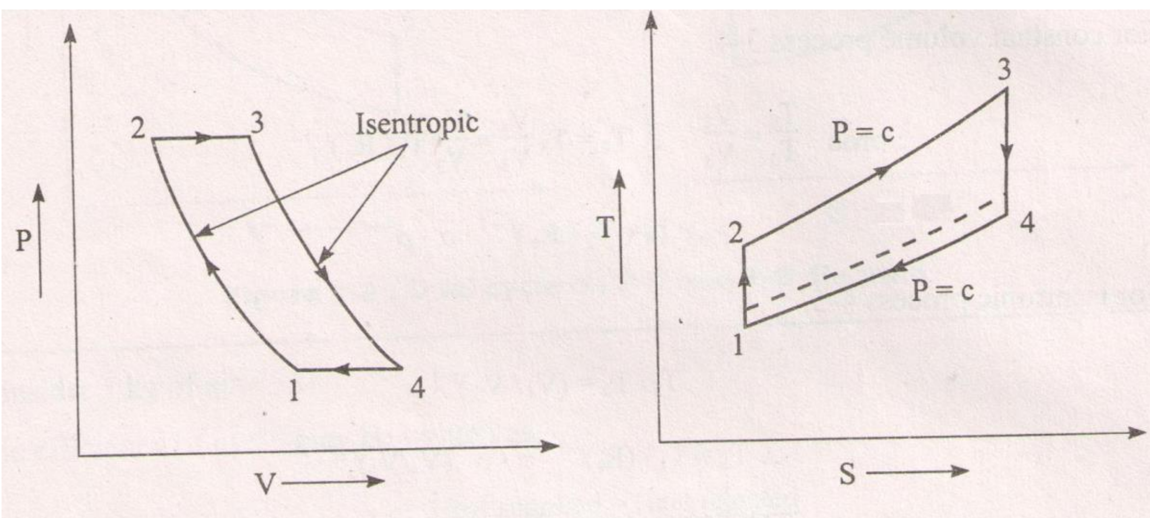
Important Instructions to examiners:

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 (A)

Brayton Cycle : (02 marks for each figure)



Process 2-3 & 4-1: Both are constant pressure process (In T-S diagram)

(b) (02 marks for each definition)

i) FAD – It is the volume of air delivered under the intake conditions of temperature and pressure. **(2 marks)**

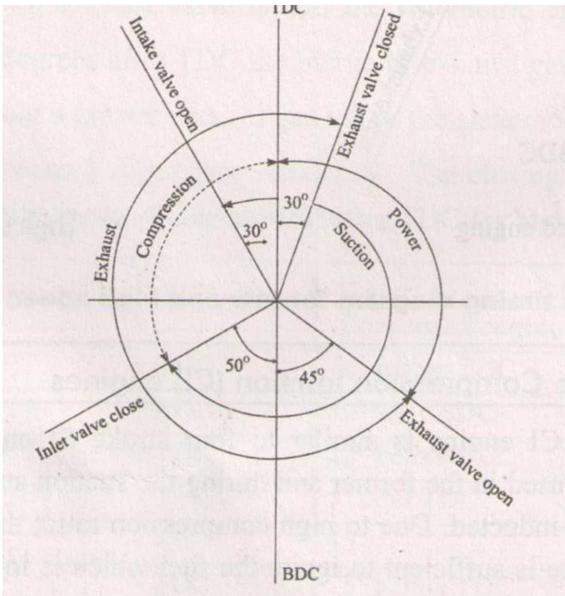
ii) Compression ratio – It is defined as the ratio of absolute discharge pressure to the absolute inlet pressure. **(2 marks)**

(c) Following are the applications of compressed air - *(Any Four)* 1/2 mark each

1) To drive air motors in coal mines.
2) To inject fuel in air injection diesel engines.
3) To operate pneumatic drills, hammers, hoists, sand blasters.
4) For cleaning purposes.
5) To cool large buildings.
6) In the processing of food and farm maintenance.
7) For spray painting in paint industry.
8) In automobile & railway braking systems.
9) To operate air tools like air guns.
10) To hold & index cutting tools on machines like milling.

d) (04 marks for figure)

Valve timing diagram of four stroke diesel engine



Q.1 (B) (06 marks for explanation)

(a) Procedure to conduct Morse test

First engine is allowed to run at constant speed and brake power of engine is measured when all four cylinder working.

$(IP_1 + IP_2 + IP_3 + IP_4) = (BP)_{1234} + (FP)_{1234}$ ……………………………………………(1)

Where, IP- indicated power.

BP – brake power develop.

FP – frictional power.

I, 2, 3, 4 – cylinder number respectively.

Now the first cylinder is cut off by short circuiting spark plug in case of S.I engine and by cutting fuel supply in case of C.I engine. Due to this, cylinder 1 will not develop IP_1 but continue to consume FP to measure BP $_{(234)}$.reduce speed to bring to initial speed by reducing load.

