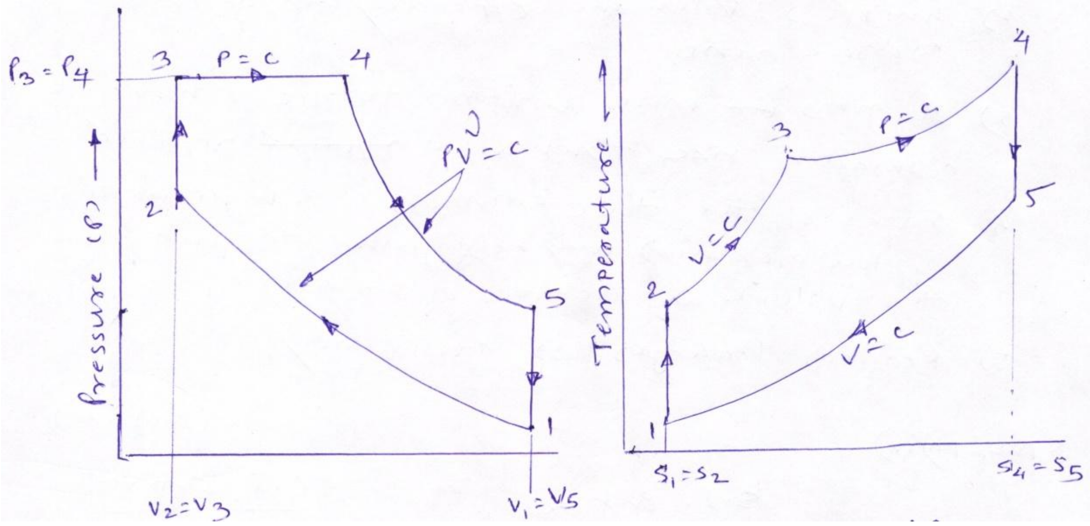
WINTER – 12 EXAMINATION

Subject Code : 12155 **Model Answer**

Q.1.a. Dual cycle on P.V. & T-S diagram (1½ + 1½ + 1) **04**

i)



Volume (V) ⟶ Entropy (S) ⟶

1 – 2 – Isentropic compression of air.
2 – 3 – Combustion of fuel at constant volume.
3 – 4 – Combustion of fuel at constant pressure.
4 – 5 – Isentropic expansion.
5 – 1 – Heat rejection at constant volume.

ii) Swept volume :- The volume swept through by the piston in moving between top dead centre and bottom dead centre is called swept volume. It is denoted by Vs & is equal to area of piston multiplied by stroke length. $Vs = \pi/4\ D^2 \times L$. **02 + 02**

Stroke:- The distance travelled by the piston from one dead centre position to the other dead centre position is called stroke.

iii) Advantages of multistage compression (four points) **1 each**

1) The work done per kg of air is reduced with intercooler as compared to single stage compression for the same delivery pressure.
2) Improves volumetric efficiency for given pressure ratio.
3) It gives more uniform torque & hence a smaller size flywheel is required.
4) Sizes of the two cylinder (i.e. high pressure & low pressure) may be adjusted to suit the volume & pressure of the air.
5) Reduces leakages loss considerably.

iv) **04**

		S.I. engine	C.I. engine
1	Thermodynamic	Otto cycle (constant value combustion)	Diesel cycle (constant pressure combustion)
2	Fuel used	Petrol	Diesel
3	Air fuel ratio	5 to 9	14 to 22
4	Applications	Used in light duty vehicles & in aeroplanes. (two wheeler & small cars)	Used in heavy duty vehicles like bus, truck, earth moving m/c etc.

Q.1.b. i) Necessity of testing **01**

1) To determine the information, which cannot be obtained by calculation.
2) To confirm the data used in design, the validity of which may be doubtful.
3) To satisfy the customer regarding the performance of the engine i.e. power developed & fuel consumption.

ii) Different test carried out **02**

1) Measurement of indicated power.
2) Measurement of brake power.
3) Morse test for indicated power.
4) Heat balance sheet.

5) Will as live method.
6) Motoring test.
7) Retardation test.

iii) Morse test **03**

This method is used to measure the indicated power without the use of indicator, in multicylinder engines. The brake power of the engine is measured by cutting off each cylinder in turn. The cylinder of a petrol engine is cut off by shorting the spark plug and in case of diesel engine this is done by cutting off the fuel supply to the required cylinder. Let there be n cylinders in an engine and all the cylinder be working.

Then $(B.P.)_n = (I.P.)_n - (F.P.)_n$

Where F.P. is the frictional power per cylinder.

If one cylinder is cut-off then the power developed by that cylinder is cut-off. Then the power developed by that cylinder (I.P.) is lost and the speed of the engine falls as the load on the engine remains the same. The engine speed can be brought back to its original value by reducing the load on the engine. This is required to maintain the F.P. constant, because it is assumed that the F.P. is independent of the load and depends only on the speed of the engine.

