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.

1	**A**	**Attempt any three**	
	a.	**Following are the applications of compressed air** (any four) 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) In vehicle to operate air brake. 8) For spray painting in paint industry.	One Mark each
	b.	**advantages of Mulitstaging :** (any four) 1. The air can be cooled in between two cylinders 2. The power required is less 3. Mechanical balance is good 4. Reduced leakage losses 5. More volumetric efficiency 6. High pressure range 7. Comparatively lighter in construction	One Mark each

	c.	c) Classify gas turbine according to 1) Combustion - ⓐ continuous combustion or constant pressure gas turbine ⓑ explosive type or constant volume gas turbine 2) Thermodynamic cycle :- Brayton or Joule cycle (for constant volume gas turbine), Atkinson cycle for const. volume gas turbine) Ericsson cycles (for constant pressure gas turbine 3) Cycle of operation 1) const. volume open cycle 2) constant pressure open & closed cycle gas turbine 4) Arragement of shafts - 1) Single shaft gas turbine (compressor is run by power turbine 2) Multishaft - gas turbine (separate compressor & power turbine 5) Fuel - liquid, gaseous, solid. 6) Application - stationary, automotive, Locomotive marine and air craft gas turbine.	4 marks
	d.	i) Tonnage of Refrigeration – is defined as the amount of refrigeration effect produced by uniform melting of one ton (1000Kg) of ice from and at 0^0in 24 hours. ii) Coefficient of performance- is the ratio of heat extracted in refrigerator to work done on the refrigerant COP = Q/W where Q= amount of heat extracted and W= amount of workdone	2 marks each
	B. a.	a) Classification of I.C engine, According to (6) i) Cycle of operation - two stroke cycle engine - four stroke cycle engine. ii) cycle of combustion - otto cycle engine, Diesel cycle engine, dual combustion cycle engine, Semi diesel cycle engine iii) Arrangement of cylinder - horizontal, Vertical, V-type, radial engine etc. iv) Number of cylinders - Single, Multicylinder engine v) Speed of engine - low, medium, high vi) Types of fuel used - Petrol, Diesel, gas engine. vii) Method of igniting fuel - spark ignition (SI) compression ignition (CI) engine. viii) Method of cooling the cylinder - air cooled and water/coolant cooled engine. ix) Method of fuel supplied - carburator engine, air injection engine. (x) Suction pressure - naturally aspirated engine and supercharged engine (xi) Application - stationary, portable, marine engine, automobile, tractor, aero engine	

b.

- To conduct Morse test, first engine is allowed to run at constant speed and brake power is measured when all cylinders (four) runs & developing power, Measure the B.P. of four cylinder

$\therefore IP(1234) = BP(1234) + FP(1234)$ — (1)

Now first cylinder is cutt off by short circuiting spark plug, speed will reduce, to increase speed to initial speed by reducing weight, and measure B.P. 1st cylinder cutt off

$\therefore IP(234) = BP(234) + FP(1234)$ — (2)

In this way cutt off remaing cylinder with same procedure follow

IInd cylinder cutt off,

$\therefore (IP)(134) = BP(134) + FP(1234)$ — (3)

IIIrd cylinder cut off

$IP(124) = BP(124) + FP(1234)$ — (4)

4th cylinder cut off

$IP(123) = BP(123) + FP(1234)$ — (5)

substracted eqn (2) from (1) we will get IP of Ist cylind

$IP(1234) = BP(1234) + FP(1234)$

$- \; IP(234) = BP(234) + FP(1234)$

$IP_1 = BP(1234) - BP(234)$ — (6)

In this way substract eqn (3) (4) (5) from eqn (1) we will get

$IP_2 = BP(1234) - BP(134)$

$IP_3 = BP(1234) - BP(124)$

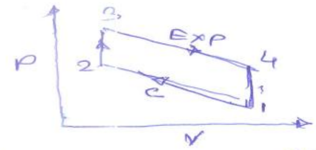
$IP_4 = BP(1234) - BP(123)$

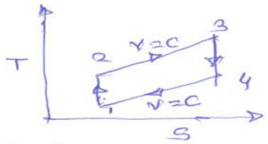
Adding IP of each cylinder we will get $IP(1234) = IP_1 + IP_2 + IP_3 + IP_4$

In this way to find out IP of each cylinder as well as IP of four cylinder.

2 a.

