WINTER – 2022 EXAMINATION

Model Answer

Subject Name: Refrigeration & Air conditioning **Subject Code:** **22660**

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.
8) As per the policy decision of Maharashtra State Government, teaching in English/Marathi and Bilingual (English + Marathi) medium is introduced at first year of AICTE diploma Programme from academic year 2021-2022. Hence if the students in first year (first and second semesters) write answers in Marathi or bilingual language (English +Marathi), the Examiner shall consider the same and assess the answer based on matching of concepts with model answer.

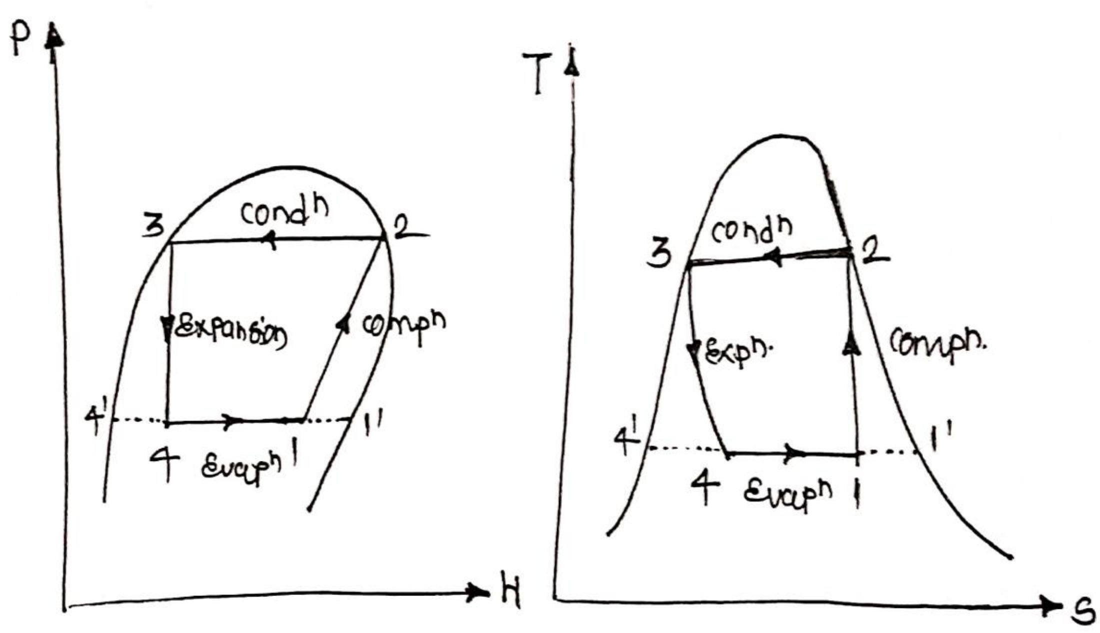
1		Attempt any FIVE of the following:	10 Marks
	(a)	**Give unit of Refrigeration and define it.**	
	Ans.	**Unit of refrigeration is Ton.** **One Ton of refrigeration:** A ton of refrigeration is defined as the quantity of heat required to be removed to from one ton of ice at 0^0 C in 24 hours when initial condition of water is 0^0 C 1 Ton of refrigeration = 3.517 KJ/Sec or 3.517 kW	02
	(b)	**Give any two excellent properties of NH3, used as refrigerants.**	
	Ans.	i) High Latent heat of vaporization ii) Low mass flow rate per ton of refrigeration iii) Leaks can be easily detected because of its strong smell. iv) Easily liquefied on applying pressure even at room temperature v) It is safe to environment & does not cause depletion of the ozone layer. vi) It is cheap and easily available	Any Two Points 02

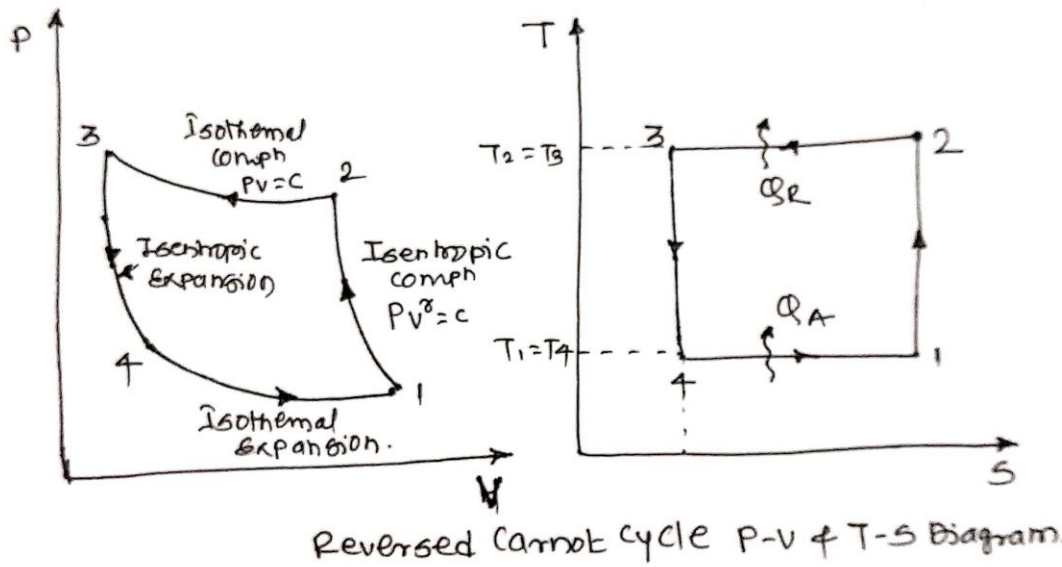
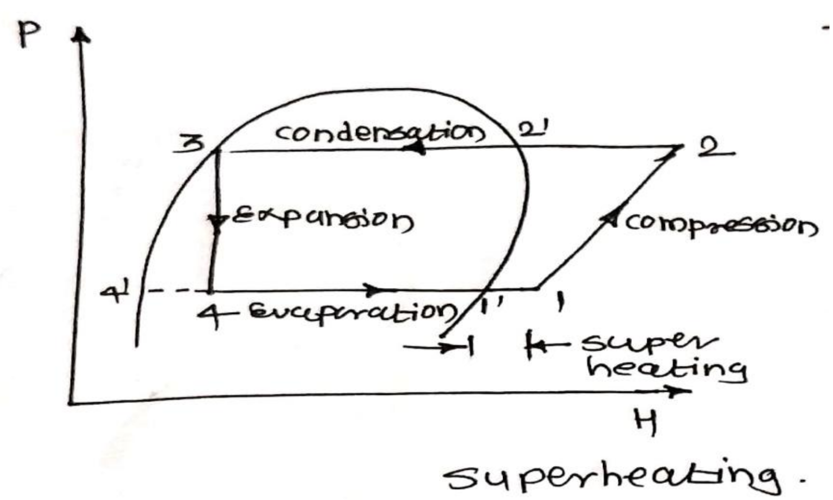
WINTER – 2022 EXAMINATION

