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.

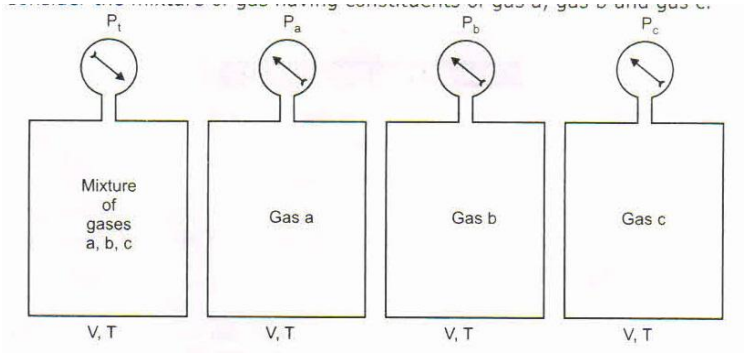
Question No.		Model Answer / Solution	Marks
1	(a)	i) Following are the desirable properties of refrigerant. a) Boiling point at atmospheric pressure should be low. b) Freezing point at atmospheric pressure should be low. c) Latent heat of vaporization of refrigerant must be high. d) Critical temperature should be high. e) It should not have corrosive action with system material. f) It should not be flammable & explosive. g) It should not be toxic. h) It leak should be easily detectable. i) It should have positive condensing pressure. j) It should have satisfactory heat transfer coefficient. k) It should have high thermal conductivity. l) It should have chemical stability. ii) Classification of evaporator with respect to 'Frost' 1) Frost type evaporator – A frost type evaporator is one in which frost continuously and always operated at temperature below 32^0F. This type of evaporator is used in frozen food storage of all types.	Any Eight Point 04

2) Defrosting type evaporator – Defrosting type evaporator is one which frosts when compressor works and defrosts (melts) when compressor stops functioning. 04

3) Non frost type evaporator - Non frost type evaporator is one which always operates nearly above the freezing point of ice. At this temperature slight coating of frost forms on the coil when compressor works and this coating disappears when compressor stops functioning. As this type of evaporator do not draw moisture rapidly it is used for pressuring raw vegetables, fruits and perishable food stuffs.

iii) Dalton's law of Partial Pressure – Dalton's law of partial pressure states that "the total pressure of mixture of gases equal to the sum of the partial pressures exerted by each gas when it occupies the mixture volume at the temperature of mixture".

Consider the mixture of gas having constituents of gas a, gas b and gas c. 04



Mixture of gas a, b, c at volume V and temperature T shows the total pressure P_t. if gas a, b, c is separated and kept at same volume V and temperature T it will show pressure P_a, P_b and P_c respectively.

Where P_a = Partial pressure of gas a.

P_b = Partial pressure of gas b.

P_c = Partial pressure of gas c.

According to Dalton's law of partial pressure , $P_t = P_a + P_b + P_c$

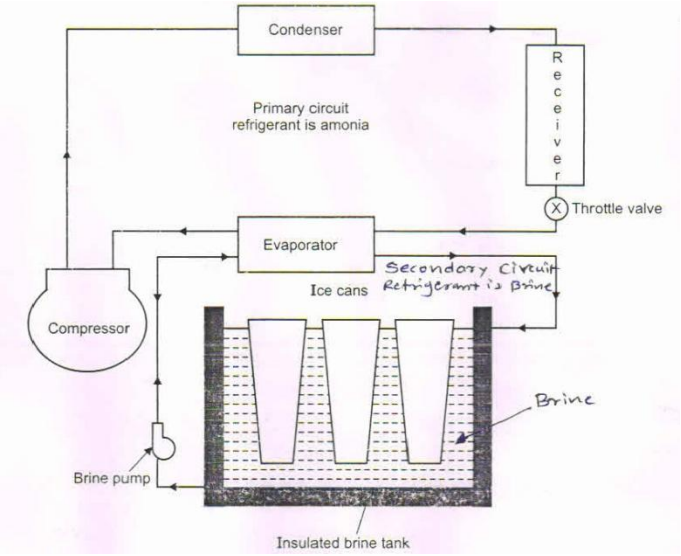
iv) Industrial Applications of Air-conditioning System – 04

According to use in industries for

i) To provide comfort to worker.
ii) To provide necessary low temperature condition regarded for manufacture of certain product in industries such as textile, printing & refineries.
iii) To provide clean room for the precision work, laboratories & quality control rooms.
iv) To provide food during storage & transportation.
v) For drying of product.
a) Textile industry.

b) Photographic industry.
c) Printing industry.
d) Food industry.
e) Refrigerant trucks.