Q. 2. (a)





Otto cycle

Given data

$P_1 = 1.01825$ bar

$T_1 = 20^\circ C + 273 = 293$ K

$r = \left(\frac{v_1}{v_2}\right) = 8$

$Q_A = 250$ kJ/kg

considering process 1-2, $PV^\gamma = C$

$\frac{T_2}{T_1} = \left(\frac{v_1}{v_2}\right)^{\gamma-1} = (r)^{\gamma-1}$

$T_2 = T_1 (r)^{\gamma-1}$

$= 293 (8)^{1.4-1}$

$\therefore T_2 = 673.13$ K

Heat added is given by

$Q_A = C_v (T_3 - T_2)$

$250 = 0.71 (T_3 - 673.13)$

$\therefore T_3 = 1025.24^\circ K$ — max temp in cycle. (2) — **2**

A.S.E. $\eta = 1 - \frac{1}{(r)^{\gamma-1}} = 1 - \frac{1}{(8)^{1.4-1}}$

$\eta = 0.5647 = 56.47\%$

$\eta = 56.57\%$ ——— (2) — **2**

$\eta = \frac{W.D}{\text{Heat supplied}}$

$0.5647 \times 250 = W.D.$

$W.D = 141.175$ kJ/kg ——— (2) — **2**

W.D = Heat added − Heat Rejected

$141.175 = 250$ − Heat Rejected

Heat Rejected $= 250 - 141.175$

Heat Rejected $= 250 - 141.175 = 108.82$ kJ/kg (2) — **2**

b.

Q-2 (b)

Air standard efficiency is given by

$\eta = 1 - \frac{1}{(r)^{\gamma-1}}$

$0.54 = 1 - \frac{1}{(r)^{1.4-1}}$

$r = 6.97$ — compression ratio ——— (1) — **1**

Relative efficiency is given by

$\eta_r = \frac{\text{Brake thermal } \eta}{A.S.E}$

$0.70 = \frac{\eta_b}{0.54}$

$\eta_b = 0.378$ ——— (1) — **1**

Brake thermal $\eta = \frac{BP}{\text{Heat supplied}}$

$0.378 = \frac{75}{\text{Heat supplied}}$

Heat ...

Heat supplied = 75/0.378
= 198.41 kW
Heat supplied is given by
Heat supplied = mf × CV
198.41 = mf × 48000
$m_f = 0.004133$ kg/s ---(1) 1

Mech efficiency $\eta = \frac{BP}{IP}$
$0.82 = \frac{75}{IP}$
$IP = 75/0.82 = 91.46$ ---(1) 1

Indicated thermal η
$\eta_i = \frac{IP}{\text{Heat supplied}} \times 100$
$= \frac{91.46}{198.41} \times 100$ 2
$\eta_i = 46.09\ \%$ ---(2)

$BSFC = \frac{m_f\ kg/hr}{BP\ kW} = \frac{0.004133 \times 60 \times 60}{75}$ 2
BSFC = 0.1983 kg/kWh ---(2).

c.

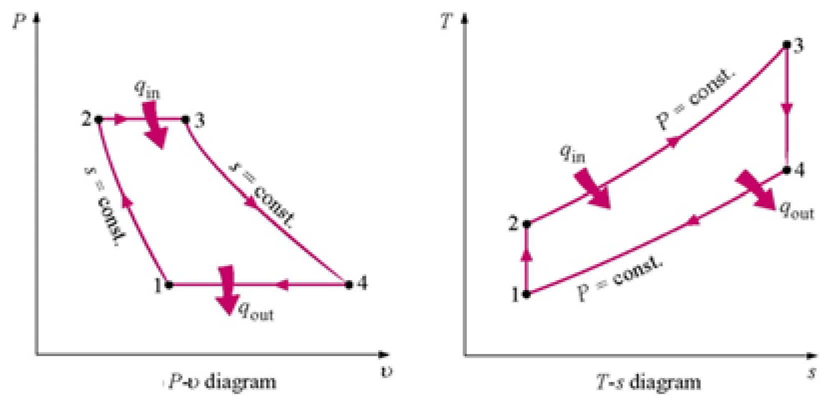
Comparison of Reciprocating & Rotary compressor

Any eight points one mark each

Reciprocating Compressor	Rotary Compressor
1. Compression of air takes place with the help of piston and cylinder arrangement with reciprocating motion of piston.	1. Compression of air takes place due to rotary motion of blades.
2. Delivery of air is 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. It needs proper lubrication and more maintenance.	6. Rotary air compressor has less number of moving parts, therefore less maintenance is required.
7. Due to low speed of rotation it cannot be directly coupled to prime mover but it requires reduction of speed.	7. Rotary air compressor can be directly coupled to prime mover.
8. Are used when small quantity of air at high pressure is required.	8. Are used where large quantity of air at lower pressure is required.

3 **Attempt Any FOUR**

a. a)



1-2 Isentropic compression (in a compressor) 2-3 Constant pressure heat addition

3-4 Isentropic expansion (in a turbine) 4-1 Constant pressure heat rejection

(Diagram 2M,Name of Processes -2M)

b. **b)**Given data:-Dc=60mm=0.06m;L= 100mm = 0.1m; m=0.0002kg

we know that swept volume of the piston is,

Vs= $\frac{\pi}{4}(0.06)^2 0.1 = 0.283\ X 10^{-3}\ \ m^3$……………………………..1M

Va= volume of charge admitted at NTP

Va= $\frac{mRT}{P} = \frac{0.0002\ X\ 287\ X 273}{1.013\ X 10^5} = 0.155X\ \ 10^{-3}\ \ m^3$……………………..1M