When 1st cylinder is cut-off, $(B.P.)_{n-1} = (I.P.)_{n-1} - (F.P.)_n$

Subtracting Eq. (17.10) from Eq. (17.9)

$(B.P.)_n - (B.P.)_{n-1} = (I.P.)_n - (I.P.)_{n-1} = I.P.$

The difference between the B.P. with n and (n-1) cylinder working gives the I.P. of the first cylinder which is cut-off. In this way the I.P. of all the cylinders is measured one by one and the sum of I.P.s of all cylinders is the total I.P. of the engine. The B.P. of the engine by making each cylinder inoperative can be measured by dynamometer discussed in the last article.

The method of measurement of I.P. of he multicylinder engine is known as Morse Test.

Q.1.b. ii) In petrol & diesel engine following pollutions are available as follows. **02**

1) Carbon monoxide (CO)
2) Hydrocarbon (HC)
3) Nitrogen oxide (NOX)
4) Carbon dioxide (CO2)
5) Sulphur dioxide (SO2)
6) Soot, particulates & smoke

Initially when Euro norms was follows the available level of HC & CO is as follows. **02**

Norms	CO gm/km		HC + NO gm/km		PM gm/km	
Euro – I	Petrol	Diesel	Petrol	Diesel	Petrol	Diesel
	3.16	3.16	1.13	1.13	-	0.18
Euro – II	2.20	1.00	0.50	0.70 to 0.90	-	0.080 to 0.10

But now Bharat stage norms are followed which are as follows

		CO %	HC in PPM
1	2 & 3 wheelers 2 stroke (vehicle manufactured after 31 march 2000)	3.5	6000
2	2 & 3 wheelers 4 stroke (vehicle manufactured after 31 march 2000)	3.5	4500
3	Bharat stage II compliant 4 wheelers	0.5	750
4	4 wheelers other than Bharat stage II compliant	3.0	1500

In diesel engine other than above stroke density is major criteria. At 60^0c maximum temperature of oil, free acculturation & maximum no load speed the maximum smoke density shall be 65 hartridge units.

Effects on human being & environment :- **02**

1) It attach on human lungs & respiratory system.
2) Attach on ozone layer depletion.
3) Increase in temperature i.e. Global worming.

Q.2. a) When one cylinder is cut out the output of the engine is given by 3 cylinders.

Ans.

Brake power for 3 cylinders = $\frac{2\pi NT}{60 \times 1000} kw.$

$= \frac{2 \times \pi \times 1201 \times 106}{60 \times 1000} = 13.33kw \cdots (2)$

Thus indicated power for one cylinder = 19 – 13.33 = 5.66 kw …..(2)

Total indicated power for 4 cylinder = 4 x 5.66 = 22.64 kw ……….(2)

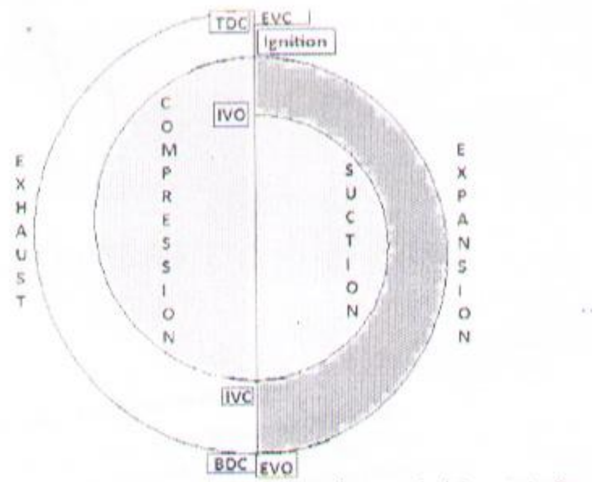
Indicated thermal efficiency is given by

$$\eta \ indicated \ \ thermal = \frac{IP \times 3600}{mf \times C.V.} = \frac{22.64 \times 3600}{0.35 \times 19 \times 42000}$$

$= 0.2918 = 29.18\%$ ....(2)

b) Theoretical & actual valve timing diagram for 4 stroke single cylinder petrol engine.

