of jet engines.
i. Turbo-jet
ii. Turpo-prop
engine, iii. Ram jet
engine,
iv. Pulse jet engines.

5.Define the principle of Ram jet engine.
The principle of jet engine is obtained from the application of Newton's law of motion. We know that when a fluid is accelerated, a force is required to produce this acceleration is the fluid and at the same time, there is an equal and opposite reaction force of the fluid on the engine is known as the **thrust**, and therefore the principle of jet propulsion is based on the reaction principle.

6.Give the components of a turbo jet.
Diffuser

Mechanicalcompressor,
Combustion chamber,
Turbine and
Exhaust nozzle.

7.What is ram effect?

When an aircraft flies with high velocity, the incoming air is compressed to high pressure without external work at the expense of velocity energy is known as "**ram effect**".

8.Give the difference between pulse jet and ram jet engine.

PULSE JET	**RAM JET**
a)Mechanical valve arrangements are used during combustion. b) The stagnation temperature at the diffuser exit is comparatively less.	a) Works without the aid of any mechanical device and needs no moving parts. b) Since the mach number in Ram jet engine is supersonic, the stagnation temperature is very high

9.Give the difference between turbojet and ram jet engine.

TURBO JET	**RAM JET**
a)Compressor and turbine are used. b) Lower thrust and propulsive efficiency at lower speeds. c) Construction cost is more	a) Compressor and turbine are not used but diffuser and nozzle are used. b) It provides high thrust per unit weight. c) In the absence of rotating machines, the construction is simple and cheap.

10. What is the difference between turbo prop engine and turbo jet engine**.**

TURBO – PROP	**TURBO - JET**
a) The specific fuel consumption based on thrust is low. b) Propulsive efficiency within the range of operation is higher. c) On account of higher thrust at low speeds the take-off role is short and requiring shorter runway. d) Use of centrifugal compressor stages increases the frontal area.	e) Higher weight per unit thrust.

a) TSFC is comparatively higher at lower speeds and altitudes.
b) Propulsive efficiency is low. c) Take – off role is longer and requiring longer run way.
d) Lower Frontal area
e) Lower weight per unit thrust.

UNIT-V SPACE PROPULSION

1. Give the difference between Jet propulsion and Rocket propulsion.

JET PROPULSION	ROCKET PROPULSION .
a) Oxygen is obtained from the surrounding atmosphere for combustion purposes. b) The jet consists of air plus combustion products. c) Mechanical devices are also used	a)The propulsion unit consists of its own oxygen supply for combustion purposes. b) Jet consists of the exhaust gases only. c) Mechanical devices are not used.

2. Define Rocket propulsion.
If the propulsion unit contains its own oxygen supply for combustion purposes, the system is known as "Rocket propulsion".

3.Define thrust for a rocket engine and how it is produced**.**
The force that propels the rocket at a given velocity is known as thrust. This is produced due to the change in momentum flux of the outgoing gases as well as the difference between the nozzle exit pressure and the ambient pressure.

4.What are the types of rocket engines?
Rocket engines are classified in the following manner.
a) On the basis of source of energy employed i. Chemical rockets,
ii. Solar rockets
iii. Nuclear rockets
and iv. Electrical rockets
b) On the basis of propellants used i. Liquid propellant
ii. Solid propellant
iii. Hybrid propellant rockets.

5.Compare solid and liquid propellant rockets.

SOLID PROPELLANT	LIQUID PROPELLANT
a) Solid fuels and oxidizers are used in rocket engines b) Generally stored in combustion chamber (both oxidizer and fuel). c) Burning in the combustion chamber is uncontrolled rate	a) Liquid fuels and oxidizers are used. b) Separate oxidizer and fuel tanks are used for storing purposes. c) Controlled rate

6.What are the types of liquid propellants used in rocket engines?
i. Mono
propellants ii.
Bi –
propellants

7.Give two liquid propellants.
Liquid fuels : Liquid hydrogen, UDMH, hydrazine
Solid fuels : Polymers, plastics and resin material

8.What is mono-propellants? Give example.
A liquid propellant which contains both the fuel and oxidizer in a single chemical is known as "mono propellant".
e.g., i. Hydrogen peroxide
ii. Hydrazine
iii Nitroglycerine
and iv
Nitromethane,
etc.