Model Answer

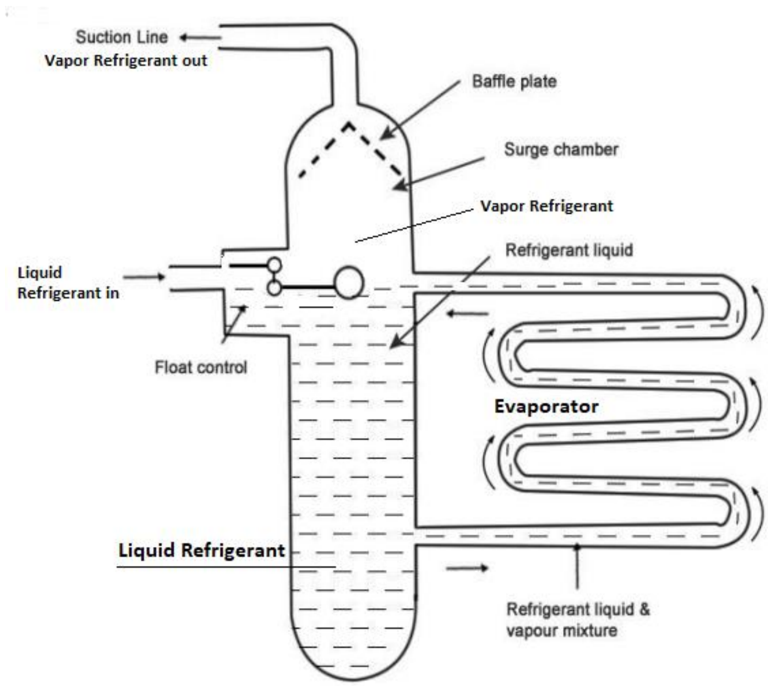
Subject Name: Refrigeration & Air conditioning Subject Code: 22660

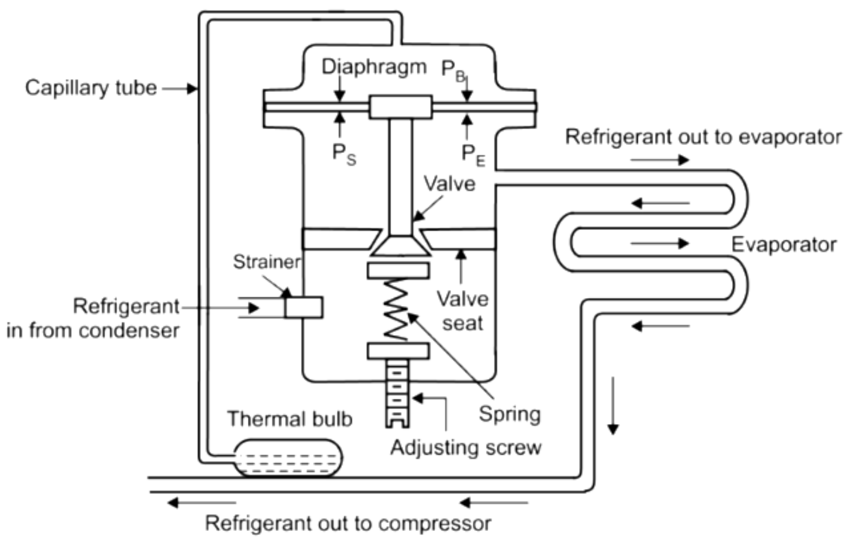
	(c)	**List parameters controlled in 'air-conditioning' system.**	
	Ans.	i) Temperature of air ii) Humidity of air iii) Motion of air iv) Purity of air	½ Each point
	(d)	**A refrigerator works on reversed Carnot cycle between the temperature limits of -5⁰ C and 35⁰ C. Find out its COP.**	
	Ans.	Given:- $T_L = -5^0 + 273 = 268\ ^0K$ $T_H = 35^0 + 273 = 308\ ^0K$ COP = ? We know that $(COP)_{Carnot} = T_L / T_H - T_L$ = 268 / 308-268 = 6.8	01 01
	(e)	**Give classification of ducts**	
	Ans.	The ducts may be classified as follows: **i) According to type of air in duct:** 1. Supply duct 2. Return duct 3. Fresh air duct **ii) According to pressure of air in duct:** 1.Low pressure duct 2..Medium pressure duct 3.High pressure duct **iii) According to velocity of air in duct:** 1. Low velocity duct 2. High velocity duct	Any two 02

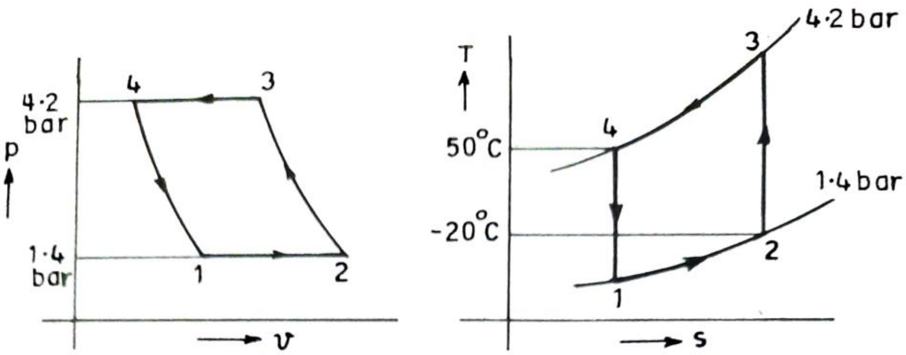
	(f)	**Enlist advantages of Hermetically sealed compressor over open type compressor**	
	Ans.	i) there is no chance of leakage of costly refrigerant ii) high efficiency and reliability of the compressor motor iii) Less noise & vibration iv) Require small space because of compactness v) Do not need any shaft seal assembly, because the compressor and the motor are mounted on a common shaft and in a common housing. vi) Less maintenance and long life	Any Four Points 02
	(g)	**On p-H and T-S diagram shown vapour compression cycle started compression with wet inlet and dry outlet.**	
	Ans.	 VCC on p-H & T-S diagram.	02

