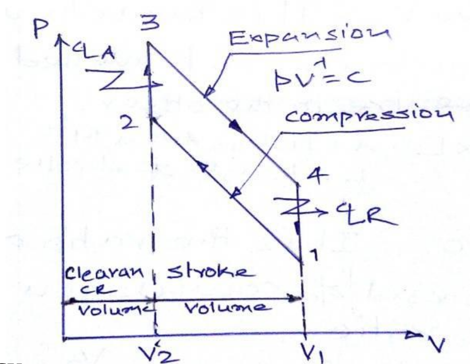
Important Instructions to examiners:

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 judgment 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 A) Attempt any Three

a) Air standard efficiency – Otto cycle



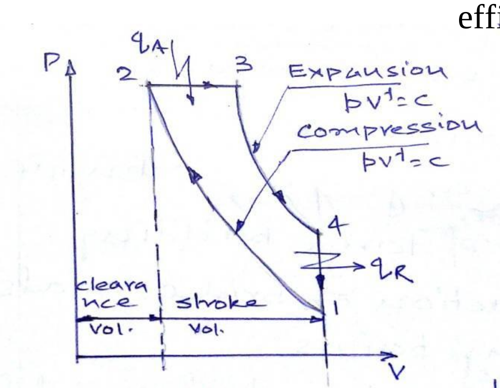
ASC efficiency

$\eta_{Otto} = 1/\ 1 - (r_c)^{\gamma-1}$

Where R_c= Compression Ratio

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

Air standard efficiency – Diesel Cycle



Air standard efficiency

$$\eta_{Diesel} = 1 - \frac{1}{R^{\gamma-1}}\left[\frac{\left(\alpha_c^{\gamma} - 1\right)}{\gamma(\alpha_c - 1)}\right]$$

Where – R_c- Comp. ratio $=\frac{V_1}{V_2}$ $\alpha_c - cutoff\ ratio - \frac{V_3}{V_2}$

b) i) Compression Ratio R_c – It's a ratio of total cylinder volume to the clearance volume.

$R_c = \frac{V_c+V_s}{V_c}$

ii) Swept Volume V_S – It is the volume swept by piston when travelled from one dead centre to the other.

V_s = A x L   A – Piston area cm^2, L – Length of stroke cm

iii) Cut off Ratio – It is the ratio of volume at the end of combustion to the clearance ***volume*** ratio $\alpha_c = \frac{V_3}{V_2}$ $\rho = v_3/v_2$

iv) Clearance Volume V_C = The nominal volume of the space on the combustion side of the piston of TDC

c) Uses of compressed air:- (Any 8 uses each for ½ mark)

1. Cleaning automobiles

2. Pneumatic tools

3. Supercharging in I.C. engines

4. Cooling of large building

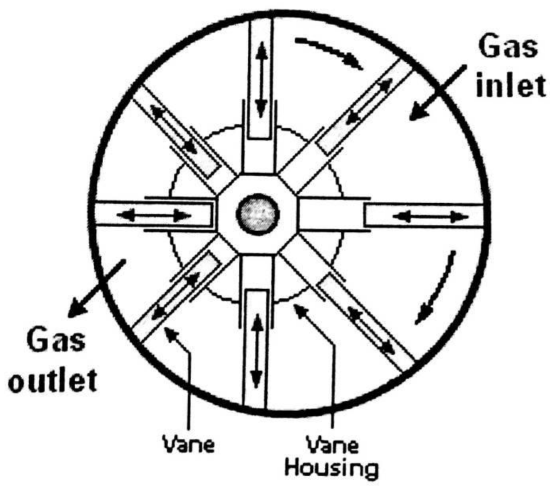
5. Construction of bridges, roads etc.

6. Spraying points

7. Spraying fuel in high speed diesel engine

8. Starting of I.C. engines

d) Sketch of vane compressor



Q.1 B Attempt any one

a) Necessity of I.C. engine testing

i) To get information, that is not possible to be determine by calculations.

ii) To confirm the validity of data used while designing the engine.

iii) To satisfy the customer as to rated power with guarantied fuel consumption.

iv) To reduce the cost and to improve the power output and reliability of an engine.

v) To know & improve the performance of an engine.

Test carried out on I.C. Engine – 1) Commercial Tests 2) Thermodynamic Tests

1) Commercial Tests – These tests are carried out in order to check following
   a) Rated power out-put with guarantied fuel consumption in kg/kw hr
   b) Quantity of lubricating oil per kw-hr
   c) Quantity of cooling water per kw-hr
   d) Steadiness of engine under varied load conditions
   e) Overload carrying capacity of the engine
2) Thermodynamic Tests – These tests are carried out for the purpose of comparing actual results with theoretical results by measuring following parameters and then drawing heat balance sheet.
   i) Indicated power
   ii) Brake power
   iii) Frictional power
   iv) Rate of fuel consumption
   v) Rate of flow of cooling water and its temperature rise

vi) Heat carried by exhaust gas

b) Morse Test – This test carried out for multi cylinder I.C. engine. In this test, first engine is allowed to run (4-cylinder I.C. engine) at constant speed and brake power of engine is measured when all four cylinders are working and developing indicated power.

$\therefore I_2+I_3+I_4 = (BP)_{engine} +(F_1+F_2+F_3+F_4)$

Where I_1, I_2, I_3 and I_4 – Indicated power of four cylinders

$(BP)_{engine}$ – Brake power of engine when all cylinders are working

F_1, F_2, F_3, F_4 – Frictional power of all four cylinders

The first cylinder is cut off by short circuiting in case S.I. engine or cutting fuel supply in case C.I. engine. This causes the speed to drop due to non working of first cylinder and consumption of frictional power. This speed is once again maintained to its original value by reducing load on the engine

$\therefore I_2+I_2+I_3+I_4 = (BP)_{2,3,4} +(F_1+F_2+F_3+F_4)$

Where $(BP)_{2,3,4}$ – Brake power of 2,3 & 4 cylinders only.