$(IP_2 + IP_3 + IP_4) = (BP)_{234} + FP_{(1234)}$ ………………………………………………….. (2)

When cylinder 2 is cut off and speed of engine returned to initial speed and to measure BP $_{(134)}$

$(IP_1 + IP_3 + IP_4) = (BP)_{134} + FP_{(1234)}$ ………………………………………………...… (3)

When cylinder 3 is cut off and speed of engine returned to initial speed and to measure BP $_{(124)}$

$(IP_1 + IP_2 + IP_4) = (BP)_{124} + FP_{(1234)}$ ……………………………………………………. (4)

When cylinder 4 is cut off and speed of engine returned to initial speed and to measure BP $_{(123)}$

$(IP_1 + IP_2 + IP_3) = (BP)_{123} + FP_{(1234)}$ ……………………………………………………. (5)

Each cylinder of IP will get by,

i) Subtracting equation 2 from equation 1,

$IP_1 = BP_{(1234)} – BP_{(234)}$

ii) Subtracting equation 3 from equation 1,

$IP_2 = BP_{(1234)} – BP_{(134)}$

iii) Subtracting equation 4 from equation 1,

$IP_3 = BP_{(1234)} – BP_{(124)}$

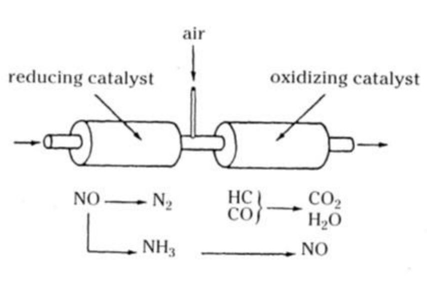
iv) Subtracting equation 5 from equation 1,

$IP_4 = BP_{(1234)} – BP_{(123)}$

Thus indicated power of engine

$IP = IP_1 + IP_2 + IP_3 + IP_4$

(b) Three way catalytic convertor **(sketch -3, explanation – 3 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°C, 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.

Q.2a (08 marks for full solution)

Q2 (a) $V_1 = 15\ m^3/min$ $P_1 = 1.0132$ bar

$P_2 = 10$ bar $n = 1.3$

For single stage compression

$$W_1 = \frac{n}{n-1} P_1 V_1 \left[\left(P_2/P_1 \right)^{n-1/n} - 1 \right]$$

$$= \frac{1.3}{1.3-1} \times 1.0132 \times 10^5 \times \frac{15}{60} \left[\left(\frac{10}{1.0132} \right)^{\frac{1.3-1}{1.3}} - 1 \right]$$

$$= 76.06\ kW$$

For Two stage compression

$$W_2 = \frac{2n}{n-1} P_1 V_1 \left[\left(P_3/P_1 \right)^{\frac{n-1}{2n}} - 1 \right]$$

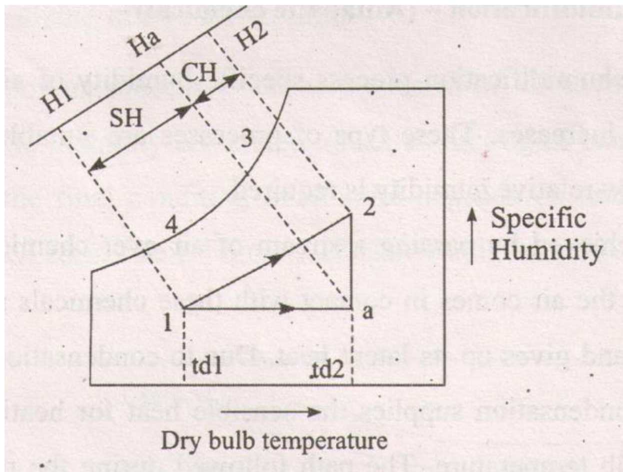
$$= \frac{2 \times 1.3}{1.3-1} \times 1.0132 \times 10^5 \times \frac{15}{60} \left[\left(\frac{10}{1.0132} \right)^{\frac{1.3-1}{2 \times 1.3}} - 1 \right]$$

$$= 66.38\ kW$$

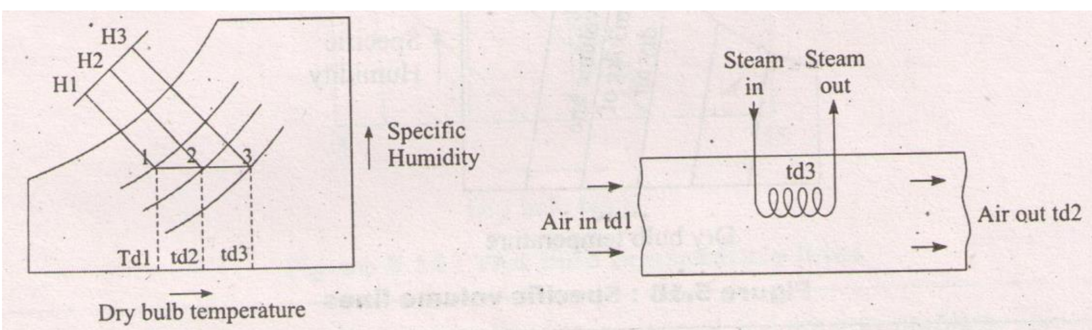
In case of two stage compression, less power is required to drive the compressor.