Theoretical valve timing diagram **02**



Valve Timing Diagram-4stroke engine/otto cycle (Theoretical)

The exact moment at which the inlet and outlet valve opens and closes with reference to the position of piston and crank shown diagrammatically is known as Valve Timing Diagram. The timing is expressed in terms of degrees of crank rotation. **02**

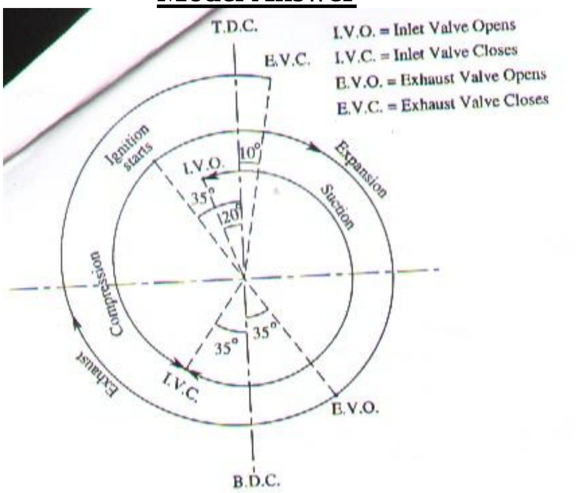
Suction Stroke:- Inlet valve is open. Piston moves form the top dead centre (TDC) to bottom dead centre (BDC). Air-fuel mix is sucked in by negative pressure in cylinder.

Compression Stroke:- Inlet and outlet valves closed. Piston moves upwards from BDC to TDC. Air-fuel mix is compressed.

Expansion / Power Stroke:- Inlet and outlet remains closed here also. Piston moves form down from TDC to BDC. This happens as a result of ignition of the mixture inside the cylinder. Ignition is started by spark plug.

Exhaust Stroke:- Exhaust valve opens. Piston moves up from BDC to TDC. Exhaust gases are pushed out of the cylinder.

02



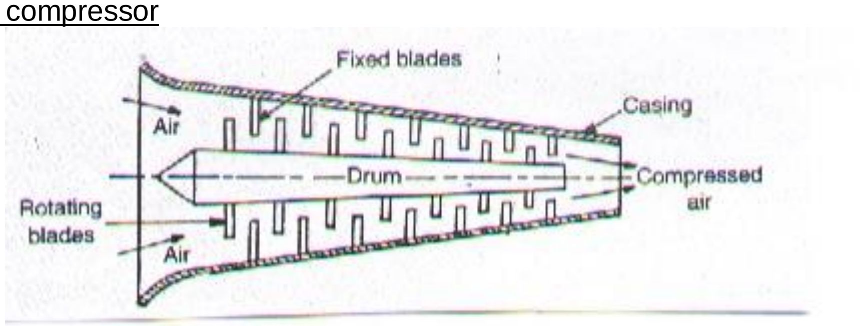
Valve timing diagram of four stroke petrol engine

02

During the suction stroke, the piston moves in downward direction and the pressure decreases in the cylinder, as a result, the air and petrol mixture is admitted into the cylinder. In modern I.C. engine, the speed of the piston is very high. Therefore, there is a possibility that the full amount of air-fuel mixture will not produce the same power as that produced by full charge. To avoid the loss of power, it is necessary that the inlet valve should remain open even after the completion of theoretical suction stroke. This helps to admit the full amount of air-fuel mixture inside the engine cylinder even during the beginning of compression stroke until the pressure equalises the atmospheric pressure. At this moment the inlet valve is closed. The inlet valve opens 10^0 to 30^0 in advance of T.D.C. position. It is shown as 20^0 in advance. The inlet valve closes 30^0 to 60^0 after B.D.C. position. Theoretically the exhaust valve opens at the end of and expansion stroke.

But in actual practice it is necessary to open the exhaust valve before the completion of expansion stroke and should remain open even after the completion of the exhaust stroke. Otherwise the full amount of burnt gases cannot be expelled out from the engine cylinder a large amount of the burnt gases will remain compressed in the clearance space of the cylinder. In fig., the exhaust valve opens 35^0 before the completion of the expansion stroke and closes 10^0 after the completion of the exhaust stroke. Thus the exhaust valve remains open for $35^0 + 180^0 + 10^0 = 225^0$.

c) Axial flow compressor **02**



An axial flow compressor, in its simplest form, consists of a number of rotating blade rows fixed to a rotating drum. The drum rotates inside an airtight casing to which are fixed stator blade rows a shown in fig. The blades are made of aerofoil section to reduce the loss caused by turbulence and boundary separation. **04**

The mechanical energy is provided to the rotating shaft which rotates the drum. The air enters from the left side of the compressor. As the drum rotates the airflows through the alternately arranged rotor and rotor. As the air flows from one set of stator and rotor to another it gets compressed. Thus successive compression of the air in all the sets of stator and rotor, the air is delivered at a high pressure at the outlet point.

The flow of air is parallel to axis of compressor. It has high manufacturing & running cost. It required high starting torque. It is suitable for multistaging. It requiring less formatted area for a given rate of flow. It makes the compressor suitable for air craft.

