56
9/11/23

17
Nov-23

SET 2

Scoring Indicators

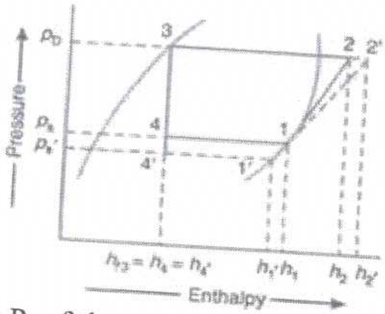
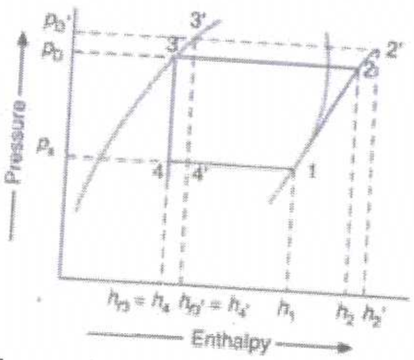
COURSE NAME: REFRIGERATION AND AIR CONDITIONING

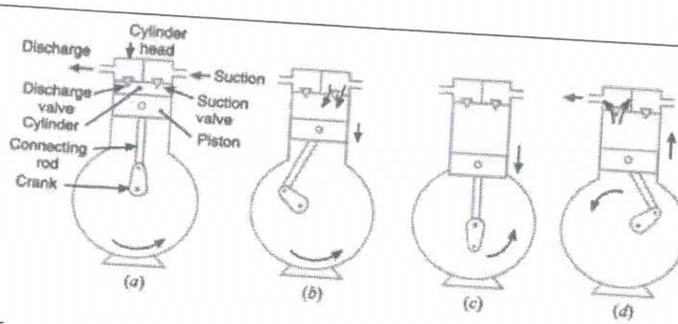
COURSE CODE: 5022

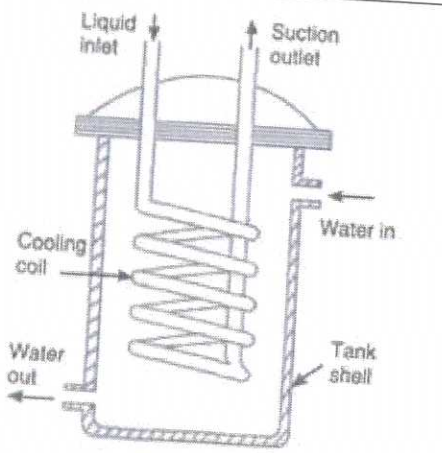
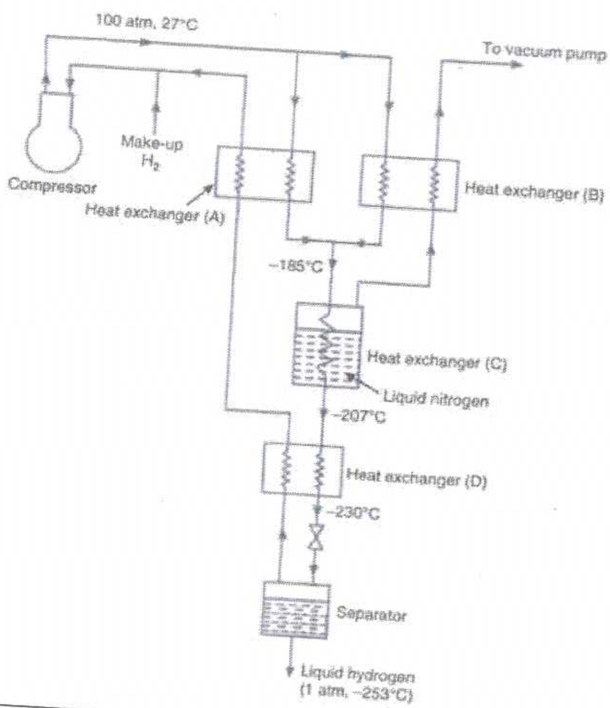
QID: 2109230036

