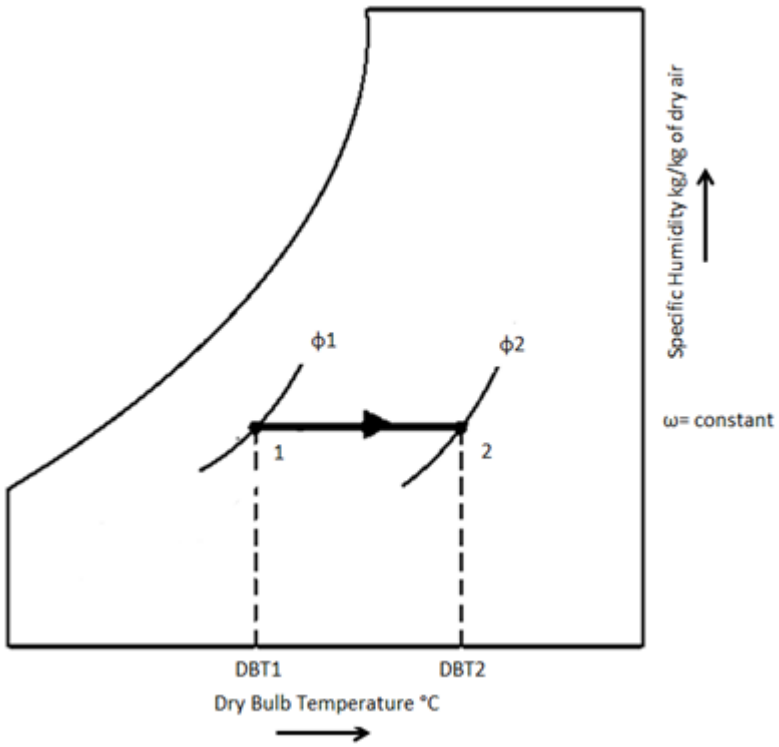
SUMMER – 2022 EXAMINATION

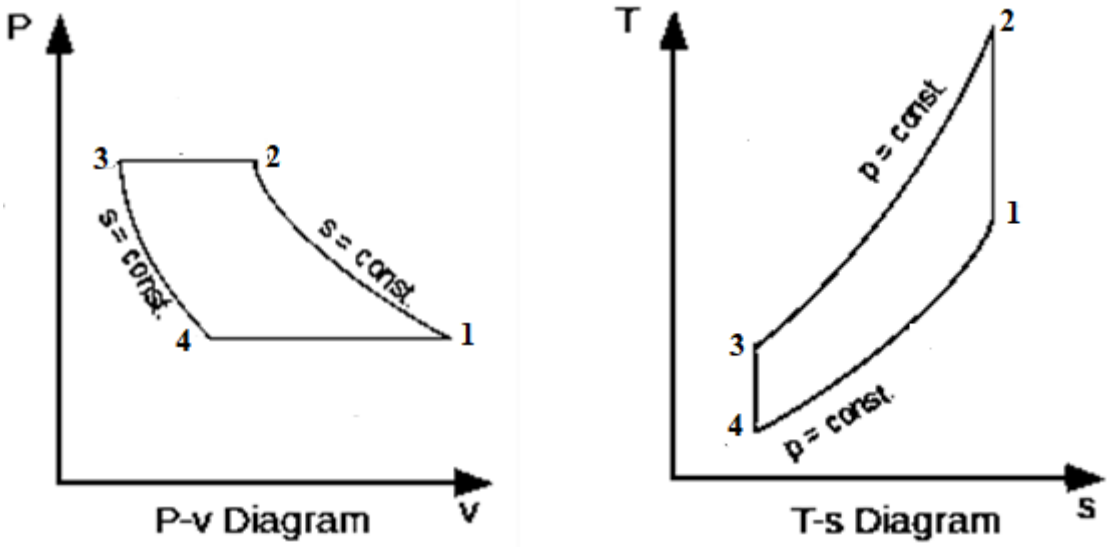
Subject Name: Refrigeration & Air Conditioning **Model Answer** **Subject Code: 22660**