Volumetric efficiency= $\frac{v_a}{v_s} = \frac{0.155X\ \ 10^{-3}}{0.283\ X 10^{-3}} = 0.548 = 54.8\%$…………...2M

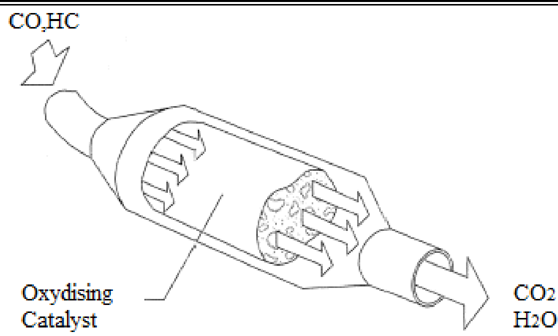
c. **C)** Catalytic Convertor: -.

A catalytic converter is cylindrical unit about the size of small silencer and is installed into exhaust system of vehicle. It converts the harmful gases from the engine into harmless gases and escapes them into atmosphere. Inside converter there is honeycomb structure of ceramic or metal which is coated with alumina base material and therefore a second coating of precious metal platinum, palladium or rhodium or combination of same.

As a result of catalytic reaction, the exhaust gases pass over the converter substance, the toxic gases such CO, HC and NOx are converted into harmless CO_2, H_2 and N_2.

Two way catalytic converter: Through catalytic action a chemical changes converts carbon monoxide (CO) and hydrocarbon (HC) into carbon dioxide (CO_2) and water (oxidation).

(Sketch 2M , Explanation 2M)



d.

d)

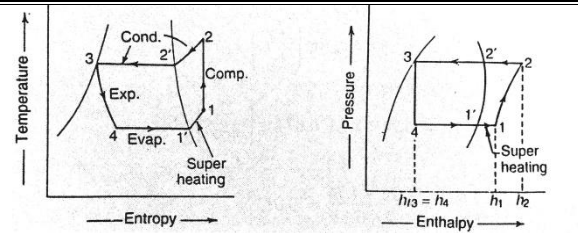
Closed Cycle Gas Turbine	Open Cycle Gas Turbine
1. The compressed air is heated in heating chamber.	1. The compressed air is heated in combustion chamber.
2. As the gas is heated by an external source, hence the amount of gas remains same thought the cycle	2. The products of combustion are get mixed up in the heated air hence same gas doesn't remain in cycle.
3. The gas after turbine is passed into the cooling chamber.	3. The gas after turbine is exhausted into the atmosphere.
4. The working fluid is circulated continuously.	4.The working fluid is replaced continuously.
5. Any fluid with better thermodynamic properties can be used.	5. Only air is used as the working fluid.
6. The turbine blades do not wear away earlier, as the enclosed gas does not get contaminated while flowing through heating chamber.	6. The turbine blades wear away earlier, as the air from atmosphere get contaminated while flowing through combustion chamber.
7.The mass of installation per Kwatt is more	7.The mass of installation per Kwatt is less
8. High maintenance cost	8. Maintenance cost is low

(1Mark for each point 4x1=4M)

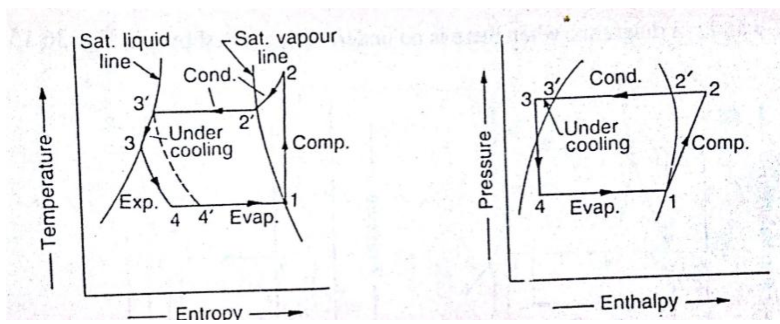
e.

e)Effect of superheating: As shown in the figure a & b the effect of superheating is to increase the refrigerating effect, but this increase in the refrigerating effect is at the cost of increase in amount of work spent to attain upper pressure limit. Since the increase in work is more as compared to increase in refrigerating effect, therefore overall effect of superheating is to give a low value of C.O.P.

(1M explanation,1M diagram =2+2=4)



ii) Effect of sub-cooling: sub-cooling is the process of cooling the liquid refrigerant below the condensing temperature for a given pressure. In figure the process of sub-cooling is shown by 2'-3'. As is evident from the figure the effect of sub-cooling is to increase the refrigerating effect. Thus sub-cooling results in increase of C.O.P provided that no further energy has to be spent to obtain the extra cold coolant required.