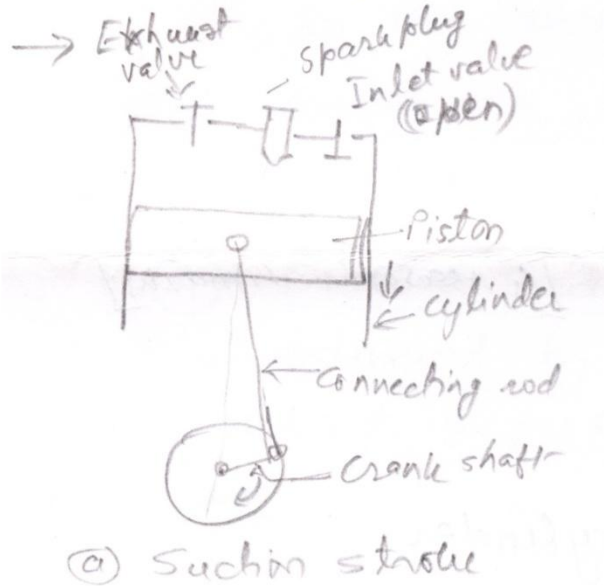
Applications **02**

1) Gas turbines
2) Gas power plant
3) Jet engine

Q.3. Attempt any FOUR **16**

a) Write working principle of 4-stroke petrol engine with the help of P-V diagram.

Ans.



i) 4-stroke petrol engine, cycle completes in two revolution of crankshaft.

ii) Cpotist of 4-stroke 02

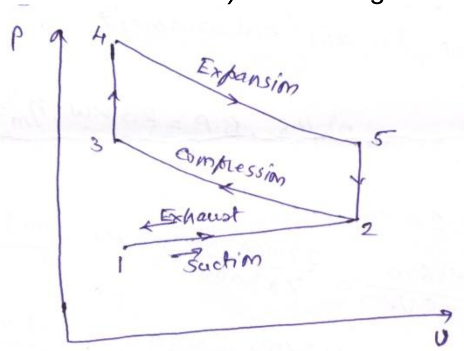
a. Suction stroke.
b. Compression stroke.
c. Expansion or power stroke.
d. Exhaust stroke.

a) <u>Suction stroke</u>:- i) starts when piston at TDC & about to more downwards ii) Inlet valve open 4 exhaust valve closed iii) Due to low for created fresh charge (air + fuel) is sucked into the cylinder.

b) <u>Compression stroke</u>:- i) piston moves from BDC to TDC ii) Inlet & exhaust valve closed iii) charge compressed up to clearance volume iv) jart before completion of compression stroke spark is produced by spark plug & fuel is ignited.

c) Expansion or power stroke:- i) because of high pressure to BDC ii) both inlet & exhaust valve closed iii) poser is obtained hence called power stroke.

d) <u>Exhaust stroke</u>:- i) exhaust valve open & inlet valve closed ii) piston moves from BDC to TDC iii) the burnt gases are exhausted from cylinder.



[working principle – 3 marks
P-V diagram – 1 mark] 02

b) <u>Effect of detonation</u> (any four – 4 marks) 01 each

i) Noise
ii) Mechanical damage
iii) Increase in heat transfer
iv) Pre-ignition
v) Decrease in power output & efficiency

c) <u>Reasons of occurring pre-ignition</u> (4 reasons – 4 marks)

i) High compression ratio
ii) Overheating spark plug
iii) Overheated exhaust valve
iv) Incandescent carbon deposite in cylinder

d) Lubricant additives & their advantages (any 4 additives – 4 marks)
i) Detergents:- To keep engine such as piston & piston rings clean & free from deposits. Act as acid neutralizer.
ii) Dispersant:- Reduce wear of crank shaft rods & main bearing.
iii) Anti-rust:- Reduce rusting by acid neutralisation of formation by protective film.
iv) Viscosity index improver:- Increases viscosity.
v) Anti-foam:- Reduce oil foaming by casting collapse of bubble due to air entrainment.
vi) Anti-oxidant
vii) Pour point depressant

e) Given:- mf = 7kg/hr, C.V. = 30000 kJ/kg, B.P. = 23 kW, ηm = 85% = 0.85
i) Indicated thermal eff.

