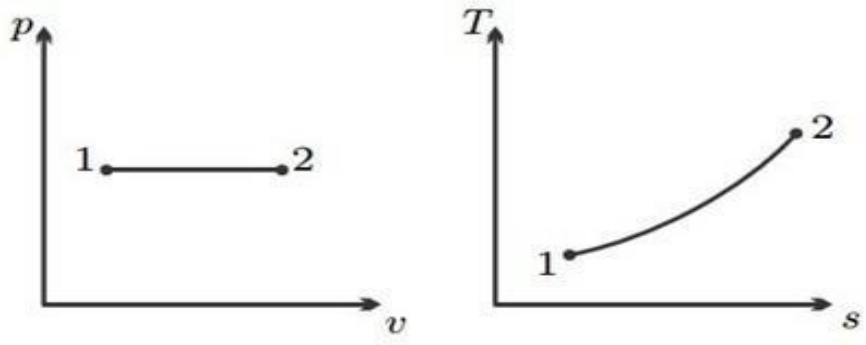
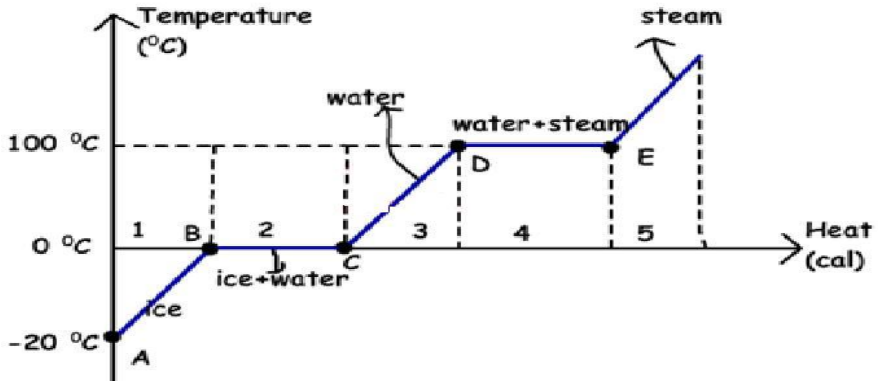
Important Instructions to examiners:

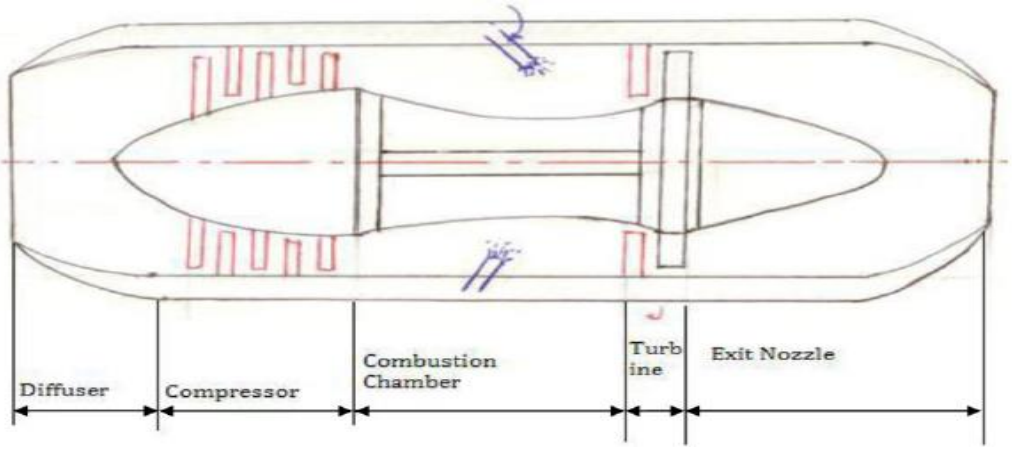
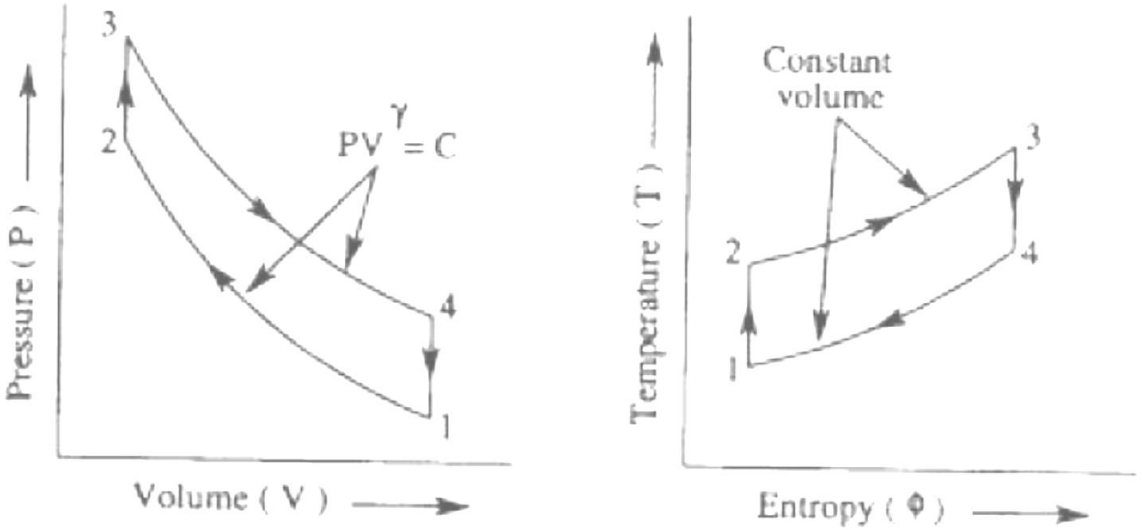
1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more Importance (Not applicable for subject English and Communication Skills.
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