2		Attempt any <u>THREE</u> of the following:	12 Marks
	(a)	**Plot 'reversed Carnot cycle on P-V and T-S diagram. Also mention processes involved in the cycle.**	
	Ans.	 Process involved : 1. Process 1-2 Isentropic compression 2. Process 2-3 Isothermal compression 3. Process 3-4 Isentropic expansion 4. Process 2-3 Isothermal expansion	Diagram 03 Process 01
	(b)	**Explain effect of 'Superheating' on COP with the help of p-H diagram**	
	Ans.	 	Diagram 02

		i) Superheating causes increase in specific volume at suction of compressor which reduces capacity of compressor ii) Superheating increase refrigerating effect, at the same time it increases the amount of workload supplied to compressor. Hence COP of cycle remain unaffected or in some cases it reduces.	Explanation 02
	(c)	**Give important desirable properties of an 'Ideal refrigerant'**	
	Ans.	1) Boiling point at atmospheric pressure should be low. 2) Freezing point at atmospheric pressure should be low. 3) Latent heat of vaporization of refrigerant must be high. 4) Critical temperature should be high. 5) It should not have corrosive action with system material. 6) It should not be flammable & explosive. 7) It should not be toxic. 8) It leak should be easily detectable. 9) It should have positive condensing pressure. 10) It should have satisfactory heat transfer coefficient. 11) It should have high thermal conductivity. 12) It should have chemical stability.	Any 8 points 04
	(d)	**For 'storage tank type water cooler' suggest -**	
	Ans.	i) Compressor - Hermetically sealed compressor ii) Condenser – Force convection air cooled condenser iii) Expansion device – Capillary tube & thermodynamic expansion valve iv) Evaporator – Dry expansion type evaporator v) Refrigerant – R-134-a or R-22	04
3		Attempt any <u>THREE</u> of the following:	12 Marks
3	a) **Ans**	**Enlist factors affecting human comfort**. 1. Effective temperature 2. Heat production and regulation in human body 3. Heat and moisture losses from the human body 4. Moisture content of air 5. Quality and quantity of air 6. Air motion	½ Marks each

		7. Hot and cold surfaces 8. Air stratification	
	b) Ans:	**Explain working of 'Flooded Type Evaporator' with a neat sketch.** Flooded type of evaporator feeds excess of liquid refrigerant so that the exit of the evaporator will be a mixture of liquid and vapor refrigerant.  **Working:** In the flooded type of evaporator coil remains completely filled with liquid refrigerant as shown in the figure. The level of liquid refrigerant is maintained constant in the surge chamber by using float control. The liquid refrigerant enters into evaporator coil from the surge chamber. In evaporator coil, part of liquid refrigerant boils and converts into vapor. The vapor formed is collected at the top of the surge chamber and the remaining liquid refrigerant is returned to the surge chamber. From the top of the surge chamber, refrigerant vapors are drawn in the suction line of the compressor. In the flooded type evaporator rate of heat transfer is very high as the whole evaporator coil remains in contact with liquid refrigerant but this type of refrigerant requires a large amount of refrigerant.	Labeled Sketch 2 Marks Working 2 Marks
3	c) Ans	**Enlist pressure losses occurred in the duct.** **1) <u>Frictional Losses</u>** The pressure is lost due to friction between the moving particles of the fluid and the interior surfaces of a duct. This is termed as friction loss. **2) <u>Dynamic Losses:</u>**	1 Marks

		Pressure is also lost dynamically at the changes of direction such as in bends, elbows, etc. and at the cross-section changes of the duct. This is termed as dynamic loss. i) Pressure Loss in Elbows ii) Loss due to enlargement iii) Loss due to contraction iv) Losses at suction and discharge openings v) Pressure losses in fittings (valves, grills and others)	3 Marks ½ mark for each Dynamic loss
3	d) Ans	**Explain working of Thermostatic Expansion Device with neat sketch.**  **Figure: Thermostatic Expansion Device** **<u>Working:</u>** • The thermostatic expansion valve consists of a needle valve, a seat, a metallic diaphragm, a spring, adjusting screw and a feeler bulb. • The opening or closing of valve depends upon following forces acting on the diaphragm: i. Spring pressure acting on bottom of diaphragm **P_s** ii. Evaporator pressure acting on bottom of diaphragm **P_E** iii. Feeler bulb pressure acting on top of diaphragm **P_B** • If load on evaporator increases, it causes the liquid refrigerant to boil faster in evaporator coil. Since feeler bulb is installed on the suction line, therefore it is at the same temperature as refrigerant at that point. So temperature of the bulb increases due to early vaporization of refrigerant. • Thus the feeler bulb pressure increases and gets transmitted through the capillary	Labeled Sketch 2 Marks

		tube to the diaphragm. The diaphragm moves downwards, opening the valve to admit more liquid refrigerant into the evaporator. • This continues till pressure equilibrium on diaphragm is reached, at which feeler bulb pressure acting at top of diaphragm is balanced by spring and evaporator pressure acting at bottom of diaphragm. • When evaporator load decreases, less liquid refrigerant evaporates in the coil, and the excess liquid flows towards the outlet. This cools the feeler bulb and its pressure and temperature decreases. • This pressure makes the diaphragm move upward, reducing the valve opening and in turn decreasing refrigerant flow to evaporator. This causes decrease in evaporator pressure and again continues till diaphragm pressure equilibrium is reached.	Working 2 Marks
3	e Ans:	**A dense air machine operates on reversed Brayton Cycle and having capacity 10 TR. Its pressure limits are 1.4 bar and 4.2 bar. The air is cooled in cooler to a temperature of 50 ^{0}C and temperature of air at inlet to compressor is -20 ^{0}C. Determine** **i) COP of the cycle** **ii) Mass of air circulated per minute.** **Given:** Q=10 TR; $P_1 = P_2 = 1.4$ bar; $P_3 = P_4 = 4.2$ bar; $T_2 = -20°C = 253K$ $T_4 = 50°C = 323K$ For ideal gas C_P = 1.07 kJ/kg-K (for dense air)  $T_2 = -20 + 273 = \mathbf{253\ K}$ and $T_4 = 50 + 273 = \mathbf{323\ K}$ $\frac{T_4}{T_1} = \left(\frac{p_4}{p_1}\right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{4.2}{1.4}\right)^{0.286} = 1.37$ $T_1 = \frac{T_4}{1.37} = \frac{323}{1.37} = \mathbf{235.8\ K}$ $\therefore \frac{T_3}{T_2} = \left(\frac{p_3}{p_2}\right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{4.2}{1.4}\right)^{0.286} = 1.37$ $T_3 = 253 \times 1.37 = \mathbf{346.6\ K}$ (i) $\text{COP} = \frac{R}{W} = \frac{C_p(T_2 - T_1)}{C_p(T_3 - T_2) - C_p(T_4 - T_1)}$ $= \frac{(253 - 235.8)}{(346.6 - 253) - (323 - 235.8)} = \mathbf{2.43}$ (ii) Heat carried by air from evaporator = Load in evaporator $\therefore mC_p(T_2 - T_1) = 10 \times 3.5 \times 60$ $\therefore m = \frac{600 \times 3.5}{1.07\ (253 - 235.8)} = \mathbf{114\ kg/min.}$	2 Marks 2 Marks
4		**Attempt any THREE of the following:**	12

a)

Ans

Explain Frosting of evaporator. On this basis classify evaporators.

Frosting of evaporator:

The condensation of water vapour of the room/cold storage causes formation of frost over the evaporator.

Formation of ice takes place in all the evaporators which are operating below the freeing point of water (0 ºC).

The accumulation of ice over the heat transfer surface reduces the heat transfer rate as the ice is poor conductor of heat. Therefore, it is necessary to remove the ice deposited over the evaporator at periodic time interval.