Indicated power I.P. = $\frac{B.P.}{\eta_m} = \frac{23}{0.85} = 27.06$ 02

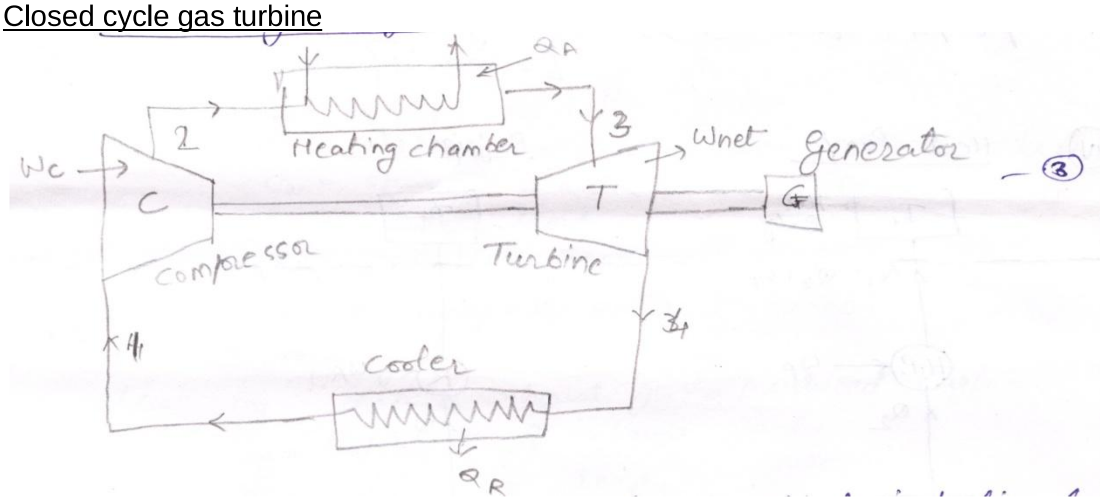
$\therefore$ Indicated thermal eff. $\eta_{it} = \frac{I_1 P \times 3600}{mf \times C.V.} = \frac{27.06 \times 3600}{7 \times 30000} = 0.46\, or\, 46\%\, Ans.$

ii) Brake thermal eff. $\eta_{bth} = \frac{B.P. \times 3600}{mf \times C.V.} = \frac{23 \times 3600}{7 \times 30000} = 0.394\, or\, 39.4\%\, Ans.$ 02

Q.4.a. Attempt any THREE **12**

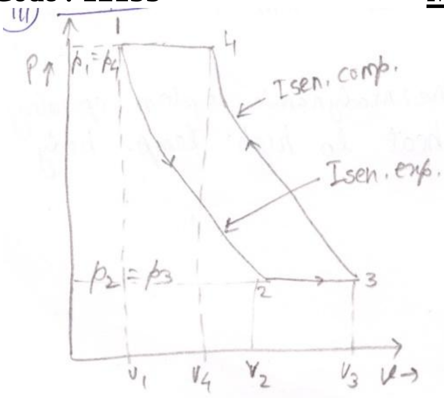
i)
i) Intake pressure:- Absolute pressure of air at the inlet of a compressor. **01 each**
ii) Compression ratio:- Ratio of absolute discharge pressure to the absolute inlet pressure.
iii) Compressor capacity:- It is the volume of air delivered by the compressor. Expressed in m^3/min or m^3/s.
iv) Free air delivered:- It is the actual volume delivered by a compressor when reduced to the normal temperature & pressure condition.

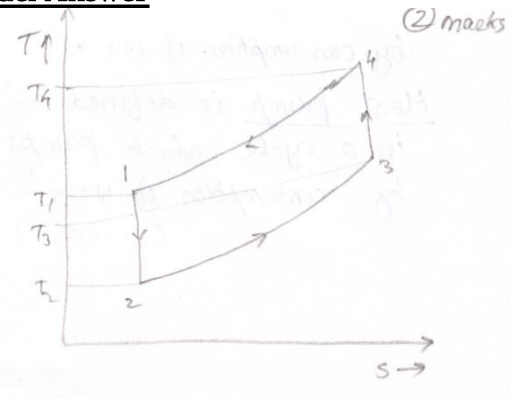
ii) Closed cycle gas turbine



Function of heat exchanger:-
i) Heat added in heating chamber by air heater **01**
ii) Heat rejected in cooler with cooling media.
iii) Bell coleman cycle

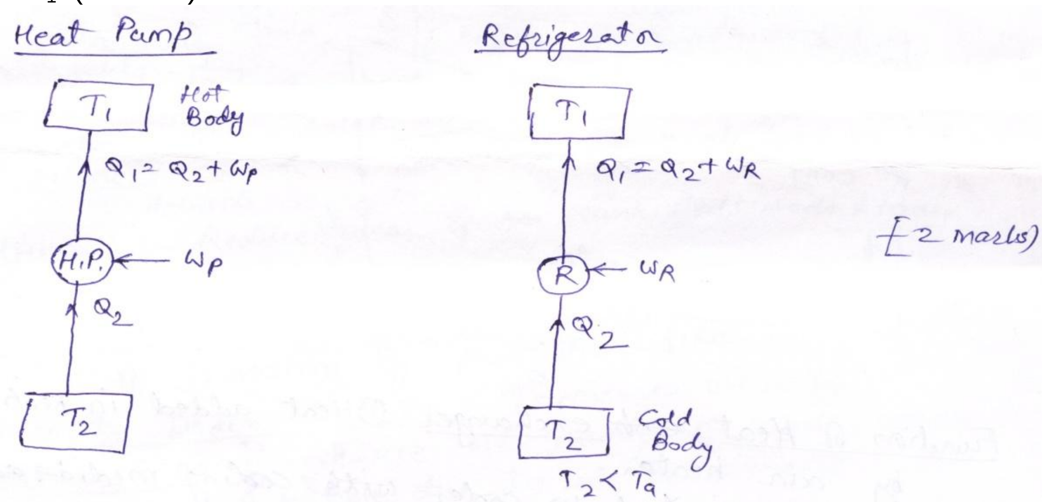
iii)





