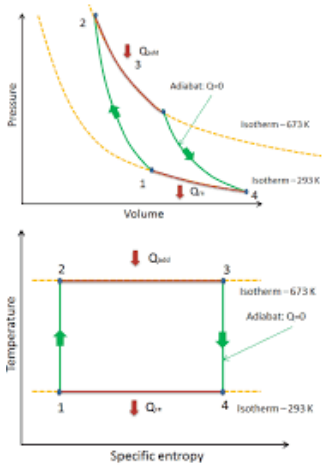
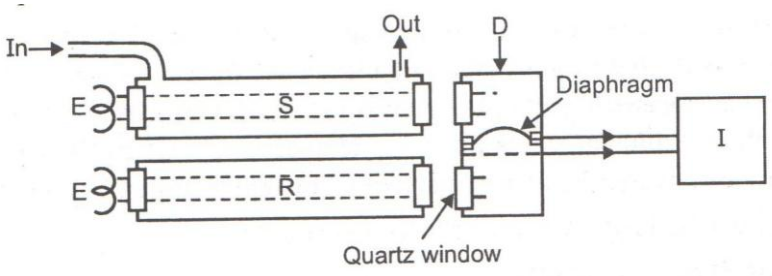
nImportant Instructions to examiners:

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. No.	Sub Q. No.	Answer	Marking Scheme
1.A		**Attempt any THREE**	
	a)	**Carnot Cycle on P-V and T-S diagram** :  **Processes :** 1-2 : Isothermal expansion 2-3 : Isentropic (reversible adiabatic) expansion 3- 4 Isothermal compression 4-1 Adiabatic reversible compression	**Fig. 3 Marks** **1M for processes**

	b)	**i) Mechanical Efficiency-** It is the ratio of the power available at the engine crankshaft (b.p.) to the power developed in the engine cylinder (i.p.). **ii) Indicated Power:** The total power developed by combustion of fuel in the combustion chamber is called indicated power.	**2M each**
	c)	**i) Pressure ratio – –** It is the ratio of the absolute discharge pressure to the absolute inlet pressure. **ii) Swept Volume –** It is the volume swept through by the first stage piston in cubic metre per minute.	**1 mark each**
	d)	**Following are the advantages of multi staging of compressor – (Any four)** 1) Reduced work of compression per kg of refrigerant 2) Wall thickness of L.P. cylinder is reduced, since it has to withstand lower pressures. This makes compressor lighter and cheaper. 3) Volumetric efficiency of compressor increases due to reduced pressure ratio in each stage. 4) Temperature at end of compression would be less. As a result lubrication would be effective. Hence, compressor life increases. 5) Leakages past the piston are reduced 6) Operating cost is reduced 7) It gives more uniform torque; hence size of flywheel is reduced.	4M

1.B		Attempt any ONE	
	a)	Q.1 (B) (a) B.P. with all cylinder working = 15.8 KW I.P.$_1$ = (B.P.)$_{\text{all cylinder working}}$ − (B.P.)$_{2,3,4}$ = 15.8 − 11.14 = 4.66 KW I.P.$_2$ = 15.8 − 11.2 = 4.6 KW I.P.$_3$ = 15.8 − 11.36 = 4.44 KW I.P.$_4$ = 15.8 − 11.3 = 4.5 KW } 2 marks Total I.P. = I.P.$_1$ + I.P.$_2$ + I.P.$_3$ + I.P.$_4$ = 4.66 + 4.6 + 4.44 + 4.5 = 18.2 KW — 2 marks $\eta_{\text{mechanical}} = \frac{B.P}{I.P.} = \frac{15.8}{18.2} = 86.81\%$ 2 marks	
	b)	Non dispersive infra red gas analyzer (NDIR) : The working principle of infra red gas exhaust gas analyzer is as shown in figure . It works on the principle of hetero atomic gases absorb infra red energy at distinct and separated wavelength. The absorbed energy raises the temperature and pressure of confined gas. This enables to measure contents of hydro carbon and carbon monoxide. This is a faster method of gas analysis. The standard sample is filled in reference cell R . The sample of gas under testing is filled in cells . The detector cell D is filled with specific gas to be measured, say CO_2 . the detector cell is divided into two compartments by diaphragm. It is very sensitive. Initially infra red energy in both compartments is same and indicator reading is zero. The sample is connected to exhaust gas. This lowers pressure on sample side. It will absorb energy in proportion to concentration of CO2 in sample and detector gives percentage of CO2 present in the sample. 	3M 3M