(b) i) Ice Plant –



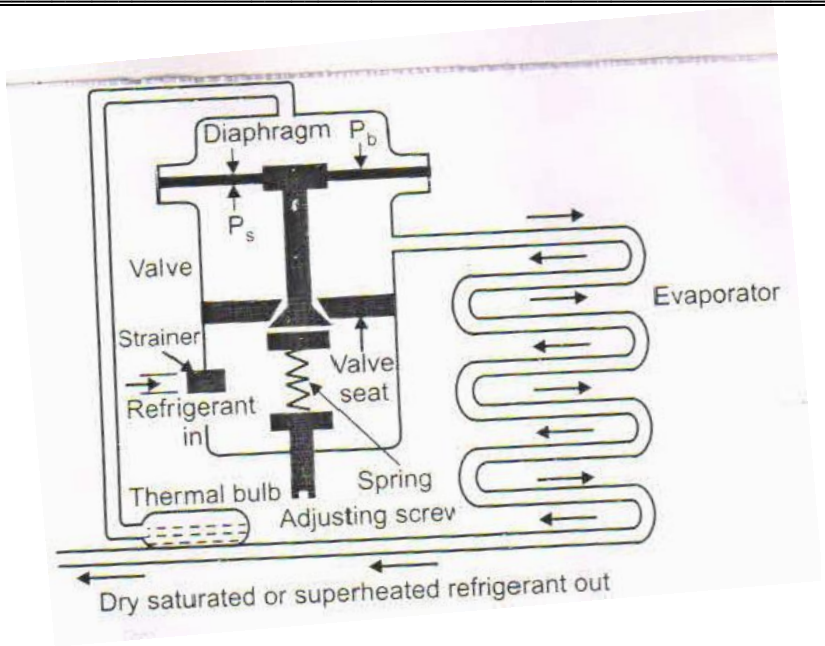
Sketch 03

Explanation 03

The ice plant is shown in Fig. The cycle used for the ice plant is vapour 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 first in evaporator and then it is circulated around the can which contains water. The heat is extracted from the water through the can and is given to brine. The brine is continuously circulated around the can and is given to brine. The brine is circulated around the can with the help of pump till entire water in can is converted into ice.

In primary circuit, ammonia is used as refrigerant. Ammonia vapour coming out of evaporator is compressed to high pressure and then vapours are condensed in condenser. Open type of compressor is generally used for ice plant. Evaporative condenser is used, in which same cooling water can be used again and again. High pressure liquid ammonia is collected in receiver and then it is passed through the expansion valve. The throttled ammonia at low temperature and low pressure enters in evaporator, which is coil dipped in brine. The liquid ammonia absorbs heat from brine and converts into vapours, which are drawn by compressor. The ice can after removing from brine solution is dipped into thawing tank for few minutes, which helps for easy removal of ice slab from can. The temperature of brine circulated is about 10^0c and the ice formation is continued fill its temperature is 6^0c.

ii) Thermostatic Expansion Valve – Thermostatic expansion valve consists of diaphragm valve, valve seat, spring adjusting screw and thermal bulb. Thermal bulb is used to check temperature in evaporator. In thermal bulb same refrigerant can be used, which is filled in refrigeration system. The valve used in TEV open in downward direction by changing pressure on diaphragm.

		 The pressures acting on diaphragm are:- 1) Bulb pressure from thermal bulb acting in downward direction. 2) Spring pressure acting in upward direction. 3) Evaporator pressure from evaporator. Thermostatic expansion valve is fitted in liquid line just ahead of evaporator in direction of arrow provided on it and thermal bulb is clamped with exit line of evaporator. For constant load operation adjusting screw is adjusted such that it allows constant mass flow rate of refrigerant to evaporator. The valve responds to change in temperature in evaporator. When there is load on evaporator, superheated vapours are coming at exit of evaporator, which transfers its heat to thermal bulb. Due to this, refrigerant filled in thermal bulb vaporizes and increases the bulb pressure to open up valve allowing more liquid refrigerant into evaporator. When there is decrease in load on evaporator, vapours at the exit of evaporator absorbs heat from thermal bulb and reduces the pressure on diaphragm to reduce opening of valve resulting in reduction in mass flow rate of refrigerant entering in evaporator.	Sketch 03 Explanation 03
2	**(a)**	Infiltration load – The infiltration load is the amount of heat addition due to infiltration that is the air that enters a conditioned space through window crack and opening of doors. This is caused by pressure difference on the two sides of the window & door. It depends upon the wind velocity and its direction and difference in densities due to the temperature difference between the inside & outside air. There are two methods of calculating the infiltration load. I) crack length method ii) Air change method. Normally air change method is used for calculating the quantity of infiltrated air. As follows - amount of infiltrated air through window & wall = $\frac{L \times W \times H \times AC}{60} m^3/min.$	04

Where L = Room length in meters

W = Room width in meters

H = Room height in meters

Ac = Air changes per hour (Taken from standard tables)

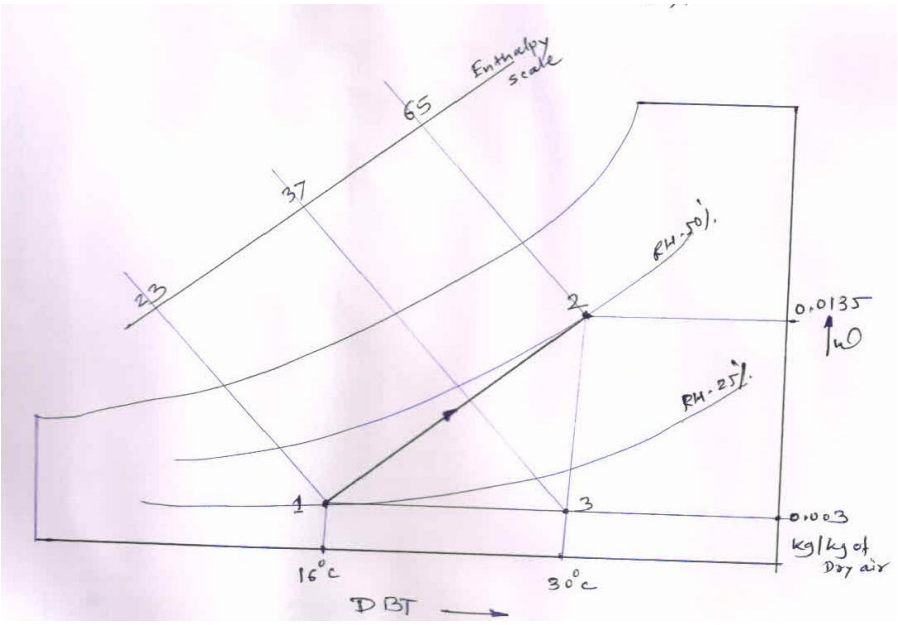
The total room infiltration air for an entire building is taken one half of the above calculated value.