- Isentropic expansion:- Air from cooler is drawn into the expander cylinder where it is expanded isentropically from pressure P_1 to the refrigerator pressure P_2 i.e. atm. Pr.
- Const. Pressure expansion:- The cold air from the expander is now passed to the refrigerator where it is expanded at const pr. P_3 (equal to P_2), The temp of air increases from T_2 to T_3.
- Isentropic compression (process 3-4):- The cold air from refrigeration is drawn into the compressor cylinder, when it is compressed isentropically, both pr. & temp. in creases.
- Const pressure cooling:- The warm air from compressor is now passed into the cooler where it is cooled at const pr. P_4 (equal to P_1), reducing temp from T_4 to T_1. (2 marks)

iv)



iv) Refrigeration is defined as 'thermodynamic system operating in a cycle, which removes heat from low temp. body by consumption of work'.

v) Heat pump is defined as 'thermodynamic system operating in a cycle, which pumps heat to high temp body by consumption of work. (2 marks)

Q.4.b. Attempt any ONE **06**

i) Necessity of heat balance sheet:- To know heat energy supplied to engine in the form of fuel only a small amount of energy is utilised for use full work & remaining lost to atmosphere. Heat balance sheet is prepared to trace the energy distribution i.e. to determine how the input energy is distributed.

Heat distribution:- (3 marks)

i) Heat supplied by the fuel = mf x C.V. kJ/min.
ii) Heat equivalent to B.P.
iii) Heat rejected to the cooling water = $M_w C_w (t_2 – t_1)$ kJ/min
where M_w – mass of cooling water supplied in kg/min.
C_w – sp. heat of water = 4.2 kJ/kgk

t_1 – inlet temp.
t_2 – outlet temp.

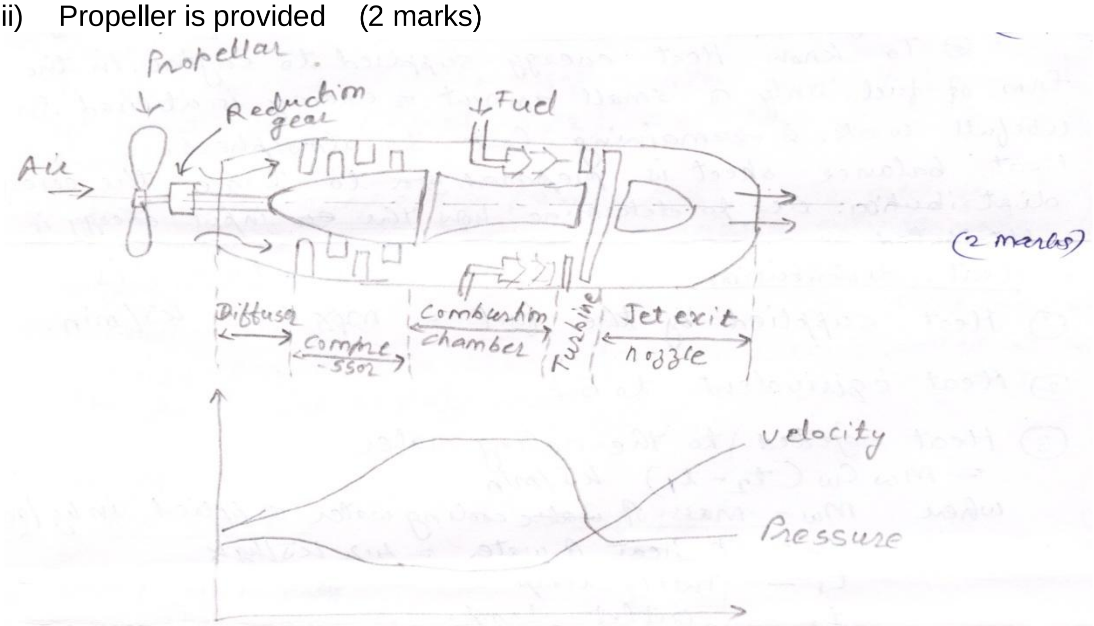
iv) Heat carried away by exhaust gases = Mg.Cg.t.
Where Mg – mass of exhaust gases produced in kg/min
Cg – sp. heat of exhaust gases
t – rise in temp.