4. A **Attempt Any FOUR**

a.

a) i) Stroke – Distance travelled by piston from one dead Centre to other dead Centre (Say TDC to BDC).

ii) Bore:- The nominal Inner diameter of engine cylinder is called cylinder bore.

iii) Piston Speed- Distance traveled by piston in one minute.(= 2LN m/min.)

iv) The Mean Effective Pressure (MEP*)* :-It is a fictitious pressure that, if it operated on the piston during the entire power stroke, would produce the same amount of net work as that produced during the actual cycle. **OR** The average pressure acting on the piston which will produce the same output as is done by the varying pressure during the cycle

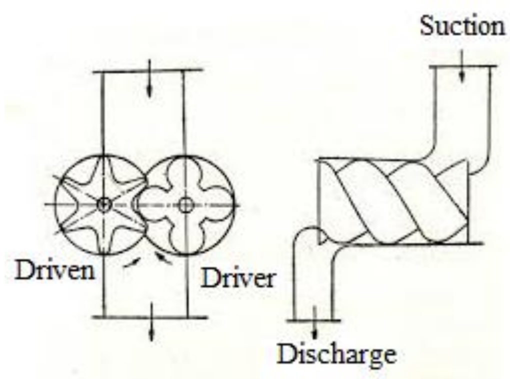
(1M for Each Definition4x1= 4M)

b.

b) A **rotary-screw compressor** is a type of gas compressor that uses a rotary-type positive-displacement mechanism. They are commonly used to replace piston compressors where large volumes of high-pressure air are needed, either for large industrial applications or to operate high-power air tools.

(Digram 2M, Explaination2M)

Rotary-screw compressors use two meshing helical screws, known as rotors, to compress the gas. In a dry-running rotary-screw compressor, timing gears ensure that the male and female rotors maintain precise alignment. In an oil-flooded rotary-screw compressor, lubricating oil bridges the space between the rotors, both providing a hydraulic seal and transferring mechanical energy between the driving and driven rotor. Gas enters at the suction side and moves through the threads as the screws rotate. The meshing rotors force the gas through the compressor, and the gas exits at the end of the screws.



c. c)

Basis	1	2
Working Cycle	Brayton(P=constant)	Atkinsons(V=constant)
Application	Aero-derivative gas turbines, Amateur gas turbines, Auxiliary Gas turbines, Industrial Gas turbines.	
Cycle of operation	Open Cycle	Closed Cycle
Fuels	Coal, Producer gas, Blast Furnace gas, Diesel, paraffin, oil and pulverized coal	

(1M for each point)

d. d)

Water cooler	R-600a(Isobutane)
Domestic Refrigerator	Freon(R-12)
Ice plant	NH_3 primary, Brine secondary
Cold storage	R717(NH_3)

(1M for each)

Attempt Any ONE **06**

4.B i) i) **Heat Balance Sheet** :-The complete record of heat supplied and heat rejected during a certain time(Say one minute)by an IC engine is entered in a tabulated form called as heat balance sheet.

i) Heat supplied by the fuel= Mf x C……………………………………1M

where Mf= mass of fuel supplied in Kg/min

C = Lower calorific value of fuel kj/kg

ii) Heat absorbed in IP produced

we know that IP produced by IC engine is

IP $= \frac{100 P_m LAn}{60}$………..kwatt

Heat absorbed in IP = $100P_m LAn$………kj/minute…………………………..1M

iii) Heat rejected to the cooling water

The mass of cooling water, circulating through the cylinder Jackets, as well as its inlet and outlet temperatures are measured in order to determine heat rejected to cooling water.

Heat rejected to cooling water $= m_w C_w (t_1 - t_2)$….kj/minute…………….1M

$Where,$

$m_w = Mass\ of\ cooling\ water\ suppliedin\ kg/min$

$C_w = specific\ heat\ of\ water$

$t_1 = Inlet\ temperature$

$t_2 = Outlet\ temperature$

iv) Heat carried away by exhaust gases = $m_g C_g\ t \ldots\ldots.kj/min$…………1M

$Where,$

$m_g = Mass\ of\ cexhaust\ gasses\ produced\ in\ \ kg/min$

$C_g = specific\ heat\ exhaust\ gases$

$t = Rise\ in\ temperature$

v) Un accounted Heat= It is the difference of Heat supplied by the fuel and Heat absorbed in IP produced, Heat rejected to cooling water , Heat carried away by exhaust gases………………………………….1M

Table………………………………….1M

Sr No	Particulars	Heat In	
		Kj	%
	Total Heat Supplied	…….	100
1	Heat absorbed in IP produced		

2	Heat rejected to cooling water		
3	Heat carried away by exhaust gases		
4	Un accounted Heat		

ii)