Q. No.	Scoring Indicators	Split Score	Sub Total	Total Score
	PART A			**9**
I. 1	Greater than one.	1	1	1
I. 2	Reversed Brayton cycle.	1	1	1
I. 3	Compression	1	1	1
I. 4	Super-heated vapour	1	1	1
I. 5	Volumetric efficiency	1	1	1
I. 6	Steel	1	1	1
I. 7	Constant	1	1	1
I. 8	Relative humidity	1	1	1
I. 9	Cooled and dehumidified	1	1	1
	PART B			**24**
II. 01	Open air refrigeration: In an open air refrigeration cycle, the air is directly led to the space to be cooled (i.e. a refrigerator), allowed to circulate through the cooler and then returned to the compressor to start another cycle. Since the air is supplied to the refrigerator at atmospheric pressure, therefore, volume of air handled by the compressor and expander is large. Thus the size of compressor and expander should be large. Another disadvantage of the open cycle system is that the moisture is regularly carried away by the air circulated through the cooled space. This leads to the formation of frost at the end of expansion process and clog the line. Thus in an open cycle system, a drier should be used.	1.5x2=3	3	3

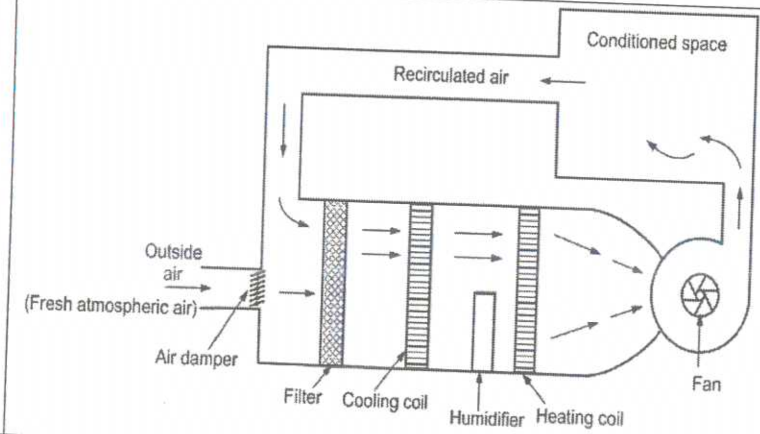
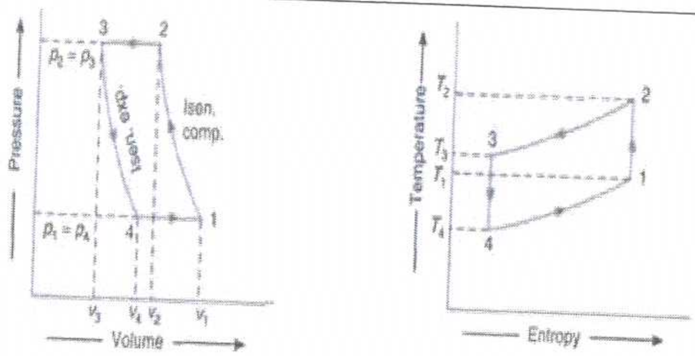
	Closed air refrigeration: In a closed or dense air refrigeration cycle, the air is passed through the pipes and component parts of the system at all times. The air, in this system, is used for absorbing heat from the other fluid (say brine) and this cooled brine is circulated into the space to be cooled. The air in the closed system does not come in contact directly with the space to be cooled. The closed air refrigeration cycle has the following thermodynamic advantages : 1. Since it can work at a suction pressure higher than that of atmospheric pressure, therefore the volume of air handled by the compressor and expander are smaller as compared to an open air refrigeration cycle system. 2. The operating pressure ratio can be reduced, which results in higher coefficient of performance.			
II. 02	1. The term refrigeration may be defined as the process of removing heat from a substance under controlled conditions. It also includes the process of reducing and maintaining the temperature of a body below the general temperature of its surroundings. 2. Refrigerating Effect. This is the heat absorbed in the evaporator per kg of refrigerant. It is determined by the difference in enthalpy of a kg or refrigerant vapor leaving the evaporator and that of a kg of liquid just upstream (ahead) of the expansion valve at the evaporator. 3. The practical unit of refrigeration is expressed in terms of 'tonne of refrigeration' (TR). A tonne of refrigeration is defined as the amount of refrigeration effect produced by the uniform melting of one tonne (1000 kg) of ice from and at 0°C in 24 hours.	3x1=3	3	3
II. 03	Effect of suction pressure: The suction pressure (or evaporator pressure) decreases due to the frictional resistance of flow of the refrigerant. From the figure the decrease in suction pressure, decrease in refrigerating effect from (h1 –h4) to (h1`- h4`) and increasing compressor work (h2-h1) to (h2`-h1`).	1.5x2=3	3	3