v) Unaccounted heat :- Heat loss due to friction, radiation etc. which cannot be determined experimentally unaccounted heat = heat supplied – [heat in B.P. + cooling + exhaust gases]

ii) Turbo prop engine:-

i) Turbine is designed to develop shaft power for driving propeller to provide most of a propulsive thrust (80 to 90%) & small amount of thrust provided by jet (10 to 20%)

ii) Propeller is provided (2 marks)



Advantages :- low sp. weight small frontal area, simplicity, lower vibration. **01**
Application :- used in power helicopter & for various land & marine applications. **01**

Q.5.a. m = 6 kg/min
p_2 = 16 bar
p_1 = 1 bar
$T_1 = 15^0c$
n = 1.3
Perfect intercooling.
Take – R = 287 J/kg ^{0}k

$$P_2 = \sqrt{P_1\ P_3} = \sqrt{1 \times 16} = 4bar$$ **01**

1) Work required

$$w = 2 \times \frac{n}{n-1} mRT_1 \left[\left(\frac{P_2}{P_1} \right)^{\frac{n-1}{n}} - 1 \right]$$

$$= 2 \times \frac{1.3}{1.3-1} \times 6 \times 287 \times 288 \left[\left(\frac{4}{1} \right)^{\frac{1.3-1}{1.3}} - 1 \right]$$

$$= 2 \times \frac{1.3}{0.3} \times 495936 (0.377)$$ **03**

$$= 1620428.6 \; N.m/\min$$

Power required

$$\frac{1620428.6}{60 \times 1000} kw$$

$$= 27.007 kw$$

2) Isothermal work required refers to 15^0c of air

$$w = mRT_1 \log_e \left(\frac{p_3}{p_1} \right)$$

$$= \frac{6}{60} \times 287 \times 288 \log_e \left(\frac{16}{1} \right)$$ **02**

$$= 22.92 \; kw$$

$$\eta \quad isometric = \frac{Isothemal \; work}{Power \; \mathrm{Re}quired} = \frac{22.92}{27} = 0.8488 = 85\%$$

3) FAD

The value of 6 kg of air at 1.01325 bar & 15^0c is

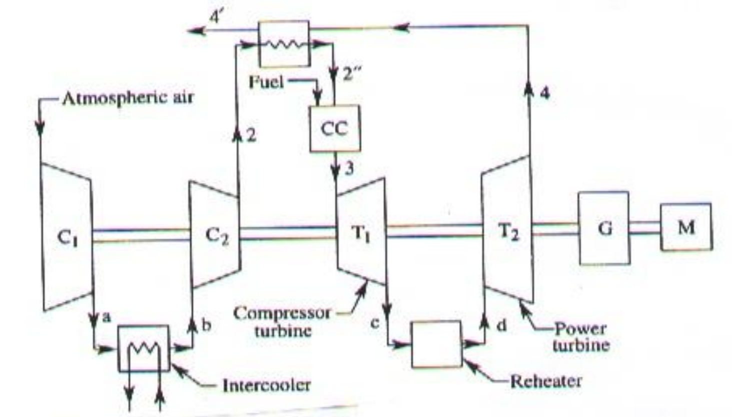
$$V = \frac{mRT}{p} = \frac{6 \times 0.287 \times 288}{1.01325 \times 100}$$

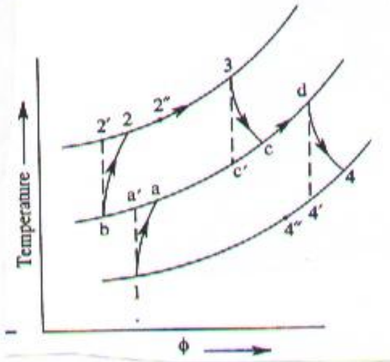
$$= 4.8945 \quad m^3 \quad of \;\; free \; air \;\; per \; \min .$$

02

Q.5.b. Regeneration in gas turbine:-

The thermal efficiency of gas turbine plant can be increased with the help of regeneration.





Regeneration:- The exhaust gases carry large amount of heat. The heat of this exhaust gas is utilised by providing a regenerator (heat exchanger) for pre-heating the compressed air before it enters the combustion chamber thus reducing the mass of the fuel supplied in the combustion chamber and consequently improved the thermal efficiency. The gas turbine plant with regenerator is shown in fig. The T-ϕ diagram is shown in figs.