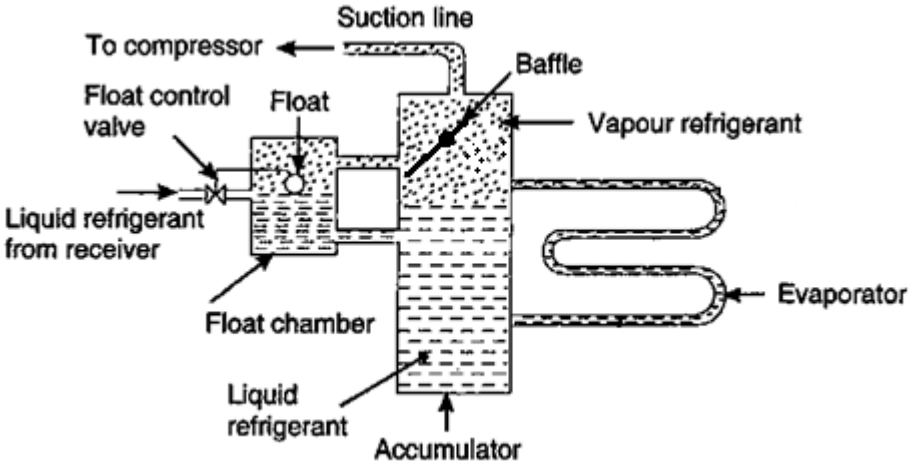
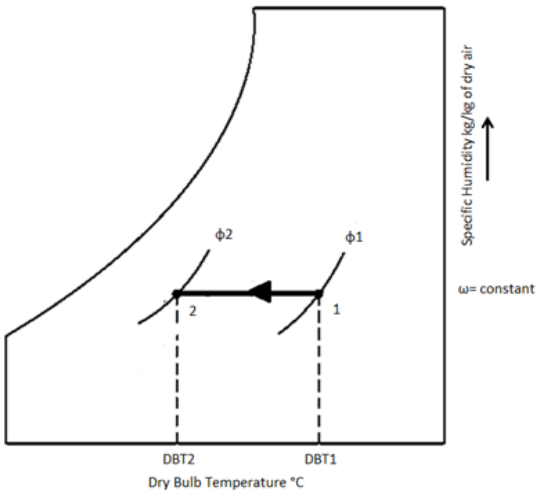
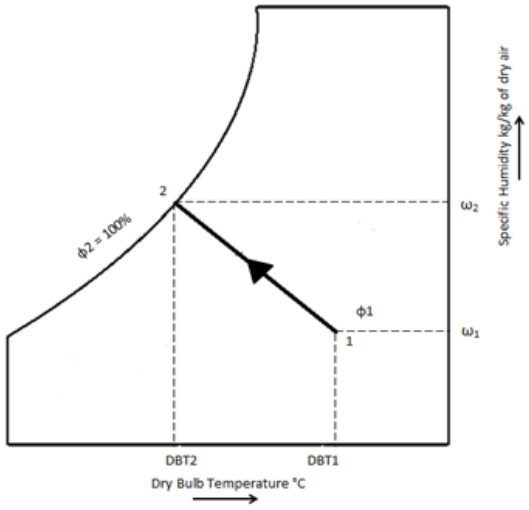
Important Instructions to examiners:

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.

Q. No.	Sub Q. N.	Answer	Marking Scheme
1.		**Attempt any Five of the following: (5 x 2)**	**10**
	(a)	**Define unit of Refrigeration.**	
	Ans.	**Unit of Refrigeration** Unit of refrigeration is ton of refrigeration which is defined as; The quantity of heat removed to freeze one ton (1000kg) of water into one ton of ice in duration of 01 Day or 24 hours at 0°C (or 32°F).	**02**
	(b)	**State the factors affecting on human comfort.**	
	Ans.	i. Temperature i.e. dry bulb temperature ii. Humidity iii. Quality of air iv. Air motion v. Metabolic rate vi. Presence of cold and hot surfaces vii. Air stratification	**02** **(0.5 for each point)**
	(c)	**Write designation (Number) of refrigerants $CHClF_2$ and $C_2Cl_2F_4$.**	
	Ans.	i. $CHClF_2$ - R22 ii. $C_2Cl_2F_4$ - R114	**02 (01 mark for each point)**
	(d)	**List the advantages of hermetically sealed compressor.**	
	Ans.	**Advantages of hermetically sealed compressor are as follows;** i. It is a compact unit which requires less space	**02**

		ii. Leakage of refrigerant to the surrounding atmosphere is completely prevented iii. It is less noisy iv. It is moisture and dust free v. As motor and compressor are enclosed in a casing, it prevents chances of accident during operation vi. The power required per ton of refrigeration is also less as compared with open type of refrigerant vii. Shaft seal is also not required in this compressor viii. It is a less vibrating compressor as compared with others types ix. It is easy to handle as motor and compressor are enclosed in a single compact unit	**(0.5 for each point)**
	(e) **Ans.**	**Represent sensible heating process on psychrometric chart.**  	**02**
	(f) **Ans.**	**Define wet bulb depression.** The difference between dry bulb temperature and wet bulb temperature is called Wet bulb depression.	**02**
	(g) **Ans.**	**List the desirable properties of insulating materials used in air conditioning systems.** i. It should have low thermal conductivity ii. It should be odorless iii. It should be moisture resistance iv. It should be fire resistance and inflammable v. It should have proper strength to withstand different loads vi. It should have a low thermal expansion coefficient vii. It should be lightweight viii. It should be easily available at low cost	**02** **(0.5 for each correct point)**

Q. No.	Sub Q. N.	Answer	Marking Scheme
2		**Attempt any <u>Three</u> of the following: (3 x 4)**	**12**
	(a)	**Represent Bell-Coleman air refrigeration cycle on P-V and T-S diagram.**	
	Ans.		**04** **(02 marks for each correct diagram)**
	(b)	**List the desirable properties of Ideal refrigerants.**	
	Ans.	A. Thermodynamic Properties i. Low boiling point ii. Low freezing point iii. High latent heat of vaporization iv. High critical temperature and pressures B. Chemical Properties i. Non-toxicity ii. Non-flammable iii. Non-corrosive iv. Non-explosive v. Odorless and non-irritating C. Physical Properties i. Low specific heat ii. Low specific volume of vapor refrigerant iii. Low viscosity D. Other Properties i. Ease of leak detection ii. Ease of handling iii. Low power consumption per ton of refrigeration iv. High COP	**04** **(0.5 marks for any eight properties)**