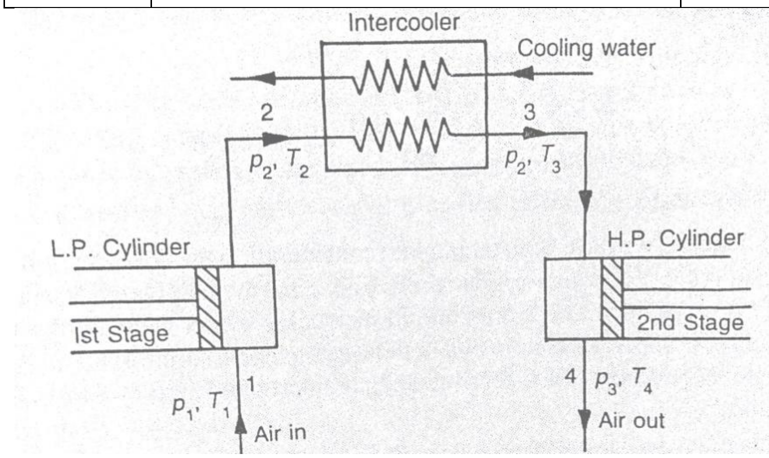
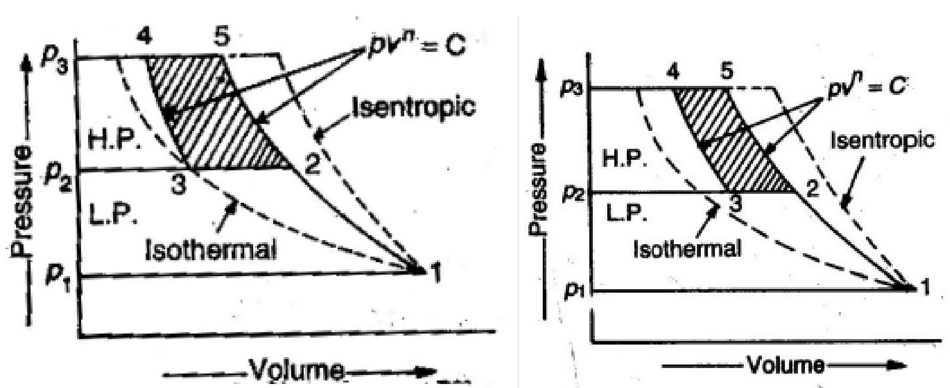


Fig.Two stage reciprocating air compressor……………………………………..2M

Working:- Let P1, V1 be the pressure and volume of air entering the low pressure cylinder P2, V2 be the pressure and volume of air leaving the low pressure cylinder or pressure and volume of air entering the intercooler P3, V3 be the pressure and volume of air entering the high pressure cylinder P4, V4 be the pressure and volume of air leaving the stage and 'n' be the index of compression(As suitable). ……………………………………………..2M

Work saved=Area(2-3-4-5)



Perfect Intercooling   Imperfect Intercooling

………2M

5	a	**FOUR STROKE PETROL ENGINE (04 Marks for Introduction & description of no. of strokes & 04 Marks for Diagram with valve position)** The four stroke-cycles refers to its use in petrol engines, gas engines, light, oil engine and heavy oil engines in which the mixture of air fuel are drawn in the engine cylinder. Since ignition in these engines is due to a spark, therefore they are also called spark ignition engines.	4+4

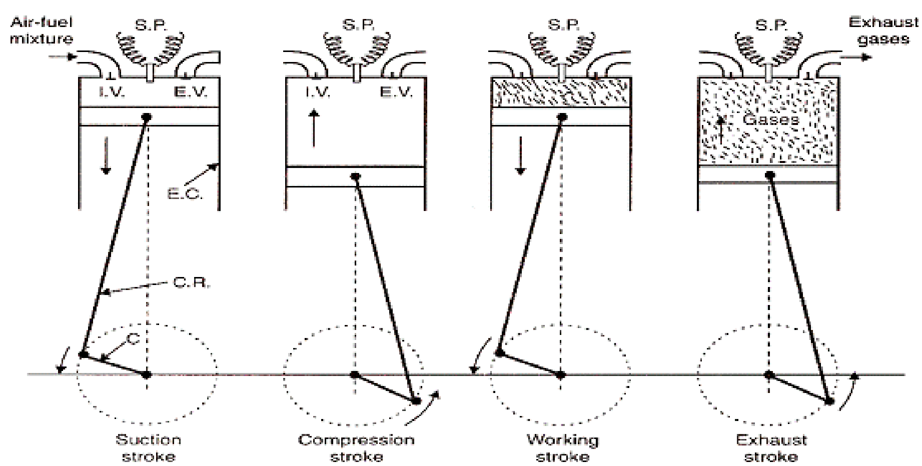
In four stroke cycle engine, cycle is completed in two revolutions of crank shaft or four strokes of the piston.
Each stroke consists of 180^0 of crankshaft rotation. Therefore, the cycle consists of 720^0 of crankshaft rotation.

Cycle consists of following four strokes

1) **Suction Stroke**
2) **Compression Stroke**
3) **Expansion or Power Stroke**
4) **Exhaust Stroke**

SUCTION STROKE:
In this Stroke the inlet valve opens and proportionate fuel-air mixture is sucked in the engine cylinder. Thus the piston moves from top dead centre (T.D.C.) to bottom dead centre (B.D.C.). The exhaust valve remains closed through out the stroke.

COMPRESSION STROKE:
In this stroke both the inlet and exhaust valves remain closed during the stroke. The piston moves towards (T.D.C.) and compresses then closed fuel-air mixture drawn. Just before the end of this stroke the operating.
plug initiates a spark which ignites the mixture and combustion takes place at constant pressure.

