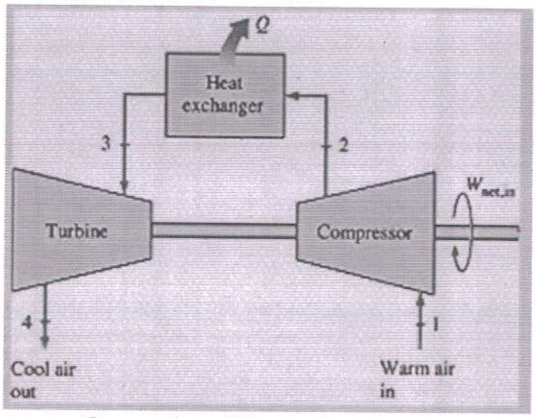
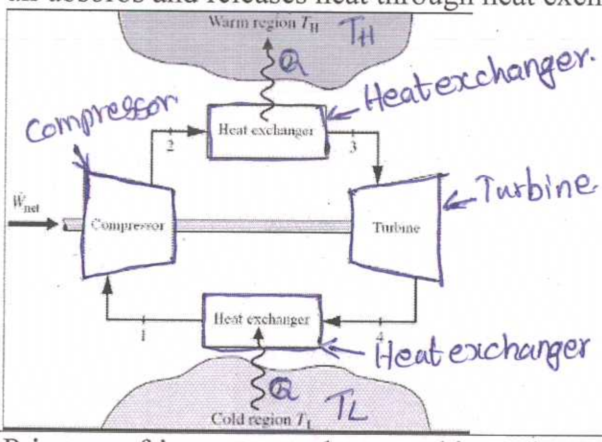
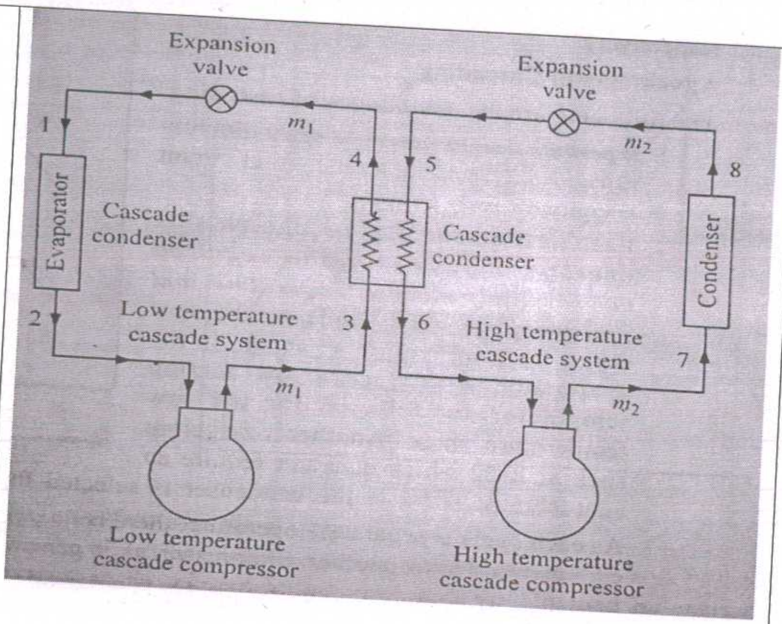
REVISION:2015				COURSE CODE:6023
COURSE TITLE:REFRIGERATION & AIRCONDITIONING				
Q. No.	**SCORING INDICATOR**	**SPLIT UP SCORE**	**SUB TOTAL**	**TOTAL**
	PART-A (Answer all questions)			
1	COP $=\frac{Refrigeration\ effect}{Work\ input}$	2	2	10
2	1.Isentropic compression 2.Isothermal heat rejection 3.Isentropic expansion 4.Isothermal heat absorption	0.5 0.5 0.5 0.5	2	
3	NH_3 -H_2O LiBr – H_2O	1 1	2	
4	Specific humidity is defined as the mass of water vapour per unit mass of dry air in a mixture of air and water vapour	2	2	
5	Effective temperature is defined as the sensory index that combines into single factor the effects of temperature, humidity and air movement on human comfort in a noise free pure environment	2	2	
	PART-B (Answer any 5 questions)			30
1	Mass of milk,m = 1500 kg Initial temperature of milk, T_i = 30°C Final temperature of milk, T_f = 3°C Time for cooling ,t = 3hr =3×60×60 seconds =10800 seconds Specific heat of milk C_p =3.92 kJ/kg.K. 1 TR = 3.5 kW Rate of cooling required = $\frac{mCp(Ti-Tf)}{t}$ $=\frac{1500\times3.92\times(30-3)}{10800}$ =14.7 kW	 1 2 2	6	