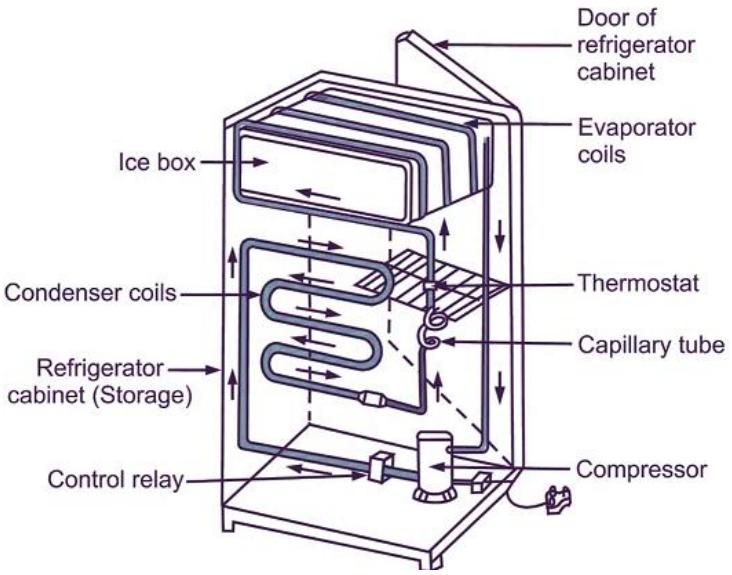
	(c) **Ans.**	**Explain with neat sketch the working of flooded evaporator.**  **Working:** In a flooded evaporator, the evaporator is almost completely filled with liquid refrigerant. Float control valve is used to maintain a constant liquid refrigerant level in an accumulator (surge tank or surge drum) which is used as a storage tank for liquid refrigerant. The liquid refrigerant from the accumulator enters into the evaporator where it converts into vapor refrigerant. This vapor refrigerant from the evaporator is then collected at the top of the accumulator tank. Now, as evaporator liquid refrigerant is converted into vapor refrigerant, the level of liquid in the evaporator falls down to some extent which is maintained by the accumulator tank by supplying additional liquid refrigerant. After supplying additional liquid refrigerant to the evaporator, the level refrigerant in the accumulator also falls down which is then maintained with the help of a float control valve. The vapor refrigerant from top of the accumulator then goes to the suction line of the compressor. Baffle is also provided at the top of the accumulator which helps in preventing the liquid refrigerant from going to the suction line.	**02 marks** **02 marks**
	(d) **Ans.**	**Represent following psychrometric processes on Psychrometric chart:** **(i) Sensible cooling** **(ii) Cooling with adiabatic humidification**  (i) Sensible cooling  (ii) Cooling with adiabatic humidification	**04** **(02 marks for each correct diagram)**

Q.3	(a)	**Attempt any THREE of the following:**	**12 Mark**
		A refrigerator of 12 tons capacity works on reversed carnot cycle and in temperature range of 35^{O}c and -15^{O}c. Determine- i) COP of system (ii) Power required to run the system(kW) (iii) Heat rejected by the system in kJ/S. **Given data: T_2 =35+273=308 K & T_1= (-15+273) =258 K** **R.E = 12 ton =12 ×3.517 = 42.204 KW** **Solution: 1. COP of the system:** COP = T_1 / T_2-T_1 = 258 / (308 – 258) COP = 5.16 **2. Power required to run the system (kw):** COP = R.E / W.D W.D = R.E / COP = 42.204 / 5.16 W.D = 8.17 KW **3. Heat rejected by the system (KJ/S):** Q_R = W.D. + R.E. Q_R = 8.17 + 42.204 = 50.374 KJ/S	**2 mark** **1 mark** **1 mark**
	(b)	**Explain the concept of of Global warming and Ozone layer Depletion.** **Ozone Layer Depletion & Global warming:** In the outer atmosphere of earth up to 50 Km, there is layer called Stratosphere. In this layer there is more concentration of Ozone gas. This ozone layer forms a protective layer around earth's surface which absorbs the Harmful Ultraviolet rays (UV) from Sun's rays and allows only beneficial light and heat rays to reach on earth's surface. Prevention of UV rays reaching to earth's surface protects human and Depletion of Ozone layer leads to formation of "Ozone Holes" in the Ozone layer and through these ozone holes Harmful Ultra Violet rays enters into the atmosphere endangering the earth's biolife. **Ozone Layer Depletion:** Continuous Destruction of protective Ozone gas layer around earth's atmosphere by chemical reaction of CFC refrigerants which are leaked from innumerable refrigeration systems on earth's surface is known as **"Ozone Layer Depletion".**	**2mark**

Global warming:
Due to "Ozone Layer Depletion" the 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.** **2mark**

(c) **Explain the working of household refrigerator with neat sketch.**

Working of Refrigerator:



2 marks for fig.

Household Refrigerator: The internal parts of the refrigerator are ones that carry out actual working of the refrigerator. Some of the internal parts are located at the back of the refrigerator, and some inside the main compartment of the refrigerator.

0.5 mark for any four component.

1) Refrigerant: The working substance used to make refrigeration is called the refrigerant. The refrigerant run through all the inner parts of the refrigerator. It is the refrigerant that carries out the cooling effect in the evaporator. It absorbs the heat from the body to be cooled in the evaporator (chillier or freezer) and throws it to the atmosphere via condenser. The refrigerant keeps on recalculating through all the inner parts of the refrigerator in cycle.

2) Compressor: The compressor is to be found at the rear of the refrigerator and in the bottom area. The compressor sucks the refrigerant from the evaporator and discharges it at high pressure and temperature. The compressor is driven by the electric motor and it is the major power intense devise of the refrigerator. In most of the refrigerator reciprocating and hermitically sealed compressor are used.

3) Condenser: In refrigerator air-cooled condenser is used since, the constriction of air cooled condenser is very simple. The condenser is the thin coil of copper tubing situated at the back of the refrigerator. The refrigerant from the compressor come in the condenser where it is cooled by the atmospheric air thus losing heat absorbed by it in the evaporator and the compressor. To increase the heat transfer rate of the condenser, it is finned externally.