Repeat the above procedure for remaining cylinders and calculate I.P. of the engine.

- Cylinder 2 is cut off – $I_1+I_3+I_4 = (BP)_{1,3,4} +(F_1+F_2+F_3+F_4)$
- Cylinder 3 is cut off – $I_1+I_2+I_4 = (BP)_{1,2,4} +(F_1+F_2+F_3+F_4)$
- Cylinder 4 is cut off – $I_1+I_2+I_3 = (BP)_{1,2,3} +(F_1+F_2+F_3+F_4)$

$\therefore$ I.P. of cylinder 1 is calculated as Eq. 1 – Eq.2

$I_1 = (BP)_{engine} – (BP)_{2,3,4}$

Similarly $I_{2,}I_3$ and I_4 is calculated as follows

$I_2 = (BP)_{engine} – (BP)_{1,3,4}$

$I_3 = (BP)_{engine} – (BP)_{1,2,4}$

$I_4 = (BP)_{engine} – (BP)_{1,2,3}$

$\therefore$ Indicated power of engine = I.P.

$IP = I_1+I_2+I_3+I_4$

$\therefore$ Frictional power of engine

$FP = IP – (BP)_{engine}$

and mechanical efficiency

$\eta_{Mech} = (BP)_{engine}$

Thus Morse test is used to calculate IP, FP and η_{Mech} by assuming FP of each cylinder remains constant.

2. Attempt any Two

a) Mass flow rate of fuel = m = 6 kg/hr

$$mf = \frac{6}{60} = 0.1 kg/min$$

C.V. of fuel = 44,000 kJ/kg

Mass flow rate of cooling water = m_w

m_w = 11.5 Kg/min

$\Delta tw = 25^0 c$

Mass flow rate of exhaust gases = m_g

m_g = 4.2 Kg/min

$\Delta tg = 220^0 c$

Sp. Heat of exhaust gas – 1 kJ/kg^{0}k

Heat supplied by fuel = m_f x C.V. of fuel

= 0.1 x 44,000

= 4,400 kJ/min

Heat equivalent of BP = 18 x 60 = 1080 kJ/min

Heat carried by cooling water

= m_w x Cp_w x Δtw

= 11.5 x 4.187 x 25

= 1203.76 kJ/min

Heat carried by exhaust gas = mg x Cp_g x Δtg

= 4.2 x 1 x 220

= 924 kJ/min

Unaccounted heat =

Heat supplied – (Heat equivalent of BP + Heat carried by cooling water + Heat carried by exhaust. gas)

= 4400 – (1080 + 1203.76 + 924)

= 1192.24 kJ/min

Heat balance sheet

Heat supplied	kJ/min	%	Heat expenditure	kJ/min	%
Heat supplied by fuel	4400	100	Heat equivalent BP heat in C.W. Heat in exh. gas uncounted heat	1080 1203.76 924 1192.24	24.54 27.36 21.00 27.10
	4400	100		4400	100

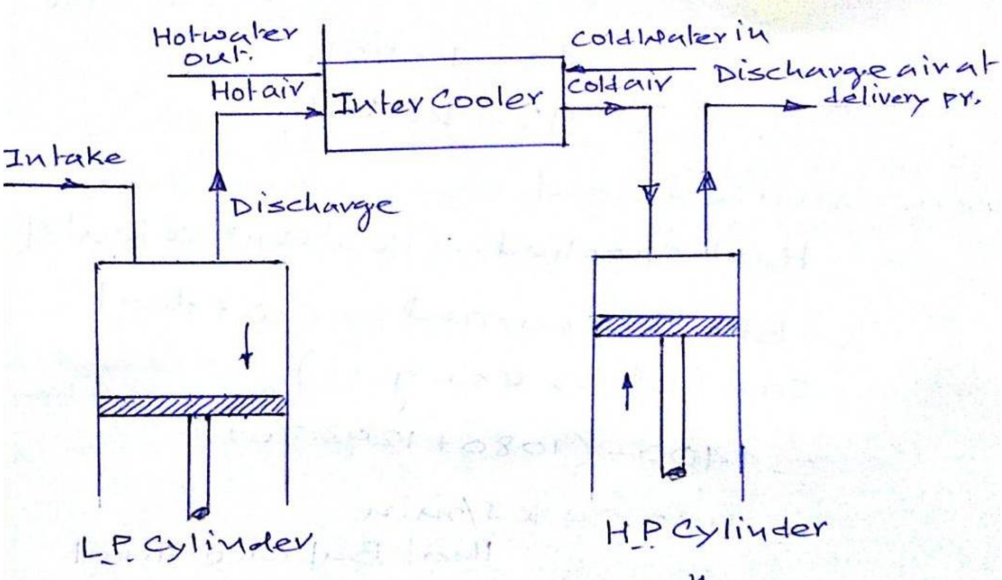
b) Necessity of multistage compression

i) As index of compression 'n' increases it increases compression work.

ii) Increase in pressure ratio (P_2/P_1) it increases work as well as size of cylinder.

iii) Increment in pressure ratio (P_2/P_1) beyond certain limit, volumetric efficiency decreases while it increases leakage loss on either sides the piston and valves.

Due to above pointes and for higher pressure ratio compressor needs multistaging.