9.Name some oxidizers used in rockets

A liquid propellant which contains the fuel and oxidizer in separate units is known as bi-propellant. The commonly used bi-propellant combinations are:
OXIDIZER FUEL
a) Liquid oxygen
b) Hydrogen
peroxide c)
Nitrogen tetroxide

d) Nitric acid
a) Gasoline
b) Liquid
bydrogen c)
UDMH
d) Alcohol, ethanol

10.Name few advantages of liquid propellant rockets over solid propellant rockets.

i. Liquid propellant can be reused or recharged. Hence it is economical.
ii. Increase or decrease of speed is possible when it is in operation.
iii. Storing and transportation is easy as the fuel and oxidizer are kept separately. iv. Specific impulse is very high.

PART – B

UNIT-I BASIC CONCEPTS & ISENTROPIC FLOWS

1. Air (c_p=1.05kJ/kgk, γ=1.38) at p_1=3X105 N/m^2 and T_1= 500K flows with a velocity of 200m/s in a 0.3m diameter duct. Calculate: Mass flow rate, stagnation temperature, mach number and stagnation pressure values assuming the flow as compressible and incompressible respectively.

2. Explain for a convergent nozzle the variation of pressure and mach number when the back pressure is gradually lowered from stagnation pressure.
3. A conical diffuser has entry and exit1 diameters as 0.15m and 0.3m respectively. The pressure, temperature and velocity of air at entry are 0.96 bar, 340 K and 185 m/s respectively. Determine : Exit pressure, Exit velocity and Force exerted on the diffuser walls. Assume γ=1.4 and c_p =1.005 kJ/kgk.
4. (i) An aircraft is driven by propellers with a diameter of 4m. At what engine speed will the tips of the propellers reach sonic velocity if the air temperature is 288K?
   (ii) Derive the energy equation.
   $(a^2 / \gamma\text{-}1) + (c^2 /2) = (c^2_{max} /2) = (a_0^{\ 2} / \gamma\text{-}1) = h_0$
5. Explain the effect of Mach number on compressibility. Calculate the percentage deviation due to the assumption of incompressibility when Mach number is equal to 0.5 and specific heat ratio is 1.4.
6. Air flows through a nozzle which has inlet area of 10cm^2. If the air has a velocity of 80m/s, a temperature of 301K, and a pressure of 700kPa at the inlet section

and a pressure of 25kPa at the exit, find the mass flow rate through the nozzle and, assuming one dimensional isentropic flow, the velocity at the exit section of the nozzle.

7. 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 310K. The cross sectional area of the throat is 1000 cm^2 . Determine the following quantities for the tunnel for one dimentional isentropic flow:

(i) Pressures, temperatures and velocities at the throat and test sections. (ii) Area of cross section of the test section

(iii) Mass flow rate

(iv) Power required to drive the compressor.

8. Starting from the continuity equation derive the expression for the area variation in terms of mach number and velocity variation and hence obtain the shape (geometry) for both subsonic and supersonic nozzles and diffusers.

UNIT-II FLOW THROUGH DUCTS

1. (a) (i) Compare Fanno flow with Rayleigh Flow with suitable figures. (6) a. (ii) A pipe receives air at 3 bar pressure and 32°C temperature and discharges 10.23 kg/s of air at the exit with the Machnumber of0.65. The coefficient of friction of the pipe is 0.005. If the Mach number at entry is 0.2, determine the diameter and length of the pipe, pressure and temperature at the exit and stagnation pressure loss.

2. (a) 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.