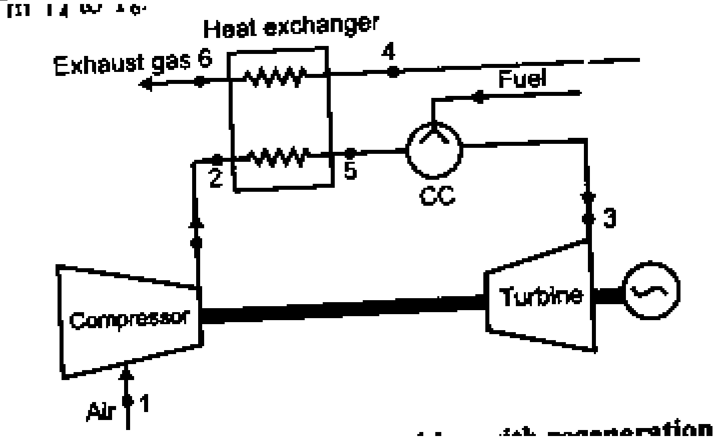


I.V = Intel valve, E.V. = Exhaust valve, E.C. = Engine cylinder, C.R. = Connecting rod
C = Crank, S.P. = Spark plug.

POWER STROKE OR EXPANSION STROKE:
In this stroke both the valves remain closed during the start of this stroke but when the piston just reaches the B.D.C .the exhaust valve opens. When the mixture is ignited by the spark plug the hot gases are produced which drive or throw the piston from T.D.C. to B.D.C. and thus the work is obtained in this stroke.

EXHAUST STROKE:
This is the last stroke of the cycle. Here the gases from which the work has been collected become useless after the completion of the expansion stroke and are made to escape through exhaust valve to the atmosphere. This removal of gas is accomplished during this stroke. The piston moves from B.D.C. to T.D.C. and the exhaust gases are driven out of the engine cylinder; this is also called scavenging.

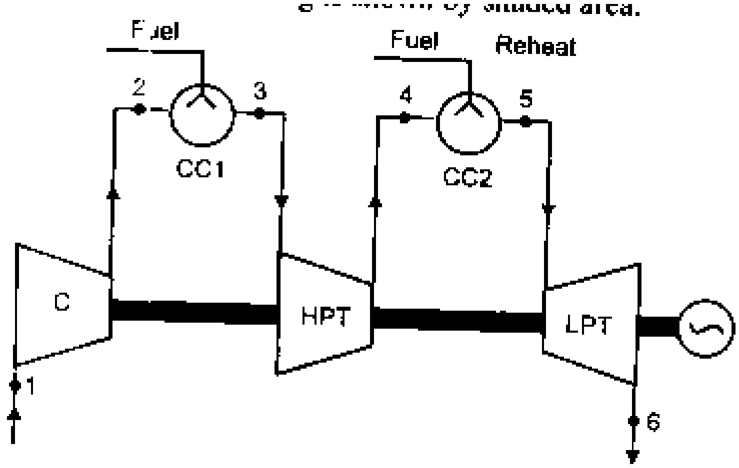
	b	**Methods to improve thermal efficiency of gas turbine Regeneration** – This is done by preheating the compressed air before entering to the combustion chamber with the turbine exhaust in a heat exchanger, thus saving fuel consumption.	(List of methods -2 marks, explanat



ion of any one – 06 marks)

2) **Improving turbine output: this can be done by**

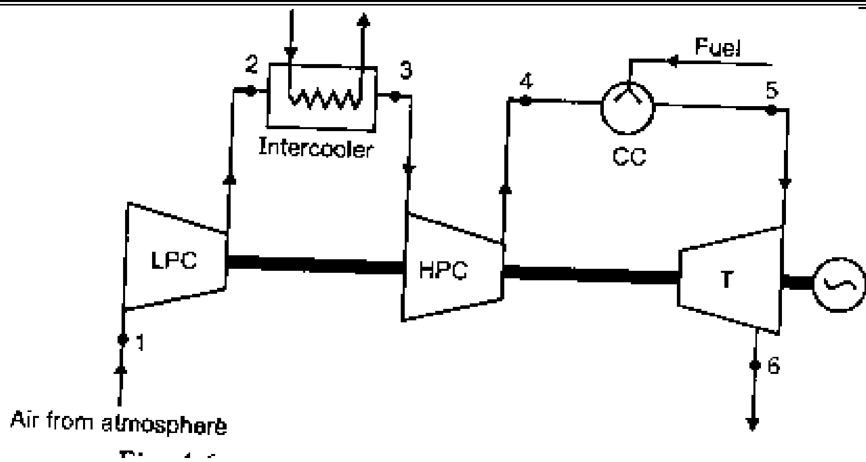
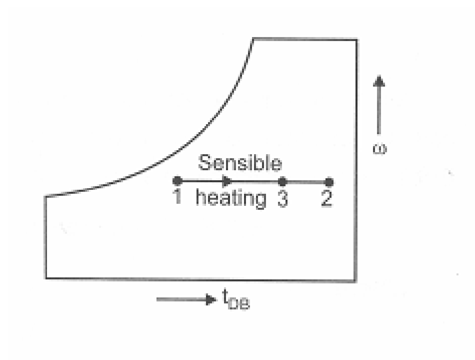
(a) Reheating : The whole expansion in the turbine is achieved in two or more stages &reheating is done after each stage.