2		Attempt any TWO	

Q2 (a)

Heat supplied = $m_f \times C.V.$

$= \frac{6}{60} \times 43,000$

$= 4300$ KJ/min **1M**

Heat equivalent to b.p. = 21 KW

$= 1260$ KJ/min **1M**

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

$= 11 \times 4.187 \times 23$

$= 1159.31$ KJ/min **1M**

Heat lost to exhaust gases = $m_{eg} \times C_{peg} \times \Delta T$

$= 4.6 \times 1 \times 250$

$= 1150$ KJ/min **1M**

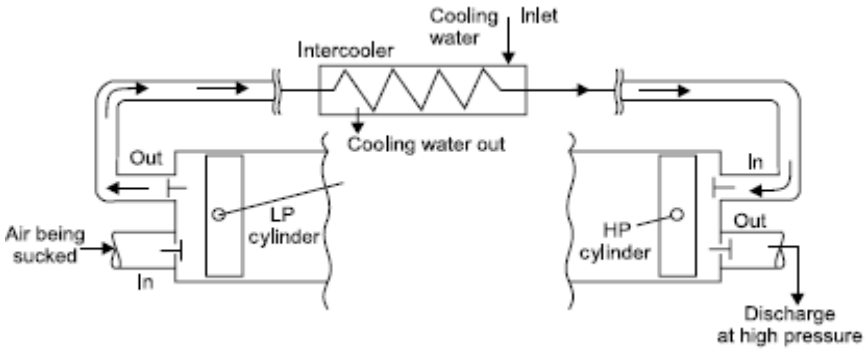
a)

Heat unaccounted = $4300 - (1260 - 1159.31 + 1150)$

$= 830.69$ KJ/min **1M**

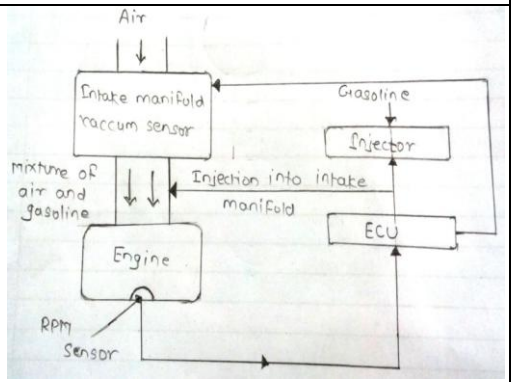
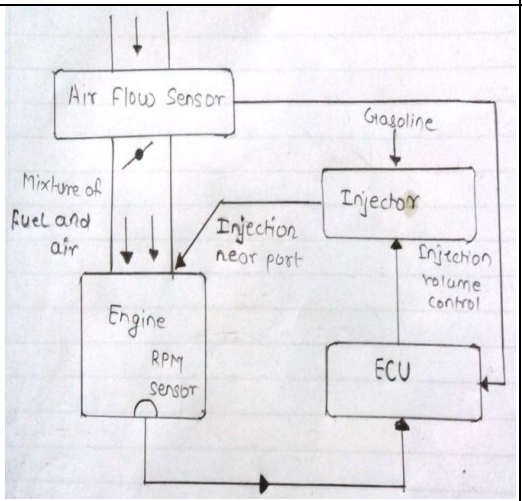
Heat Supplied = 4300 KJ/min	100%	Heat equivalent to b.p. = 1260 KJ/min	29.3%
		Heat lost to cooling water = 1159.31 KJ/min	24.6%
		Heat lost to exhaust gases = 1150 KJ/min	26.7%
		Heat unaccounted = 830.69 KJ/min.	19.3%
		Total = 4300 KJ/min	100%