The operation of removing frosted ice from the evaporator is known as defrosting of evaporator. The period of defrosting depends on type of evaporator, relative humidity of the cold room, evaporation temperature etc.

Classification of Evaporators based on Frost

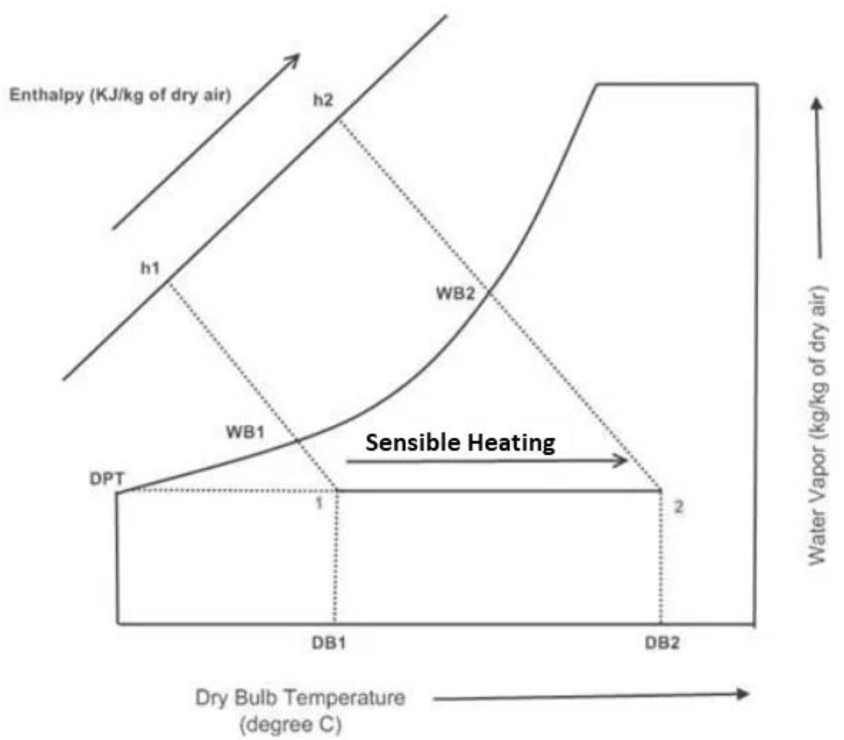
i) Frosting Evaporators
ii) Non-Frosting Evaporators
iii) Defrosting Evaporators

Frosting 2 Marks

Classifica 2 marks

4 b) **Show 'Sensible Heating' process on psychrometric chart. Find out By-Pass factor of heating coil.**

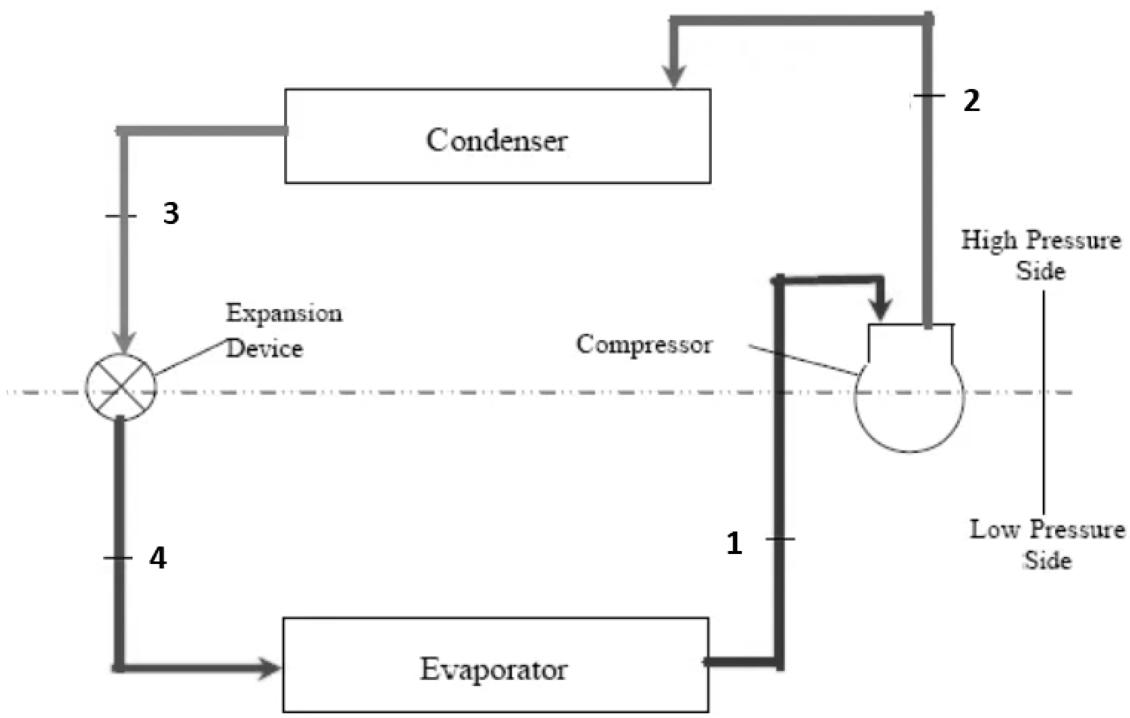
Ans:

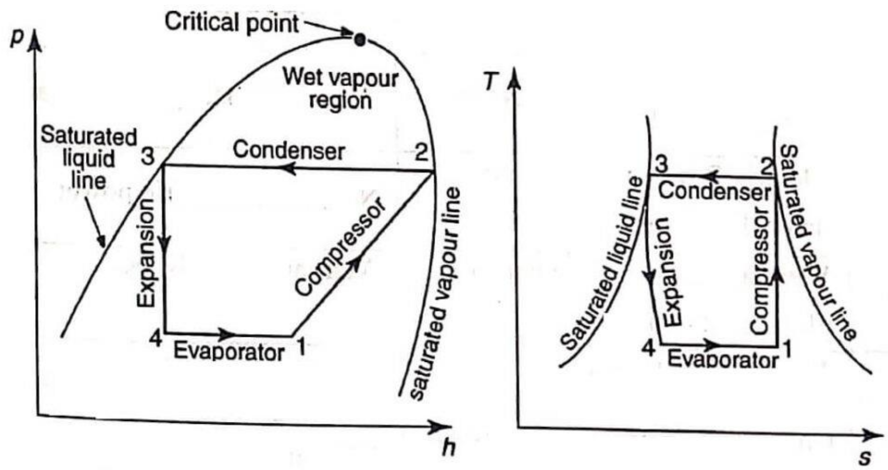


2 Marks

By-Pass Factor:

It is defined as the ratio of loss in cooling or heating to the ideal cooling or heating.