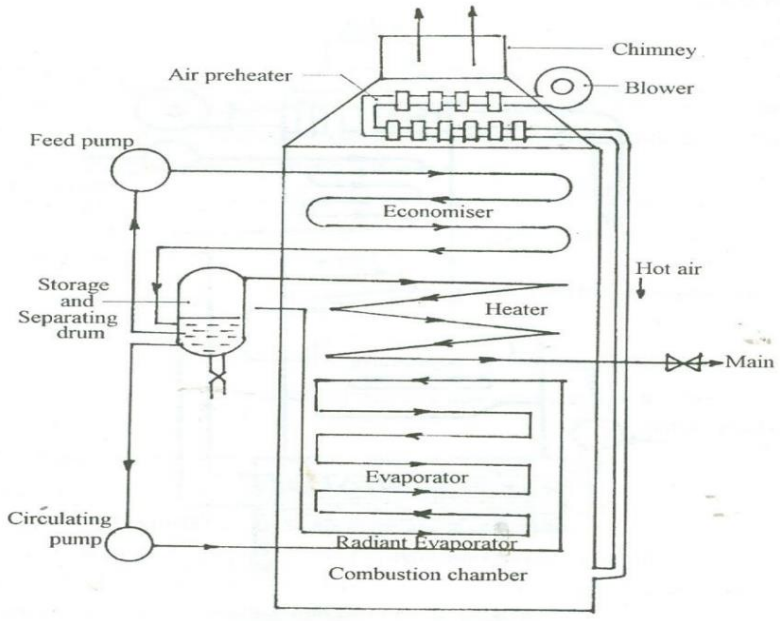
Q.1.		Attempt any SIX of the following:	12 Marks
a)	i)	**Plot P-V & T-S Diagram for isobaric process**	2 marks
	Sol.	 **P-V Diagram** **T-S Diagram**	01 mark each
	ii)	**Define Dryness fraction & Degree of superheat**	2marks
	Sol.	**i) Dryness fraction:** Dryness fraction is defined ratio of the mass of the dry steam present in the total mass of steam. Or Dryness fraction is ratio of the mass of actual dry steam to the mass of wet steam. Therefore, x = ms/ (ms + mw) Where **ms and mw** are the masses of steam and **(ms + mw)** masses of water in the mixture **ii) Degree of superheat:** It is difference between the temperature of Superheated Steam and the saturation temperature correspondingly to given pressure is said to be Degree of Superheat.	01 mark 01 mark
	iii)	**Define: 1) Free Air Delivered 2) Volumetric Efficiency of compressor**	2 marks
	Sol.	**Free Air Delivered (FAD):** It is the actual volume of air delivered by the Compressor when reduced to NTP.	01 mark

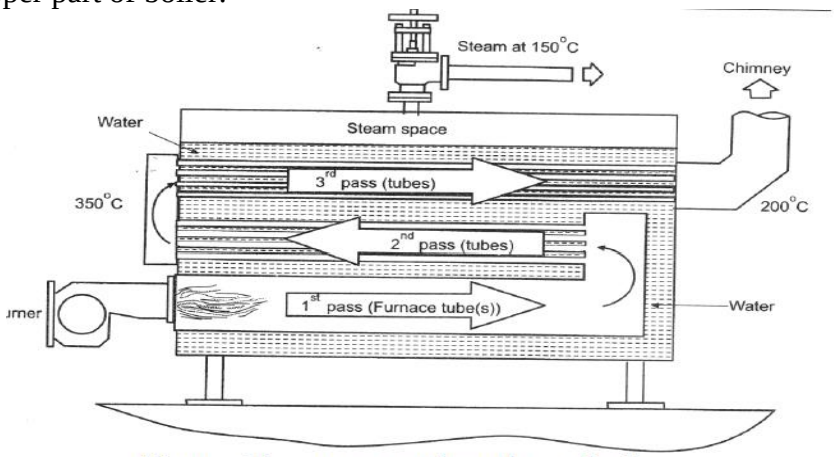
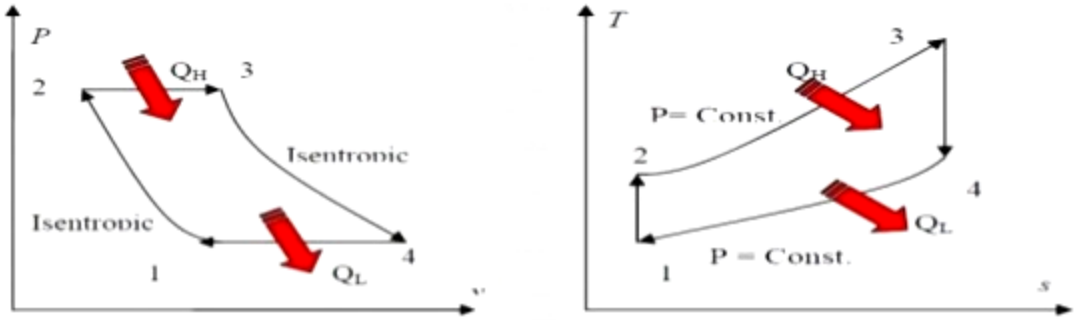
		Volumetric efficiency of compressor: It is the ratio of free air delivered per stroke to the swept volume of the piston.	**01 mark**
	iv)	**Write the classification of gas turbines**	**2 marks**
	Sol.	**Answer: Classification of gas turbine: (** ***Any two points: 1 Mark each)*** **1. According to the path of the working substance:** i) Open cycle gas turbine ii) Close cycle gas turbine iii) Semi-closed cycle gas turbine **2. According to process of combustion:** i) Constant pressure gas turbine ii) Constant volume gas turbine **3. According to direction of flow:** i) Radial flow ii) Axial flow iii) Tangential flow 4. According to principle of action of expanding gases: i) Impulse turbine ii) Reaction turbine **5. According to their usage:** i) Constant speed ii) Variable speed	**02 marks**
	v)	**List two renewable & non-renewable sources of energy**	**2 marks**
	Sol.	**Renewable sources of energy : (Any Two)** **1)** Solar power, 2) Hydro-electric power, 3) Wind power, 4)Tidal power, 5) Ocean wave power, 6) Geothermal power, 7) Ocean thermal power, 8) Biomass, 9) Bio-fuel etc. **Non renewable sources of energy : (Any Two)** 1)Coal, 2) natural gas, 3) oil, 4) firewood , 5) Petrol , 6) Kerosene, 7) Diesel etc	**01 mark** **01 mark**
	vi)	**State any two advantages & disadvantages of CNG**	**2 marks**
	Sol.	**Advantages of CNG : (Any Two)** 1) It is a very cheap fuel	**01 mark**