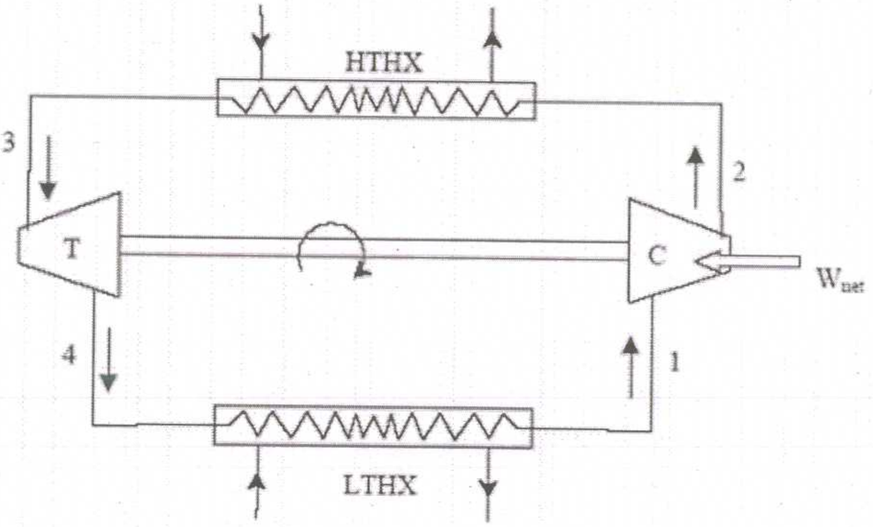
	capacity of refrigerating machine $=\frac{14.7}{3.5} = 4.2$ TR	1		
2.	**Open air refrigeration system :** In this system, the cold air expanded to atmospheric pressure is supplied to the space to be cooled.	1	6	
	 Open air refrigeration system	2		
	closed air refrigeration system : In this system, the air refrigerant remains with in the refrigeration system. The air absorbs and releases heat through heat exchangers.	1		
		2		
3.	Primary refrigerants are those working substances which directly take part in the refrigeration process and cool the substance by the absorption of latent heat. Eg : Ammonia, Freon group refrigerants, Methyl chloride (1 example)	2 1		

	Secondary refrigerants are those circulating substances which are first cooled with the help of the primary refrigerants and are then employed for cooling purpose. Eg: water, carbon dioxide, brines etc. (1 example)	2 1	6	
4	In hermetic compressors, the motor and the compressor are enclosed in the same housing . The housing has welded connections for refrigerant inlet and outlet and for power input socket. As a result of this, there is virtually no possibility of refrigerant leakage from the compressor. In some hermetic units, the cylinder head is usually removable so that the valves and the piston can be serviced. This type of unit is called a semi-hermetic (or semi-sealed) compressor.	2 1 1 2	6	
5	Instrument capable of measuring the psychrometric state of air is called a psychrometer. The sling psychrometer consists comprises of two thermometers with the bulb of one covered by a moist wick. The thermometers are mounted side by side and fitted in a frame with a handle for whirling the device through air. The required air circulation (≈ 3 to 5 m/s) over the sensing bulbs is obtained by whirling the psychrometer (≈ 300 RPM). Readings are taken when both the thermometers show steady-state readings.	1 2 3	6	
6	In cascade system, the condenser for low temperature cycle works as an evaporator for the high temperature cycle. In cascade system, a series of refrigerants with progressively lower freezing points is used in a series of single stage units.	2 1	6	

		3			
7	factors affecting human comfort 1. Temperature : A human body is very sensitive to temperature. The body temperature must be maintained within a narrow range to avoid discomfort, and within a somewhat wider range, to avoid danger from heat or cold stress.	1.5	6		
	2. Humidity : Large proportion of body heat is lost by evaporation. Evaporation is promoted by a low relative humidity of the air. Extreme humidity causes discomfort to human beings.	1.5			
	3. Air motion :Air movement over the body increases rate of heat and moisture dissipation, thereby modifying the feeling of warmth or coldness.	1.5			
	4. Air purity : People feel uncomfortable when breathing contaminated air. Proper filtration, cleaning and purification of air is necessary	1.5			