		It is denoted by X. Bypass factor (X) for heating coil = Loss in heating / Ideal heating The bypass factor (B.P.F.) in case of sensible heating of air is = td3−td2 / td3−td1 Where, td_1 = Dry bulb temperature of air entering the heating coil, td_2 = Dry bulb temperature of air leaving the heating coil and td_3 = Dry bulb temperature of heating coil	1 Mark 1 Mark
4	c) Ans	**Enlist insulating materials used in refrigeration field.** i) Cork ii) Mineral Wool iii) Fiber/Cellular glass or glass wool, iv) Cellulose v) Polyurethane Foam (PU Foam) **vi)** Polystyrene or thermocole **vii)** Gypsum **viii)** Aluminium Foils **ix)** Vermiculite **x)** Blast Furnace slag	Any four 1 mark each
4	d) Ans:	**Explain working of 'Vapor Compression Cycle' with block diagram. Plot it on p-h and T-S diagram**  **Figure: Vapor Compression Cycle**	Block dia 1 Mark



(a) p-h diagram (b) T-s diagram

2 Marks P-h and T-S dia

Working:

The high pressure vapor refrigerant from the condenser enters the expansion or throttle valve where it expands to the required pressure. During expansion pressure is reduced and the vapour becomes partially converted to liquid and produces cooling effect. This process is represented in p-h diagram as 3-4.

A mixture of low temperature vapor and liquid from expansion valve is then enters the evaporator and absorbs heat from the space to be refrigerated. Thus the "Refrigerating effect" is obtained. This process is represented in p-h diagram as 4-1.

Because of this, liquid becomes vapour (state 1) and this vapour enters the compressor. There it is compressed, thus the pressure goes up. This process is represented in p-h diagram as 1-2.

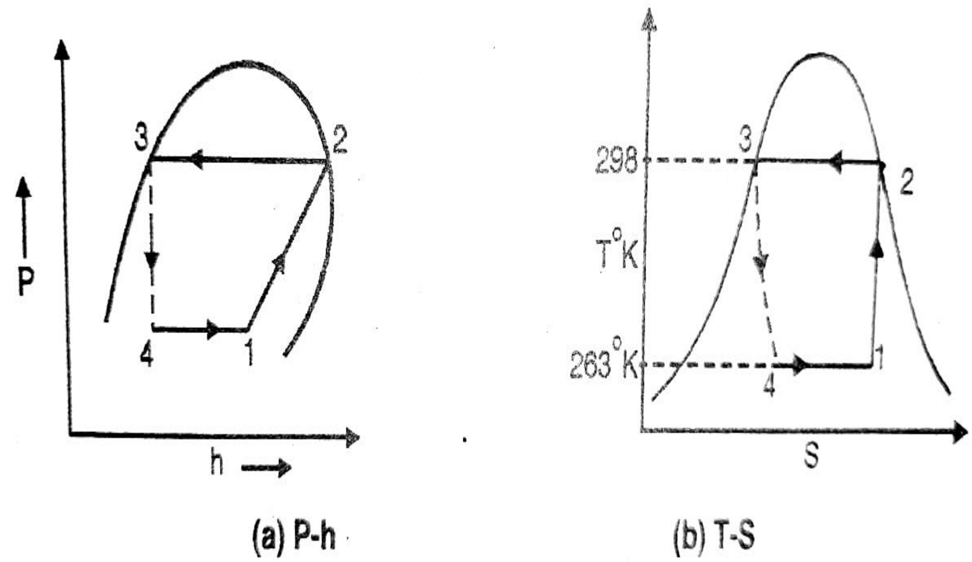
This high pressure vapour enters the condenser. There, it loses its latent heat and becomes liquid. (Process 2-3)

The liquid refrigerant is stored in a receiver and supplied to the expansion valve, and the cycle continues.

1 Mark Working

Q. 5		**Attempt Any TWO of the following:**	**12 Marks**
05	A	**The temperature limits of an ammonia refrigerating system are 25^0C and -10^0C. If the gas is dry at the end of compression, calculate COP of the system assuming there is no sub-cooling of liquid refrigerant. Use following table as properties of NH_3**	

Temp °C	Liquid Heat (kJ/kg)	Latent Heat (kJ/kg)	Liquid Entropy (kJ/kg °k)
–10	133.37	1297.68	0.5443
25	298.9	1166.94	1.1242

	Ans	(a) P-h (b) T-S	2 M
		Given data :- $T_1 = -10 + 273 = 263\ K$ $T_2 = 25 + 273 = 298\ K$ from table of properties of NH_3 $H_2 = h_{f_2} + h_{fg_2} = 298.9 + 1166.94 = 1465.84\ KJ/kg$ $H_3 = H_4 = 298.9\ KJ/kg.$ $S_1 = S_2 = S_{f_2} + x_2 \left[\frac{h_{fg}}{T_2}\right]$ $\therefore\ S_2 = 1.1242 + 1 \times \left[\frac{1166.94}{298}\right] = 5.040$ $\therefore\ S_1 = S_{f_1} + x_1 \left[\frac{h_{fg_1}}{T_1}\right]$ $\therefore\ 5.040 = 0.5443 + x_1 \left[\frac{1297.68}{263}\right]$	2 M
		$x_1 = 0.91$ or 91% dry **Now** $H_1 = h_{f_1} + x_1 h_{fg_1} = 133.37 + 0.91 \times 1297.68$ $\therefore\ H_1 = 1314.25\ KJ/kg$ $\therefore\ C.O.P. = \frac{\text{Refrigerating effect}}{\text{Work of compressor}} = \frac{H_1 - H_4}{H_2 - H_1}$ $\therefore\ COP = \frac{1314.25 - 298.9}{1465.84 - 1314.25} = 6.698$	2 M

<table>
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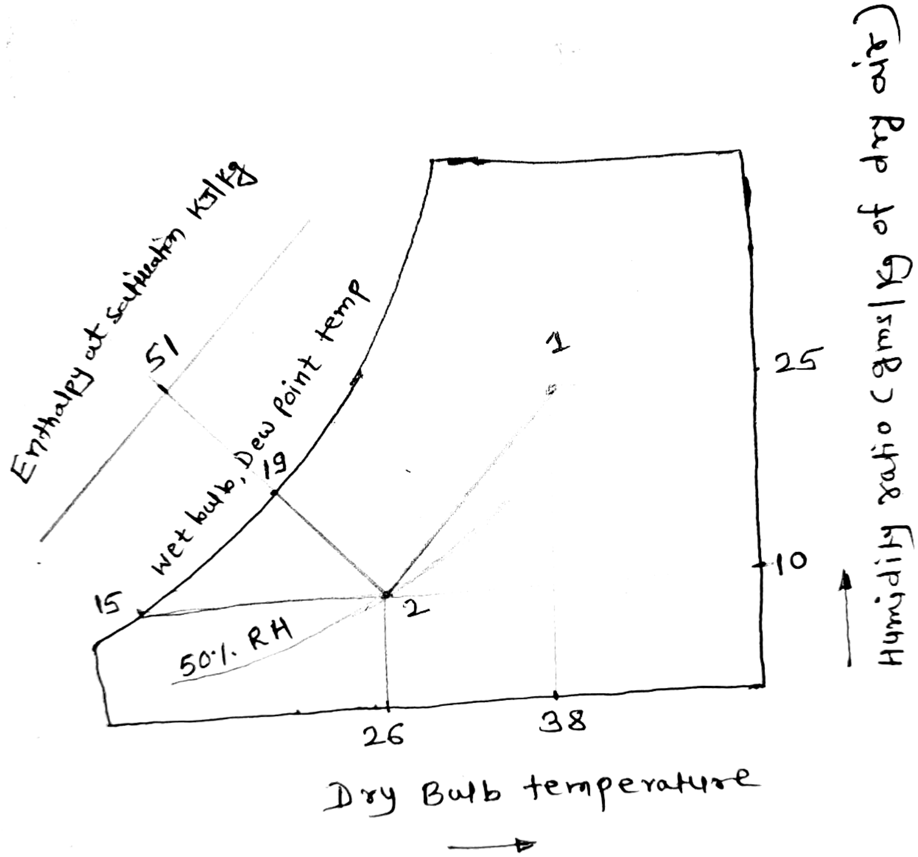
<td>5</td>
<td>b)