3M

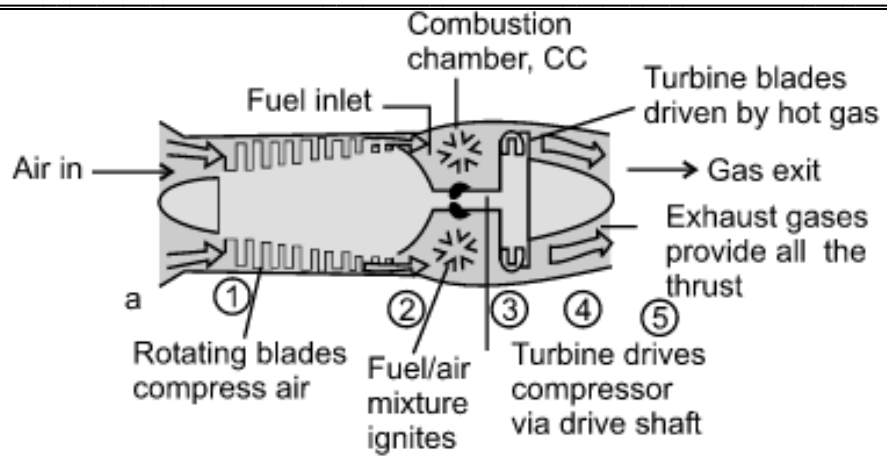
	b)	**Following are the methods to improve efficiency of air compressor** 1. Cooling cylinder by spraying water during compression stroke. 2. Circulation of water surrounding to cylinder by providing jackets 3. Installing inter cooler between two cylinders 4. Providing greater fins on cylinder 5. By selecting suitable material for cylinder 6. By providing suitable choice of cylinder proportions i.e. short stroke and large bore in construction with sleeve valve **Two stage reciprocating air compressor :**  **Two stage reciprocating compressor** Multistage compression refers to the compression process completed in more than one stage i.e. a part of compression occurs in one cylinder (L.P. cylinder) and subsequently compressed air is sent to subsequent cylinders (H.P. cylinder) for further compression. Figure shows the schematic of two stage compressor with intercooler between stages. The total work requirement for running this shall be algebraic summation of work required for low pressure (LP) and high pressure (HP) stages. The size of HP cylinder is smaller than LP cylinder as HP cylinder handles high pressure air having smaller specific volume. Intake temp of air at LP =intake temp of air at HP for perfect intercooling.	**4M** **Fig. 2M** **2M**

<table>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>C</td><td>Differences between Vapour Absorption and Vapour Compression refrigeration system (Any eight points)
<table>
<tr><th>No</th><th>Vapour Absorption system</th><th>Vapour Compression System</th></tr>
<tr><td>1.</td><td>Uses low grade energy like heat. Therefore, may be worked on exhaust systems from I.C engines, etc.</td><td>Using high-grade energy like mechanical work.</td></tr>
<tr><td>2.</td><td>Moving parts are only in the pump, which is a small element of the system. Hence operation is smooth.</td><td>Moving parts are in the compressor. Therefore, more wear, tear and noise.</td></tr>
<tr><td>3.</td><td>The system can work on lower evaporator pressures also without affecting the COP.</td><td>The COP decreases considerably with decrease in evaporator pressure.</td></tr>
<tr><td>4.</td><td>No effect of reducing the load on performance.</td><td>Performance is adversely affected at partial loads.</td></tr>
<tr><td>5.</td><td>Liquid traces of refrigerant present in piping at the exit of evaporator</td><td>Liquid traces in suction line may damage the compressor</td></tr>
<tr><td>6.</td><td>Automatic operation for controlling the capacity is easy.</td><td>It is difficult.</td></tr>
<tr><td>7</td><td>Charging of refrigerant is simple</td><td>Charging of refrigerant is difficult</td></tr>
<tr><td>8</td><td>Part load performance is low</td><td>No effect of variation of load</td></tr>
</table></td><td>8 M</td></tr>
<tr><td>3</td><td>a)</td><td>Attempt any FOUR

Differentiate between D-MPFI and L-MPFI system (01 mark each)
<table>
<tr><th>Sr. No.</th><th>D-MPFI System</th><th>L-MPFI System</th></tr>
<tr><td>1</td><td>It is Manifold injection system</td><td>It is Port injection system</td></tr>
<tr><td>2</td><td>Vacuum in the intake manifold and volume of air by its density are</td><td>Fuel metering is regulated by the engine speed and amount of air that actually enters in the engine.</td></tr>
</table></td><td></td></tr>
</table>

			sensed in this type of MPFI system		
		3			
		4	As air enters into intake manifold the manifold pressure is sensor detects the intake manifold vacuum and sends the information to the ECU	As air enters into the intake manifold, the air flow sensor measures the amount of air and sends information to ECU.	
	b		**Effects of detonation (any four- 4 marks)** (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.		

	c)	**Additives** **(any four – 4 marks)** **(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.	**04 M**
	d)	**Working principle of Turbojet**: shows the schematic of turbojet engine. It has a diffuser section at inlet for realizing some compression of air passing through this section. Due to this air reaching compressor section has pressure more than ambient pressure. This action of partly compressing air by passing it through diffuser section is called “ramming action” or “ram effect”. Subsequently compressor section compresses air which is fed to combustion chamber and fuel is added to it for causing combustion. Combustion products available at high pressure and temperature are then passed through turbine and expanded there. Thus, turbine yields positive work which is used for driving compressor. Expanding gases leaving turbine are passed through exit nozzle where it is further expanded and results in high velocity jet at exit. This high velocity jet leaving nozzle is responsible for getting desired thrust for propulsion.	**Working – 2 marks**