Q.2 (b) (02 marks for each)

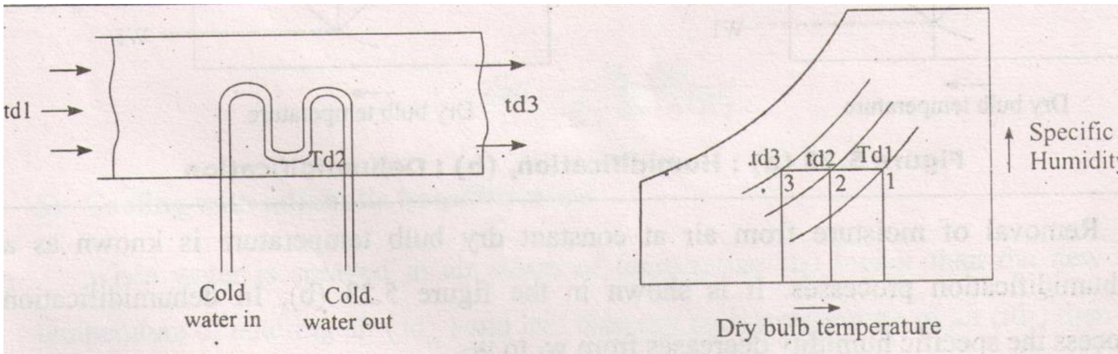
i) Heating with humidification



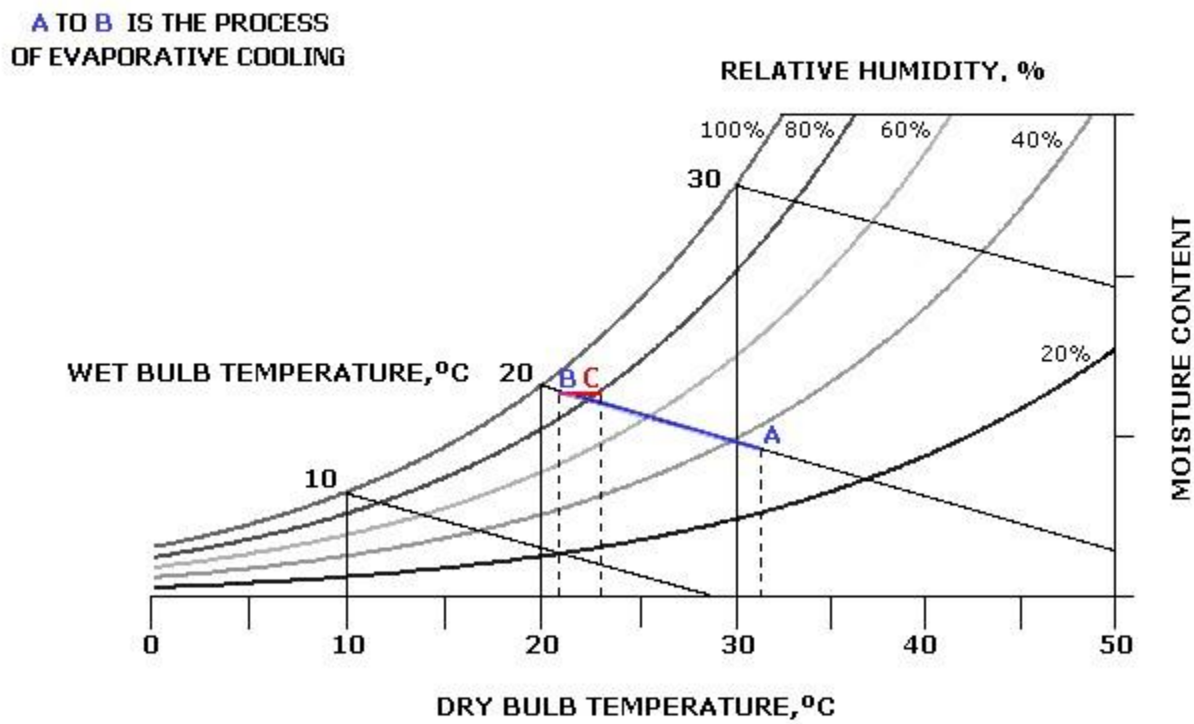
ii) Sensible heating



iii) Sensible cooling



iv) Evaporative cooling



Q.2 (C) (08 marks for full solution) i) 4marks ii) 4marks

Q2 (c) Given,

$n = 240$ r.p.m. Duration of trial = 30 min.