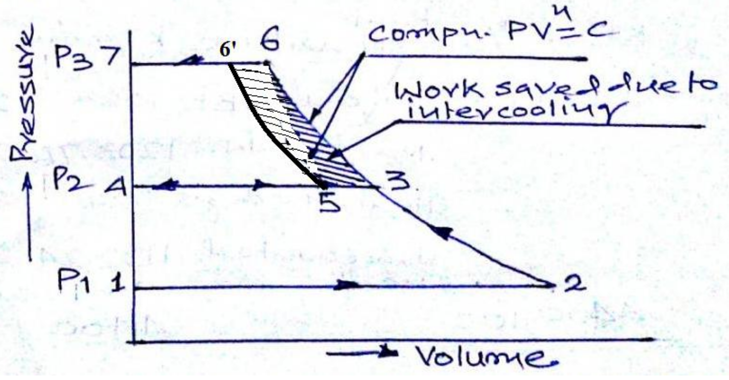


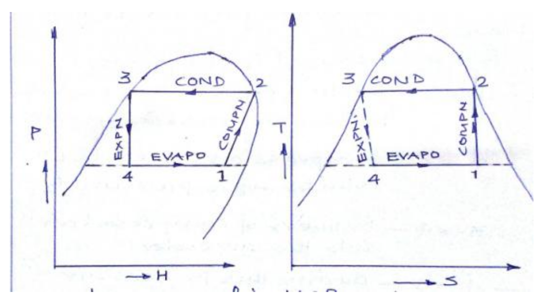
Fig. shows arrangement of two stage reciprocating air compressor with inter cooler and its working shown on P.V. diagram plane.

Processes occurred in the cycle

- \- 1 – 2 – suction process by LP cylinder to draw atmospheric pressure
- \- 2 – 3 – compression process by LP cylinder up to pressure P_2
- \- 3 – 4 – delivery of compressed air into the air cooler
- \- 4 – 5 – during this process air rejects the heat to the cold water and at the same time suction process by HP cylinder to draw air from air cooler.
- \- 5 – 6 – compression pressure by HP cylinder up to required pressure P_3
- \- 6 – 7 – delivery of compressed air at required pressure to the point of use.

This completes the process and system has shown saving in work shown by shaded portion.

Q.2. c) Vapour compression refrigeration on P-H and T-S diagram plane.



Processes in VCR cycle

1) The point 1 represents condition of refrigerant at entry of compressor which is wet.

Process 1 – 2 – Isentropic compression of refrigerant vapour till it becomes dry and saturated.

Process 2 – 3 – Condensation of vapour refrigerant up to saturated liquid condition at constant pressure.

Process 3 – 4 – Expansion of liquid refrigerant by expansion device. This reduces pressure as well as temperature of liquid refrigerant.

Process 4 – 1 – Evaporation of liquid refrigerant in the evaporator thus establishing required refrigerating effect.

Thus it completes one cycle of refrigeration.

Refrigerating effect = RE = m $(h_1 - h_4)$

Compressor power = m $(h_2 - h_1)$

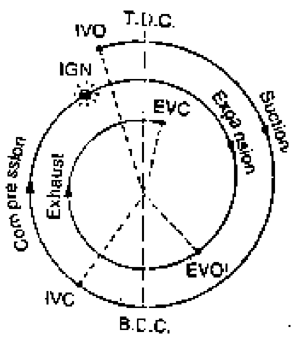
Where m = mass flow rate of refrigerant in kg/sec.

$$\therefore COP = \frac{RE}{compressor\ power}$$

$$COP = \frac{h_1 - h_4}{h_2 - h_1}$$

Q.3 Attempt any four.

(a) **Valve timing diagram for 4 stroke petrol engine** (4-marks)



TDC : Top dead centre

BDC : Bottom dead centre

IVO : Inlet valve opens (10^0-20^0 before *TDC*)

IVC : Inlet valve closes (30^0- 40^0 after *BDC*)

IGN : Ignition (20^0-30^0 before *TDC*)

EVO : Exit valve opens (30^0-50^0 before *BDC*)

EVC : Exit valve closes (10^0-15^0 after *TDC*)

(b) Turbocharging: (sketch -2, explaination – 2 marks)

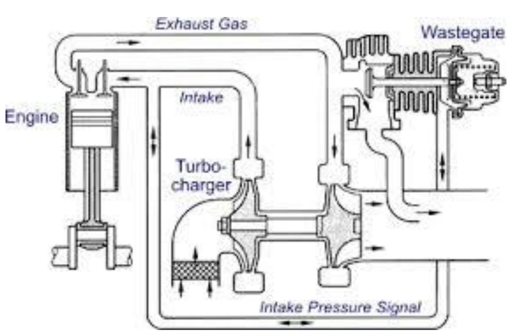
-Turbocharger is a gas turbine driven by exhaust gas of engine.

- About 30% of heat input goes with exhaust gases. This exhaust gas can be used to run a gas turbine.

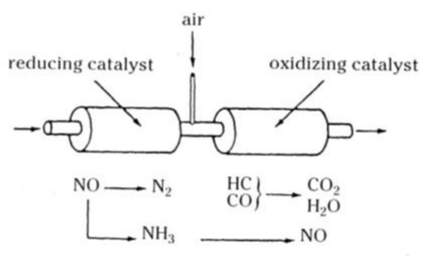
- The gas turbine develops the sufficient power to drive centrifugal compressor, which is used to supply the air to engine. This results in increased power output & better thermal efficiency of engine. Thus, supercharging done by driving compressor with the help of engine turbine utilizing exhaust of engine is called as turbocharging.

- In order to supply sufficient energy to the turbo charger, the exhaust valve is opened much before the BDC as compared to naturally aspirated engine, to allow the exhaust gas to escape at higher pressure & temp giving the turbocharger enough energy to drive the compressor.

- Fig. below shows turbocharger.



(c) Three way catalytic convertor (sketch -2, explaination – 2 marks)



- Three way convertor uses thin coating of platinum , palladium and rhodium over a support metal (generally alumina) & acts on all three major constituents of exhaust gas pollution i. e. hydrocarbons, carbon monoxide & oxides of nitrogen, oxidizing these to water , carbon dioxide & free hydrogen & nitrogen respectively.

- It operates in two stages, the first convertor stage uses rhodium to reduce the NO_2 in the exhaust into nitrogen & oxygen. In second stage convertor platinum or palladium acts as oxidation catalyst to change HC & CO into harmless water & CO_2.