ii) Occupants load - The human body in a cooled space constitutes cooling load of sensible & latent heat. The heat gain from occupants is based on the average number of people that are present in air-conditioned space. The heat load produced by each person depends upon the activity of person, gender of person, age of person. According to this criteria directly one can select the load from the standard tables and multiply it by no person doing that activity. 04

(b)

Condition at 1 – DBT 16^0c and RH 25%

Condition at 2 – DBT 30^0c and RH 50%



i) Heat added to the air = Enthalpy at 2 – Enthalpy at 1
= 65 – 23
= 42 KJ/kg of dry air 02

ii) Moisture added to air = Sp. Humidity at 2 – Sp. Humidity at 1
= 0.0135 – 0.003
= 0.0105 kg/kg of dry air 02

iii) Sensible heat factor (SHF) –

Sensible heat added SH = Enthalpy at 3 – Enthalpy at 1

= 37 – 23

= 14 KJ/.kg of dry air

Latent heat added LH = Enthalpy at 2 – Enthalpy at 3

= 65 – 37

= 28 KJ/kg of dry air.

02

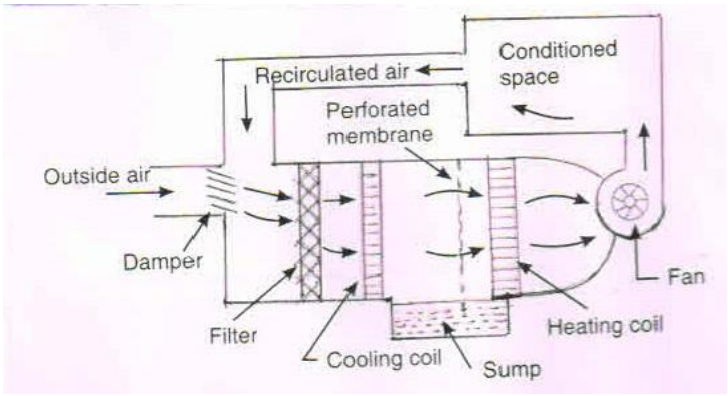
02

$$SHF = \frac{SH}{SH+LH} = \frac{14}{14+28} = \frac{14}{42} = 0.33$$

(Note – 5% variation in values taken from psychometric chart may be considered)

(c)

Summer Air-conditioning –



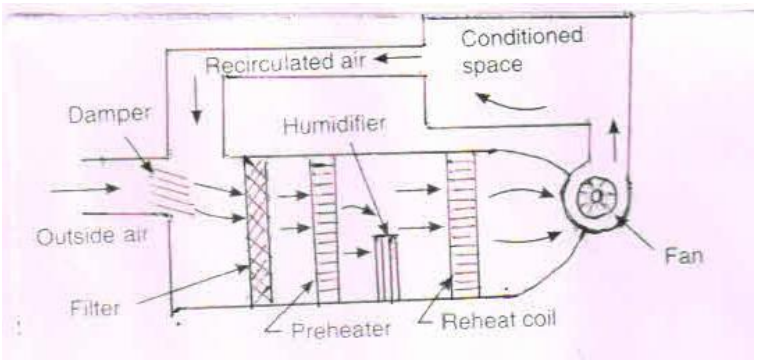
Sketch 02

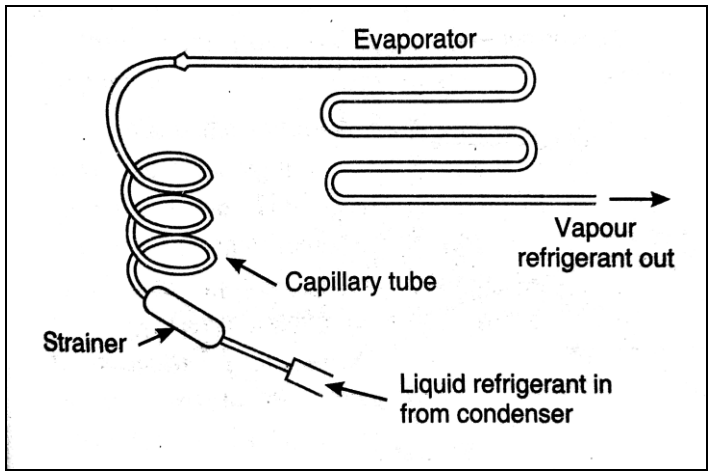
Explanation 02

Summer air conditioning system is used to provide human comfort in summer season. In summer season outdoor temperature is high and occupant feel comfortable at relatively low temperature. Air is passed over cooling coil where it reduces its temperature but relative humidity exceeds human comfort range. The air is passed over heating coil which restores humidity within comfort zone and observe slight increase in temperature. Thus, the measure problem in summer air conditioning is to cool air and remove excess moisture from it.