4) Expansion valve or the capillary: The refrigerant leave-taking the condenser enters the expansion devise, which is the capillary tube in case of the household refrigerators. The capillary is the thin copper tubing made up of number of turns of the copper coil. When the refrigerant is passed through the capillary its pressure and temperature drops down suddenly
And it is a constant enthalpy process.

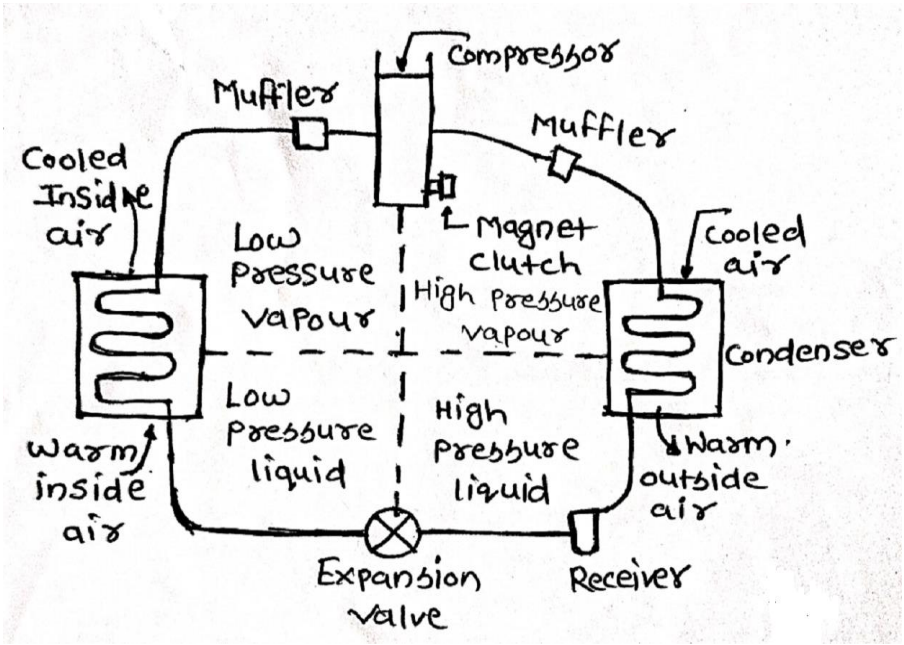
5) Evaporator or freezer: The refrigerant at very low pressure and temperature enters the evaporator or the freezer. The evaporator is the heat exchanger made up of several turns of copper or aluminum tubing. In domestic refrigerators the plate types of evaporator is used as shown in the figure above. The refrigerant absorbs the heat from the substance to be cooled in the evaporator, gets evaporated and it then sucked by the compressor. This cycle keeps on repeating.

6) Temperature control devise or thermostat: To control the temperature inside the refrigerator there is thermostat, whose sensor is connected to the evaporator. The thermostat setting can be done by the round knob inside the refrigerator compartment. When the set temperature is reached inside the refrigerator the thermostat stops the electric supply to the compressor and compressor stops and when the temperature falls below certain level it restarts the supply to the compressor.

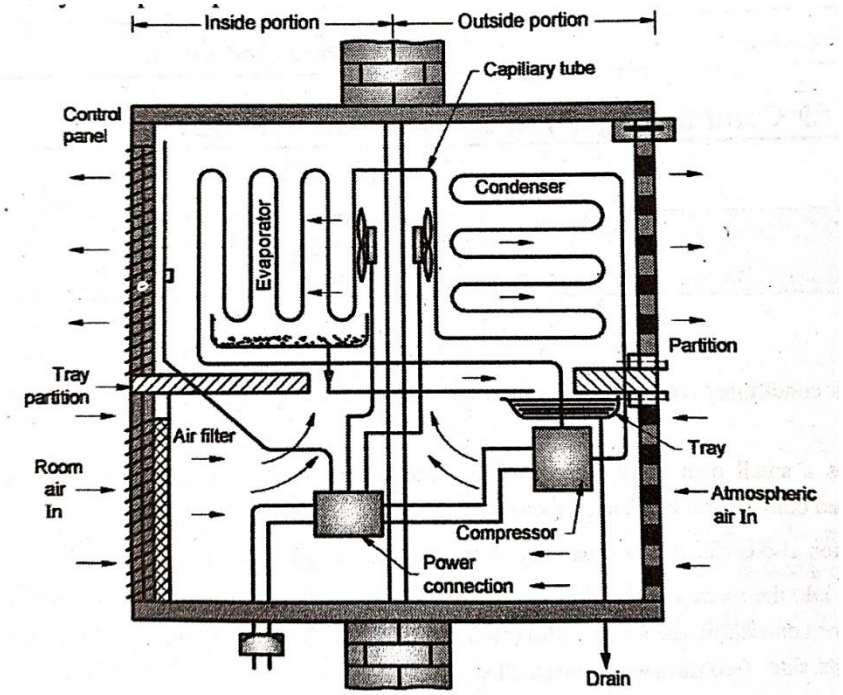
7) Defrost system: The defrost system of the refrigerator helps removing the excess ice from the surface of the evaporator. The defrost system can be operated manually by the thermostat button or there is automatic system comprising of the electric heater and the timer.

(d) Draw layout of Automobile air conditioning system. **4 marks**

Layout of Automobile air conditioning system:



Q. 4		**Attempt any THREE of the following**:	**12 marks**
	(a)	Explain the working of window air conditioning with neat sketch.	