			**Fig.- 2 marks**
	e)	**i) DBT –** Dry bulb temperature - t_{DB} - It is the temperature of air recorded by an ordinary thermometer and it is not affected by the moisture present in air. ii) **WBT** -It is the temperature recorded by thermometer when its bulb is covered with wet cloth known as wick and is exposed to air. **iii) DPT –** Dew point temperature t_{DP} D.P.T. of mixture is defined as the temperature at which water vapours starts to condense. **iv) Relative humidity**:- It is defined as the ratio of partial pressure of water vapour in a given volume of mixture to the partial pressure of water vapour when same volume of mixture is saturated at the same temperature. $\therefore$ RH = $\frac{P_V}{P_V sat} \times 100$	**01 M each**
4	**A**	**Attempt any THREE**	
	a)	**Effect of supercharging on S.I. engine with respect to following parameters** **Parameters** / **SI Engine** Detonation: Increases possibility of detonation Combustion: Rate of combustion is faster and is prove to knocking *Increased flame speeds and the engine cannot run without knocking.* Fuel Economy: Poor fuel economy as costly fuel needs to be used Lower thermal efficiency Greater fuel consumption Quality of fuel: High quality of fuel is required to reduce knocking	**01 M each**

b)

Q4 (A) (b)

$$I.P. = P_m \cdot L \cdot A \cdot N$$

$$= 6 \times 10^5 \times (0.5) \times \frac{\pi}{4} \times (0.2)^2 \times \frac{120}{60}$$

$$= 18.85 \text{ KW}$$

2M

$$B.P. = 6 \text{ KW}$$

$$\eta_{mech} = \frac{6}{18.85} = 31.83\ \%$$

2M

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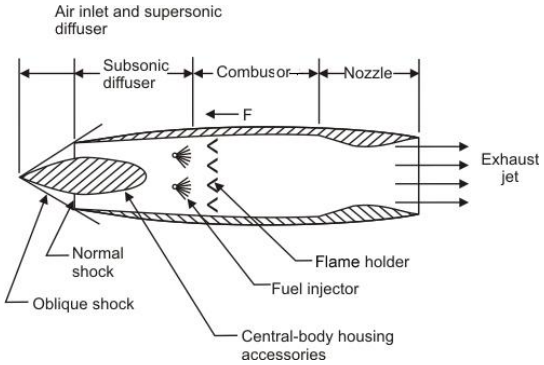
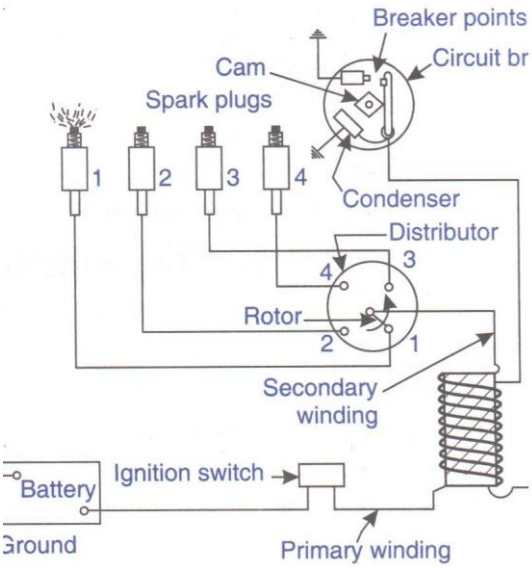
c)

Sr. No.	Factors	Open cycle gas turbine	Closed cycle gas turbine	Any four differences 1M each
1.	**Pressure**	Lesser pressure	Higher pressure	
2.	**Size of the plant for given output**	Larger size	Reduced size	
3.	**Output**	Lesser output	Greater output	
4.	**Corrosion of turbine blades**	Corrosion takes place due to contaminated gases	No corrosion since there is indirect heating.	
5.	**Working medium**	Loss of working medium	No loss of working medium.	
6.	**Filtration of incoming air**	It may cause severe problem.	No filtration of air is required.	
7.	**Part load efficiency**	Less part load efficiency	More part load efficiency	
8.	**Thermal efficiency**	Less thermal efficiency	More thermal efficiency	