- For supplying the oxygen required in the second stage air is fed into the exhaust after the first stage.

- Reactions within catalyst produce additional heat that reaches temperature of 900^oC, which is required for the catalytic converter to operate at complete efficiency. To safeguard from this high temperature, the catalytic converter is made of stainless steel &special heat shields are also used.

(d) Turbopropellar : (sketch -2, explaination – 2 marks)

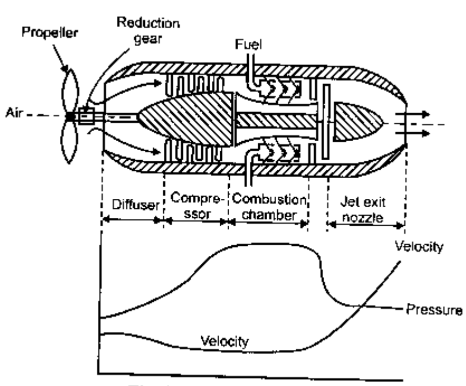


Fig. 4.11 : Turbo propeller

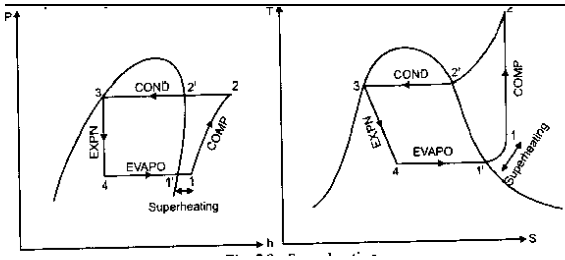
-In turboprop engine propeller is present.

- The turbine is designed so that it develops shaft power for driving a propeller to provide most of the propulsive thrust, and only a small amount thrust is provided by jet.

- In this case, nearly 80 to 90% of the power propulsion is generated by turbine & is transmitted to the propeller through reduction gear. The remaining 10 to 20% of the thrust is developed by expanding the turbine exhaust in a nozzle of suitable design.

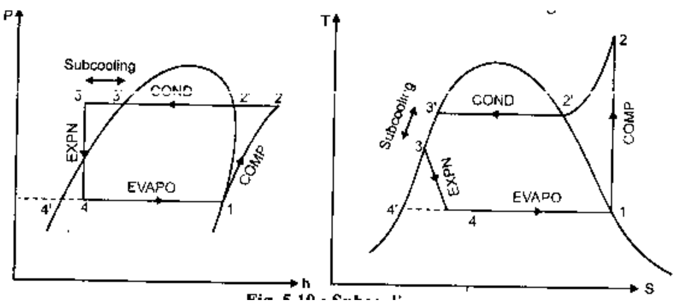
- The turboprop combines in it the merits of turbojet engine and propeller i. e. Low specific weight, small frontal area, simplicity, lower vibrations, high power for the take off and high propulsive efficiency at high speed.

(e) **Superheating**



-Due to superheating suction temperature of compressor increases , increasing compressor power but it also increases the refrigerating effect therefore COP of system remains more or less constant. The superheating is not done to increase the refrigerating effect or COP but it is done to increase the life of compressor.

Subcooling

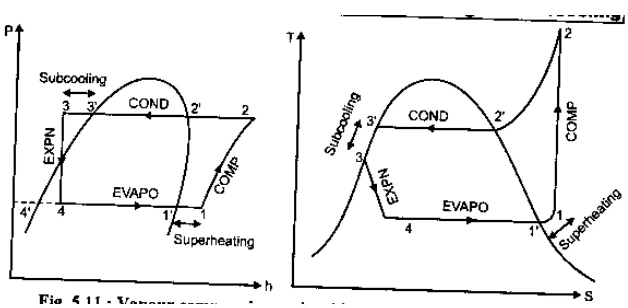


The process of cooling refrigerant below condensing temperature for a given pressure is known as subcooling.

-Due to subcooling the refrigerating effect increases or for same refrigerating effect the circulation rate refrigerant decreases and therefore COP of system increases. Thus subcooling is desirable & is done to increase refrigerating effect & COP of system.

(sketch -2, explaination – 2 marks)

OR – combined fig of superheating & subcooling



Q.4 (A) Attempt any three.

(a) **Detonation** (any four causes – 4 marks)

The loud pulsating noise heard within the engine cylinder is known as detonation.

The following are the certain factors which causes detonation.

(1) The shape of the combustion chamber.

(2) The relative position of the sparking plugs in case of petrol engines.
(3) The chemical nature of the fuel.
(4) The initial temp & pressure of fuel
(5) The rate of combustion of that portion of fuel which is the first to ignite. This portion of fuel in heating up , compresses the remaining unburnt fuel, thus producing the condition for auto ignition to occur.

(b) Effect of pollutants on environment **(any four – 4 marks.)**

The major air pollutants emitted by petrol & diesel engines are CO_2, CO, HC, NO_x, SO_2, smoke & lead vapour.

Effect of CO:
(1) Carbon monoxide combines with hemoglobin forming carboy hemoglobin ,which reduces oxygen carrying capacity of blood.
(2) This leads to laziness, exhaustion of body & headache.
(3) Prolong exposure can even leads to death.
(4) It also affects cardiovascular system, thereby causing heart problem

Effect of CO_2: Causes respiratory disorder & suffocation.

Effect of NO_x:

- It causes respiration irritation, headache, bronchitis, pulmonary emphysema, impairment of lung, loss of appetite , & corrosion of teeth to human body.