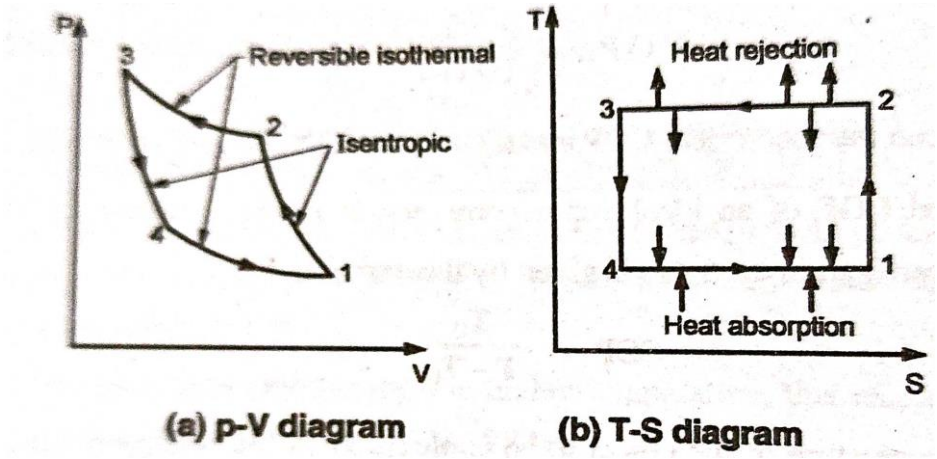
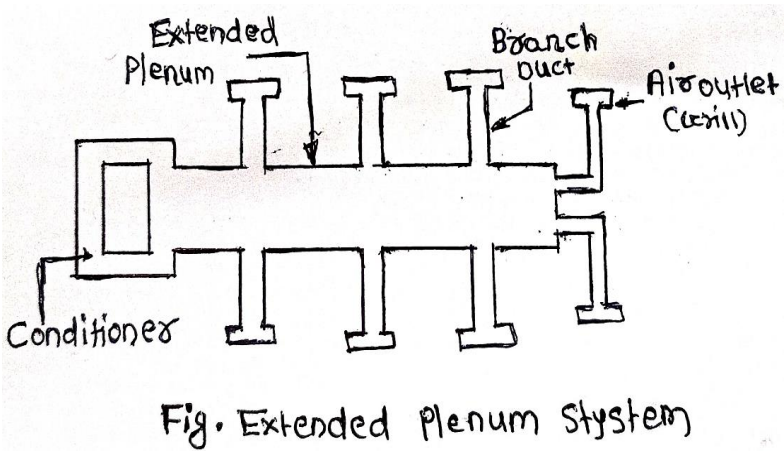
2mark diagram

working of window air conditioning system:

- First the low pressure, low temperature refrigerant vapour is sucked by hermitically sealed compressor and compressed to high pressure, high temperature and it is then discharged to condenser to reject the latent heat.
- The liquid refrigerant passes through the filter into the capillary tube where it is throttled and the flows to the evaporator coil at lower pressure.
- This liquid refrigerant than rapidly boils at low pressure and picks up evaporation enthalpy from the evaporator surface.
- A fan or blower is used to drive the air from room through air filter from the lower part of the unit and forces it to flow over the evaporator coil.
- The temperature of the cooling coil absorbs the heat from the air and is circulated back into the conditioned room.
- Due to this the temperature of room air is reduced hence air becomes chilled and circulated back into the conditioned room.
- But due to reduction in the temperature of the air dew is formed on the surface of the cooling coil. For this purpose the temperature of the cooling coil is lower than then the dew point temperature of the air.
- This moisture present in circulating air is removed and flows from coil surface and drips in the tray at the bottom. This moisture in the tray (pan) evaporates to some extent which helps in cooling the compressor and condenser.

This type of air conditioning is used for office, bed room, drawing office etc.

2marks explain

	(b)	**Represent the Carnot cycle on P-V and T-S diagram.** **Carnot cycle on P-V and T-S diagram:**  (a) p-V diagram (b) T-S diagram	**2marks each diagram.**
	(c)	Sketch and explain extended plenum duct system.  Fig. Extended Plenum Stystem . In this system, large main supply trunk of equal size is connected directly to the air handler. 2. Smaller branch duct and run outs are connected to the trunk. The arrangement provides airflows that are easily balanced and easily designed to be located inside the conditioned space of the building. 3. The limitation of the extended plenum is maximum length of the main supply trunk which is usually limited to about 24 feet. 4. When the length is exceeded, pressure tends to build up towards the end of the duct, resulting in too much air flow near the end and insufficient air flow in branches closer to the air handler. 5. In this system, the outlet duct can be located at any required point as per structural demand. 6. This air conditioning which is commonly used for residence purpose known as trunk duct system.	**02 marks for sketch** **02 marks for explain**

(d) **Explain Air conditioning system for Hot and Dry weather with neat sketch. Represent it on psychometric chart.**

2 marks for representation and 02 marks for explanation.