	 Since the C.O.P. of the system is the ratio of refrigerating effect to the work done, therefore with the decrease in suction pressure, the net effect is to decrease the C.O.P. of the refrigerating system for the same amount of refrigerant flow. Hence with the decrease in suction pressure, the refrigerating capacity of the system decreases and the refrigeration cost increases. Effect of discharge pressure:  From the figure the decrease in discharge pressure, decrease in refrigerating effect from (h1 –h4) to (h1- h4`) and increasing compressor work (h2-h1) to (h2`-h1). From above, we see that the effect of increase in discharge pressure is similar to the effect of decrease in suction pressure. But the effect of increase in discharge pressure is not as severe on the refrigerating capacity of the system as that of decrease in suction pressure.			
II. 04	The refrigerants which directly take part in the refrigeration system are called primary refrigerant whereas the refrigerants which are first cooled by primary refrigerants and then used for cooling purposes are known as secondary refrigerant. The primary' refrigerants are further classified into the following four groups : 1. Halo-carbon or organic refrigerants,(R-11, R-12, R-22) 2. Azeotrope refrigerants. (R-500, R-502, R-503) 3. Inorganic refrigerants,(R-717, R-729) and 4. Hydro-carbon refrigerants (R-170, R-290) Secondary refrigerants are water, brine solution, Sodium chloride, Calcium chloride, Ethylene glycol, etc.	3	3	3

II. 05	 Let us consider that the piston is at the top of its stroke as shown in Fig. (a). This is called top dead centre position of the piston. In this position, the suction valve is held closed because of the pressure in the clearance space between the top of the piston and the cylinder head. The discharge valve is also held closed because of the cylinder head pressure acting on the top of it. When the piston moves downward (i.e. during suction stroke), as shown in Fig. (b), the refrigerant left in the clearance space expands. Thus the volume of the cylinder (above the piston) increases and the pressure inside the cylinder decreases. When the pressure becomes slightly less than the suction pressure or atmospheric pressure, the suction valve gets opened and the vapour refrigerant flows into the cylinder. This flow continues until the piston reaches the bottom of its stroke (i.e. bottom dead centre). At the bottom of the stroke, as shown in Fig. (c), the suction valve closes because of spring action. Now when the piston moves upward (i.e. during compression stroke), as shown in Fig.(d), the volume of the cylinder decreases and the pressure inside the cylinder increases. When the pressure inside the cylinder becomes greater than that on the top of the discharge valve, the discharge valve gets opened and the vapour refrigerant is discharged into the condenser and the cycle is repeated.	Fig-1 Exp-2	3	3

II. 06	 Shell and coil evaporator The shell and coil evaporators, as shown in Figure, are generally dry expansion evaporators to chill water. The cooling coil is a continuous tube that can be in the form of a single or double spiral. The shell may be sealed or open. The sealed shells are usually found in shell and coil evaporators used to cool drinking water. The evaporators having flanged shells are often used to chill water in secondary refrigeration systems. It may be noted that the shell and coil evaporator is restricted to operation above 5°C in order to prevent the freezing problems.	1.5 + 1.5	3	3
II. 07	Liquefaction of hydrogen.  	1.5 +1.5	3	3

		The hydrogen is the most difficult gas to liquefy because of its extremely low liquefaction temperature. The schematic arrangement of equipment for liquefying hydrogen is shown in Figure. In this system, pure hydrogen gas at a pressure about 100 atmospheres and 27°C from the compressor is precooled in two heat exchangers A and B. In heat exchanger A, the incoming high pressure hydrogen is cooled by the outgoing low pressure hydrogen while in heat exchanger 6, it is cooled by nitrogen. The high pressure hydrogen gas from both the heat exchangers is passed through a third heat exchanger C where the hydrogen gas is further cooled to about -207°C by nitrogen boiling under reduced pressure. This hydrogen gas is further cooled to about -230°C in the fourth heat exchanger D by the low pressure hydrogen gas returning from (he separator. The liquid hydrogen is produced by throttling the hydrogen gas from the heat exchanger D to atmospheric pressure.			
II. 08		1. Saturated air. It is a mixture of dry air and water vapour, when the air has diffused the maximum amount of water vapour into it. The water vapours, usually, occur in the form of superheated steam as an invisible gas. However, when the saturated air is cooled, the water vapour in the air starts condensing, and the same may be visible in the form of moist, fog or condensation on cold surfaces. 2. Wet bulb temperature. It is the temperature of air recorded by a thermometer, when its bulb is surrounded by a wet cloth exposed to the air. Such a thermometer is called wet bulb thermometer. The wet bulb temperature (briefly written as WBT) is generally denoted by t_w or t_{wb}. 3. It is the temperature of air recorded by a	3X1	3	3