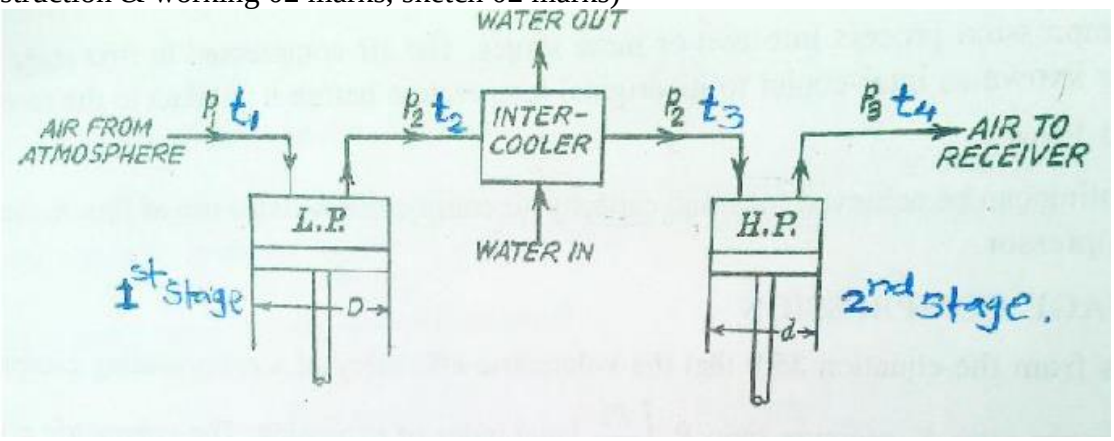
		2) It's environmentally friendly 3) It's less costly compared to other fossil fuel energy sources 4) Minimizes dependency on foreign oil **Disadvantages of CNG: (Any Two)** 1) The More storage space is required 2) Its highly combustible 3) Non-renewable energy source	**01 mark**
	vii)	**List the properties of liquid fuels**	**2 marks**
	Sol.	**Answer: (½ Mark each property)(any four)** 1. High calorific value 2. Moderate ignition temperature 3. Low moisture content 4. Low NOx combustible matter 5. Moderate velocity of combustion 6. Products of combustion not harmful 7. Low cost 8. Easy to transport 9. Combustion should be controllable 10. No spontaneous combustion 11. Low storage cost 12. Should burn in air with efficiency.	**2marks**
	viii)	**State two applications of compressed air in automobile workshop**	**2 Marks**
	Sol.	**Application of compressed air:** *(Any two)* 1. Operating tools in factories 2. Operating drills and hammers in road building 3. Starting diesel engines 4. Operating brakes on buses, trucks and trains 5. Spray painting 6. Excavating **7.** To clean the large workshops	**02 marks**
b)		**Attempt any <u>TWO</u> of the following:**	**08 Marks**
	i)	**Explain the terms related to the thermodynamics 1) Work done 2) Change in internal energy 3) Change in Enthalpy**	**04**
	Sol.	**1)Work Done:** Work done is a product of pressure & difference between volume .Work done by the system is considered as +ve. e.g : an expansion of gas in the cylinder-piston assembly pushing a piston and work done on the system is –ve. e,g: Compression of gas by piston. For const. volume process W .D = 0 For const. pressure process W.D = m.R.(T2-T1) For Const.Temp process =W.D = P1V1 log (p1/p2)	**1 mark**

		2) Change in internal energy: The change in internal energy is equal to heat added to the system minus work done by the system. ▲U = Q – W work done by a system decreases the internal energy of the system For const. volume process , du = m.Cv.(T2-T1) For const. pressure process ,du = m.Cv.(T2-T1) For Const. Temp process, du = 0 **3) Change in Enthalpy:** it is the amount of heat absorbed or lost by system during a process at const. pressure dH= H2-H1 For const. volume process , dH = m.Cp.(T2-T1) For const. pressure process , dH = m.Cp.(T2-T1) For Const. Temp process , dH = 0	**1 mark** **2 mark**
	ii)	**State and explain different phases in formation of steam**	**4 marks**
	Sol.	**Answer: (Explanation 2 Marks, Figure 2 Marks)** **Different phases of Formation of steam** Consider formation of steam from ice at -20^0 C **i)Solid phase-** When the heat is added in ice which is at -20^{0}C, the temperature of ice increases to 0^{0}C as shown in figure by process A-B.in this stage solid phase exists. **ii) Solid+ Liquid phase-** The point B is called is saturation point when heat is further added this heat cannot increase the temperature but ice is converted into water that means phase transformation takes place, thus in-between region B-C, solid and liquid phase exists. **iii) Liquid phase**- From point C further heat is added up to 100^0 C, in this region no phase change takes place, there is only liquid phase present. **iv) Liquid+ Vapour phase**- Point D is saturation point; further addition of heat will not increase the temperature but liquid phase change into vapours phase. In this region liquid and vapour is present. **v) Vapour phase**- Point E is called as saturation point, further adding heat increase the temperature of steam which is called as superheating and in this region only vapour is present.  	**02 marks** **02 marks**

	iii)	**Explain with neat sketch turbojet engine**	**4 marks**
	Sol.	**Answer:(Figure-02 marks, working- 02 marks)** **Working:** Turbo-jet engine consists of diffuser, compressor, combustion chamber, turbine and nozzle. As engine starts air enters in the diffuser where it slows down and part of kinetic energy is converted into pressure energy. The air enters into the compressor and gets compressed. This compressed air enters into the combustion chamber where it is mixed with the fuel. The combustion takes place at constant pressure. The hot gases enter gas turbine where partial expansion takes place. The power produced is just sufficient to drive the compressor. The hot gases are then expanded in nozzle and very high velocity jet is produced which gives forward motion to the air craft.  **Fig. Turbojet Engine**	**02 marks** **02 marks**
Q.2.		**Attempt any FOUR of the following:**	**16 Marks**
	a)	**Represent otto cycle on PV & TS Diagram and write equation for air standard efficiency.**	**04**
	Sol.	**Answer:Otto cycle on P-V and T-S diagram (2 Marks)**  	**02 marks**

		Equation for air standard efficiency of otto Cycle (2 Marks) $\eta = 1 - \frac{1}{r^{\gamma-1}}$ Where, r = compression ratio γ = specific heat ratio	**02 marks**
	b)	**Explain the different modes of heat transfer**	**4 marks**
	Sol.	**Heat Transfer takes place by three different modes :** **1) conduction , 2) convection and 3) radiation** 1. **Conduction-** It is the mode of heat transfer from one part of substance to another part of same substance or one substance to another without displacement of molecules or due to the vibrations of molecules. **Example**-Heat transfer in metal rod. 2. **Convection:** It is the mode of heat transfer from one part of substance to another part of same substance or one substance to another with displacement of molecules or due to the fluid flowing. **Example:** Heat flow from boiler shell to water. 3. **Radiation:** It is the transfer of heat through space or matter. For Radiation there is no need of medium as like convection and conduction. It passes through vacuum in the form of electromagnetic waves. **Example:** The heat energy receives from sun to the earth surface.	**01** **01** **01** **01**
	c)	**Sketch Lamont boiler with labeling**	**4 marks**
	Sol.	 **Fig. Lamont Boiler**	**02 mark Sketch** **02 mark Label**

	d)	**Explain working of three pass packed type boiler**	**4 marks**
	Sol.	**Answer: (description 02marks and sketch 02marks)** **Working of three pass packaged type boiler:** In this boiler pulverized coal is used as a fuel. Hot gases are produced by burning coal. The flue gases coming from first pass or combustion chamber passes through number of tubes in different passes. Tubes are surrounded by water. Heat released by flue gases is absorbed by water and gets converted into the steam. After passing through all tubes flue gases exhausted to atmosphere through chimney and steam is collected in upper part of boiler.  Figure. Three pass packaged type boiler	**02 marks** **02 marks**
	e)	**What are the factors affecting volumetric efficiency of air compressor**	**4 Marks**
	Sol.	**Factors affecting volumetric efficiency of reciprocating air compressor: (Any 4)** 1) Clearance Volume 2) Restricted passage and leakage at inlet valves 3) Speed of rotation 4) Piston ring leakages 5) If fresh air comes in contact with hot wall, it get expanded, which decreases the charge taken in therefore volumetric efficiency decreases.	**01 mark Each**
	f)	**Explain construction and working of closed cycled gas turbine with P.V & T.S diagram**	**4 marks**
	Sol.	**Closed cycle gas turbine:(PV & TS diagram 02marks, construction and working 02marks)**  **PV and TS Diagram for Closed cycle gas turbine**	**PV & TS 02 mark**