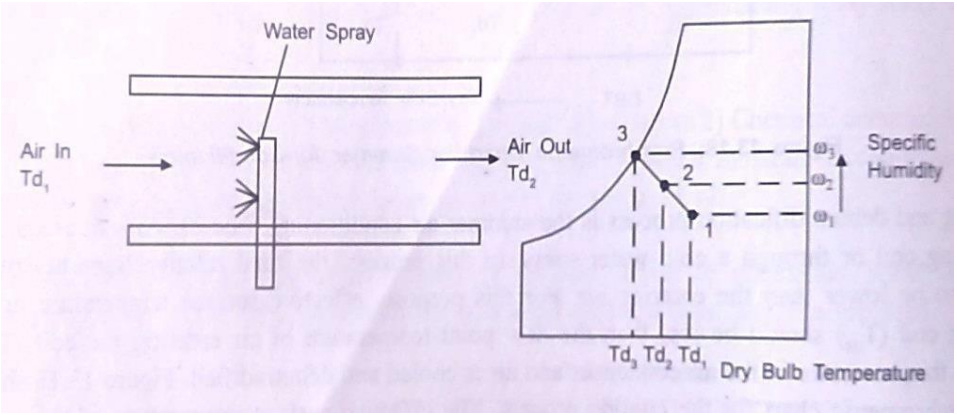
For hot and dry weather condition, air conditioning with cooling with humidification will give better comfort. In cooling with dehumidification process, air is passed through an insulated chamber with water being sprayed in the air stream as shown in figure given below

Let, T_{d1} = Dry Bulb Temperature of air entering the apparatus

T_{d2} = Dry Bulb Temperature of air leaving the apparatus

The water temperature is higher than Dew Point temperature of entering air (T_{dp1}), but lower than the DBT of entering air (T_{d1}). The air is now cooled and humidified Since no heat is supplied or rejected, the same water is re circulates and adiabatic condition can be achieved. In ideal case the exit temperature of air should be equal to T_{d3}.However due to imperfect humidification, we obtain the temperature T_{d2}

Humidifying efficiency=$(T_{d1}-T_{d2}) / (T_{d1}-T_{d3})$



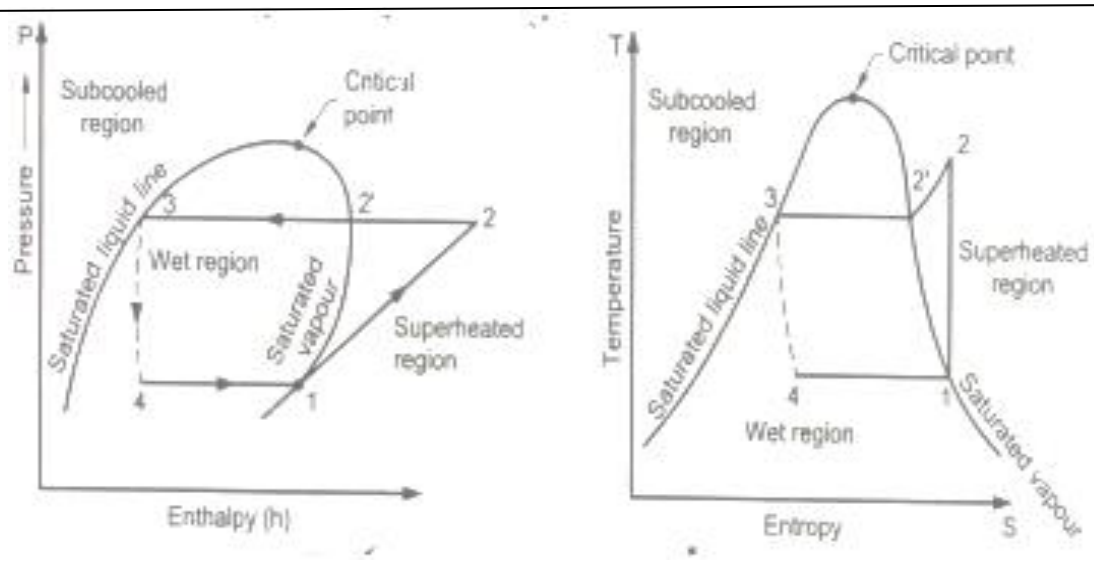
(e) **Differentiate between Air cooled and Water cooled condenser: (any 4points)**

4 marks any four points.

Air cooled condenser	Water cooled condenser
1.Construction is very simple	1.Construction is complicated
2.Initial cost is less	2.Initial cost is high
3.Maintenance cost is low	3.Maintenance cost is high
4. There is no handling problem with air cooledcondenser.	4. There is handling problem with water cooledcondenser.
5. Do not required piping arrangements for	5. Required piping arrangements for

carrying air.	carrying water
6.No problem in disposing of used air.	6.Problem in disposing of used water
7.No corrosion	7. corrosion occures

Q.5	**(a)**	**Attempt any Two of the following:**	**12 Marks**



02 Marks

Given data :- $T_1 = -5 + 273 = 268°K$

$T_{2'} = 32 + 273 = 305°K$

$C_p = 0.615\ KJ/Kg\ K$; capacity $= 5 \times 3.517 = 17.585$

From table of properties of R-12,

$H_1 = 249.3\ KJ/Kg$; $S_1 = 1.557\ KJ/Kg\ K$

$H_{2'} = 264.5\ KJ/Kg$; $S_{2'} = 1.542\ KJ/Kg\ K$

$H_3 = H_4 = 130.5\ KJ/Kg$

i] cop of the plant

$$C.O.P = \frac{\text{Refrigerating Effect}}{\text{Work of compression}} = \frac{H_1 - H_4}{H_2 - H_1}$$