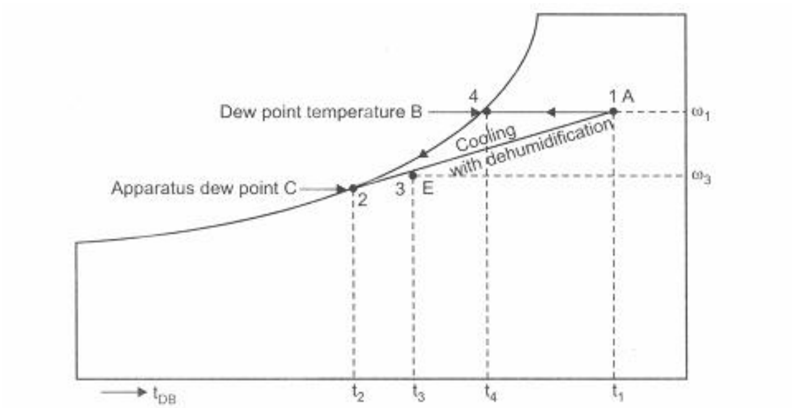
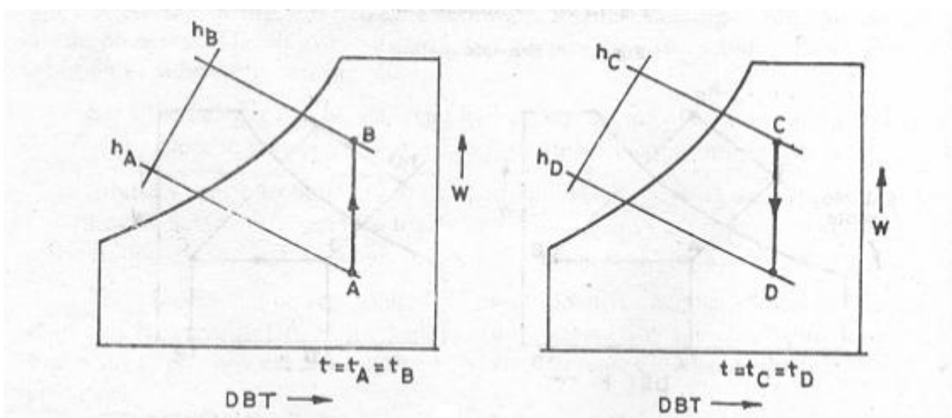


(b) Increasing the value of maximum cycle temp.

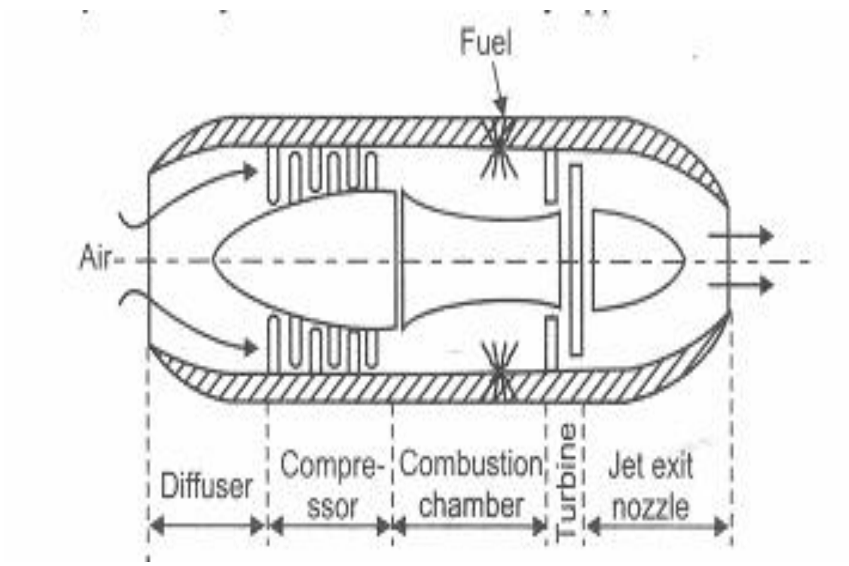
(c) Improving turbine efficiency by improving design.