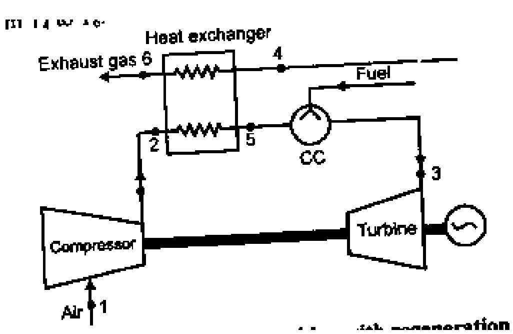
Effect of HC:

- It has effect like reduced visibility, eye irritation , peculiar odour & damage to vegetation & acceleration the cracking of rubber products.
- It induce cancer, affect DNA & cell growth are know a carcinogens.

Effect of SO_2: It is toxic & corrosive gas, human respiratory track of animals, plants & crops.

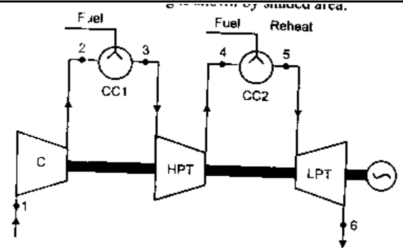
(c) Methods to improve thermal efficiency of gas turbine (List of methods -2 marks, explanation of any one – 2 marks)

1) Regeneration – This is done by preheating the compressed air before entering to the combustion chamber with the turbine exhaust in a heat exchanger, thus saving fuel consumption.



2) Improving turbine output: this can be done by

(a) Reheating : The whole expansion in the turbine is achieved in two or more stages &reheating is done after each stage.

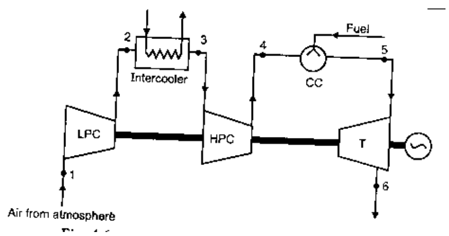


(b) Increasing the value of maximum cycle temp.

(c) Improving turbine efficiency by improving design.

3. Reducing compressor input: By

(a) Intercooling : Compressor work is reduced by intercooling the air between the compressor stages.



(b)By lowering inlet temp to compressor

(c) By increasing compressor efficiency

(d) Water injection at inlet to compressor

(d) **Jet Propulsion**: This is done by expanding the gas which is at high temperature & pressure through the nozzle so that the gas with very high velocity leaves the nozzle giving thrust in opposite direction.

- Principle is based on Newton's Second & third law of motion.

Jet propulsion – Classification

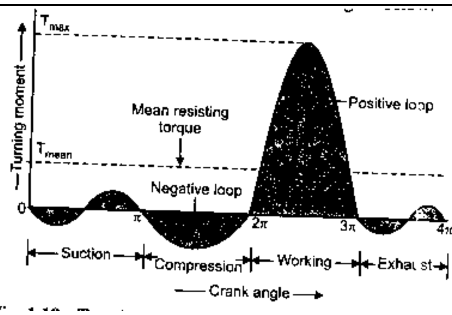
(1) Atmospheric jet engines (breathing engine)
 -Turbojet engine
 - Turbo prop engines
 - Ram jet

(2) Rocket engine (Non - breathing engine)

(Jet propulsion -2 marks, classification -2 marks)

Q.4. (B) Attempt any one.

(a) **Turning moment diagram of four stroke engine**: (sketch -2, explaination – 2 marks)



During suction stroke, negative loop is formed as pressure inside engine cylinder is less than atmospheric pressure.

During compression stroke, work is done on gases therefore higher negative loop is formed.

During expansion or power stroke, fuel burn & gases expand therefore large positive loop is formed & during this stroke we get work output.

During exhaust stroke, work is done on the gas to expel it out of cylinder , hence negative loop is formed.

(b) Given,

$(B.P.)_{engine}$ = 16.2 kW ,$(B.P.)_{2,3,4}$ = 11.55 kW, $(B.P.)_{1,3,4}$ = 11.63 kW, $(B.P.)_{1,2,4}$ = 11.68 kW

$(B.P.)_{1,2,3}$ = 11.51 kW

I.P. of 1^{st} cylinder = $I_1 = (B.P.)_{engine} - ,(B.P.)_{2,3,4} = 16.2 – 11.55 = 4.65$ kW

Similarly,

$I_2 = (B.P.)_{engine} - (B.P.)_{1,3,4} = 16.2 – 11.63 = 4.57$ kW

$I_3 = (B.P.)_{engine} - (B.P.)_{1,2,4} = 16.2 – 11.68 = 4.52$ kW

$I_4 = (B.P.)_{engine} - (B.P.)_{1,2,3} = 16.2 – 11.51 = 4.69$ kW

Indicated power of engine

I.P. = $I_1 + I_2 + I_3 + I_4 = 4.65 + 4.57 + 4.52 + 4.69 = 18.43$ kW

$$Mechanical\,efficiency = \frac{B.P.}{I.P.} * 100$$

$$Mechanical\,efficiency = \frac{16.2}{18.43} * 100$$

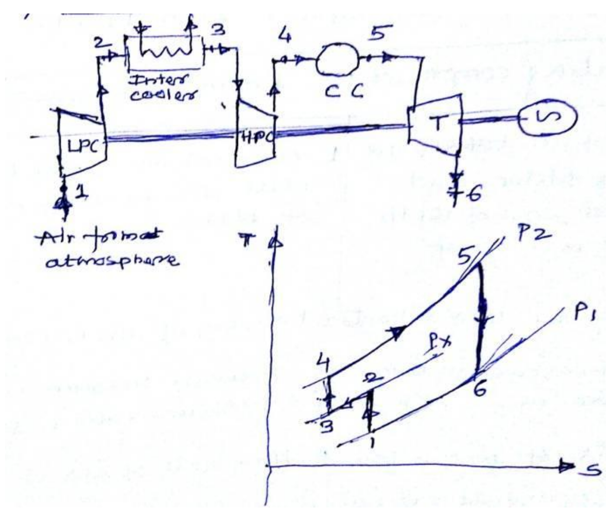
Mechanical efficiency = 87.9 % ----------------------Ans

Q.5 a) Differentiate (any eight) each 1 marks

Reciprocating compressor	Rotary compressor
1. Compressor of air take place with help of piston and cylinder arrangement with reciprocating motion of piston.	1. Compression of air take place due to rotary motion of blades.