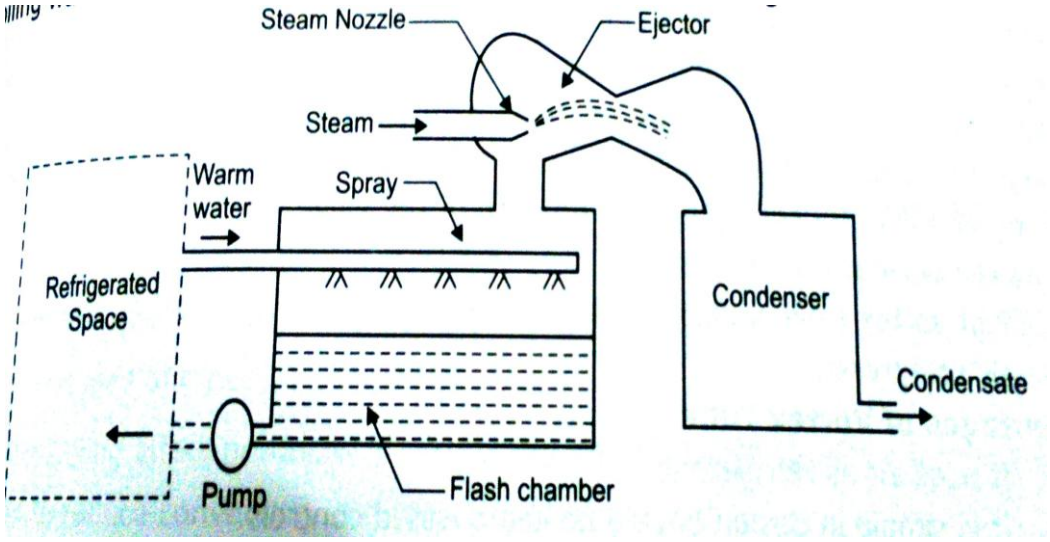
In summer air conditioning re-circulated air and fresh air are mixed together. The stream of air is passed to cooling coil through filter.

Winter Air-conditioning

		 Winter air conditioning system is used where outdoor temperature is considerably low (5^0c to 10^0c). This system can be used in cities like Delhi, Chandigarh during winter season to get comfort condition. The comfort condition commonly used is 20^0c to 23^0c temperatures and 60% relative humidity. In winter air conditioning system, recirculated air and outdoor fresh air are mixed. The stream of air is passed to spray chamber through filter and preheating coil. The function of filter is to remove dust, dirt and harmful bacteria from air to make it clean and pure.	Sketch 02 Explanation 02
Q 3	**(a)**	**Attempt any FOUR of the following:** **Name the refrigerant used:** **i) Air Conditioner –** R-22, R-114 **ii) Ice Plant –** In primary circuit Ammonia and secondary circuit Brine solution. **iii) Domestic Refrigerator –** R-12, R-134a **iv) Water cooler –** R-12, R-134a	**4*4=16** **(1marks each)**
	(b)	**What are the factors affecting on comfort Air conditioning system?** 1. Effective Temperature 2. Moisture content of air 3. Air circulation 4. Quality and quantity of air. 5. Heat and moisture losses from human body	**Four points** **1M each**

	(c)	**State working of capillary tube. State its two advantages.** **Ans-**  It is an expansion device used for refrigeration plants up to 3 ton capacity. Its purpose is to reduce high side pressure to low side pressure so that liquid evaporate and it absorbs heat. Actually restriction in the liquid line ahead of evaporator is sufficient to satisfy this function. Capillary tube is a sufficient long metallic tube of diameter 1 /16 to 1/8 inches. Usually copper material is used. Small diameter of the tube reduces condensing pressure to evaporator pressure. The pressure drop depends upon internal diameter of the tube. Therefore it is necessary to select critically two parameters i. e. internal diameter and length of the tube. **Advantages:** 1. The cost of Capillary tube is less than all other expansion devices 2. When the compressor stops, the refrigerant continues to flow into the evaporator and equalizes the pressure between the high side and low side of the system; this decreases the starting load on the compressor. 3. Since the refrigerant charge in a capillary system is critical, therefore no receiver is necessary. 4. Rough handling of appliances does not affect working of expansion device.	**1M SKETCH** **2M working** **And 1M advantage**
	(d)	**Explain working of 'steam jet refrigeration system'.** **Ans-** The main components of the steam jet refrigeration system are the flash chamber, steam nozzles, ejector and condenser. The flash chamber or evaporator is large vessel and insulated to avoid there rise in	**4M**

temperature of water due to high ambient temperature.



Four points 1M

It is fitted with perforated pipes for spraying water. The warm water coming out of the refrigerated space is sprayed into the flash water chamber where some of which converted into vapours after absorbing the latent heat, thereby cooling rest of water.

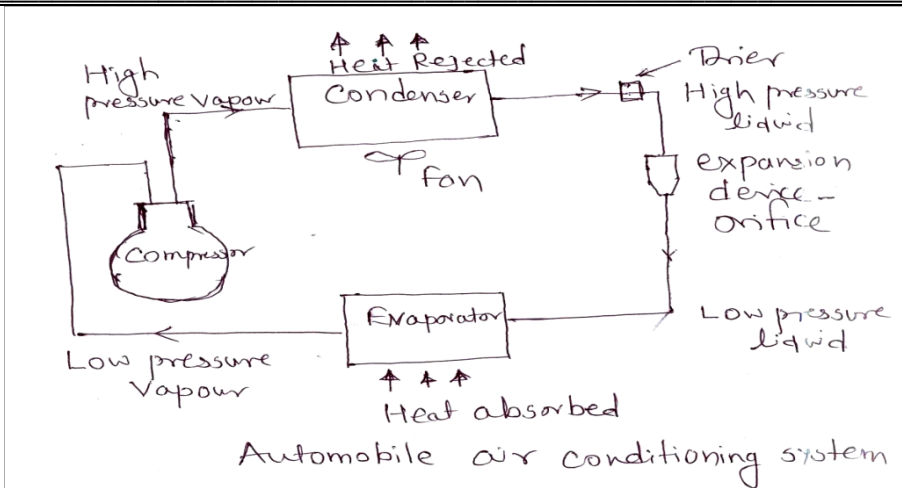
(e) **Advantages of multi-staging in vapor compression system are :**

1. Work done per kg of refrigerant is reduces by using an intercooler
2. Volumetric efficiency of compressor increases
3. It reduces leakage of refrigerant
4. It gives uniform torque therefore smaller flywheel may be used
5. Effective lubrication can be done
6. Cost of compressor reduces