Now For calcution of H_2, $S_1 = S_2$

$$\therefore \quad S_1 = S_{2'} + C_p \log_e \left[\frac{T_{sup}}{T_{sat}}\right]$$

$$\therefore \quad 1.557 = 1.542 + 0.615 \left[\log_e \left(\frac{T_{sup}}{305}\right)\right]$$

$$\therefore \quad \frac{T_2}{305} = 1.0246 \Rightarrow T_2 = 312.53^\circ K$$

$$\therefore \quad H_2 = H_{2'} + C_p (T_2 - T_{2'}) = 264.5 + 0.615(312.53 - 305)$$

$$\therefore \quad H_2 = 269.13 \text{ KJ/kg}$$

02 Marks

$$\therefore \quad COP = \frac{249.3 - 130.5}{269.13 - 249.3} = 5.99 \text{ ——— 2M}$$

ii] Mass Flow rate of refrigerant in Kg/sec

Refrigerating Effect $= H_1 - H_4 = 249.3 - 130.5$

$\therefore$ R.E. $= 118.8$

$\therefore$ capacity of plant $= m_{ref} \times R.E.$

01 Mark

$$17.585 = m_{reff} \times 118.8$$

$$\therefore \quad \boxed{m_{ref} = 0.148 \text{ kg/s}} \text{ ——— 2M}$$

iii] Power required to run the compressor in KW

compressor power $= m_{ref}(H_2 - H_1)$

$$P = 0.148(269.13 - 249.3)$$

$$\therefore \quad \boxed{P = 2.93 \text{ KW}} \text{ ——— 2M}$$

01 Mark

(b) **Draw neat label sketch of practical Aqua-ammonia vapour absorption refrigeration system and explain its working.**

Practical Aqua –Ammonia vapour absorption system

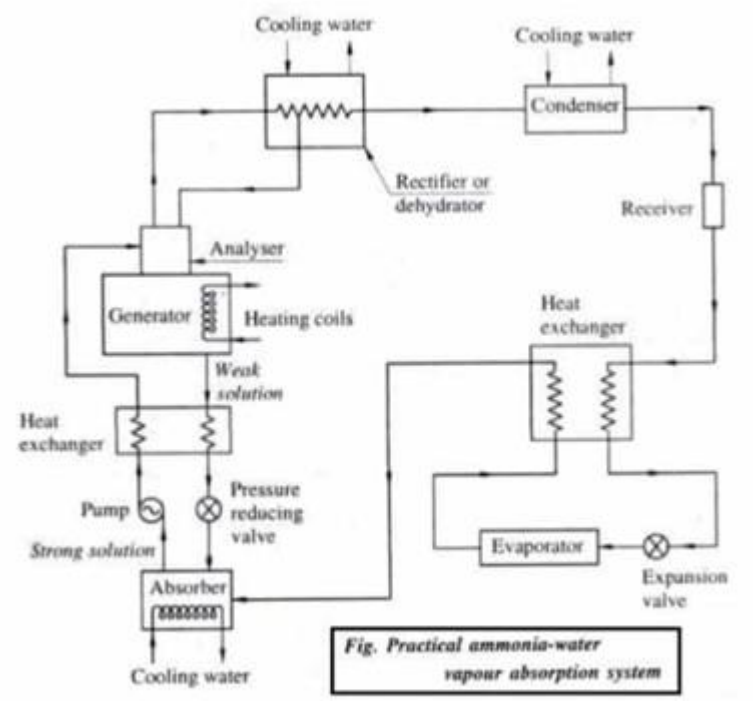


Fig. Practical ammonia-water vapour absorption system

02 marks for fig.

In simple vapour absorption refrigeration system the COP of this system is low so to improve this COP some modification is done in the system i.e., some accessories are provided which are **Analyzer, Rectifier and heat Exchanger.**

When these above accessories are used in vapour absorption refrigeration system then this is known as **Practical vapour absorption refrigeration system.**

Parts of practical vapour absorption refrigeration system:
1. Evaporator, **2. Absorber**, **3. Heat Exchanger 1**, **4. Generator**, **5. Analyser**, **6. Rectifier**, **7. Condenser**, **8. Heat Exchanger 2**, **9. Expansion valve**

Further discuss on all parts one by one,

1. **Evaporator:**

In Evaporator heat is absorbed from body. It provide the heat absorbed surface area, refrigerant ammonia has liquid phase and this liquid ammonia abstract the heat from body and gets converted into vapour phase.

2. Absorber:

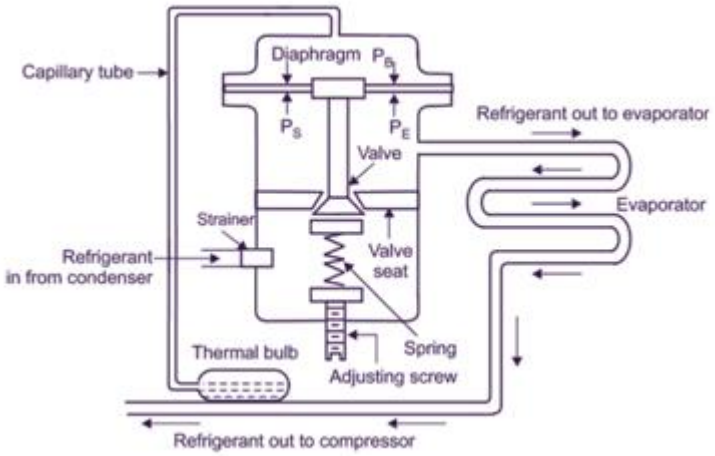
In absorber the water is already present and when the low pressure ammonia vapour after abstracting the heat it enter into the absorber. In this absorber due to absorbing of ammonia by water it makes strong solution of ammonia water.