		Construction & working : In above figure shows a closed cycle gas turbine which consists of compressor, heating chamber gas turbine which drives the generator, compressor and a cooling chamber. In this turbine air is compressed isentropically and then passed into heating chamber. The compressed air is heated with the help of some external source and made to flow over turbine blades. The gas while flowing over the blades gets expand from the turbine gas is passed to cooling chamber where it is cooled at constant pressure with the help of circulating air is circulated through compressor.	**(Const+ Working)** **02 marks**
Q.3.		**Attempt any FOUR of the following:**	**16 Marks**
	a)	**Explain construction and working of two stage air compressors.**	**4 Marks**
Sol.		(construction & working 02 marks, sketch 02 marks)  Fig. Two stages reciprocating air compressor **Construction and Working :** It consists of two cylinders (L.P. and H.P.) with water cooled intercooler and air receiver. First of all fresh air is sucked from atmosphere in low pressure (L.P) cylinder during its suction stroke at inlet pressure P1 and temp T1.The air after compression in L,P cylinder (I st stage) from 1 to 2 is delivered to intercooler at pressure P2 and temp T2.Now air is cooled in intercooler from 2 to3 at constant pressure P2 and from temp T2 to T3.After that air is sucked in high pressure (H.P) cylinder during its suction stroke. Finally air after further compression in H.P. cylinder (ie second stage) from 3 to 4 is delivered by the compressor at pressure P3 & Temp T4.	**Sketch 2 Mark** **Const+ working 02 Mark**
	b)	**Describe working of turboprop engine**	**4 marks**
Sol.		**Turboprop Engine: (working : 2 marks , Sketch 2 Marks)** Figure shows a turboprop system employed in aircrafts. Here the expansion of gases takes place partly in turbine 80% and partly 20% in the nozzle. The power developed by the turbine is consumed in running the compressor and the propeller. The propeller and jet produced by the nozzle give forward motion to the aircraft. The turboprop entails the advantages of turbojet (i.e. low specific weight and simplicity in design) and propeller (i.e. high power for take-off and high propulsion efficiency at speeds below 600km/h). The overall efficiency of the turbo prop is improved by providing the diffuser before the compressor as shown. The pressure rise takes place in the diffuser. This pressure rise take due to conversion of kinetic energy of the incoming air (equal to aircraft velocity) into pressure energy by diffuser. This type of	**02 Marks**

compression is known as "ram effect".

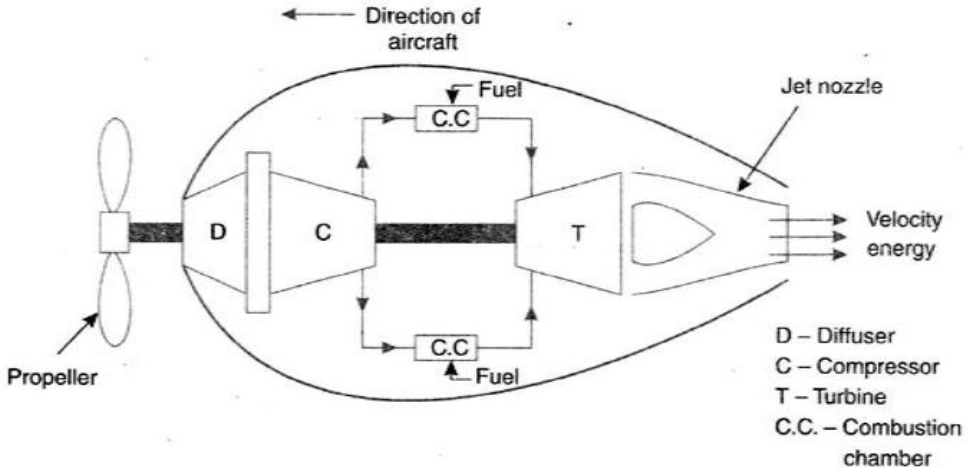


Fig. Turboprop

02 Marks

c) Sketch gas turbine power plant and label the major components. **4 Marks**

Sol. (sketch 02 marks and labelling 02 marks)

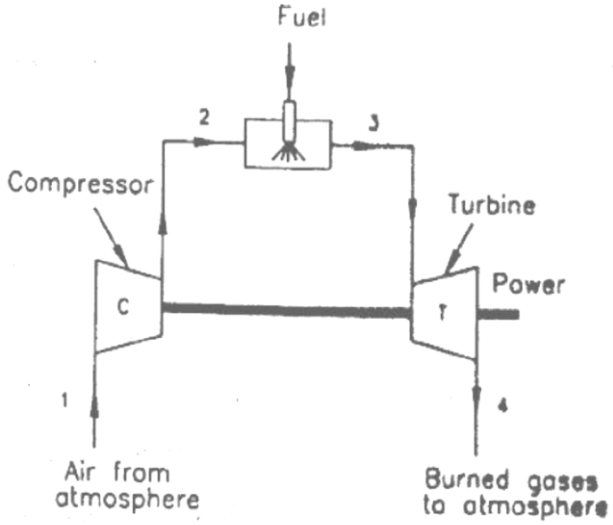


Fig. Open Cycle Gas Turbine

OR

02 Marks for Sketch

02 Marks for label.

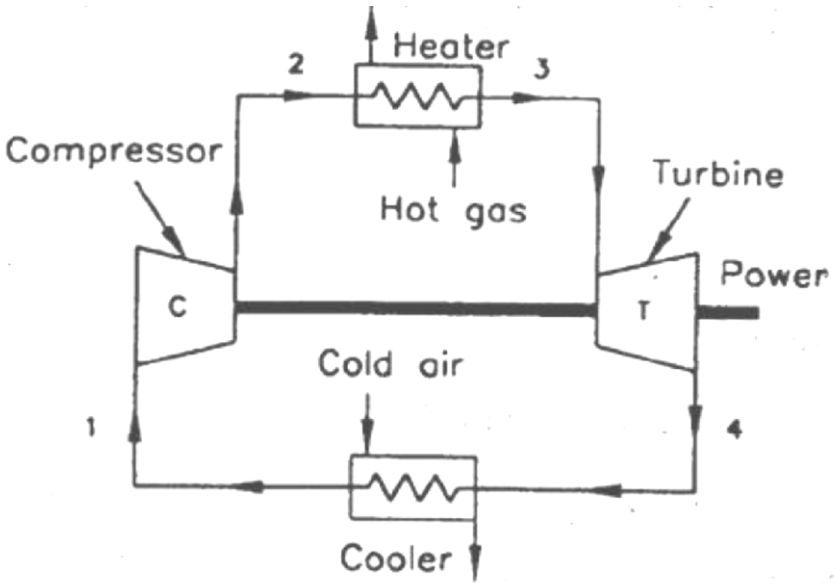
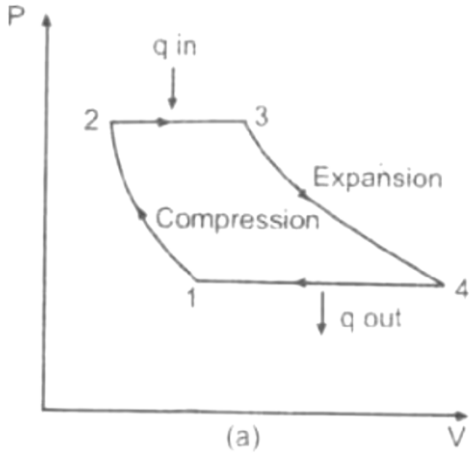