		9.	**Requirement of cooling water**	No Requirement of cooling water	Larger amount of cooling water required
		10.	**Weight of system for given power**	Less	More
		11.	**Response to the changing load**	Good response	Poor response
		12.	**Fluid friction**	More Fluid friction	Less Fluid friction

	d)	Ramjet has no compressor as the entire compression depends upon compression. Function of supersonic & subsonic difference to convert the kinetic called the ram pressure. **Working:**- The air entering into ram jet with supersonic speed is slowed down to sonic velocity in the supersonic diffuser ,increasing air pressure. The air pressure is further increase in the subsonic diffuser increasing also the temperature of air. The diffuser section is designed to get correct ram effect. it's job is to decrease the velocity & increase pressure of incoming air. The fuel injected into combustion chamber is burned with help of flame igniter. The high pressure and high temperature gases are passed through the nozzle converting into pressure energy into kinetic energy. The high velocity gas leaving the nozzle provide required toward thrust to ramjet.  	**Working – 2 marks** **Fig.- 2 marks**
4	**B**	**Attempt any ONE**	
	a)	Battery Ignition system : It consists of a battery of 6 or 12 volts, ignition switch, induction coil, condenser, distributor and a circuit breaker. One terminal of battery is ground to the frame of the engine and other is connected through the ignition switch to one primary terminal of the ignition coil . The other terminal is connected	

		to one end of contact points of the circuit breaker. To start with the ignition switch is made on and the engine is cranked. The contacts touch, the current flows from battery through the switch. A condenser connected across the terminals of the contact breaker points prevent the sparking at these points. The rotating cam breaks open the contacts immediately and breaking of this primary circuit brings about a change in the magnetic fields and voltage changes from 12 to 12000 V. due to the high voltage. The spark jumps across the gap in the spark plug and air fuel mixture is ignited in the cylinder  	02 M 02 M

	b)	Q4 (B) (b) $b.p. = P_{bm} \times L \cdot A \cdot N$ $5 \times 10^3 = 7.5 \times 10^5 \times L \times \frac{\pi}{4} \times \left(\frac{L}{1.25}\right)^2 \times \frac{2000}{2 \times 60}$ $5 \times 10^3 = 6.29 \times 10^6 \, L^3$ $L^3 = 7.945 \times 10^{-4} \ m^3$ $L = 0.0926 \ m$ $L = 9.26 \ cm$ $D = 7.4 \ cm$	1M 1M 1M 1M
5	a)	**Attempt any TWO**	
	i)	A single stage reciprocating air compressor has a swept volume of 2000 cm^3 and runs at 600 rpm. It operates on pressure ratio of 8 and clearance 5% of swept volume. Assume NTP room condition at inlet (P = 101.3 kPa , T – 15 ^{o} C) and polytrophic compression and expansion with n – 1.25 Calculate i) Indicated power ii) Volumetric efficiency iii) Mass flow rate iv) Isothermal efficiency	

Q5 (a) Let V_s = Sweep volume

$V_c = V_3$ = clearance volume

we have

$V_s = V_1 - V_3$

$V_s = V_1 - 0.05 V_s$

$V_1 = 1.05 V_s$ **1M**

$$\text{I.P.} = \frac{n}{n-1} P_1 V_1 \left[\left(\frac{P_2}{P_1} \right)^{n-1/n} - 1 \right] \times \frac{N}{60}$$

$$= \frac{1.25}{1.25-1} \times 1.013 \times 10^5 \times 1.05 \times \frac{2000}{10^6} \times \left[\left(\frac{8}{1} \right)^{\frac{0.25}{1.25}} - 1 \right] \times \frac{600}{60}$$ **1M**

$$= 5.57 \text{ KW}$$

$$\text{Isothermal Power} = P_1 V_1 \log_e \left(P_2/P_1 \right) \times N/60$$

$$= 1.013 \times 10^5 \times 1.05 \times \frac{2000}{10^6} \times \log_e 8 \times \frac{600}{60}$$ **1M**

$$= 4.424 \text{ KW}$$

$$\text{Isothermal efficiency} = \frac{\text{Isothermal Power}}{\text{I.P.}}$$

$$= \frac{4.424}{5.57} = 79.42\%$$ **1M**

$$\eta_{vol} = 1 - \frac{V_c}{V_s} \left[\left(\frac{P_2}{P_1} \right)^{1/n} - 1 \right]$$