	thermometer, when the moisture (water vapour) present in it begins to condense. In other words, the dew point temperature is the saturation temperature (t_{sat}) corresponding to the partial pressure of water vapour (p_v). It is, usually, denoted by t_{dp}.			
II. 09	1. Sensible Cooling. 2. Sensible Heating. 3. Cooling and Dehumidification. 4. Sensible Heat Factor (SHF) 5. Heating and Humidification. 6. Cooling and Humidification.	3	3	3
II. 10		3	3	3
				42
	PART C			
III. ~~01~~	(a) p-v diagram. (b) T-s diagram. The Bell-Coleman cycle (also known as reversed Brayton or Joule cycle) is a modification of reversed Camot cycle. The cycle is shown on p-v and T-s diagrams in Figure (a) and (b). At point 1, let p1, v1, and T1, be the pressure,	Fig – 3 Exp - 4	7	7

volume and temperature of air respectively. The four processes of the cycle are as follows:

1. Isentropic compression process. The cold air from the refrigerator is drawn into the compressor cylinder where it is compressed isentropically in the compressor as shown by the curve 1-2 on p-v and T-s diagrams. During the compression stroke, both the pressure and temperature increases and the specific volume of air at delivery from compressor reduces from v1, to v2. We know that during isentropic compression process, no heat is absorbed or rejected by the air.

2. Constant pressure cooling process: The warm air from the compressor is now passed into the cooler where it is cooled at constant pressure p3 (equal to p2), reducing the temperature from T2 to T3, (the temperature of cooling water) as shown by the curve 2-3 on p-v and T-s diagrams. The specific volume also reduces from v2 to v3 We know that heat rejected by the air during constant pressure per kg of air,

$q_R = Q_{2-3} = cp(T2-T1)$

3. Isentropic expansion process. The air from the cooler is now drawn into the expander cylinder where it is expanded isentropically from pressure p3 to the refrigerator pressure p4 which is equal to the atmospheric pressure. The temperature of air during expansion falls from T3 to T4 (i.e. the temperature much below the temperature of cooling water, T3). The expansion process is shown by the curve 3-4 on the p-v and T-s diagrams. The specific volume of air at entry to the refrigerator increases from v3, to v4. We know that during isentropic expansion of air, no heat is absorbed or rejected by the air.

4. Constant pressure expansion process. The cold air from the expander is now passed to the refrigerator where it is expanded at constant pressure p4 (equal to p1). The temperature of air increases from T4 to T1. This process is shown by the curve 4-1 on the p-v and T-s diagrams. Due to heat from the refrigerator, the specific volume of the air changes from v4 to v1. We know that the heat absorbed by the air (or heat extracted from the refrigerator or the refrigerating effect produced) during constant pressure expansion per kg of air is