Fuel consumption = 6 lit

C.V. = 42000 KJ/Kg Sp. gravity = 0.8

IMEP = 550 KPa Brake Load = 150 Kg

Spring balance reading = 15 Kg

$d = 30$ cm, $l = 45$ cm, $m_w = 11$ Kg/min

$\Delta t_w = 36°c$

$$I.P. = P_m \cdot L \cdot A \cdot \frac{n}{2}$$

$$= 550 \times 10^3 \times 0.45 \times \frac{\pi}{4} \times (0.3)^2 \times \frac{240}{2 \times 60}$$

$$= 35.00 \text{ KW}$$

$$B.P. = 2\pi N T$$

$$= 2\pi \times \frac{240}{60} \times (150 - 15) \times 9.8$$

$$= 33.264 \text{ KW}$$

$$\text{Heat Supplied} = m_f \times C.V. = \frac{6}{30} \times 0.8 \times 42000$$

$$= 6720 \text{ KJ/min} \quad (100\%)$$

$$B.P. = 33.264 \times 60$$

$$= 1996 \text{ KJ/min} \quad (29.7\%)$$

$$\text{Heat lost to cooling water} = m_w \times C_{pw} \times \Delta t_w$$

$$= 11 \times 4.187 \times 36$$

$$= 1658 \text{ KJ/min} \quad (24.7)$$

$$\text{Heat unaccounted} = 6720 - (1996 + 1658)$$

$$= 3066 \text{ KJ/min} \quad (45.6\%)$$

Heat supplied KJ/min	kJ/ min	%	Heat expenditure	kJ/min	Percentage

Heat supplied by combustion of fuel	6720	100	1) Heat equivalent of brake power	1996	29.7%
			2) heat lost to jacket cooling water	1658	24.7%
			3)heat unaccounted	3066	45.6%
TOTAL	3684	100%	TOTAL	3684	100%

Q.3 (a) (02 marks each for petrol and diesel)

Norms for Bharat stage III and IV :

In year 2010 – Bharat Stage III Emission Norms for 2-wheelers, 3-wheelers and 4-wheelers for entire country whereas Bharat Stage – IV (Equivalent to Euro IV) for 13 major cities for only 4-wheelers. Bharat Stage IV also has norms were implemented for 4-wheelers for 13 major cities for only 4-wheelers. Currently, BS-IV petrol and diesel are being supplied in whole of Northern India covering Jammu and Kashmir, Punjab, Haryana, Himachal Pradesh, Uttarakhand, Delhi and parts of Rajasthan and western UP. The rest of the country has BS-III grade fuel.

Emission norms for Diesel Engine Vehicles, g/kWh

Year	**Standard**	**CO**	**HC**	**NO_x**	**PM**
2010	BS III	2.1	0.66	5.0	0.10

		5.45	*0.78*	*5.0*	*0.16*
2010	*BS IV*	*1.5*	*0.46*	*3.5*	*0.02*
		4.0	*0.55*	*3.5*	*0.03*

Emission norms for Petrol Vehicles, g/km

Year	**Standard**	**CO**	**HC**	**HC+NO$_x$**	**NO$_x$**
2010	BS III	2.3 4.17 5.22	0.20 0.25 0.29	–	0.15 0.18 0.21
2010	BS IV	1.0 1.81 2.27	0.1 0.13 0.16	–	0.08 0.10 0.11

Q.3 (b) (01 mark for each)

Classification of gas turbines :

Gas turbines are classified as :

1. On the basis of combustion process

a) Constant pressure type

b) Constant volume or explosion type

2. On the basis of path of working substance

a) Open cycle gas turbine

b) Closed cycle gas turbine

3. On the basis of action of expanding gases

a) Impulse gas turbine

b) Impulse reaction gas turbine

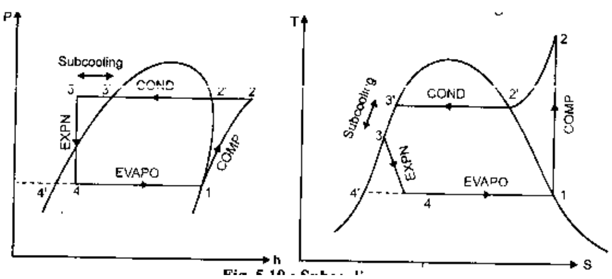
4. On the basis of direction of flow

a) Axial flow

b) Radial flow

Q.3 (C) (4 marks for explaination)

Sub cooling



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

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

Q.3 (d) (02 marks for explanation and 02 for list)

Scavenging: At the end of expansion stroke the combustion chambers of a two stroke engine is left full of products of combustion. This is because unlike four stroke engines, there is no exhaust stroke available to clear the cylinder of burnt gases in two stroke engine the process of clearing the cylinder after the expansion stroke is called scavenging process.

The scavenging systems are as follows :

1. Uniform scavenging system
2. Cross scavenging system
3. Loop or reverse scavenging system

Q.3 (e) **(**04 marks for explanation)

Supercharging: The power output of an engine depends upon the amount of air inducted in cylinder per unit time, the degree of utilization of this air and the thermal efficiency of the engine. The amount of air inducted per unit time can be increased by increasing the engine speed or by increasing the density of air at intake. As engine speed increases, the inertia load, engine friction, bearing load increases. The method of increasing the inlet air density is called as supercharging. It is usually employed to increase the power output of the engine. The increase of the amount of air inducted per unit time by supercharging is obtained mainly to burn greater amount of fuel in a given engine.