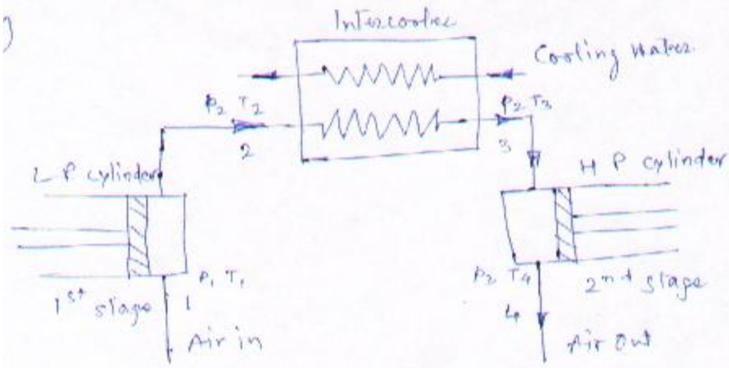
Q.5.c. Comparison of vapour compression and vapour absorption system **08**

Vapour Compression System	Vapour Absorption System
1. System is provided with compressor	1. Compressor of vapour compression system is replaced by absorber, generator, pump and reducing valve.
2. more wear & tear of due to more number of parts in compressor.	2. No wear & tear as no compressor is present.
3. Due to presence of compressor system is noisy	3. System is quiet.
4. Vapour compression system cannot built to any capacity, with the increase in capacity size of compressor increases.	4. System can be built to any capacity.
5. Cooling effect is instant.	5. System takes time to produce cooling effect.
6. Poor performance at partial load.	6. Better performance at partial load.
7. It requires high grade energy.	7. It can be used with low grade energy.
8. Energy input is about 1/3 to1/4 of refrigerating effect.	8. Energy input is about 1.5 times the refrigerating effect.
9. COP of system is high.	9. COP of system is low

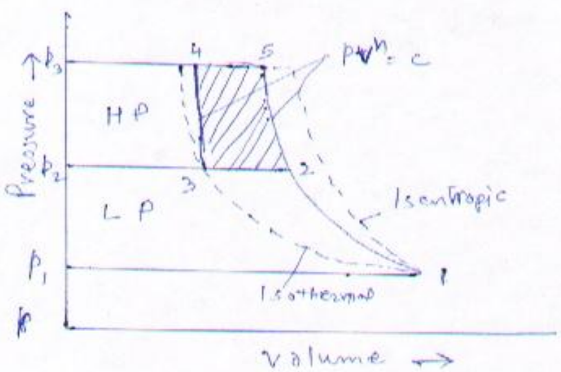
Q.6.a. Methods of energy saving in air compressor. (1 mark)

- Multistaging
- Use of intercoolers
- Reducing leakages

Multistaging with intercooler (3 marks)



Two stage air compressor with Intercooler



The amount of work saved is shown by the shaded area 2-3-4-5

- Fresh air is sucked from atmosphere in the LP cylinder during its suction stroke at pressure P_1 and temperature T_1. After compression air is delivered to the intercooler at pressure P_2 and temperature T_2. Air is cooled at pressure P_2 from temp. T_2 to T_3. after that air is sucked in HP cylinder and delivered at P_3 & T_4.

b. Suitable fuel for rocket (2 marks)

1) Solid propellant – Ammonium per chlorate mixed powdered aluminium.
2) Liquid hydrogen and liquid oxygen – RP – 1 – similar to kerosene

Rocket engine applications (2 marks)

- To launch
  - i) Satellite vehicles,
  - ii) Missile
  - iii) Aircrafts

c. Dalton's law of partial pressure **02**

The total pressure exerted by the mixture of air and water vapour is equal to the sum of the pressure which each constituent would exert if it occupied the same space by itself.

Psychrometric chart is used to find out the properties of air, which are required in the field of air conditioning and eliminate lot of calculation. **02**

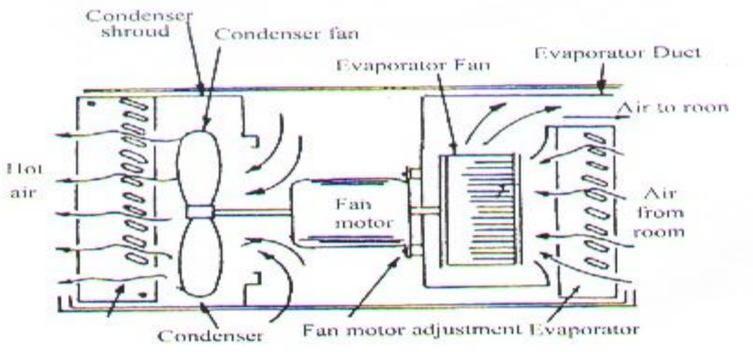
d. Air circuit of window air conditioner **02**

Window air conditioner has three separate air circuits

1) Room air over evaporate – Air room is drawn into unit though filter that removes dust and impurities. It passes over thermostat and evaporate coil.
2) Outside air over condenser – Air is drawn into the unit from side and passes

over air cool condenser.

3) Out door fresh air circuit - When occupant load incenses, fresh outdoor air is provided by fresh air damper and ventilation switch.



02

Air circuit of window air conditioner

e. **04**