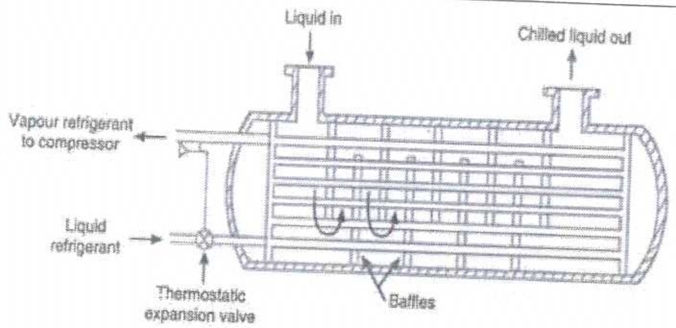
$q_A = q_{4-1} = cp(T1-T4)$

We know that work done during the cycle per kg of air

$= \text{Heat rejected} - \text{Heat absorbed} = q_R - q_A$

$= cp(T2 - T3) - cp(T1 - T4)$

	.-. Coefficient of performance, COP = Heat absorbed /Work done = $q_A/(q_R - q_A)$ =cp(T1 – T4)/cp(T2 –T3) – cp(T1-T4) =(T1 – T4)/(T2 – T3) – (T1 –T4)			
~~III. 02~~ IV	Given data: W_R = 1.25kW = 1.25 kJ/se = 75 kJ/min, T1 = 243K, Q1 = 1T = 210kJ/min Solution: COP = $Q1/W_R$ = 210/75 = <u>2.8</u> Temperature at which heat rejected COP = T1/(T2 –T1) = 243/(T2 – 243) = (2.8T2 – 680.4) = 243 T2 = 329.8K = <u>56.8^0C</u> Heat rejected per tonne of refrigeration Q2 = $Q1+W_R$ = 210+75 = 285kJ/min = <u>1.35T</u>	Data-1 Ans1-2 Ans2-2 Ans3-2	7	7
V ~~III. 03~~	A vapour compression cycle with dry saturated vapour after compression is shown on T-s and p-h diagrams in Figure (a) and (b) respectively. At point 1, let Tr p] and j,, be the temperature, pressure and entropy of the vapour refrigerant respectively. The four processes of the cycle are as follows : I. C'vitii>i-i'ssi<iit priHv.v*. The vapour refrigerant at low pressure />, and temperature T, is compressed isentropically to dry saturated vapour as shown by the vertical line 1-2 on T-s diagram and by the curve 1-2 on p-h diagram. The pressure and temperature rises from p[to p2 and 7", to 7", respectively. The work done during isentropic compression per kg of refrigerant is given by w = h-, - A,	7*1 = 7	7	7
VI ~~III. 04~~	The refrigerants which directly take part in the refrigeration system are called primary refrigerant whereas the refrigerants which are first cooled by primary refrigerants and then used for cooling purposes are known as secondary refrigerant. The primary' refrigerants are further classified into the following four groups : 1. Halo-carbon or organic refrigerants: The American Society of Heating, Refrigeration and	7	7	7

<table>
<tr><td></td><td>Air-conditioning Engineers (ASHRAE) identifies 42 halo-carbon compounds as refrigerants, but only a few of them are commonly used. The halo-carbon compounds are all synthetically produced and were developed as Freon family of refrigerants. Eg-R-11, R-12, R-22, R-40, R-100 etc
2. Azeotrope refrigerants:
The term azeotrope refers to a stable mixture of refrigerants whose vapour and liquid phases retain identical compositions over a wide range of temperatures. However, these mixtures, usually, have properties that differ from either of their components. Eg-R-500, R-502, R-503
3. Inorganic refrigerants:
The inorganic refrigerants were exclusively used before the introduction of halo-carbon refrigerants. These refrigerants are still in use due to their inherent thermodynamic and physical properties. Eg-Ammonia (R-717), Air (R-729), Carbon dioxide (R-744), Sulphur dioxide (R-764) and water(R-118)
4. Hydro-carbon refrigerants
Most of the hydro-carbon refrigerants are successfully used in industrial and commercial installations. They possess satisfactory thermodynamic properties but are highly flammable and explosive. (R-170, R-290)
Secondary refrigerants are water, brine solution, Sodium chloride, Calcium chloride, Ethylene glycol, etc.</td><td></td><td></td><td></td></tr>
<tr><td>VII
~~III. 05~~</td><td>

The shell and tube evaporator, as shown in Figure, is similar to a shell and tube condenser. It consists of a number of horizontal tubes enclosed in a cylindrical shell. The inlet and outlet headers with perforated metal tube sheets are connected at each end of the tubes.

These evaporators are generally used to chill water or brine solutions. When it is operated as a dry expansion evaporator, the refrigerant circulates through the tubes and the liquid to be cooled fills the space around the tubes within the shell. The dry expansion shell and tube evaporators are used for refrigerating units of 2 to 250 TR capacity. When it is operated as a flooded evaporator, the</td><td>3

4</td><td>7</td><td>7</td></tr>
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<tr>
<td></td>
<td>water or brine flows through the tubes and the refrigerant circulates around the tubes. The flooded shell and tube evaporators are used for refrigerating units of 10 to 5000 TR capacity.</td>
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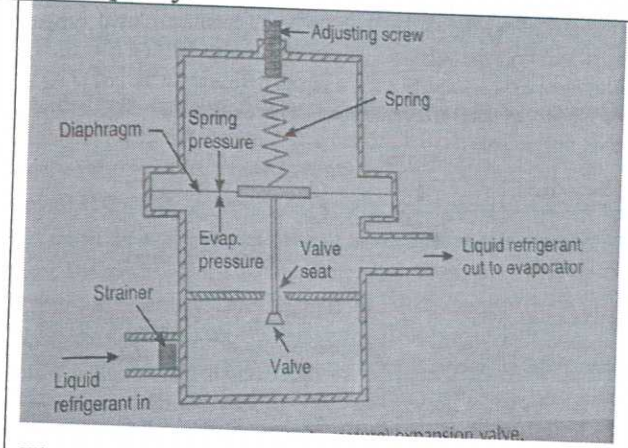
<tr>
<td>~~III.~~
~~06~~
VIII</td>
<td>