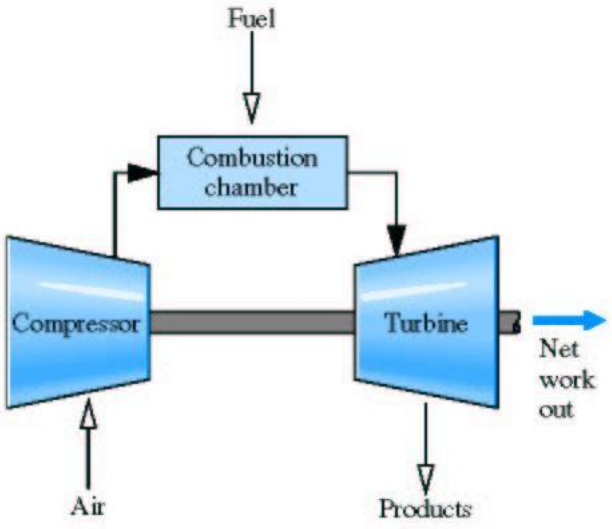
$$= 1 - 0.05 \left[(8)^{\frac{1}{1.25}} - 1 \right] = 78.60\%$$ **2M**

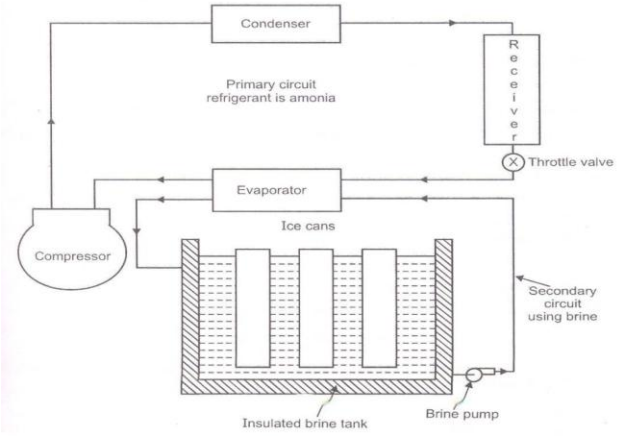
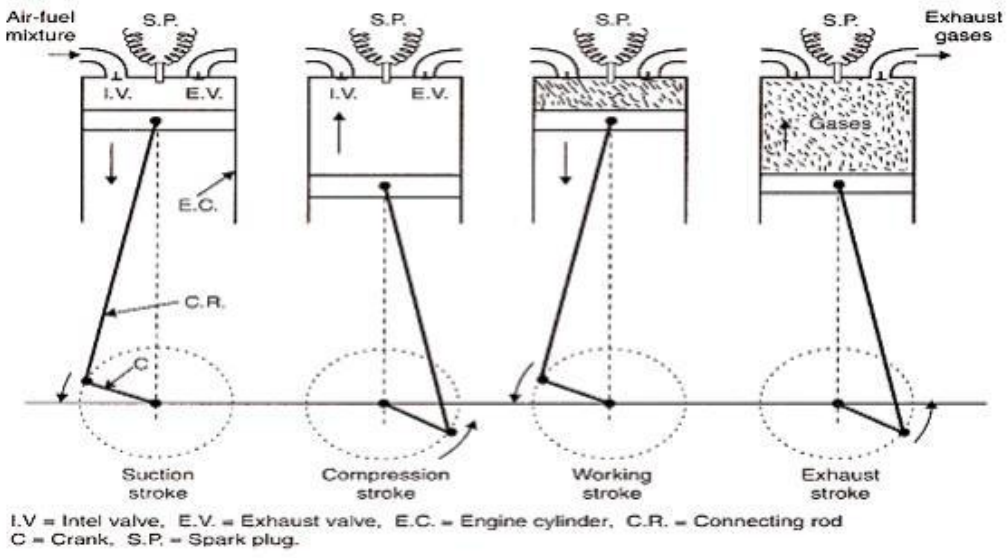
$$m = \frac{P_1 V_1}{R T_1} = \frac{1.013 \times 10^5 \times 1.05 \times 2000}{287 \times 288 \times 10^6}$$