2. Delivery of air intermittent.	2. Delivery of air is continuous.
3. Delivery pressure is high i.e. pressure ratio is high.	3. Delivery pressure is low, i.e. pressure ratio is low.
4. Flow rate of air is low.	4. Flow rate of air is high.
5. Speed of compressor is low because of unbalanced forces.	5. Speed of compressor is high because of perfect balancing.
6. Reciprocating air compressor has more number of moving parts.	6. Rotary air compressor has less number of moving part.
7. It needs proper lubrication and more maintenance.	7. It required less lubrication and maintenance.
8. Due to low speed of ration it can't be directly coupled to prime mover but it requires reduction of speed.	8. Rotary air compressor can be directly coupled to prime mover.
9. It is used when small quantity of air at high pressure is required.	9. It is used where large quantity of air at lower pressure is required.

Q.5 b) i) <u>Gas turbine with inter cooling</u>.



LPC – LOW pressure cylinder

HPC – high pressure cylinder

CC – combustion chamber

T – Turbine

(2+ 2 marks)

The net work of gas turbine cycle may be increased by saving some compression work. This is done by using several stages of compression with inter cooling of air between stages. The air from first stage of compression is cooled in inter cooler approximately to its initial temperature before entering to second stage of compressor. The effect of inter cooling is to decrease the network and increase the efficiency as compared to the simple ideal cycle without inter cooling. The ideal open gas turbine with inter cooling can be shown as 1 – 2 – 3 – 4 – 5 – 6

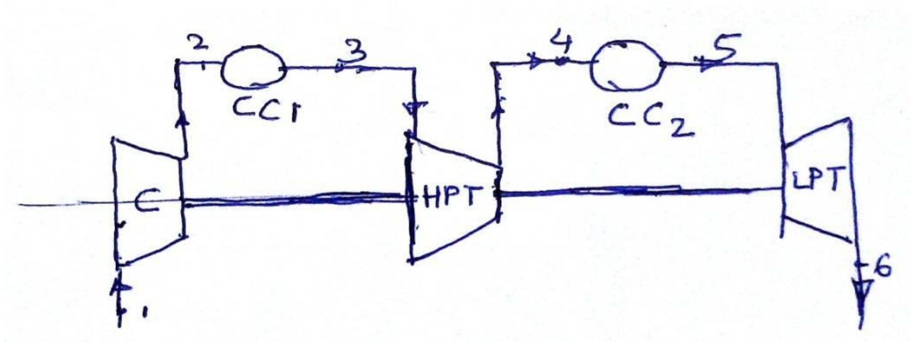
In first stage compressor atmospheric air is compressed from P_1 to P_2, it is them cooled from temperature T_2 to $T_3 = T_1$ in the inter cooler at constant inter mediate pressure P_x and finally compressed from P_x to P_2 in second stage or compressor.

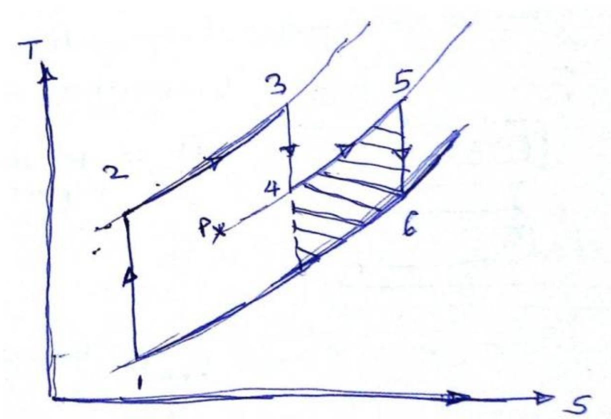
ii) <u>Gas turbine with reheating</u> (2+ 2 marks)