3. A circular duct of 13.4 cm diameter is fed with air by a supersonic nozzle .The stagnation pressure at the nozzle entry and static pressures at sections 5D and 33 D downstream are 7.00, 0.245, and 0.5 bar resp. The nozzle throat diameter is 6.46 cm. Determine (a)Mach numbers at the two sections downstream of the nozzle (b) the mean value of the skin friction between the two sections.Assume isentropic flow up to the nozzle throat and adiabatic in the rest.

4. The friction factor for a 25 mm diameter 11.5 m long pipe is 0.004.The conditions of air at entry are p1= 2 bar, T1= 301 K, M1= 0.25.Determine the mass flow rate , and the pressure ,temperature and the mach number at exit.

5. Air enters a constant area duct at M_1=3,p1=1 atm, T_1=300K. Inside the dcut the heat added per unit mass is q = 3x10^5 J/kg. Calculate the flow properties M_2,p_2,T_2,T_{O2} and P_{02} at the exit.

6. Air at inlet temperature of 60^o 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 thr friction factor 4f = 0.005, determine the inlet Mach number,mass flow rate and the exit temperature.

7. 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.

8. Show that the upper and lower branches of a Fanno curve represent subsonic and supersonic flows resp. Prove that at the maximum entropy point Mach number is unity and all processes approach this point

UNIT III NORMAL & OBLIQUE SHOCKS

1. A gas (□ = 1.3) at 345 *p*1 = mbar, 350 *T*1 = K and M 1.5 1 = is to be isentropically expanded to 138 mbar. Determine
(i) Deflection angle,
(ii) Final Mach number and
(iii) The temperature of the gas.

2. (i) Derive the Rankine—Hugoniot expression for the normal shock wave and hence deduce the maximum possible density ratio for air across the normal shock wave.

3. A supersonic nozzle is delivering air as supersonic parallel jet at 0.1 bar pressure at the exit. Due to flow resistance a normal shock wave is encountered at the exit. The downstream flow after normal shock wave is found to have Mach number 0.7011. Calculate the percentage change in Mach Number, and pressure across the shock wave. Also calculate

the reservoir pressure and exit to throat area ratio required to operate the nozzle.

4. If air at 1 bar and 310 K, moving at M = 3, encounters a flow deflection of 10°, calculate the percentage change in Mach number and pressure and wave angle. If subsequent second flow deflection also brings about the same percentage change in pressure, find that flow deflection angle.

5. A supersonic diffuser for air has an area ratio of 0.416 with an inlet Mach number of 2.4. 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 pressure ratio across the diffuser.

6. A gas(γ = 1.3, R = 0.287kJ/kg K at p1= 1 bar, T 1= 400 J enters a 30 cm diameter duct at a Mach number at a Mach number of 2 .A normal shock occurs at a Mach number of 1.5 and the exit Mach number is 1.0.If the mean value of the friction factor is 0.003 determine.

(a)Length of the duct upstream and downstream of the shock wave

(b)Mass flow rate of the gas and

(c)Change of entropy upstream of the shock ,across and the downstream of the shock

8. Staritng from the energy equations prove for the flow through a normal shock obtain the following relations: $CxCy = a*^2$.

$Mx^* My^* = 1$

<u>UNIT –IV ROCKET PROPULSION</u>

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. 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.

5. (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.

6. 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

UNIT-V SPACE PROPULSION

1(i) Explain the working of Multi-stage rocket with their merits and demerits.
(ii) Describe the importance of characteristic velocity. A weather satellite is to be launched at an altitude of 500 km above the earth surface. Determine the required orbital velocity and derive the equation used.

2 A gas ($\gamma = 1.3$) at 345 $p1$ = mbar, 350 $T1$ = K and M 1.5 1 = is to be isentropically expanded to 138 mbar. Determine
(i) Deflection angle,
(ii) Final Mach number and
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3. Explain the working of Multi-stage rocket with their merits and demerits.

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

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