Supercharging increases the power output for a given weight and bulk of engine, compensate for loss of power due to altitude and obtain more power from the existing engine.

Q.4 (A) **(a**) (1/2 mark each (**any eight**) **)**

Important Features of MPFI system

- Absence of Venturi – No Restriction in Air Flow/Higher Vol. Eff./Torque/Power
- Hot Spots for Preheating cold air eliminated / Denser air enters
- Manifold Branch Pipes not concerned with Mixture Preparation
- Better Acceleration Response
- Fuel Atomization Generally Improved.
- Use of Greater Valve Overlap
- Use of Sensors to Monitor Operating Parameters/Gives Accurate Matching of Air/fuel Requirements: Improves Power, Reduces fuel consumption and Emissions
- Precise in Metering Fuel in Ports
- Precise Fuel Distribution Between Cylinders
- Fuel Transportation in Manifold not required so no Wall Wetting
- Fuel Surge During Fast Cornering or Heavy Braking Eliminated
- Adaptable and Suitable For Supercharging
- Increased power and torque.

Q 4 A b) (04 marks for full solution)

Q4 (A) (b)

Given,

$d = 15\,cm \quad l = 40\,cm$

$m.e.p. = 5\,bar \quad r.p.m. = 120$

$b.p. = 5\,kW$

$I.P. = P_m L A n$

$= 5 \times 10^5 \times 0.4 \times \frac{\pi}{4} \times (0.15)^2 \times \frac{120}{60}$

$= 7.07\,kW$

$\eta_{mech} = \frac{b.p.}{I.P.} = \frac{5}{7.07} = 70.7\%$

Q.4 (A) (c)

Effects of detonation (any four- 4 marks ,1 mark each)

(1) **Noise** – As intensity of detonation increases, the sound intensity increases & it is harmful.

(2) **Mechanical damage** – shock waves are so violent that it may cause mechanical damage like breaking of piston. It increases the rate of wear erosion of piston.

(3) **Pre-ignition** – Due to local overheating of spark plug & this pre-ignition increases detonation.

(4) **Power output & efficiency decreases -** Power output & thermal efficiency decreases due to abnormal combustion.

(5) **Increase in heat transfer** – Temperature of cylinder in detonating engine is higher than in non – detonating engine, hence increases the heat transfer.

(6) **Carbon deposits-** Detonation results in increased carbon deposits.

Q.4 (A) (d) (02 marks each)

(i) Mean effective pressure – Defined as the average pressure acting on the piston which will produce the same output as is done by the varying pressure during the cycle.

(ii) **Cut off ratio –** Fuel is injected into combustion chamber where only air compressed and is at high temperature. Fuel is injected for a duration of time, say T. The piston would not have reached the bottom dead centre in time T. The fuel is **cut off** when the volume is, say V2. The clearance volume is V1. The **ratio** V2/V1 is **cut off ratio**.

Q.4 (B) (a) Additives **(<u>any four</u>** additives + advantage = 1+1/2 marks each **)**

(1) Detergents – To keep engine parts, such as piston and piston rings, clean & free from deposits.

(2) Dispersants – To suspend & disperse material that could form varnishes, sludge etc that clog the engine.

(3) Anti – wear – To give added strength & prevent wear of heavily loaded surfaces such as crank shaft rods & main bearings.

(4) Corrosion inhibitors – To fight the rust wear caused by acids moisture. Protect vital steel & iron parts from rust & corrosion.

(5) Foam inhibitors – control bubble growth, break them up quickly to prevent frothing & allow the oil pump to circulate oil evenly.

(6)Viscosity index improver – added to adjust the viscosity of oil.

(7) Pour point depressant - improves an oil ability to flow at very low temperature.

Q 4 B b) (06 marks for full solution)

Q4 (B) (b)

Given,

$\varepsilon_c = 8 \quad m = 1\ kg/min \quad T_1 = 300°K$

$T_3 = 2000°K \quad \gamma = 1.4$

$C_v = 0.71\ kJ/kg°K$

$$\eta_{air\ std} = 1 - \frac{1}{\varepsilon_c^{\gamma-1}} = 1 - \frac{1}{8^{1.4-1}}$$

$$= \underline{56.5\%}$$

$$\frac{T_2}{T_1} = \left(\frac{v_1}{v_2}\right)^{\gamma-1} \qquad T_2 = T_1 \times \varepsilon_c^{\gamma-1} = \underline{689.22°K}$$

Heat added $Q_s = m C_v (T_3 - T_2)$

$$= \frac{1}{60} \times 0.71 \times (2000 - 689.22)$$

$$= \underline{15.51\ kW}$$

$$\eta = \frac{W}{Q_s} \qquad W = \eta \times Q_s = 0.565 \times 15.51 = \underline{8.763\ kW}$$