$$= 2.6168 \times 10^{-3}$$

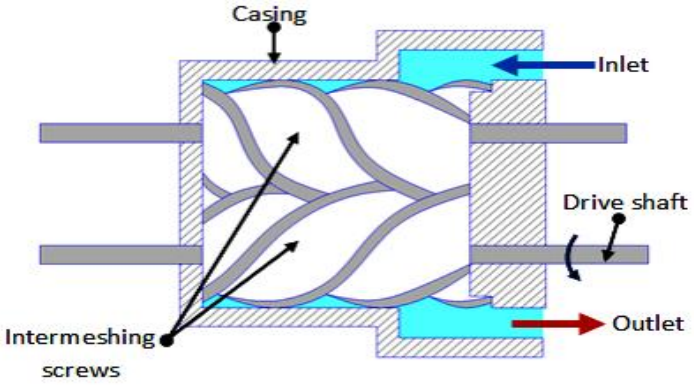
$$m = 2.6168 \times 10^{-3} \times 600$$

$$= 1.57 \text{ kg/min}$$ **2M**

	b)	**Constant volume gas turbine** Working:- Air from surrounding atmosphere is drawn in compressor and is compressed to a pressure of about 3 kN/m^2. The compressed air is then admitted to the combustion chamber through the inlet valve. When inlet valve is closed, the fuel oil is admitted by means of a separate fuel pump into combustion chamber containing compressed air. The mixture (of air and fuel oil) is then ignited by an electric spark, the pressure rising to about 12 kN/m^2, whilst the volume remains constant. Thus combustion takes place at constant volume.  	**05** **03**
	c)	**Working of Ice plant: (Explanation 05 marks ….fig 03 marks)** The main cycle used for ice plant is vapor compression cycle with ammonia as the refrigerant in primary circuit and brine solution in secondary circuit. Brine solution takes heat from water in secondary circuit and delivers the heat to ammonia in primary circuit. Thus, the indirect method of cooling is used in ice plant. In secondary circuit brine is cooled in evaporator and then it is circulated around the can which contains water. The heat is extracted from the water in the can and is given to the brine. The brine is contentiously circulated around the can with the help of brine pump till entire water in the can is converted into ice at -6^0 C. Ammonia vapor coming out of evaporator is compressed to high pressure and then these vapors are condensed in the condenser.	

		High pressure liquid ammonia is collected in the receiver and it is passed through the expansion valve to reduce its pressure and temperature as per requirement. The throttle liquid ammonia at low temperature & low pressure enters in evaporator, which are the coils dipped in brine tank. The liquid ammonia absorbs heat from brine and gets converted into vapors, which are drawn by suction line of compressor.  	
6		**Attempt any FOUR**	
	a)	**Explain four strokes of SI engine**  I.V = Intel valve, E.V. = Exhaust valve, E.C. = Engine cylinder, C.R. = Connecting rod C = Crank, S.P. = Spark plug. Four stroke petrol engine 1. **Suction stroke**: Suction stroke starts when piston is at top dead center and about to move downwards. During suction stroke inlet valve is open and exhaust valve is closed. Due low pressure created by the motion of the piston towards bottom dead center, the charge	

		consisting of fresh air mixed with the fuel is drawn into cylinder. At the end of suction stroke the inlet valve closes. The suction stroke is shown in fig 2. **Compression stroke**: During compression stroke, the compression of charge takes place by return stroke of piston, i.e. when piston moves from BDC to TDC. During this stroke both, inlet and exhaust valve remain closed. Charge which is occupied by the whole cylinder volume is compressed up to the clearance volume. Just before completion of compression stroke, a spark is produced by the spark plug and fuel is ignited. Combustion takes place when the piston is almost at TDC. The Compression stroke is shown in fig 3**. Expansion or power stroke**: piston gets downward thrust by explosion of charge. Due to high pressure of burnt gases, piston moves downwards to the BDC. During expansion stroke both inlet and exhaust valves remains closed as shown in fig . Thus power is obtained by expansion of products of combustion. Therefore it is also called as 'power stroke'. Both pressure as well as temperature decreases during expansion stroke. 4**. Exhaust stroke**: At the end of expansion stroke the exhaust valve opens, the inlet valve remains closed and the piston moves from BDC to TDC as shown in fig. During exhaust stroke the burnt gases inside the cylinder are expelled out. The exhaust valve closes at the end of the exhaust stroke but still some residual gases remains in cylinder.	
	b)	A screw compressor is a type of rotary compressor which compresses air due to screw action. The main advantage of using this compressor is that it can supply compresses air continuously with minimum fluctuation in delivery pressure. It is usually applied for low pressure applications up to 8 bars. **Construction:** A screw compressor comprises of two screw like rotating elements, a casing, an air filter, rubber seals, suction valve and delivery valve mainly. **Working principle:** In a screw compressor one of the shafts is driving shaft and the other is driven shaft. The driving shaft is connected to the driven shaft via timing gears which help to match speeds of both the shafts. The driving shaft is powered by an electric motor generally. The two shafts are enclosed in an air tight casing. Firstly the suction valve is opened to allow air suction. Then the motor is turned on which drives the shaft. The driven shaft, thus, also starts rotating counter to the driving shaft because of timing gears. The air enters the gap between the two screws cut over the shafts. As the two screws turn in opposite direction the air gets trapped in the groove between the two screws. The gap between the two screws decreases gradually from suction end to delivery end, which leads to compression of air. Also due screw action the air moves from the suction end to the delivery end. When the compressed air reaches the delivery end, it passes through the delivery valve to the storage tank	**2 Marks each**