4M

(f) **Draw neat labelled sketch of automobile air conditioning system.**

4M



Automobile air conditioning system

4	(a)	**Attempt any TWO of the following:**	**2*6=12**
	i	**Select the component and refrigerant for 1. Ice plant 2. Domestic refrigerator.**	
		Ans- Components for Ice plant :	
		It has two circuits primary and secondary.	
		Primary circuit consist:	
		i) compressor	
		ii) Condenser	
		iii) Expansion device	
		iv) Evaporator.	
		Secondary circuit consist:	
		i) Brine tank	
		ii) Ice cane	
		iii) Stirring mechanism	**3M**
		iv) Pump	
		Refrigerant for Ice plant	
		Primary refrigerant: Ammonia	
		Secondary refrigerant: Brine	
		Components for Domestic refrigerator:	

i) compressor

ii) Condenser

iii) Expansion device

iv) Evaporator.

Refrigerant for Domestic refrigerator: **3M**

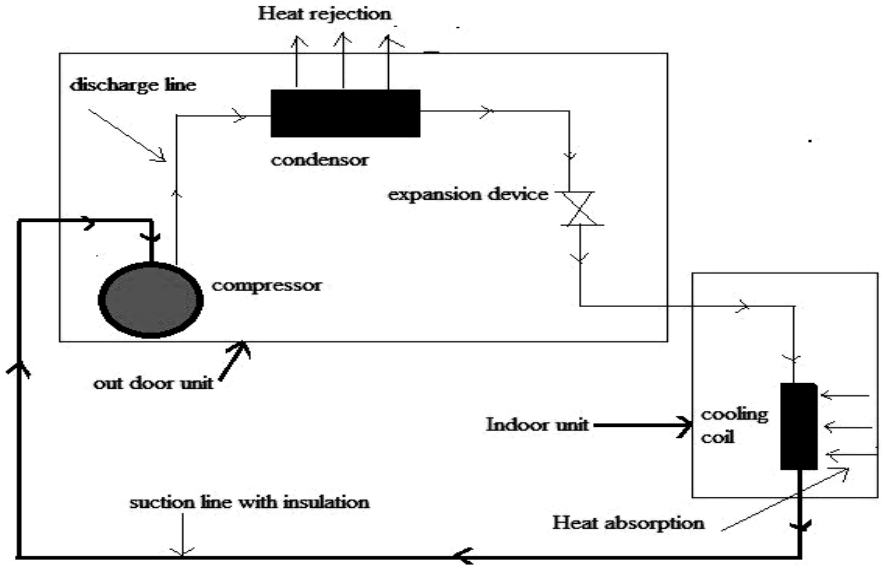
R-134a , 143a

ii) **Differentiate between 'air cooled' and 'water cooled' condenser.**

Sr. no.	Air cooled condenser	Water cooled condenser
1	Air is used as cooling media.	Water is used as cooling media.
2	Simple construction.	Complicated construction.
3	Low cost.	High cost
4	Low maintenance cost.	High maintenance cost.
5	No piping required to carry air.	piping required to carry water.
6	No corrosion, no fouling effect	Corrosion and fouling effect
7	Low heat transfer capacity.	High heat transfer.
8	Shorter compressor life.	Longer compressor life.

(Any six points 6marks)

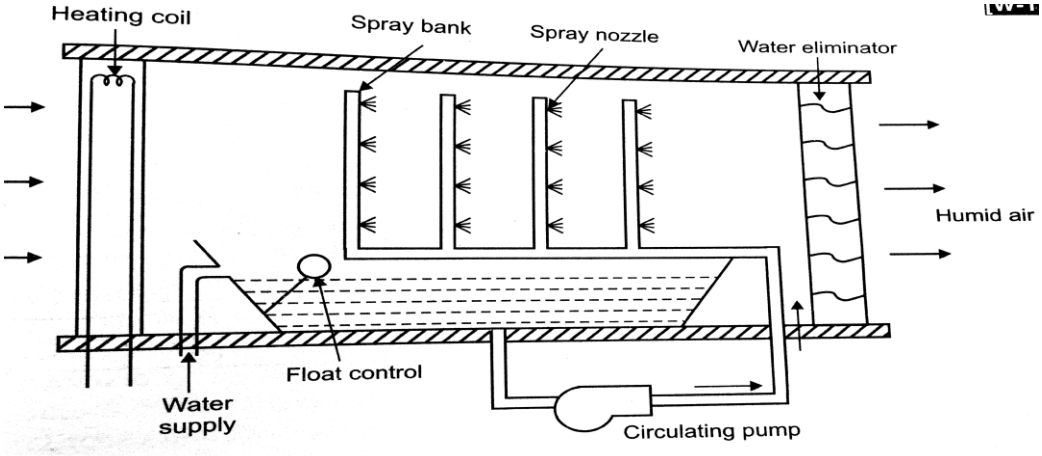
iii) **Explain working of split air conditioning system.**