Power Developed $= \underline{8.763\ kW}$

Q. 5 (a) Working of Simple Vapor absorption system:

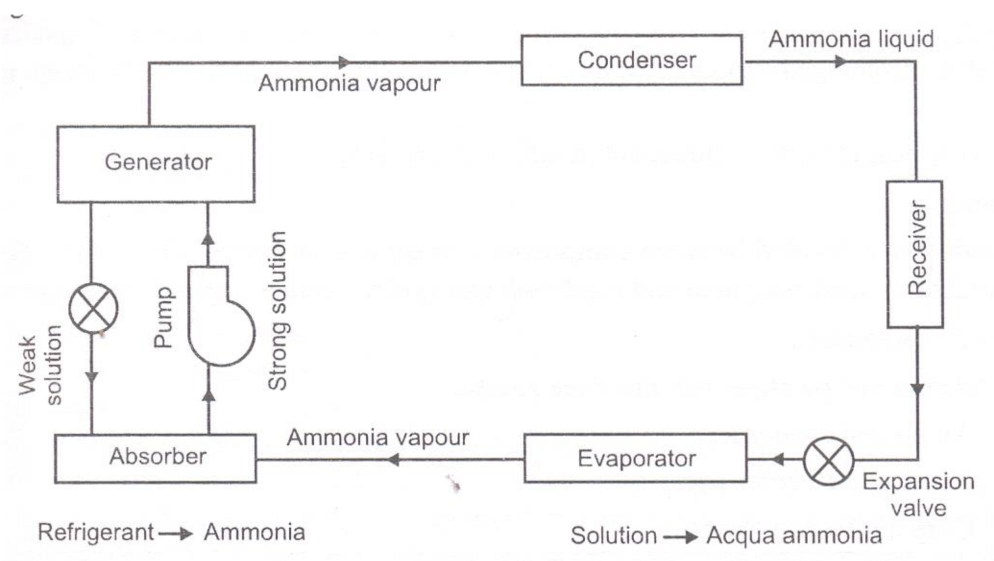
A Simple Vapor absorption system consists of evaporator, absorber, generator, condenser, expansion valve, pump & reducing valve. In this system ammonia is used as refrigerant and solution is used is aqua ammonia.

Strong solution of aqua ammonia contains as much as ammonia as it can and weak solution contains less ammonia. The compressor of vapor compressor system is replaced by an absorber, generator, reducing valve and pump.

The heat flow in the system at generator, and work is supplied to pump. Ammonia vapors coming out of evaporator are drawn in absorber. The weak solution containing very little ammonia is spread in absorber. The weak solution absorbs ammonia and gets converted into strong solution. This strong solution from absorber is pumped into generator.

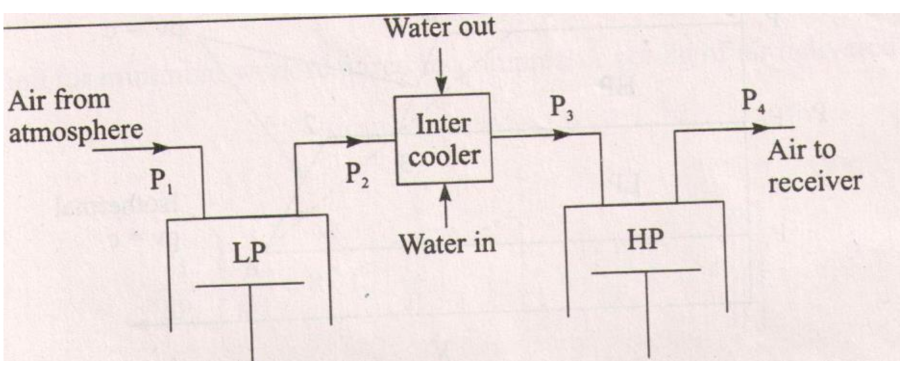
The addition of heat liberates ammonia vapor and solution gets converted into weak solution. The released vapor is passed to condenser and weak solution to absorber through a reducing valve. Thus, the function of a compressor is done by absorber, a generator, pump and reducing valve. The simple vapor compressor system is used where there is scarcity of Electricity and it is very useful at partial and full load. **------- 6 Marks**