CC – Combustion Chamber

C – Compressor

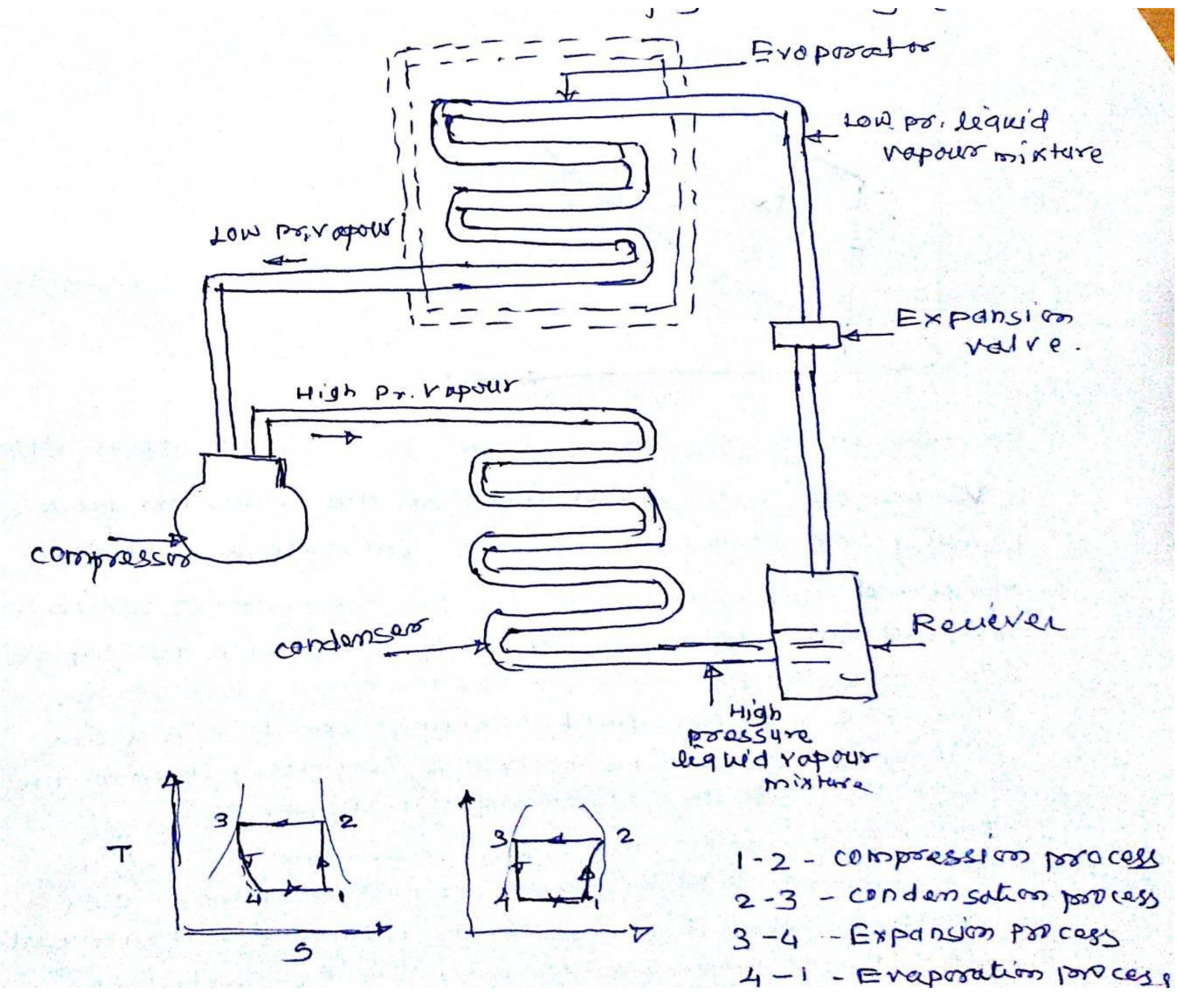
T – Turbine





By reheating or adding heat to exhaust gases after have passed through a part of the rows of turbine balding (or stages), a further increase in work done obtained. In reheating, the gas temperature which has dropped due to expansion is brought back to approximately the initial temperature for expansion in next stage. Since the working fluid contains about 85% of air, additional fuel can be burnt by injecting it into the gases without any additional air supply. The reheat cycle can be shown as 1 – 2 – 3 – 4 – 5 – 6. The combustion gases from combustion chamber CC1 at temperature T_3 is partially expanded in the HP turbine from P_2 to intermediate pressure P_x. After this, it is them passed through combustion chamber CC2 where it is reheated at constant pressure P_x so that the temperature of gas is raised from T_4 to T_5. After this gas is expanded in second stage of turbine reheating is shown by shaded area.

Q.5 c) (4+ 4 marks)



Vapour compression refrigeration cycle

Vapour compression refrigeration cycle consist of four different processes 1) Compression 2) Condensation 3) Expansion 4) Evaporation

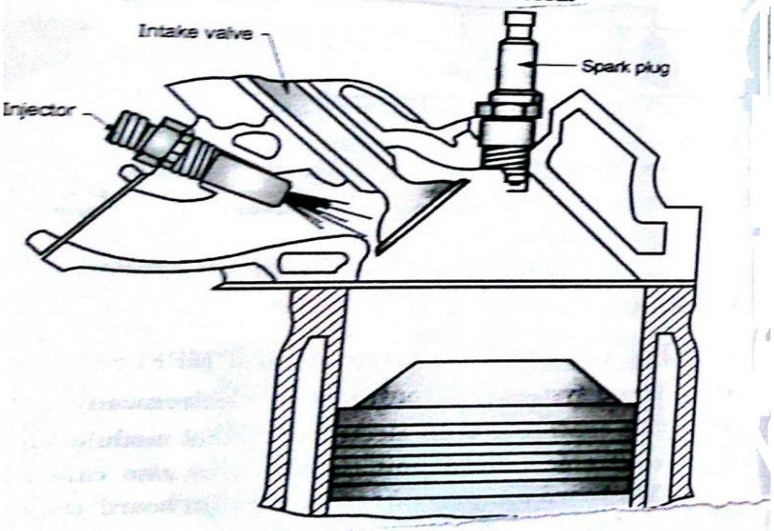
Components and its functions

1) Compressor – The low pressure & temperature refrigerant from evaporator is drawn into compressor. It is compressed to a high pressure & high temp. vapour refrigerant is discharged into condenser.
2) Condenser – High pressure & temperature vapour refrigerant is cooled and condensed by using air or water & form liquid vapour refrigerant. Heat is rejected
3) Expansion valve – to control flow of refrigerant and reducing it pressure and temperature
4) Evaporator – liquid vapour refrigerant at low pressure and low temperature is evaporated by absorbing heat from system or substance and change into vapour refrigerant.

Q.6 a) The MPFI means multi point injection system. In this system each cylinder has number of injector to supply/ spray fuel in cylinder as compared to one injector located centrally to supply and spray fuel in case of single point injection system. **(1+ any one method 3 marks)**

(a) Port injection system :

- In the port injection arrangement, the fuel injectors are mounted on the side of the intake manifold. The injector sprays petrol into the air stream inside the intake manifold.