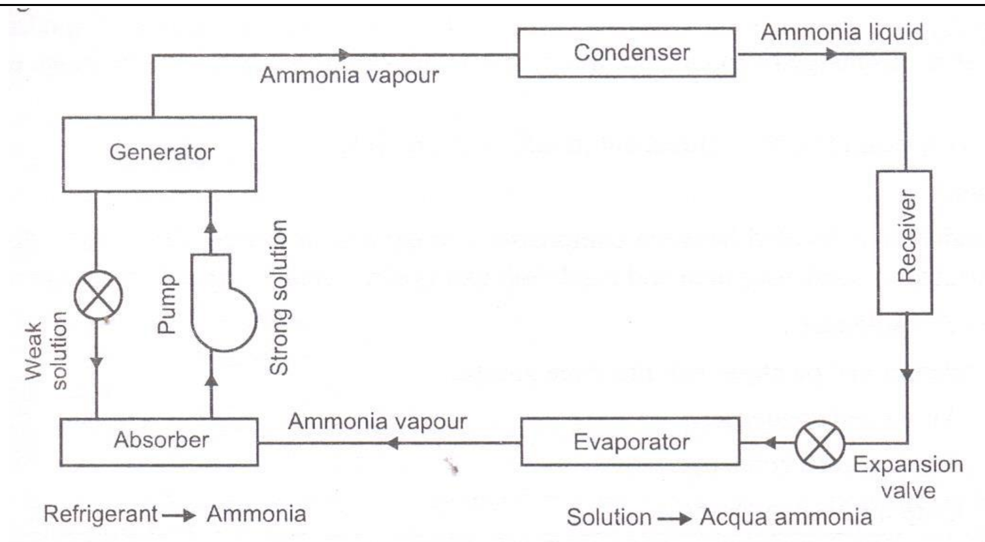
3. Reducing compressor input: By
(a) Intercooling : Compressor work is reduced by intercooling the air between the compressor stages.

		 (b)By lowering inlet temp to compressor (c) By increasing compressor efficiency (d) Water injection at inlet to compressor	
5	c	**(02 Marks for representation of each process on psychrometric chart.** **Psychometric chart representing various psychometric processes:** **i) Sensible Heating**  ii) **Sensible Cooling with dehumidification**	

		 iii) Humidification iv) Dehumidification  Latent Heating - Humidification Latent Cooling - Dehumidification.	
6	a	i) Give Data : **(02 Marks for find out IP of each cylinder & 02 Marks for Mechanical Efficiency)** Brake Power Engine (BP)engine = 16.2 kW Brake Power developed when 1st Cylinder cut-off (BP)2,3,4 = 11.5 kW Brake Power developed when 2nd Cylinder cut-off (BP)1,3,4 = 11.6 kW Brake Power developed when 3rd Cylinder cut-off (BP)1,2,4 = 11.68 kW Brake Power developed when 4th Cylinder cut-off (BP)1,2,3 = 11.5 kW Indicated Power of 1st cylinder IP1 = (BP)engine - (BP)2,3,4	

		= 16.2 – 11.5 = 4.7 kW IP2 = (BP)engine - (BP)1,3,4 = 16.2 – 11.6 = 4.6 kW IP3 = (BP)engine - (BP)1,3,4 = 16.2 – 11.68 = 4.52 kW IP4 = (BP)engine - (BP)1,2,3 = 16.2 – 11.5 = 4.7 kW Indicated Power of Engine IP = IP1 + IP2 + IP3 + IP4 = 4.7 + 4.6 + 4.52 + 4.7 = 18.52 kW Mechanical Efficiency of the Engine ηm = (BP / IP) x 100 = (16.2 / 18.52) x 100 = 87.47 %	
6	b	**Necessity:** The air sucked by the compressor is not clean. It contains various types of solid, liquid and gaseous contaminants such as dust, dirt, moisture etc. The presence of contaminants may have high damaging effects such as corrosion, wear and tear on the finely finished mating surfaces of pneumatic components. Air lines may get chocked or damaged. Therefore, purification of air by removing oil, moisture and dust is done to protect the pneumatic system from failure, so that the system should work efficiently. 1) **Particulate Filters (Dry Air Filters)** Particulate filters are used to remove dust and particles out of the air. This will allow air to travel faster in the piping system and prevent clogs. The main element in this filtration is the membrane. The membrane acts like a gate which only lets air pass through while anything bigger gets blocked by the membrane material. 2) **Coalescing Filters** Coalescing filters are used to capture oil and tiny moisture droplets and	(2 Marks) (2 Marks)

		prevent condensate from developing in the system. This will prolong the life of the piping system and other components by avoiding rust. The main component used is the flow of the air. The filter may contain a membrane element in it as well but altering the flow of the air in a tight space causes condensate or oil to gather at the bottom of the filter.	
6	c	Turbo Jet Engine 	(2 Marks for neat sketch & 2 Marks for Labeling)
6	d	i) WBT: Wet bulb Temperature twb : It is the temperature recorded by a thermometer when its bulb is covered by a wet cloth exposed to the air. ii) DPT: Dew point temperature tdp :It is the temperature of air recorded by thermometer, when the moisture (water vapour) present in its, begins to condensed. iii) DBT: Dry Bulb Temperature tdb : It is the temperature of air recorded by ordinary thermometer with a clean, dry sensing element . iv) Degree of Saturation (μ):Degree of saturation is defined as ‘the ratio of mass of water vapour associated with unit mass of dry air to mass of water vapour associated with saturated unit mass of dry air at same temperature.	(01 Mark Each)

6	e	 **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.	