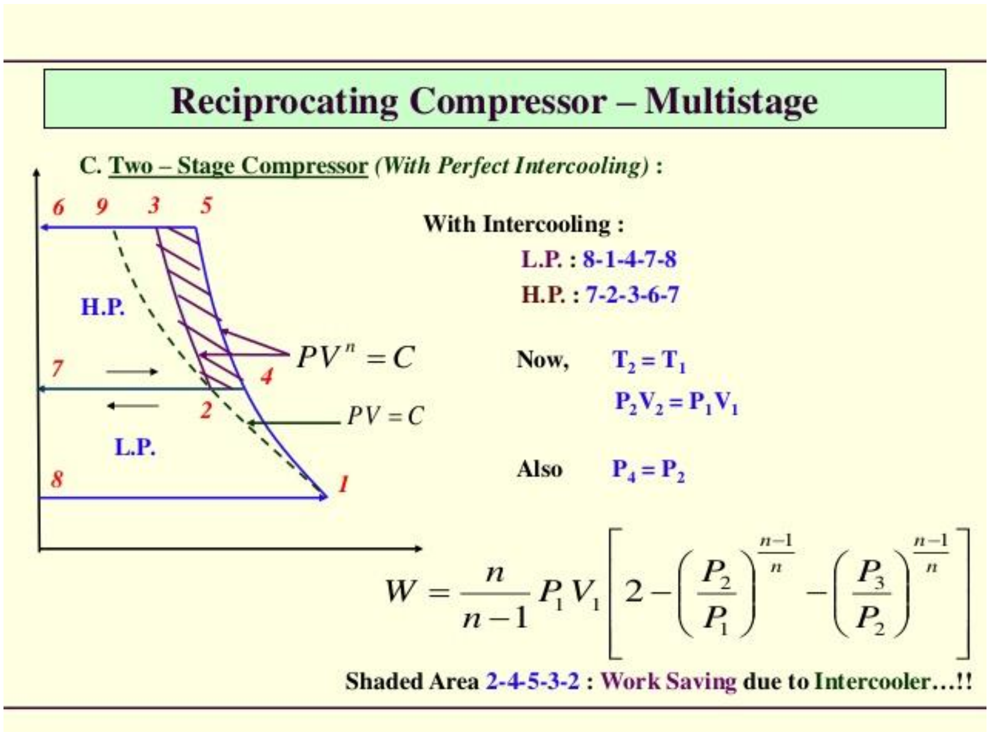
Figure -2 Marks



Q 5 b) (03 marks for each sketch and 02 for definition)

Intercooling : In perfect intercooling the temperature of air after passing out of intercooler is same as that of the temperature of air before compression of LP cylinder.





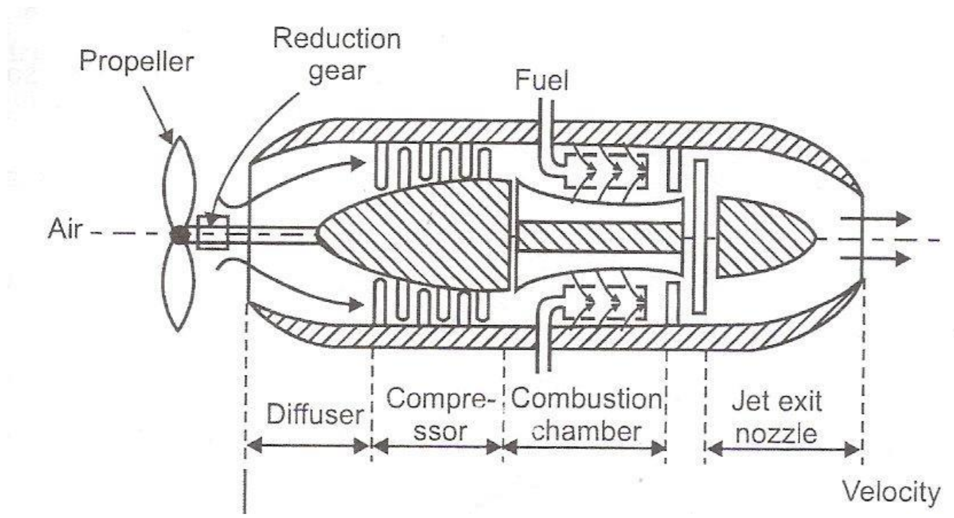
Q. 5 (C)

Working of Turbo-prop Engine:

The main components of turbo-prop engine are a propeller, gear reduction unit, a compressor, a combustor, gas turbine and the nozzles. In this engine 80 to 90% of the total propulsive thrust is generated by the gas turbine and the remainder is developed by the expansion of the gases in nozzles. Due to this the power generated in the gas turbine is used for driving the compressor and the propeller, while in case of turbojet engines the turbine power is only used to drive the compressor and the auxiliaries.

The gas turbine drives the propeller through the reduction gear unit and it draws a large amount of air. A large part of this air drawn by the propeller is passed through the ducts around the engine and the remainder is compressed in the diffuser by ram compression and further in the compressor. Fuel is burnt in the combustor and the resultant high temperature gases are expanded in the turbine and finally in the nozzles. The total thrust developed is the sum of thrust developed by the propeller and the nozzle. Unlike the turbojet engines the turboprop engines are widely used for commercial and military air crafts, due to their low specific fuel consumption and high flexibility of operation at reasonably high speed.

Explaination 5 Marks Figure -3 Marks



Q. 6 (a) (i) Tons of refrigeration – It is the quantity of heat required to remove from one ton of ice within 24 hours when initial condition of water is $0^{0.}$

One ton of refrigeration is equivalent to 210 kJ/ min or 3.5 kW

(ii) **C.O.P.** – is the ratio of heat extracted from refrigerator to the work done on the refrigerator.