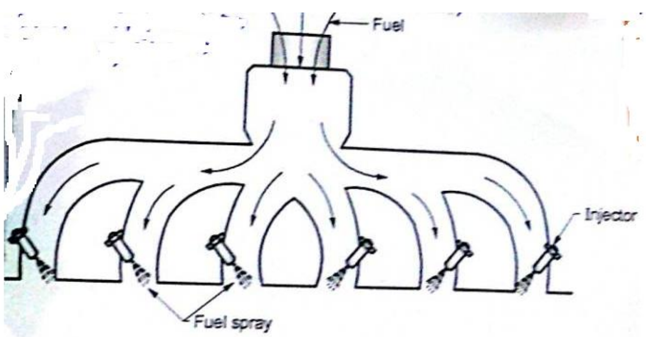


Fig. : Port injection or Multi-point fuel injection

- The petrol mixed in the air stream completely. This mixture of petrol and air then passes through the intake valve and enters into the cylinder.
- Each cylinder is provided with an injector in its intake manifold.
- The number of injector is always equal to number of cylinder (Fig. shows a simplified view of a port or multi point fuel injection (MPFI) system.

b) Define i) Free air delivered (FAD) – It is volume of air delivered under the condition of temperature and pressure existing at compressor intake, i.e. volume of air delivered at surrounding air temperature & pressure. In absence of any given free air conditions these are generally taken as 1.101325 bar and 15^0c.

ii) Compressor capacity – It is quantity of free air actually delivered by compressor in m^3/min.

iii) Swept volume – It is the volume of air taken during sanction stroke. It is expressed in m^3.

iv) Pressure ratio – It is defined as delivery pressure to suction pressure.

One mark each

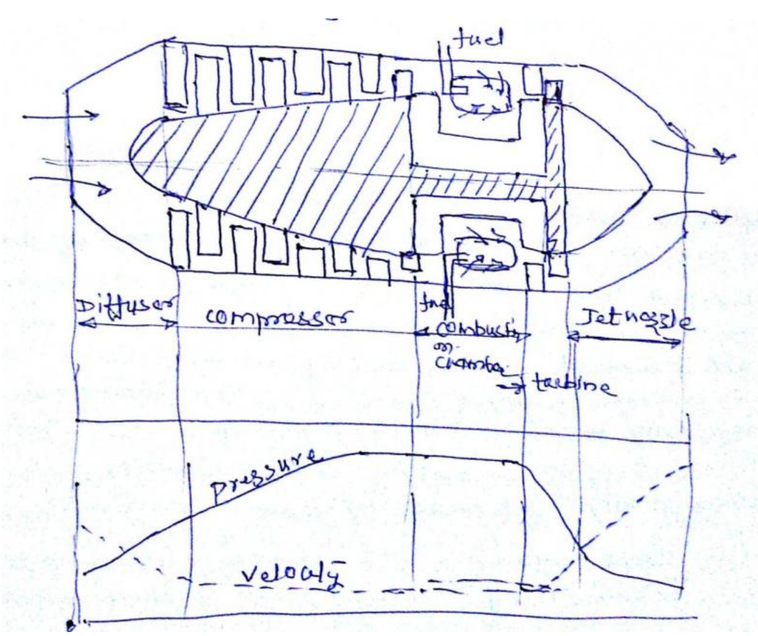
c) Working principle of jet propulsion **(2+ 2 marks)**

- Jet propulsion is based on Newton's second law and third law's of motion.

- Means producing forward axial thrust by means of reaction of jet of gases which are discharged rearward with a high velocity (aircraft, missile & submarine)

- As applied to vehicle operating in fluid, a momentum is imparted to a mass of fluid in a such a manner that the reaction of imparted momentum furnishes a propulsive force. The magnitude of this propulsive force is termed as thrust.

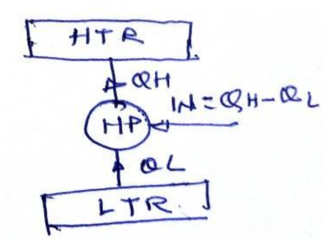
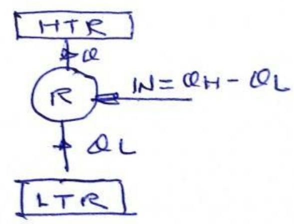
- For efficient production of large power, fuel is burnt in an atmospheric of compressed air combustion chamber, the product of combustion expanding first in gas turbine which drive the air compressor and second in nozzle from which thrust is desired for turbojet engine.



Turbojet consist of 1) Diffuser 2) Compressor 3) Combustion chamber 4) Turbine 5) Jet-nozzle.

Function – Diffuser is to convert the K.E. or air into state pressure rise, air is compressed in compressor air is entered into combustion chamber where fuel is supplied and combustion take places at const. It expanded in turbine where drops or pressure & increased in velocity. After gases leaves the turbine, they further expanded in nozzle & its leaves with high velocity to produce forward thrust…?

d) Differentiate **each point 1 mark**

Heat pump	Refrigerator
1. It is a device to maintain temperature of system above the atmospheric temp.	1. It is a device to maintain temperature of the system below the atmospheric temperature.
2. Heat pump is to transfer heat energy from low thermal reservoir to high thermal reservoir with some external work supplied	2. Refractor is to transfer heat energy from LTR to HTR by supplying external work.
3. 	3. 
4. $COP_{HP} = \frac{desired\ heating\ effect}{work\ supplied}$ $COP_{HP} = \frac{QH}{QH - QL}$ $OR = \frac{TH}{TH - QL}$	4. $COP_{(R)} = \frac{desired\ cooling\ effect}{work\ supplied}$ $COP_{(R)} = \frac{QL}{QH - QL}$ $OR = \frac{TL}{TH - TL}$

e) Working of window air conditioner **(2+ 2 marks)**

The low pressure and low temperature refrigerant vapour from evaporator is sucked by compressor. The compressor compresses the vapour to high pressure and high temperature and discharges to the condenser. On the condenser the refrigerant vapour condenses by dissipating heat to the cooling medium (air) the liquid refrigerant coming out of condenser passes through filter, dryer into capillary tube where it is again throated back to the evaporated pressure. The low pressure low temp liquid refrigerant then flows to evaporator which it boil off by extracting heat from air to be circuited to the conditioned space.