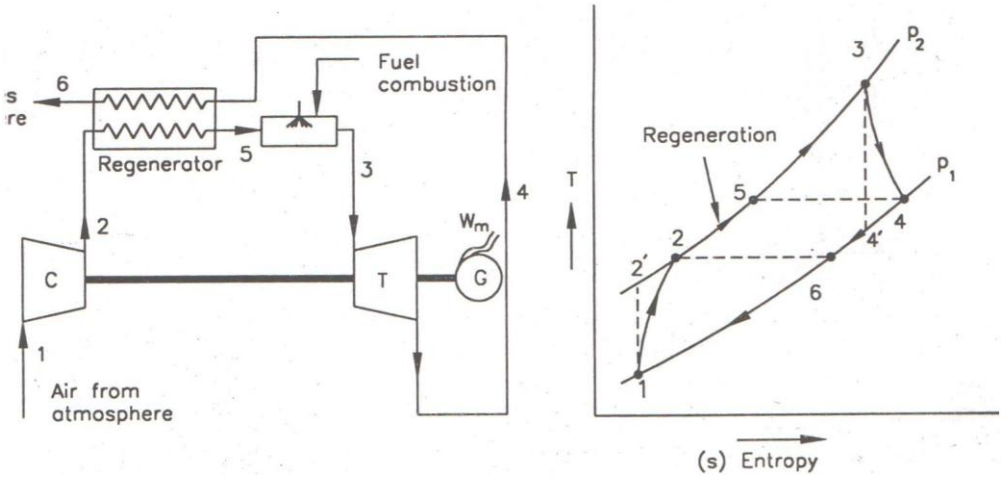
c) **State different methods for improving thermal efficiency of gas turbine and explain regeneration method along with P-V and T-S diagram** — 02 M

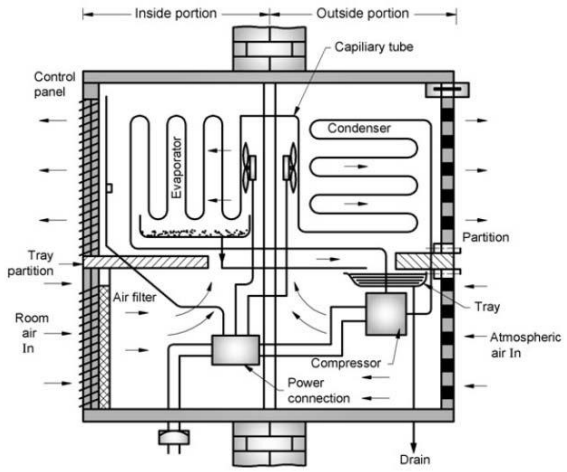
Following methods are used for improving thermal efficiency of gas turbine

1) Regeneration 2) Reheating : 3) Intercooling

Regenerative method to improve thermal efficiency in gas turbines: The exhaust gases a lot of heat as their temperature is far above the ambient temperature. The heat of exhaust gases can be used to heat the air coming from the compressor thus reducing the mass of the fuel supplied in the combustion chamber as shown in the figure. This method is called regenerative method.

02M



	d)	Enlist the four effects of sub cooling on the performance of VCC refrigeration cycle Effect of sub-cooling of liquid. 'sub-cooling' is the process of cooling the liquid refrigerant below the condensing temperature for a given pressure. In Fig. the process of sub-cooling is shown. As is evident from the figure the effect of sub-cooling is to increase the refrigerating effect. Thus sub-cooling results 1. Increase of C.O.P. provided that no further energy has to be spent to obtain the extra cold coolant required. 2. Due to sub cooling the refrigerating effect increases or for same refrigerating effect the circulation rate refrigerant decreases 3. Increasing refrigerating effect and specific compression work.	**04 M**
	e)	**Draw a neat sketch of window air conditioner and name the parts** 	**04 M**