COP of refrigerator = $\frac{Q}{W} = \frac{Amount\ of\ heat\ extracted}{Work\ done}$

(2 marks each)

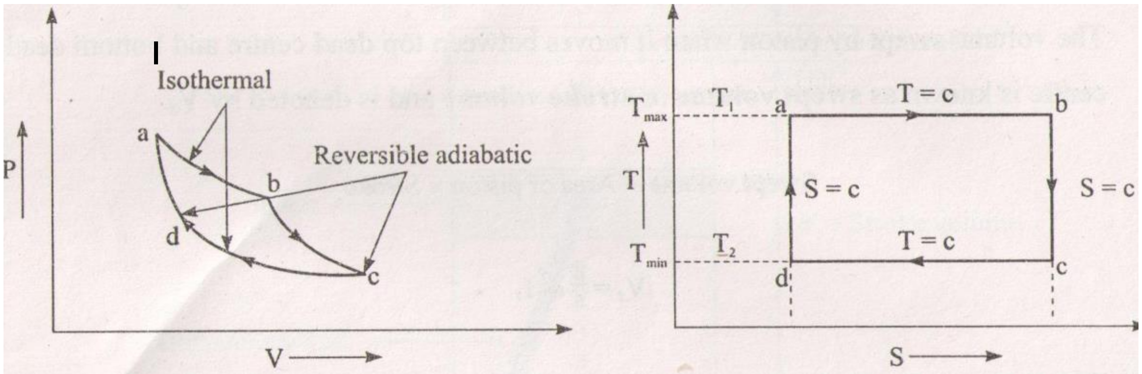
Q. 6 (b) (01 mark each any four)

Multi-stage air compressors feature many benefits and so, they are mostly used in the market. Some of those features are given below

1. Higher air pressures are achievable by multi-staging (about 175 PSI against 120 PSI in single stage)
2. It requires less power for running
3. Light weight cylinders can are used
4. Leakages are less
5. Overall discharge temperatures are lower
6. Intercooler increases the efficiency of unit
7. It has a greater durability
8. Many multi-stage air compressors have the crankcase cast separate from the pump cylinders, which makes it easier to repair.
9. Multi-stage compressors Air compressors can perform (are suitable) many different functions in industrial applications

Q. 6 (c) (02 marks each)

Representation of Carnot Cycle on P – V and T - S diagram (2 marks each)



Process 1-2:- Isentropic or reversible adiabatic Compression process.

Process 2-3:- Reversible Isothermal heat addition process.

Process 3-4:- Isentropic or reversible adiabatic expansion process.

Process 4-1:- Reversible Isothermal heat rejection process.

Q. 6 (d) (01 mark each any four)

comparison of Split AC and Window AC

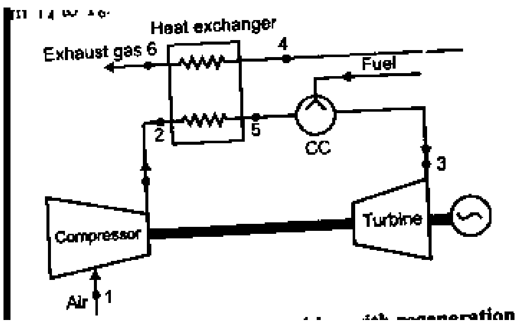
Sr No	Split AC	Window AC
1	It incorporates two units as indoor and outdoor (evaporator indoor and compressor condenser outdoor)	It is a single unit that incorporates all necessary components
2	Noise level to occupants is very less	Higher noise level
3	There is need of copper connector between indoor and outdoor units	No need of copper connector
4	Installation is easy as only a hole for connector is required	It requires more space (window) to install this AC
5	Technician / professional necessary for installation	Not necessary
6	Because cooling unit is separate, it allow the designer to take up more powerful AC	For a fixed space a specific window AC only can be installed

7	Preferable for large cooling space	Preferable for small rooms

Q. 6 (e) (04 marks any one method with sketch)

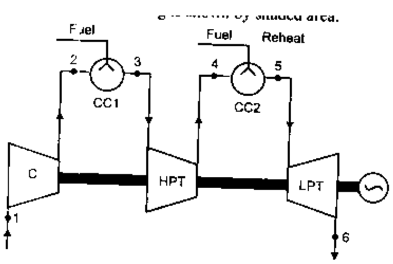
Methods to improve thermal efficiency of gas turbine

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.

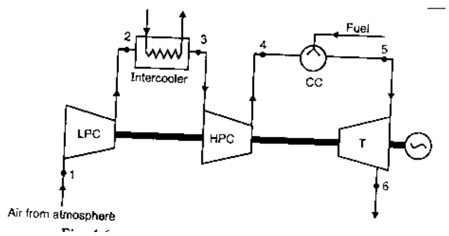


(b) Increasing the value of maximum cycle temp.

(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