Ans</td>
<td>

A Surrounding air having DBT =38^{0}C and 25gm/kg of DA humidity ratio is converted to conditioned air having DBT = 26^{0}C and RH =50%. Plot the processes on the psychrometric chart and find out all the other properties of the conditioned air



Properties of conditioned air:-

1) DPT= 15^0 C
2) WBT= 19^0 C
3) Humidity Ratio= 10 gm/kg of DA.
4) Enthalpy = 51 kg/kg of dry air.

</td>
<td>3 M (For Chart)

Any three properties 3 M</td>
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<td>5</td>
<td>C

Ans:</td>
<td>

List Various types of heat loads while designing air conditioning system.

Two main components of heat load are-

1. Sensible heat load and 2.Latent heat load.

1.Sensible heat gain through structure by conduction

$$Q=U^* A^*(to-ti)$$

Where-
Q=Total heat transfer,
A=Outside area of wall,
to= Outside air temperature,
ti= Inside air temperature,

2. Sensible heat gain from solar radiation through walls and roof

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<td>(01 mark each)</td>
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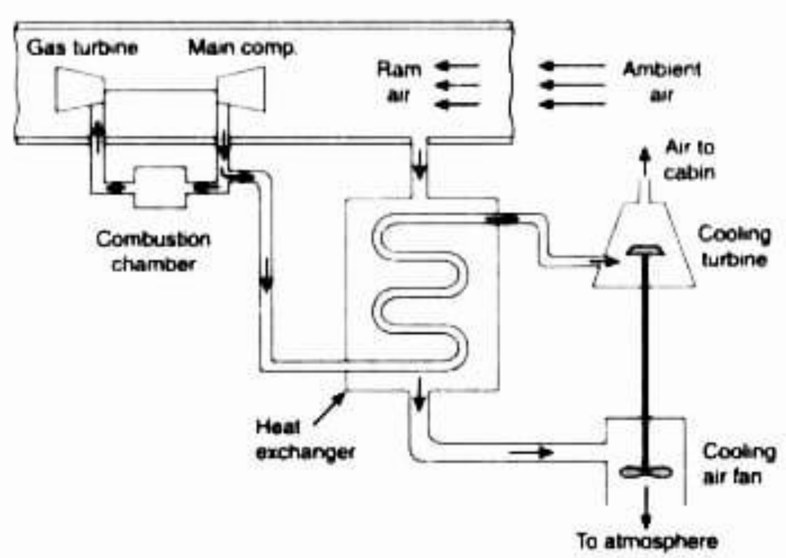
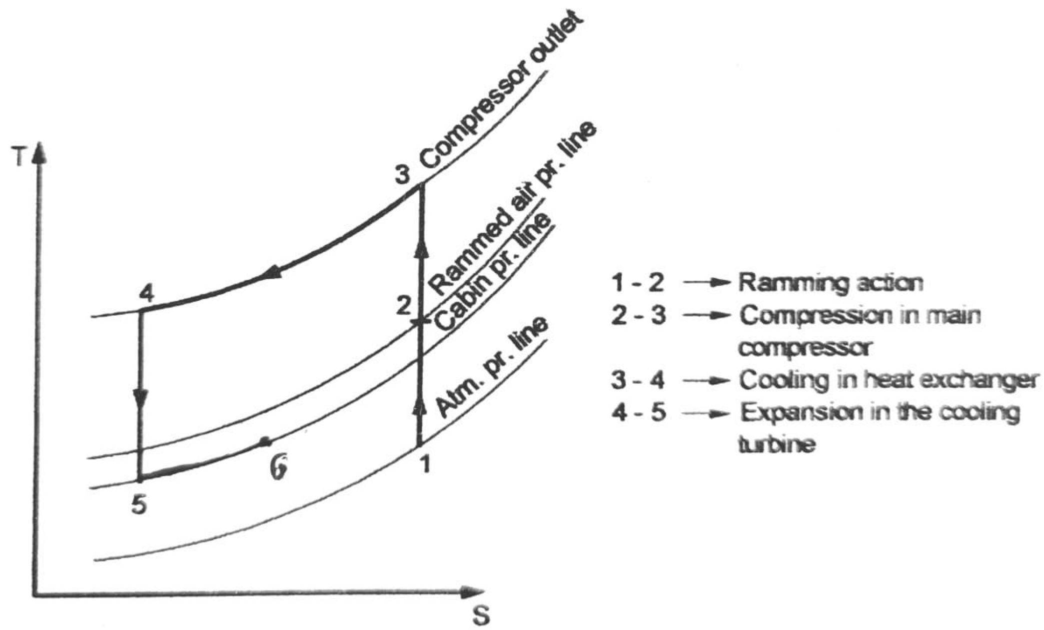
		Q=U*A*te Where, Q=Total heat transfer, A=area of roof or wall, te = Equivalent temperature differential. 3.**Heat gain due to infiltration (using air change method)** Amount of infiltrated air through windows and wall is = (L*W*H*Ac)/60 m3 /min. Both sensible and latent heat load gain. **4.Heat gain through ventilation** The ventilation (supply of outside air) is provided to the conditioned space in order to minimize carbon dioxide and other undesirable gases. ½ air should be change per hour in buildings in normal ceiling heights. The outside air adds sensible as well as latent heat load. **5. Heat gain from appliances/lightening equipment's –** Appliances used may be Projector, lights etc. Heat gain can be calculated as Q= (Total Wattage *use factor*Allowance Factor). **6. Heat gain from Occupants** The amount of heat dissipated would depend on the number of persons and their activities, age, sex, cloths. Heat gain depends on average number of people present in Auditorium. Q= (no of persons)*(load per person).	
6		**Attempt any TWO of the following:**	12
	a Ans	**Explain 'Air Refrigeration System' used for aircraft with block diagram. Also represent it on T-S diagram and find out its COP.**  Simple air cooling system. The main components of air cooling system are the main compressor driven by a gas turbine, a heat exchanger, a cooling turbine and a cooling air fan. The air required for refrigeration system is bled off from the main compressor. This high pressure and high temperature air is cooled initially in the heat exchanger where ram air is used for cooling. It is further cooled in the cooling turbine by the process of expansion. The work of this turbine is used to drive the cooling fan which draws cooling air through the heat exchanger. The various process consist of this system are:	2 M (Sketch) 2 M (Working)

Ramming process: ideal ramming action is shown by vertical line 1-2
Compression: isentropic compression by line 2-3
Cooling process: shown by curves 3-4.
Expansion process: isentropic expansion in the cooling turbine shown by curve 4-5
Refrigeration process: cooling effects curves 5-6.