Fig. Closed cycle gas turbine

	d)	**Explain Bryton cycle with the help of PV diagram.**	**4 marks**
Sol.		**Bryton Cycle**  The Brayton cycle is a theoretical cycle for simple gas turbine. This cycle consists of two isentropic and two constant pressure processes. Above Fig. Shows the Brayton cycle on P-V coordinates. The cycle is similar to the Diesel cycle in compression and heat addition. The isentropic expansion of the Diesel cycle is further extended followed by constant pressure heat rejection. Brayton cycle is having following processes: Process1-2: Isentropic compression process Process 2-3 : heat addition process at Constant pressure Process 3-4: Isentropic expansion process Process 4-1: Heat rejection at constant pressure The thermal efficiency is given by,	**Diagram 2 Marks** **Explain 2 Marks**

$$\eta_{th} = \frac{Heat\ Added - Heat\ Rejected}{Heat\ Added}$$

$$\eta_{th} = \frac{mC_p(T_3 - T_2) - mC_p(T_4 - T_1)}{mC_p(T_3 - T_2)} = 1 - \frac{(T_4 - T_1)}{(T_3 - T_2)}$$

OR

$$\eta_{th} = 1 - \frac{1}{(r_p)^{\frac{(\gamma-1)}{\gamma}}}$$

e) Compare ultimate analysis and proximate analysis.

Sol.

Ultimate Analysis: Ultimate analysis is complete breakdown of coal into chemical constituents. This analysis is important for large scale trials. It serves the basis
For calculation of the amount of air required for complete combustion of 1kg of fuel. It gives percentage content on mass basis of carbon, hydrogen, oxygen, Sulphur and ash. We are able to calculate the Calorific value of coal. **02 marks**

Proximate Analysis: Proximate analysis is complete breakdown of coal into Physical constituents without knowledge of analytical chemistry. This analysis made by means of a chemical balance &temperature control Furnace. The component in the analysis is fixed carbon volatile matter, moisture& ash. This is used to calculate the heating value of coal. **02 marks**

f) A sample of coal has the following composition by mass carbon 75%, hydrogen 6%,oxygen 8%,nitrogen 2.5%, sulpher 1.5 % and ash 7.1%. Calculate higher and lower calorific of per kg.

Sol.

Composition of coal on mass basis.
Carbon (C) = 75% = 0.75
Hydrogen (H_2) = 6% =0.06
Oxygen (O_2) = 8% = 0.08
Nitrogen (N) = 2.5 % = 0.025
Sulphur(s)=1.5%=0.015
Ash = 7.1% = 0.071
Dulong‟s formula.

1) H.C.V. of Coal = 33800 C+144000 (H_2 - O_2/8) +9270 S KJ/Kg.
= 33800 x 0.75 + 144000 (0.06 – 0.08/8) + 9270 x 0.015
= 25350 + 7200 + 139.05
H.C.V. = 32689.05 KJ/Kg. **02 marks**

2) L.C.V. of Coal = H.C.V. – 9 H2 x 2466 KJ/Kg.
= 32689.05 – 9 x (0.06) x 2466
= 32689.05 – 1331.64
L.C.V. = 31357.41 KJ/Kg. **02 marks**

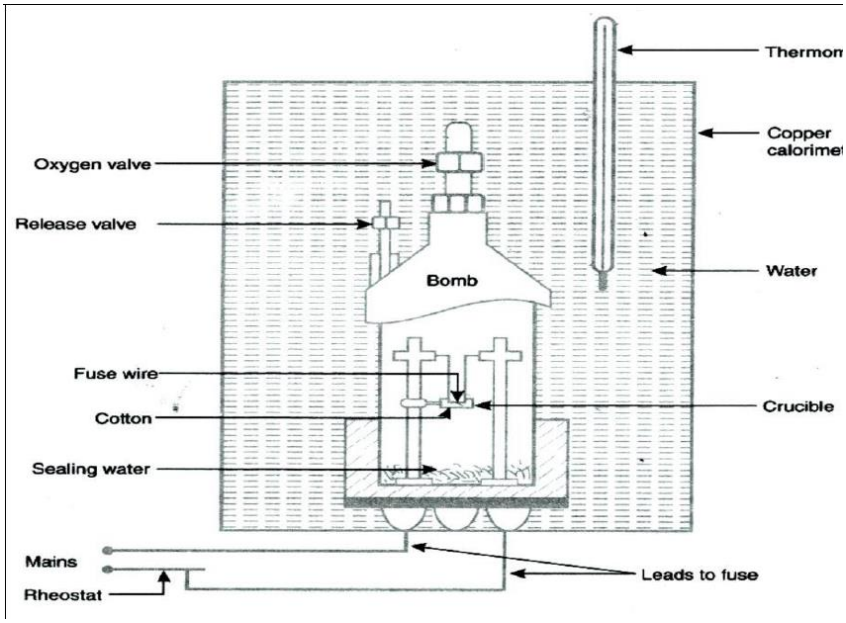
Q.4.		Attempt any Two of the following:	16 Marks
	a)	**Differentiate between conventional and non-conventional energy sources**	08

Sol. **(Any Eight points, 1 marks each)** — **08 marks**

Sr. No.	conventional source of energy	Non-conventional source of energy
1	These are non-renewable energy sources	These are renewable energy sources
2	Creates pollution	Does not creates pollution
3	It is not clean energy source	It is clean energy source
4	Harnessing cost is more	Harnessing cost is less
5	Efficiency is more	Efficiency is less
6	Fuel is required	Fuel is not required
7	Exhaustible energy source	Non-Exhaustible energy source
8	Affects on ozone layer	Does not affects on ozone layer
9	Ex.-Petrol, Diesel, Kerosene etc.	Ex.-Solar, Wind, Tidal, Geothermal, Biomass, Etc.

	b)	**Describe with neat sketch construction and working of Bomb calorimeter. Write Dulong's formula and state its use.**	8 marks

Sol.