Split Air Conditioner

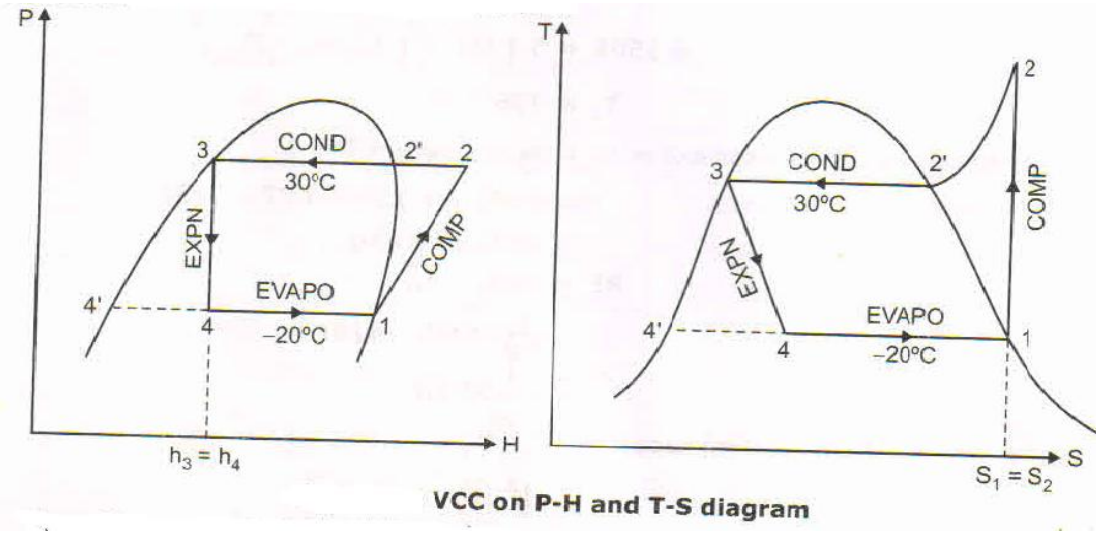
3M

Ans- 1. A split air conditioner is modification of a window air conditioner which is divided into two units, by using two separate casing.

	b) i)	2. The indoor and outdoor unit is located at small distance. As distance increases the pressure drop in the suction and liquid line also increases resulting in decreases in capacity. 3. The compressor circulates a refrigerant gas, increasing the pressure and temperature of the refrigerant and discharges to condenser. Condenser removes heat from refrigerant and the gas changes phase to liquid. This chilled liquid refrigerant is forces through tubing indoor until it reaches the evaporator system. 4. Evaporator fan collects warm air and passes it over a coil containing the chilled liquid refrigerant. the fan system blow this cooled air back into the room by lowering the overall temperature of the space or room **Explain working of Humidification by air washing with neat sketch.** **Ans- Humidification by air washing:**  System consists of components like water tank, pump, heating/cooling coil, spray pipe & nozzles, air damper for air in-flow and eliminator plate. Humidification can be achieved by spraying water in the stream of air. The air washer has a chamber in which water is sprayed through the nozzles from the top. Air enters into the chamber through air dampers and it flows through the sprays of water. While flowing, it absorbs the water particles & gets humidified. The complete process is known as Humidification by air washing. **ii) Unit of refrigeration is Ton.** **One Ton of refrigeration :** A ton of refrigeration is defined as the quantity of heat required to be removed to from one ton of ice at 0^{o} C in 24 hours when initial condition of water is 0^{o} C 1 Ton of refrigeration = 3.517 KJ/Sec or 3.517 kW	**3M** **3M diagram** **3M explanation**

		2) COP: Coefficient of Performance of refrigerator is the ratio of heat removed from sink (Refrigerating effect) by the device and work done required. COP = Refrigerating effect / Work done The value of COP is always greater than 1 **3) Energy efficiency ratio (EER):** Energy Efficiency Ratio, or EER, is a way to exhibit how well an air-conditioner is operating based on the power being used. EER = Capacity / Power	**2M each**
5		Attempt Any two 0f the following.	08 Marks
	a.	Solution-	

The refrigerant is dry and saturated at compressor inlet, the process can be shown on P-H and T-S diagram as : -