T-S Diagram of simple air craft cooling system

COP = $\dfrac{\text{Refrigerating effect produced}}{\text{work done}}$

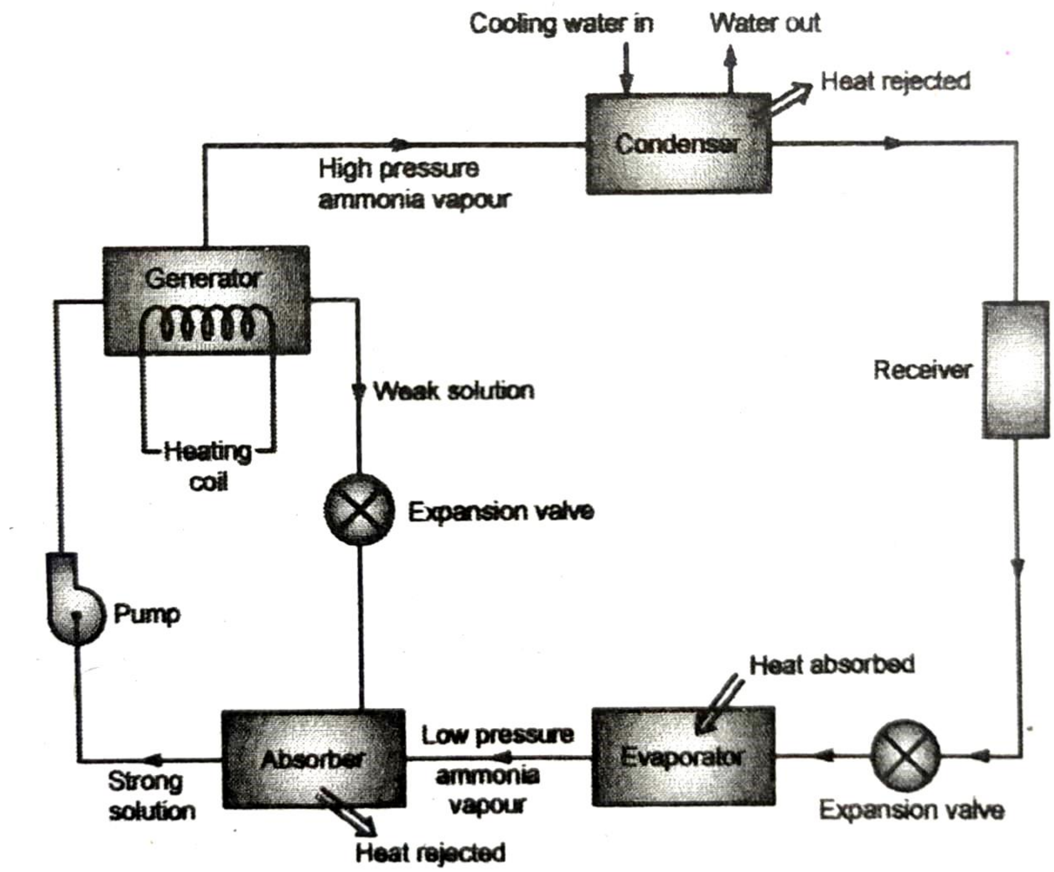
$$= \frac{m_a c_p\,(T_6 - T_5)}{m_a c_p (T_3 - T_2)}$$

COP = $\dfrac{(T_6 - T_5)}{(T_3 - T_2)}$

2 M

(T-S Diagram and COP)

6	b)	**Only draw 'Simple vapor Absorption System' with block diagram. How it is converted to 'Practical Vapor Absorption System'.**	



2 Marks Sketch

Simple Vapour Absorption System

The simple absorption system is not very economical. In order to make the system more practical, it is fitted with an analyzer, a rectifier and two heat exchangers as shown in fig. These accessories help to performance and working of the plant, as discussed below:

1.Analyser

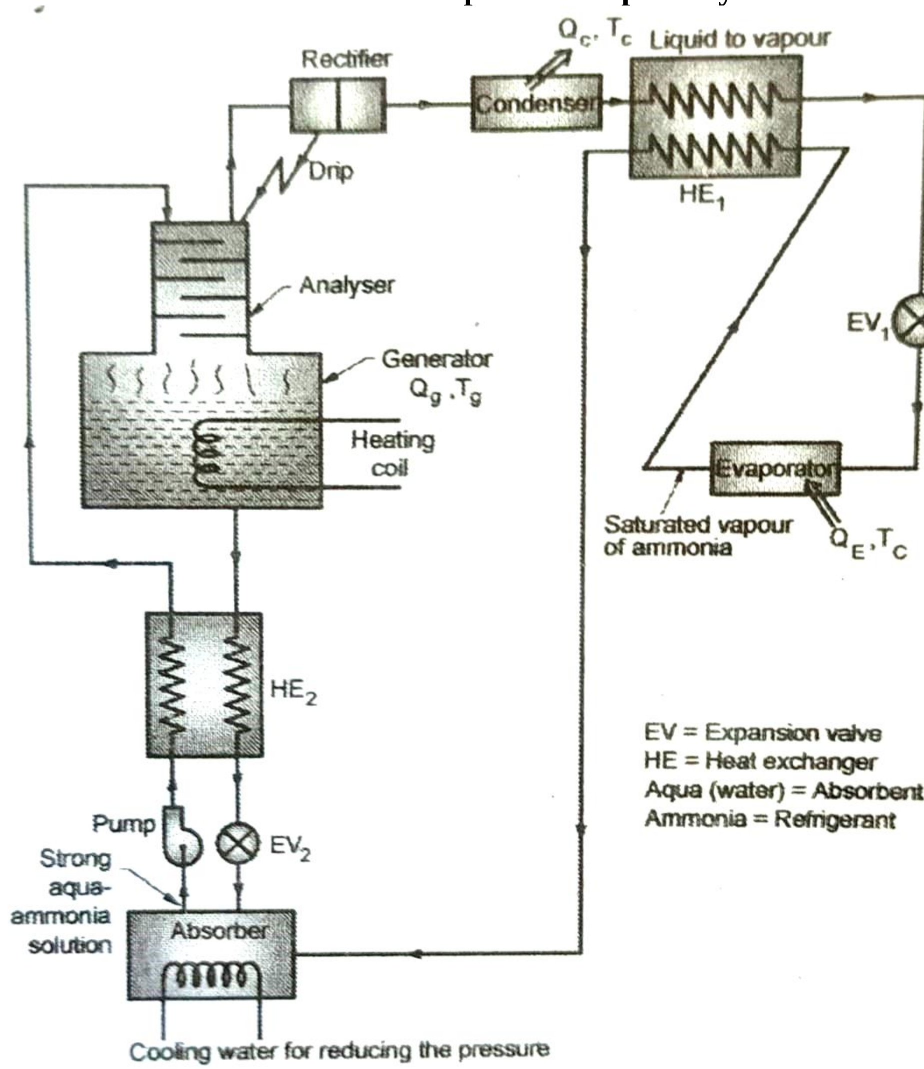
When ammonia is vaporized in the generator, some water is also vaporized and will flow into the condenser, along with the ammonia vapours in the simple system. If these unwanted water particles are not removed before entering into the condenser, they will enter into the expansion value where they freeze and choke the pipeline. In order to remove these unwanted particles flowing to the condenser, an analyzer is used. The analyzer may be built as an integral part of the generator or made as a separate piece of equipment. It consists of a series of trays mounted above the generator. The strong solution from the absorber and the aqua from the rectifier are introduced at the top of the analyzer and flow downward over the trays and into the generator. In this way, considerable liquid surface area is exposed to the vapour rising from the generator. The vapour is cooled and most of the water vapour condenses, so that mainly ammonia vapour (approximately 99%) leaves the top of the analyzer. Since the aqua is heated by the vapour, less external heat is required in the generator.