The automatic expansion valve, as shown in Figure consists of a needle valve and a seat (which forms an orifice), a metallic diaphragm or bellows, spring and an adjusting screw. The opening and closing of the valve with respect to the seat depends upon the following two opposing forces acting on the diaphragm: 1. The spring pressure and atmospheric pressure acting on the top of the diaphragm, and 2. The evaporator pressure acting below the diaphragm.
When the compressor is running, the valve maintains an evaporator pressure in equilibrium with the spring pressure and the atmospheric pressure. The spring pressure can be varied by adjusting the tension of the spring with the help of spring adjusting screw. Once the spring is adjusted for a desired evaporator pressure, then the valve operates automatically to maintain constant evaporator pressure by controlling the flow of refrigerant to the evaporator.</td>
<td>4
3</td>
<td>7</td>
<td>7</td>
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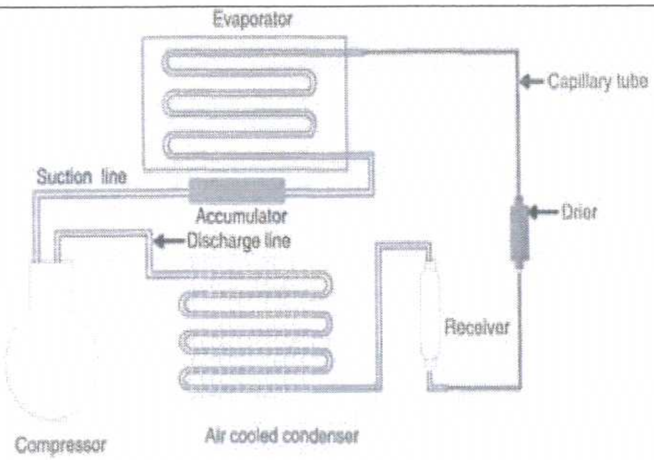
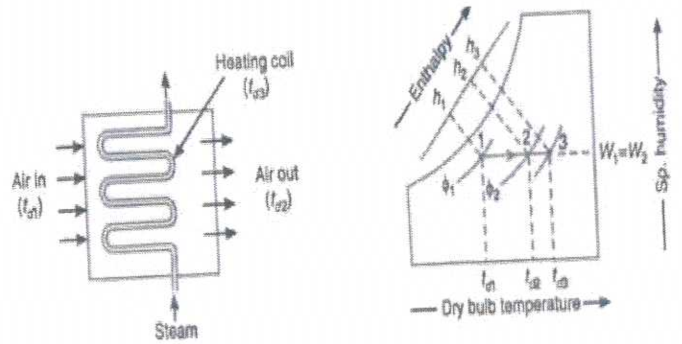
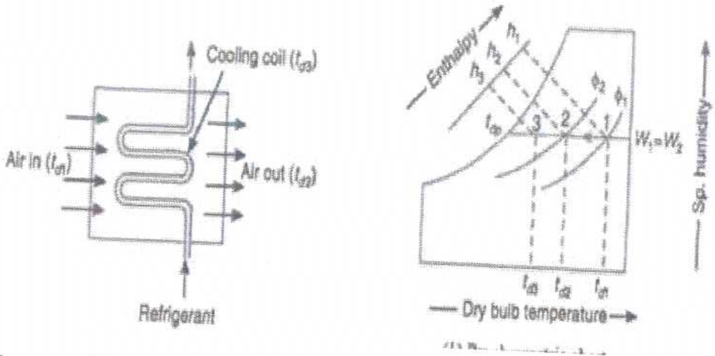
IX ~~III. 07~~	 The mechanical vapour compression cycle as well as absorption cycle may be adopted for domestic refrigerators and freezers, but the mechanical vapour compression system is actually used over absorption system, because of its compactness and more efficient use of electrical energy, as shown in Figure. The refrigerants used are generally R-12 or R-22. The compressor is mounted at the bottom of the refrigerator frame. The condenser is put at the back about 40 to 60 mm away from the cabinet. The condenser may be either chassis type or tube and wire type. In the former, the condenser tube is mounted on a metal sheet which acts as fins. The tube and wire type condensers are quite simple in which few lubes are held tightly under wire frame from both sides. These wires act as cylindrical fins increasing the rate of heat transfer. The capillary tube is kept in contact with the evaporator inlet pipe. A drier is connected between the receiver and the evaporator to eliminate traces of moisture if any. In some cases, the temperature of two cabinets of the refrigerator have to be controlled independently. Under such circumstances, independent compressors and cooling coils are used. The evaporator coil is wrapped around the freezer in a suitable manner to give efficient heat transfer. Sometimes, the freezer chamber is made from a pair of sheet joined together in	Fig-3 Exp-4	7	7