VCC on P-H and T-S diagram

From the properties of refrigerant,

$h_4 = 181.76\ kj/kg$ $h_1 = 342.6\ kj/kg,$

$h_3 = 228.54\ kj/kg,$ $h_2 = 363.56\ kj/kg,$

$S_1 = 1.566\ kj/kg\ K,$ $S_2 = 1.543\ kj/kg\ K.$

Enthalpy at the compressor inlet = $h_1 = 342.6\ kj/kg$

Enthalpy at condenser exit = $h_3 = 228.54\ kj/kg$

Consider the process 3-4; Throttling process

Enthalpy before throttling = Enthalpy after throttling

$h_3 = h_4 = 228.54\ kj/kg$

Consider process 1-2 $PV^y = C'$

Entropy before compression = Entropy after compression

$S_1 = S_2$

$S_1 = S_2 + C_p log_e \frac{T_2}{T'_2}$

$1.566 = 1.543 + 0.165\, log_e \frac{T_2}{273 + 30}$

$T_2 = 348.32\ K$

Enthalpy at compressor exit, $h_2 = h_2 + C_p(T_2 + T'_2)$

$= 363.56 + 0.165(348.32 - 303)$

$= 371\ kj/kg$ — 02 Marks

Refrigerating capacity = 1 Ton
RE = 3.517 kW
Refrigeration effect is given as,

$RE = m(h_1 - h_4)$

$3.517 = m(342.6 - 228.54)$

$m = 0.03083\ kg/s$ — 02 Marks

Power required per ton of refrigeration $= m(h_2 - h_1)$

$= 0.03083(371 - 342.6)$

$= 0.8755\ kw$ — 02 Marks

COP of system is given as,

$(COP)_{ref} = \frac{RE}{Compressor\ Power}$

$= \frac{3.517}{0.8755}$

$= 4.017$ — 02 Marks

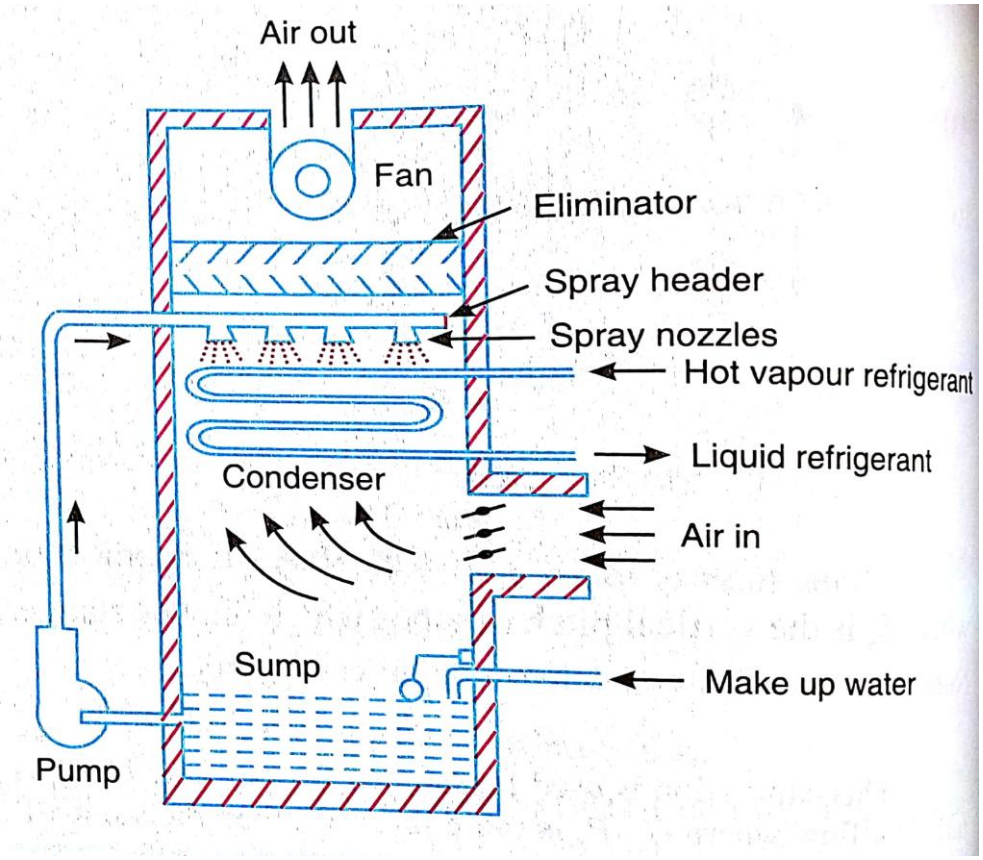
b. What is the function of condenser in a refrigeration cycle? Explain the working of Evaporative condenser with neat sketch.

Condenser function is to remove heat of the hot vapour refrigerant discharged from the compressor The heat from the hot vapour refrigerant in the condenser is removed first by transferring it to walls of condenser tubes and then from the tubes to the condensing medium. Saturated vapour refrigerant gives up its latent heat and get condensed into saturated liquid vapour, this process is called condensation. **(02Marks)**

Evaporative Condenser- Both air and water used as a condensing medium to condense hot vapour refrigerant. Water pumped from the sump to spray header and sprayed through nozzles over the condenser coils through which the hot vapour refrigerant is passing. The heat transfer from the refrigerant through the condensing tube walls and into the Water that is wetting the outside surface of the tube. At the same time air drawn from the bottom side of the condenser and discharged out at the top of the condenser. Most of cooling takes place by evaporation; air can absorb more some sensible heat from water. Eliminator is provided above the spray header

to stop particles of water escaping along with the discharge air.

Figure Evaporative Condenser. **(03 Marks)**



(03 marks)

c. **Differentiate between Central and Unitary air conditioning system.**

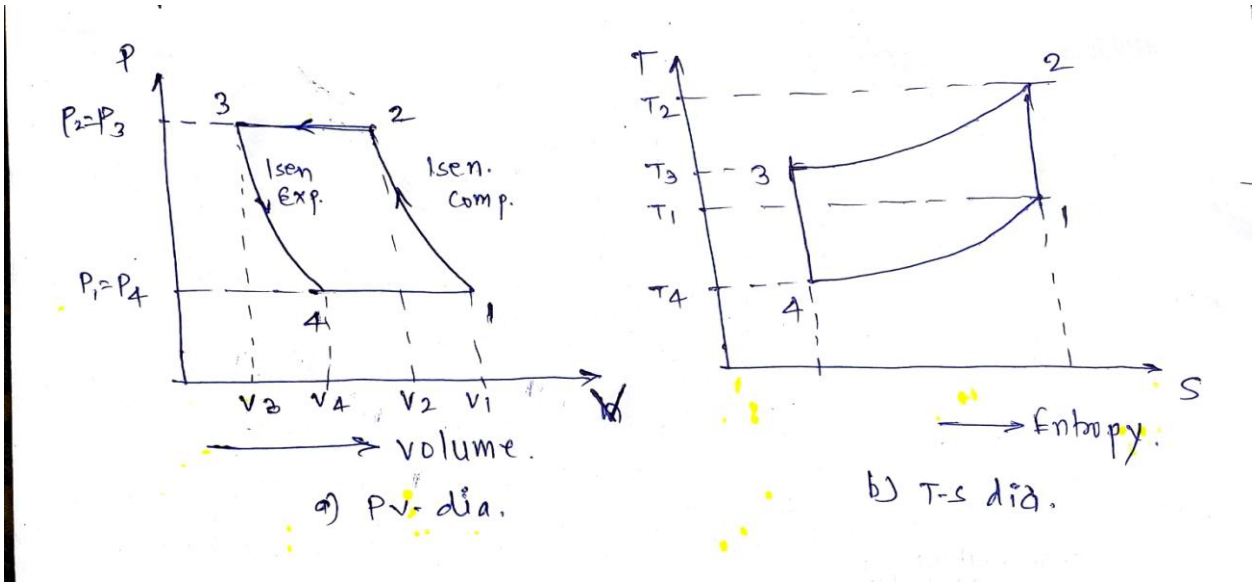
Sr. No	Central	Unitary
1	Ton capacity is more than 40 Ton of refrigeration	Ton capacity is less than 25 Ton of refrigeration
2	Mass flow rate of air handled is around 2000m3/min	Mass flow rate of air handled is less.
3	Central air conditioning is located in basement or outside the building.	Unitary air conditioning is located in every room which required to be air conditioned.
4	Central air conditioning is quite in operation as noise making Components are located outside.	Unitary air conditioning may be noisy. It is quite in operation if used as split unit.