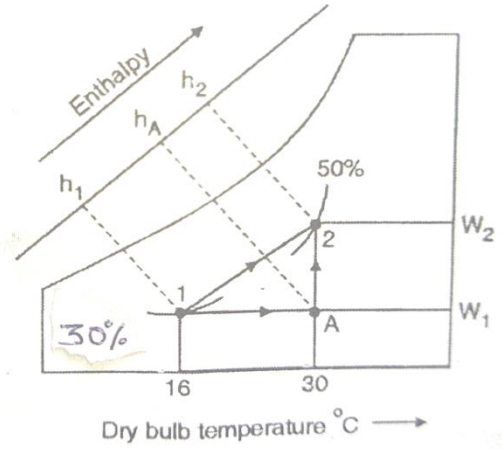
3. Heat Exchanger 1:

The heat exchanger between generator and absorber, transfer the heat energy of weak solution to the cold strong solution going in the generator, so that the heat input required to raise the temperature and pressure will be less which increase the COP.

compressor near the outlet of the evaporator coil.

Working-04 marks

		• The filler bulb is partly filled with the same liquid refrigerant as used in refrigeration system. The opening or closing of valve is depended upon the force on the diagram. **Working:** • The remote bulb is charged with fluid which is open on one side of the diaphragm through capillary tube is firmly to evaporate outlet. • The pressure (Pb) of the fluid in the bulb tends to open the valve. This pressure is balanced by pressure due to spring (PS) and in the evaporator (Pe). • If the evaporator temperature is high or the load on the evaporator increase, more fluid from feeler bulb will be vaporized and bulb pressures will rises which exert this force on diaphragm.	
	(c)	• This will widen the valve opening and the refrigerant flow will increase to meet load demand and if load on evaporator decreases reverse action takes place. Explain with neat sketch the working og thermostatic expansion valve. **Thermostatic Expansion valve**  The operation of this valve is based on the principle of constant degree of superheat for the vapour at or exists i.e. by controlling the flow of liquid refrigerant through the evaporator. • The thermostatic expansion valve consists of a needle valve and a seat, a metallic diaphragm, spring and adjusting screw. • In addition to this it has a feeder or thermal bulb which is mounted on the suction line of compressor near the outlet of the evaporator coil. • The filler bulb is partly filled with the same liquid refrigerant as used in refrigeration system. The opening or closing of valve is depended upon the force on the diagram. **Working:** • The remote bulb is charged with fluid which is open on one side of the diaphragm through capillary tube is firmly to evaporate outlet.	**(Sketch-2M)** **Working-04M**

		• The pressure (Pb) of the fluid in the bulb tends to open the valve. This pressure is balanced by pressure due to spring (PS) and in the evaporator (Pe). • If the evaporator temperature is high or the load on the evaporator increase, more fluid from feeler bulb will be vaporized and bulb pressures will rises which exert this force on diaphragm. • This will widen the valve opening and the refrigerant flow will increase to meet load demand and if load on evaporator decreases reverse action takes place.	
Q. 6	**(a)**	**Attempt any TWO of the following**	**12 marks**
		 i) Heat added to the air = Enthalpy at 2 – Enthalpy at 1 = 64.5 – 24.5 = 40 KJ/kg of dry air ii) Moisture added to air = Sp. Humidity at 2 – Sp. Humidity at 1 = 0.0135 – 0.0035 = 0.010 kg/kg of dry air iii) Sensible heat factor (SHF) Sensible heat added SH = Enthalpy at A – Enthalpy at 1 = 40 – 24.5 = 15.5 KJ/kg of dry air Latent heat added LH = Enthalpy at 2 – Enthalpy at A = 64.5 – 40 = 24.5 KJ/kg of dry air. $SHF = \frac{SH}{(SH+LH)} = \frac{15.5}{(15.5+24.5)} = \frac{15.5}{40} =$ 0.3875 (Note – 5% variation in values taken from psychometric chart may be considered)	**Representation on chart – 03 marks** **01 mark each.**

	(b)	**List Different Pressure losses in Ducts** **1. Surface frictional loss** The surface frictional resistance of a duct of any cross section is given by Darcy's equation $$H_f = flV^2/2gD$$ D=Diameter of circular duct, V= velocity of the fluid flowing in m/sec., f=Friction factor, l=length of duct in meters **2. Dynamic losses in duct** • Whenever there is change in direction or velocity in the flow through duct, the pressure loss is inevitable. The additional loss is called dynamic loss. • The change in magnitude of velocity occurs when the area of duct changes. • The pressure loss due to the change of direction or velocity at elbow is known as velocity pressure head. **3. Loss due to enlargement** When the area of changes, the velocity of air flowing through the duct changes. When area increase, the velocity decrease with rise in pressure which form eddies at the corner thus sudden or abrupt change is neglected. **4. Loss due to sudden contraction** • When air is flowing and having a sudden or abrupt contraction, the eddies are formed at the shoulders of large section and beyond the entry of the smaller section forming a vena-contracta. • The loss of pressure due to sudden contraction is not due to contraction itself but it is due to sudden enlargement of flow area from vena contracta to the section of smaller duct. **5. pressure losses in Elbow and Bend** • The value of (Le/Kd) is different for different elbow. The value of (Le/Kd) is mostly affected by the geometry of elbow and surface roughness of duct wall and remains unaffected by the air velocity. • To minimize the pressure loss in bend, the splitters are generally used, aspect ratio is small. **6. Losses at Suction and Discharged openings** • When the abrupt suction opening is provided the air is accelerated at the opening, forming a vena contracta inside the duct. **7. Pressure losses in Fittings and leakages**	**Any six losses** **01 mark each.**

		• Whenever air is diverted from main duct to the branch duct, there is velocity reduction in the main duct. • If there is no loss, the change in the velocity pressure is completely converted into static pressure.	
	c)	**List of Heat sources in Auditorium** **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** 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. (no of persons)*(load per person).	**01 mark each)**
		END	