	such a way that the passage between the sheets act as an evaporator coil. The cooling of lower space is accomplished by free convection (due to density gradient). The thermostatic sensing element is provided to the evaporator coil which can control temperature in the freezer upto -I5°C in steps or continuously depending upon the type of controlling switch employed.			
III. 08	1. High cooling power: Liquid nitrogen has a very low boiling point (-196°C), which makes it highly effective for cooling and preserving perishable items such as food, medical supplies, and biological specimens. 2. Long-term preservation: Liquid nitrogen can be used to freeze items to temperatures far below those achievable with traditional refrigeration systems, allowing for long-term preservation of sensitive materials. 3. Portability: Liquid nitrogen is stored in containers that are easy to transport, making it ideal for use in remote locations or for quick transfer of materials from one location to another. 1. Food Industry Cryogenic gases play an important function in the food business. Cryogenic refrigeration speeds up cooling operations, protecting the quality of the product. Therefore the cryogenic tunnel freezers and cooling trays are popular in the food processing business. Cryogenic Tunnel-Freezer (CTF) One of the fastest and most efficient ways to chill items down quickly and effectively is by using a tunnel freezer. Cooling Trays One can rapidly chill products by submerging them in liquid nitrogen using cooling trays or dipping trays. Cooling trays are very efficient and useful for freezing the	2 5	7	7

	surface of a product. 2. Medical Industry Cryogenic technology has grown in popularity in the medical field for a variety of reasons. Cryogenic dewars and filling stations are both well-known medical-industry examples of cryogenics in practice. Cryosauna therapies are also becoming increasingly common. 3. Pharmaceutical Industry Cryogenic procedures are utilized in a variety of ways in pharmaceutical manufacturing and packaging. Dry freezing and cryogenic palletizing are two of the most common uses in this business. 4. Automotive Industry Cryogenics has a wide range of applications in the automotive industry. The cooling box is common cryogenic use in the automobile sector. 5. Electronics Industry One can attain very low temperatures and inert working conditions using cryogenic methods. Inert manufacturing conditions and microchip testers are two common uses in this business.			
XI ~~III. 09~~	 The heating of air, without any change in its specific humidity, is known as sensible heating. Let air at temperature t_{d1}, passes over a heating coil of temperature	Fig- 1.5+1.5 Exp- 2+2	7	7

t_{d3}, as shown in Figure. It may be noted that the temperature of air leaving the heating coil t_{d2} will be less than t_{d3}. The process of sensible heating, on the psychrometric chart, is shown by a horizontal line 1-2 extending from left to right as shown in Figure (b). The point 3 represents the surface temperature of the heating coil.



The cooling of air, without any change in its specific humidity, is known as sensible cooling. Let air at temperature tdl passes over a cooling coil of temperature t_{d3} as shown in Figure (a). It may be noted that the temperature of air leaving the cooling coil t_{d2} will be more than t_{d3}. The process of sensible cooling, on the psychrometric chart, is shown by a horizontal line 1-2 extending from right to left as shown in Figure (b). The point 3 represents the surface temperature of the cooling coil.