One mark for each point

		5	All the rooms are required to be maintained at more or less similar condition.	Each room can be maintained at different condition.		
		6	It requires duct design and installation.	No duct design and installation is required.		
		7	Capital cost of central air conditioning equipment is less.	Capital cost of unitary air conditioning equipment is more.		
		8	Maintenance is convenient and easy.	Maintenance is difficult.		

6 **Attempt Any four of the following.** **04** Marks

a **Represent Bell Coleman cycle on PV and TS diagram. (Two marks for each diagram)**



04 Marks

b **Define-** **(Two marks for each definition)**

i) Dew point Temperature: Dew point temperature is the saturation corresponding to the partial pressure of water vapour. OR It is the temperature of air recorded by a thermometer, when the moisture (water vapour) present in it begins to condense. Temperature at which first drop of dew formed.

ii) Specific humidity: It is the mass of water vapour present in one kg of dry air and is generally expressed in terms of gram per kg of dry air.

04 Marks

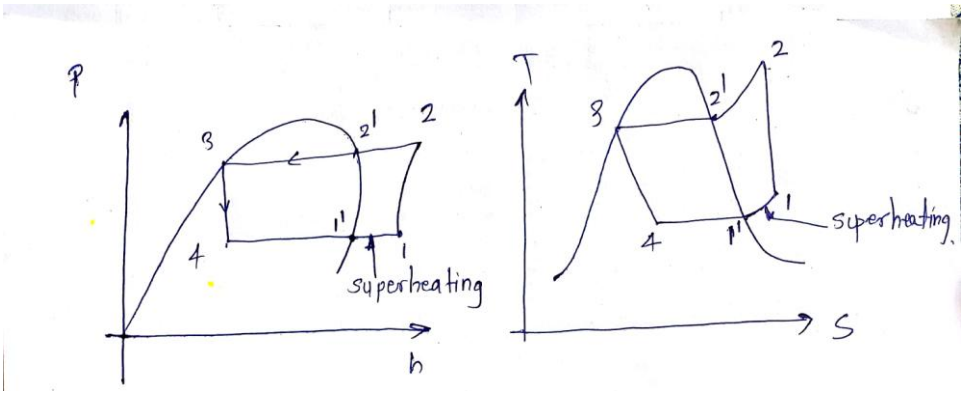
c **Explain term Greenhouse effect and Global warming**. **(Two marks for each term)**

Green House effect-leaving on earth released CO_2, which observed by trees .Due to fast

growing industrialization and deforestation, increases the content of CO2 in the atmosphere. The excess of CO_2 disturb ozone (O_3) layer which results in solar rays directly fall on earth .This effect of reducing ozone (O_3) layer due to excess of CO_2 is known as **greenhouse effect.**

Global Warming- Due to "Ozone Layer Depletion" **t**he atmosphere allows a large percentage of the rays of visible light from the sun to reach the earth surface and heat it. Out of the incident radiation some infrared radiation is trapped by the earth atmosphere due to molecules of carbon dioxide and water vapour in the atmosphere and causes the earth's surface and lower atmospheric layer to warm to high temperature. This is called as **global warming.**

d **Explain in brief superheating with the help of PH and TS diagram.**



03 Marks

In Superheating ,the evaporation takes place at point 4 and continues up to 1 by passing the vapour through superheater,In this cycle the heat is observed in two stages firstly from point 4 to1' and secondely from point 1' to 1.Superheating increasing the refrigerant effect and amount of work supplied to the compressor. Increases refrigerant effects and compressor work.

(01 mark)

e **Differentiate between vapour absorption and vapour compression refrigeration system.**

(Any four difference ,for 1 marks each)

04Marks.

Sr No	Vapour Absorption	Vapour Compression
1	Energy input is mainly heat energy.	Energy input is Mechanical energy
2	COP is lower than vapour compression system.	COP is higher than vapour absorption system
3	Takes more time to produce refrigerant effects	Less time required to produce refrigerant effects.
4	Less no of moving parts.	More wear and tear and noise due to

		moving parts.
5	Needs more space.	It's compact in size.
6	Charging of the refrigerant is difficult.	Charging of refrigerant is easy.
7	No compressor no leakage's	Chances of leakages.
8	Liquid droplets of refrigerant have no effect or no danger.	Liquid droplets in suction line may damages.

f. **Explain the effect of change in suction pressure in vapour compression refrigeration system.** **(Figure 02 marks and effects 02 marks)** 04 Marks

Suction pressure decreases due to the frictional resistance of flow the refrigerant.

Let us consider a theoretical vapour compressor cycle 1'-2'-3'-4' when the suction pressure decreases from P_s to $P_{s'}$

It may noted that the decrease in suction pressure

1.decreases the refrigerant effect from (h_1-h_4) to $(h_{1'}-h_{4'})$ and

2.increases the work required for compression from $(h_2 - h_1)$ to $(h_{2'}-h_{1'})$

Since the COP of the system ---with decrease in suction pressure, the net effect is to decrease the COP o0f the refrigerating system for the same amount of refrigerant flow.