Sketch 02 marks

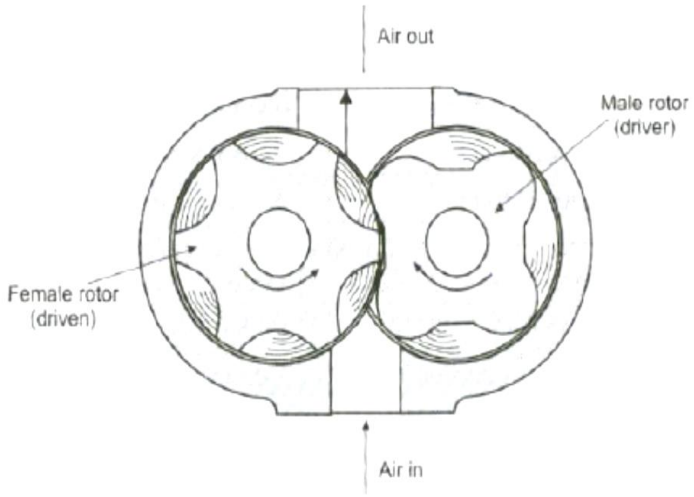
The calorific valve of solid and liquid fuels is determined in the laboratory by "Bomb calorimeter". It is so named shape resembles that of bomb. Fig. shows the schematic sketch of bomb calorimeter.

Construction & working: The calorimeter is made of austenitic steel which provides considerable resistant to corrosion and enables it to withstand high pressure. In the calorimeter use of a strong cylindrical bomb in which combustion occurs. The bomb has two values at the top. One supplies oxygen to the bomb and other releases the exhaust gases. A crucible in which

Const & working 04 marks

		a weighed quantity of fuel sample is burnt is arranged between the two electrodes as shown in fig. The calorimeter is fitted with water jacket which surrounds the bomb To reduce the losses due to radiation calorimeter is further provided with a jacket of water and air. A stirrer for keeping the temperature of water uniform and a thermometer the temperature up to accuracy of0.001^0 C is fitted through the lid of the calorimeter. The heat released by the fuel on combustion is absorbed by the surrounding water and the calorimeter. From the above data the calorific value of the fuel can be found. **Dulong's formula** used to calculate the theoretical calorific value of fuel if ultimate analysis available and the calorific value of elementary combustibles are known. Theoretical calorific Value of fuel =33800 C + 144500 ($H_2 - \frac{O_2}{8}$) + 9300 S kJ/kg Where C, H_2 O_2 & S repents the mass of carbon, hydrogen, oxygen and sulfur in kJ/Kg	**02**
	c)	**i)Write Advantages and disadvantages of Tidal power plant** **ii) write advantages of liquid fuels over solid fuels**	**8 marks**
Sol.		**i) Advantages and disadvantages of Tidal power plant** **Advantages: (Any 2 points)** 1. This source of energy doesn't generate waste or harmful emissions. 2. It is an inexpensive source of power. 3. As tides are predictable, the power generated from them is more reliable than sources like wind energy. 4. The structure built to tap tidal energy can also act as a protective barrier for the coastline during a storm. 5. The fact that it is a renewable source of energy also works in its favor. 6. Utilization of tidal power will lessen the use of nuclear power, which is costly and involves a lot of risk. **Disadvantages : (Any 2 points)** 1. These structures block the water outlet affecting salinity levels of the water, as there is less exchange of water between the inland water source and sea. 2. Marine life is threatened by the construction of tidal turbines. 3. These structures block the migratory route of species like Salmon, which migrate upstream to lay eggs. 4. The fish in the area where these turbines are located die due to the exposure to turbines. 5. Although, it is an inexpensive source of power, the initial investment is very high. **ii) Advantages of liquid fuels over solid fuels. (any four)** 1. Require less space for storage. 2. Higher calorific value. 3. Easy control of consumption. 4. Cleanliness. 5. No ash produced. 6. Non-deterioration of the oil in storage.	**02 marks** **02 Marks** **04 marks**

Q.5.		Attempt any TWO of the following:	16 Marks
	a)	**Derive the relation between P ,V &T for adiabatic process.**	08
	Sol.	**Relation between P, V and T during Adiabatic Process: Pressure (P) , Volume (V) & Temperature (T) relation for adiabatic process:** For adiabatic Process, $PV^{\gamma} = C$ — 01 Mark $P_1 v_1^{\gamma} = P_2 v_2^{\gamma}$ $\frac{P_2}{P_1} = (\frac{V_1}{V_2})^{\gamma}$ ..... (1) — 01 mark From general gas equation $\frac{PV}{T} = C$ $\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$ — 01 Mark $\frac{T_2}{T_1} = \frac{P_2 V_2}{P_1 V_1}$ .....(2) — 01 mark From (1) $\frac{V_2}{V_1} = (\frac{P_1}{P_2})^{1/\gamma}$ ..... (3) — 01 mark Put equation (3) into equation (2) $\frac{T_2}{T_1} = \frac{P_2}{P_1} (\frac{P_1}{P_2})^{1/\gamma}$ $\frac{T_2}{T_1} = (\frac{P_2}{P_1})^{\frac{\gamma-1}{\gamma}}$ $\frac{P_2}{P_1} = (\frac{T_2}{T_1})^{\frac{\gamma}{\gamma-1}}$ .....(4) — 01 Mark From equation (1) & (4) $\frac{P_2}{P_1} = (\frac{V_1}{V_2})^{\gamma} = (\frac{T_2}{T_1})^{\frac{\gamma}{\gamma-1}}$ — 01 Mark $\boxed{\frac{P_2}{P_1} = (\frac{V_1}{V_2})^{\gamma} = (\frac{T_2}{T_1})^{\frac{\gamma}{\gamma-1}}}$ — 01 Mark	
	b)	**Steam enters an engine at a pressure of 12 bar with 67^0 C of superheat. It is exhausted at a pressure of 0.15 bar and 0.95 dry. Find the drop of enthalpy in steam. Assume Cp= 2 KJ/Kg.K**	8 marks
	Sol.	**Given Data**: Pressure of steam P= 12 Bar , Dryness Fraction x= 0.95 , Cp =2 KJ/Kg.K 1)At P= 12 bar given values	

		h_f= 798.4 KJ/Kg h_{fg} = 1984.3. KJ/Kg h_1= hg+ Cp(Tsup –Tsat) h_1= 2782.7 + 2 (67) **=2916.7 KJ/Kg** 2)At P= 0.15 bar given values h_f= 226 KJ/Kg h_{fg} = 2373.2 KJ/Kg h_2= h_f + x h_{fg} = 226+ 0.95 (2373.2) **=2480.5 KJ/Kg** 3) change in Enthalpy dh= h_2 – h_1 = 2916.7 - 2480.5 =436.2 KJ/Kg.	**03marks** **03 Marks** **02 Marks**
	c)	**Explain the construction and working of screw compressor. Differentiate between centrifugal and axial flow compressor**	**8 Marks**
	Sol.	**Screw compressor:**  Fig. Screw Compressor **Construction:** It consists of two mutually engaged helical grooved rotors which are suitably housed in a casing. Out of two rotors male rotor is driver and female rotor is a driven. Male rotor has four lobes and female rotor as six flutes. **Working:** During rotation of rotor, air enters and takes space between male and female rotor. This air traps and moves axially and radically with rotation of rotors and gets compressed due to volume reduction. Then this air discharged from upward direction. Speed of rotors is different due to different number of lobes and flutes. It handles 3.5 to 300 m3/min and maximum pressure ratio of 20. This system requires lubrication. This compressor is noisy In	**02** **02**

operation. Used in refrigeration industry.