~~III. 10~~ XII	Solution. Given : $v = 7 \times 4 \times 4 = 112\ m^3$; $T_d = 38°C = 38 + 273 = 311\ K$; $p_b = 1$ bar ; $\phi = 70\% = 0.7$ *Humidity ratio* First of all, let us find the partial pressure of water vapour (p_v). From steam tables, we find that saturation pressure of vapour corresponding to a temperature of 38° C is, $p_s = 0.066\ 24$ bar We know that relative humidity (ϕ), $0.7 = \frac{p_v}{p_s}$ $\therefore\ p_v = 0.7\ p_s = 0.7 \times 0.066\ 24 = 0.046\ 368$ bar We also know that humidity ratio, $W = \frac{0.622\ p_v}{p_b - p_v} = \frac{0.622 \times 0.046\ 368}{1 - 0.046\ 368}$ $= \frac{0.028\ 841}{0.953\ 632} = 0.0302$ kg/kg of dry air $= 30.2$ g/kg of dry air Ans. *Dew point temperature* Since the dew point temperature (t_{dp}) is the saturation temperature corresponding to the partial pressure of water vapour (p_v), therefore, from steam tables, we find that corresponding to a pressure of 0.046 368 bar, the dew point temperature is $t_{dp} = 31.56°$ C Ans. *Mass of dry air* Let m_a = Mass of dry air, and p_a = Pressure of dry air $= p_b - p_v$ $= 1 - 0.046\ 368 = 0.953\ 632$ bar $= 0.953\ 632 \times 10^5 = 95363.2\ N/m^2$ ... ($\because$ 1 bar $= 10^5\ N/m^2$) We know that $p_a\,v = m_a R_a T_d$ $\therefore\ m_a = \frac{p_a\,v}{R_a T_d} = \frac{95363.2 \times 112}{287 \times 311} = 119.7$ kg Ans. ... (Taking $R_a = 287$ J/kg K) *Mass of water vapour* Let m_v = Mass of water vapour. We know that humidity ratio (W), $0.0302 = \frac{m_v}{m_a} = \frac{m_v}{119.7}$ or $m_v = 0.0302 \times 119.7 = 3.61$ kg Ans.	1+6	7	7
XIII ~~III. 11~~	The air conditioning systems may be broadly classified as follows : 1. According to the purpose (a) Comfort air conditioning system, and (b) Industrial air conditioning system. 2. According to season of the year (a) Winter air conditioning system, (b) Summer air conditioning system, and	3 4	7	7

(c) Year-round air conditioning system

3. According to the arrangement of equipment

(a) Unitary air conditioning system, and

(b) Central air conditioning system.

In comfort air conditioning, the air is brought to the required dry bulb temperature and relative humidity for the human health, comfort and efficiency. If sufficient data of the required condition is not given, then it is assumed to be 21°C dry bulb temperature and 50% relative humidity.

It is an important system of air conditioning these days in which the inside dry bulb temperature and relative humidity of the air is kept constant for proper working of the machines and for the proper research and manufacturing processes. Some of the sophisticated electronic and other machines need a particular dry bulb temperature and relative humidity. Sometimes, these machines also require a particular method of psychrometric processes. This type of air conditioning system is used in textile mills, paper mills, machine-parts manufacturing plants, tool rooms, photo-processing plants etc.

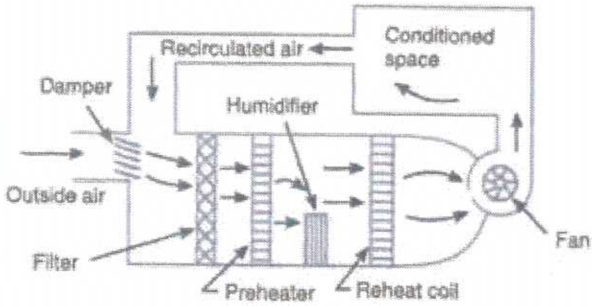
In winter air conditioning, the air is heated, which is generally accompanied by humidification.

It is the most important type of air conditioning, in which the air is cooled and generally dehumidified.

The year-round air conditioning system should have equipment for both the summer and winter air-conditioning.

In this system, factory assembled air conditioners are installed in or adjacent to the space to be conditioned. The unitary air conditioning system may be adopted for winter, summer or year round air conditioning.

This is the most important type of air conditioning

	system, which is adopted, when the cooling capacity required is 25 TR or more. The central air conditioning system is also adopted when the air flow is more than 300 rn'/min or different zones in a building are to be air conditioned			
XIV ~~III.~~ ~~12~~	 In winter air conditioning, the air is heated, which is generally accompanied by humidification. The schematic arrangement of the system is shown in Figure. The outside air flows through a damper and mixes up with the recirculated air (which is obtained from the conditioned space). The mixed air passes through a filter to remove dirt, dust and other impurities. The air now passes through a preheat coil in order to prevent the possible freezing of water and to control the evaporation of water in the humidifier. After that, the air is made to pass through a reheat coil to bring the air to the designed dry bulb temperature. Now, the conditioned air is supplied to the conditioned space by a fan. From the conditioned space, a part of the used air is exhausted to the atmosphere by the exhaust fans or ventilators. The remaining part of the used air (known as recirculaled air) is again conditioned as shown in 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 ventilation from the conditioned space.	Fig-3 Exp -4	7	7