2 M-Description

2. Rectifier

In case the water vapours are not completely removed in the analyzer, a closed type vapour cooler called rectifier (also known as dehydrator) is used. It is generally water cooled Its function is to cool further the ammonia vapours leaving the analyzer so that remaining water vapours are condensed. Thus, only dry or anhydrous ammonia vapours flow to the condenser. The condensate from the rectifier is returned to the top of the analyzer by a drip return pipe.

3. Heat exchangers

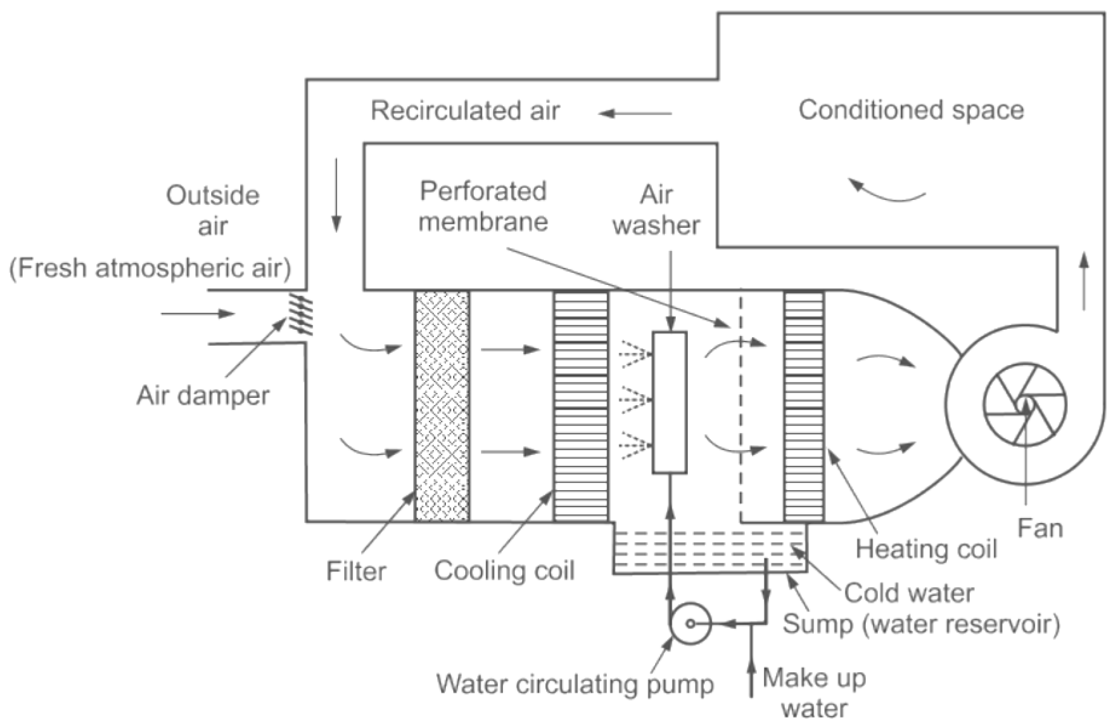
		The heat exchanger provided between the pump and the generator is used to cool the weak hot solution returning from the generator to the absorber. The heat removed from the weak solution raises the temperature of the strong solution leaving the pump and going to analyzer and generator. This operation reduces the heat supplied to the generator and the amount of cooling required for the absorber. Thus the economy of the plant increases. In this heat exchanger, the liquid refrigerant leaving the condenser is subcooled by the low temperature ammonia vapour from the evaporator as shown in fig. this sub-cooled liquid is now passed to the expansion value and then to the evaporator. In this system, the net refrigerating effect is the heat absorbed by the refrigerant in the evaporator. The total energy supplied to the system is the sum of work done by the pump and the heat supplied in the generator. **Practical Vapour Absorption System**  **:-**	2 M-Sketch
6	c) Ans:	**Explain the air conditioning system for the Delhi City** Hot and wet weather conditions like Delhi, where temperature as well as RH is high. Therefore at such places Cooling with dehumidification is supposed to be done by summer air conditioning system. This system is used in summer air conditioning applications. In this system air is cooled and generally dehumidified. Schematic diagram is shown in figure. The outside air flows through damper and mixes up with recirculated air which is obtained from air conditioned space. The mixed air passes	3M-for Explanation

through a filter to remove dirt, dust and other impurities.

The air now passes through cooling coil. The coil has a temperature less than dew point temperature of the air. When the air is cooled and passed through a membrane, some quantity of water vapours associated with air is condensed due to cooling of air below its dew point temperature. Thus the air loses the moisture in the form of condensate and is collected in sump.

Due to cooling below DPT, the temperature of air decreases below the desired temperature. Therefore this air is heated with the help of heating coil. This is done to bring the air to desire DBT and RH.

The air washer system is not operative in this case of summer air conditioning system. Now conditioned air passes to conditioned space by a fan. From the conditioned space the part of air is exhausted to atmosphere by exhaust fans or ventilators. The remaining part of the used air or recirculated air is again conditioned as shown in the figure. The outside air is sucked and made to mix with recirculated air in order to make up for the loss of conditioned or used air through exhaust fans or ventilators from conditioned space.



3M-for Sketch

------------**END**------