Differentiate between centrifugal and axial flow compressor

(Any Four)

Sr. No.	Centrifugal compressor	Axial Flow Compressor
1	Flow is perpendicular to axis of compressor.	Flow of air is parallel to the axis of compressor.
2	Low manufacturing and running cost.	High manufacturing and running cost.
3	Requires low starting torque.	Requires high starting torque.
4	Not suitable for multi-staging.	Suitable for multi-staging.
5	Requires large frontal area for given rate of flow.	Requires less frontal area for given rate of flow.
6	Pressure ratio per stage is4:1.	Pressure ratio is 1.1 to 1.2
7	Isentropic efficiency is 70%	Isentropic efficiency is 80%
8	Used in supercharging I.C. engine and for refrigerants and industrial gases.	Used universally with large gas turbine.

4 marks (1 mark each)

Q.6. Attempt any FOUR of the following: 12 Marks

a) Derive the equation for air standard efficiency of Carnot cycle. 4 marks

Sol.

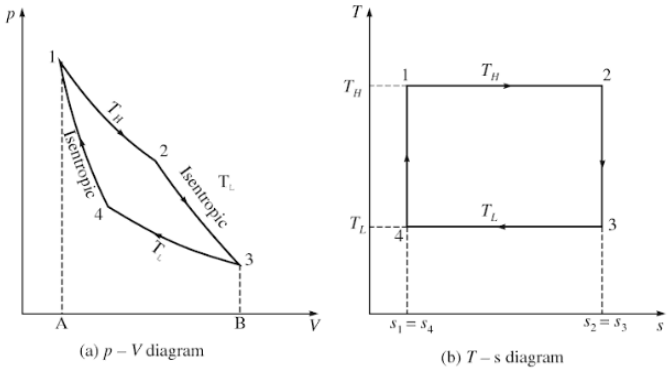


Fig. Carnot Cycle

1 marks

Thermal efficiency of a cycle,

$$\eta = \frac{\text{work done}}{\text{heat supplied}} = \frac{\text{heat supplied–heat rejected}}{\text{heat supplied}} \qquad (2.1)$$

½ marks

In the Carnot cycle, there is no heat transfer during the processes 2–3 and 4–1 as they are reversible adiabatic processes. Heat is supplied only during the constant temperature process 1–2 and rejected during the constant temperature process 3–4.

∴ Heat supplied, $$Q_s = m R T_H \ln \frac{V_2}{V_1} \qquad (2.2)$$

½ marks

and heat rejected, $$Q_R = m R T_L \ln \frac{V_3}{V_4} \qquad (2.3)$$

½ marks

From isentropic processes 2–3 and 4–1,

$$\frac{T_2}{T_3}=\left(\frac{V_3}{V_2}\right)^{\gamma-1} \quad \text{and} \quad \frac{T_1}{T_4}=\left(\frac{V_4}{V_1}\right)^{\gamma-1}$$

½ mark

or $$\frac{T_H}{T_L}=\left(\frac{V_3}{V_2}\right)^{\gamma-1} \quad \text{and} \quad \frac{T_H}{T_L}=\left(\frac{V_4}{V_1}\right)^{\gamma-1}$$

$\therefore$ $$\frac{V_3}{V_2}=\frac{V_4}{V_1}$$

or $$\frac{V_3}{V_4}=\frac{V_2}{V_1} \qquad (2.4)$$

$\therefore$ $$\eta=\frac{Q_s-Q_R}{Q_s}=\frac{mR(T_H-T_L)\ln(V_2/V_1)}{mRT_H\ln(V_2/V_1)}=\frac{T_H-T_L}{T_H}=1-\frac{T_L}{T_H} \qquad (2.5)$$

01mark

OR

$$\eta=\frac{T_2-T_1}{T_2}=1-\frac{T_1}{T_2}$$

Where, T_H = T2= temperature of source
T_L= T1= temperature of sink

b) Enlist sources of air leakage in condenser and define condenser efficiency. **4 marks**

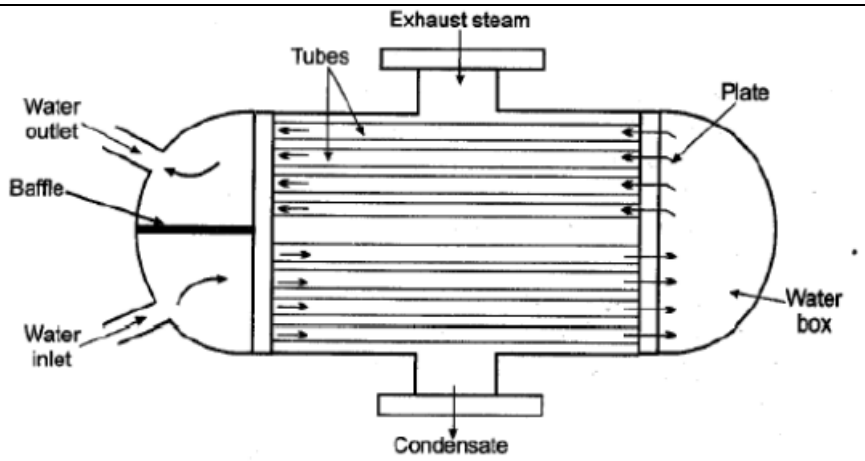
Sol. **Sources of air leakages**: **(2 Points)**

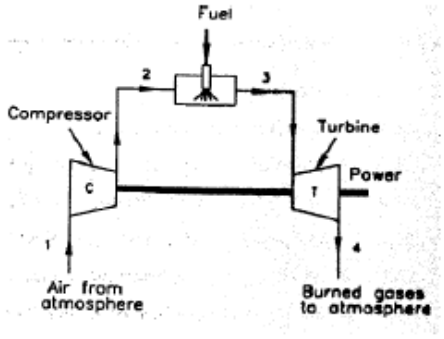
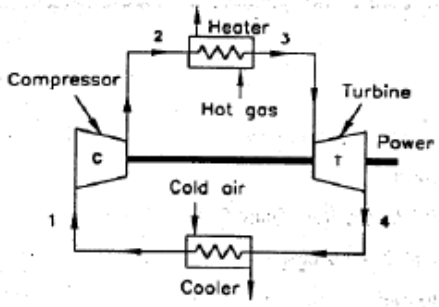
02 Marks

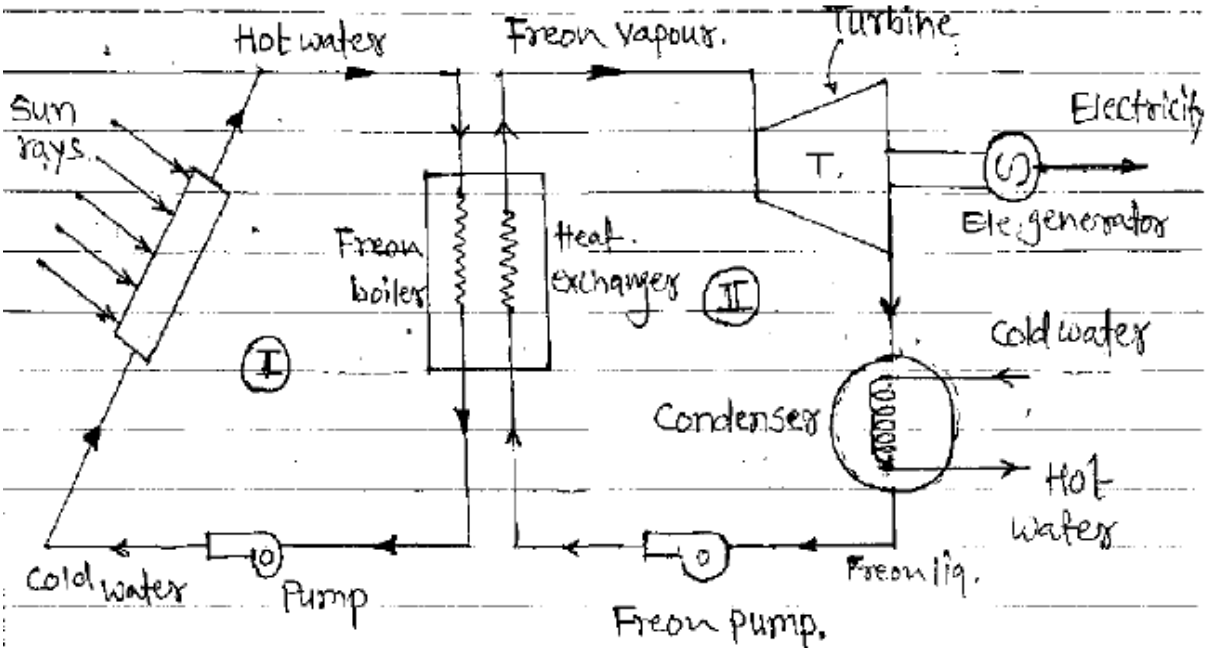
1. Air leak through joints and packing. Air leaks into condenser as pressure inside falls below atmospheric pressure.
2. Air also comes in condenser with the steam. The feed water supplied to the boiler contains certain amount of air dissolved in it. The dissolved air gets liberated when steam is formed and is carried with the steam into the condenser.
3. In jet condensers dissolved air in the cooling water enters the condenser. The dissolved air gets separated at low pressure in the condenser
4. Air leaks if any bypass seal is broken.

02 Marks

Condenser Efficiency: it is defined as ration of rise in temperature of cooling water to the difference between the saturation temperature corresponding to absolute pressure in condenser and inlet temp. of cooling water.

	c)	**Draw a neat sketch of two pass down flow surface condenser.**	**4 marks**
	Sol.	 Fig. Two pass down flow surface condenser *(Credit should be given to equivalent sketch)*	**02 Marks Sketch** **02 marks label**
	d)	**Differentiate between open cycle and closed cycle gas turbine.**	**4 marks**
	Sol.	**Answer: Difference between open cycle and closed cycle gas turbine.(Any four Points)**	4 Marks (any four points)

Sr. No.	Open cycle gas turbine	Closed cycle gas turbine
1.		
2.	Only air can be used as a working fluid.	Any type of working fluid with better thermodynamic properties can be used.
3.	Maintenance cost is low.	Maintenance cost is high.
4.	Working fluid replaced continuously.	Working fluid circulated continuously.
5.	Mass of installation per KW is less.	Mass of installation per KW is more.
6.	Pure form of fuel should be used.	Any type of fuel is used.
7.	Heat exchanger is not used.	Heat exchanger is used.
8	The turbine blades wear away earlier as it gets contaminated with air.	It avoids erosion of turbine blade due to contaminated gases.
9	The exhaust gas from the turbine is exhausted to the atmosphere.	The exhaust gas from the turbine is passed into cooling chamber.
10	This system required less space.	This system required more space.
11	Since turbine exhaust is discharged into atmosphere, it is best suited for moving vehicle.	Since exhaust is cooled by circulated water, it is best suited for stationary installation, marine use.

	e)	**Explain the use of solar energy to generate electricity with neat sketch**	**4 Marks**
		 In above fig. shows solar power plant in which for heating water flat plate collector is used. In fig there are two loops I and II which are connecting with each other by Freon boiler or heat exchanger. 1. In loop (I) with the help of pump initially we circulate cold water which is allow to pass through flat plate collector due to which at another end we get hot water then which is allow to pass through Freon boiler or heat exchanger. 2. Now in loop (II) with the help of pump there is circulation of Freon liquid when it passes through Felon boiler it takes heat from hot water & it boils (it's boiling point is very low = 23o C) so it changes phase (liquid to vapour). This Freon vapour can be used to drive turbine after that it come out from turbine & passed though condenser where condensation takes place & again Freon vapour converted into liquid form (condensate) which is used for recycle.	Sketch 2 Marks Explain 2 Marks
	f)	**State necessary of multi staging and intercooling of air compressor.**	**4 marks**
	Sol.	**Necessity of multi-staging of air compressor:** It has been experienced that if we employ single stage compression for producing high pressure air (say 8 to 10 bar) it suffers the following draw backs 1. The size of cylinder will be too large. 2. Work required to drive the compressor is more 3. Due to high pressure loss of air due to leakage is more. 4. Sometimes, the temperature of air, at the end of compression is too high. It may be heat up the cylinder head or burn the lubricating oil. 5. Volumetric efficiency of compressor is less. In order to overcome the above mentioned difficulties two or more cylinders are provided	**02 Marks**

		in series with inter-cooling arrangement between them. Such an arrangement is known as multistage compression with inter-cooling. **Necessity of inter-cooling –** In two stage air compressor air is compressed in first cylinder and the temperature of air is increased. If this high temperature air is not passed through intercooler and sent directly to second stage then because of high temperature volume of air increases so amount of air taken inside decreases and pressure is also automatically decreased and volumetric efficiency is also decreases. To avoid this intercooling is necessary.	**02 Marks**