	PART - C			

III.a

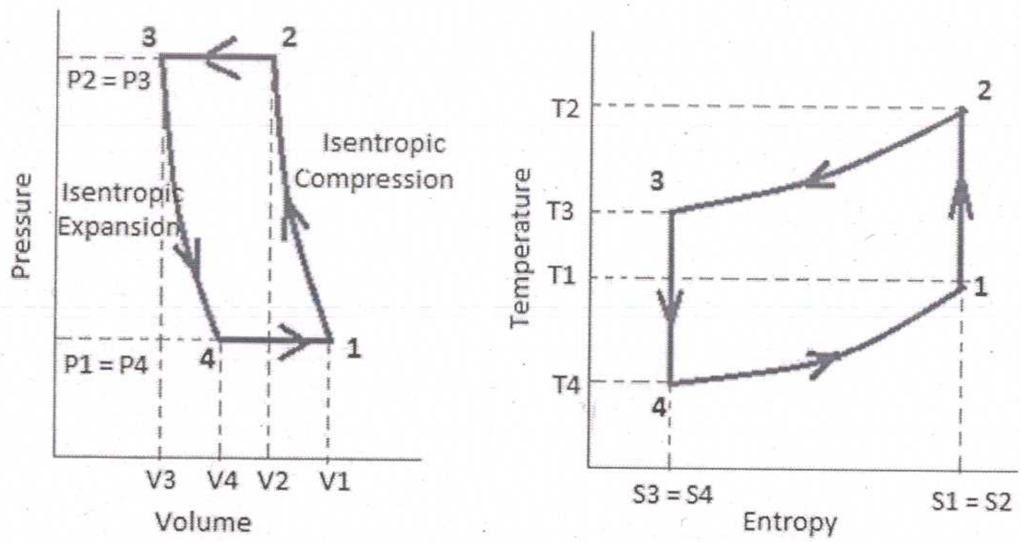


Bell-Coleman cycle – flow diagram

2

In this system, air is taken into the compressor from atmosphere and compressed. The hot compressed air is cooled in heat exchanger upto the atmospheric temperature (in ideal conditions). The cooled air is then expanded in an expander. The temperature of the air coming out from the expander is below the atmospheric temperature due to isentropic expansion. The low temperature air coming out from the expander enters into the evaporator and absorbs the heat.

2 8



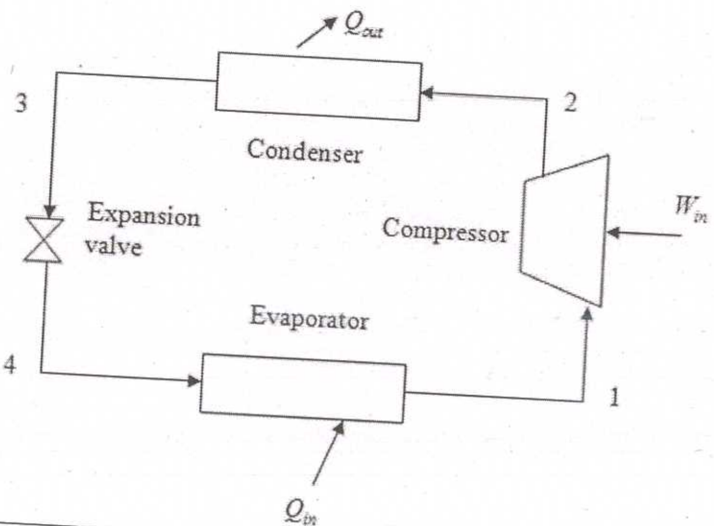
(a) P-V Diagram

(b) T-S Diagram

2

Process 1-2: Isentropic compression in a compressor
Process 2-3: Reversible, isobaric heat rejection in a heat exchanger
Process 3-4 Isentropic expansion in a turbine
Process4-1: Reversible, isobaric heat absorption in a heat exchanger

2

III.b	T_L = -10°C =263 K T_H = 30°C = 303 K		
	$COP = \frac{T_L}{T_H - T_L}$	1	
	$= \frac{263}{303-263} = 6.575$	1	
	Refrigeration effect = 10 TR =10×3.5 =35 kW		
	$\text{COP} = \frac{Refrigeration\ effect}{work\ input}$ $= \frac{35}{work\ input}$	1	7
	Work input = $\frac{35}{COP} = \frac{35}{6.575}$ = 5.323 kW	1	
	Rate of heat rejection = Refrigeration effect + work input	2	
	=35 + 5.323 =40.323 kW	1	
IV.a			8
		2	

Flow diagram

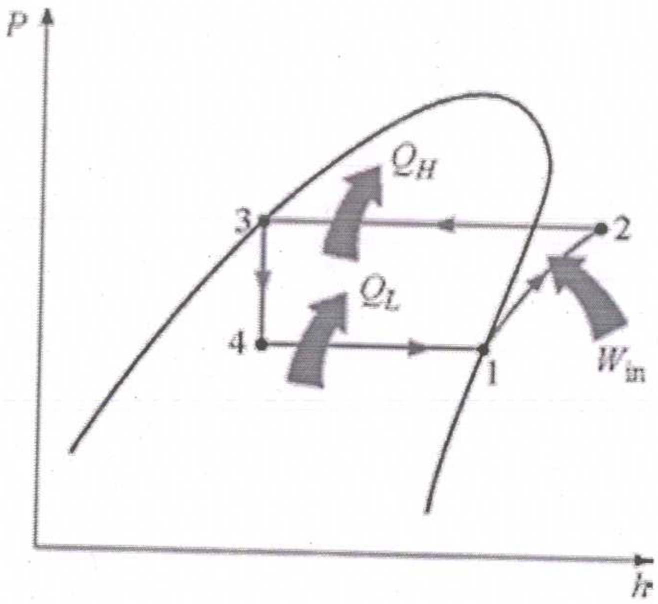
Process 1-2: Isentropic compression of saturated vapour in compressor

Process 2-3: Isobaric heat rejection in condenser

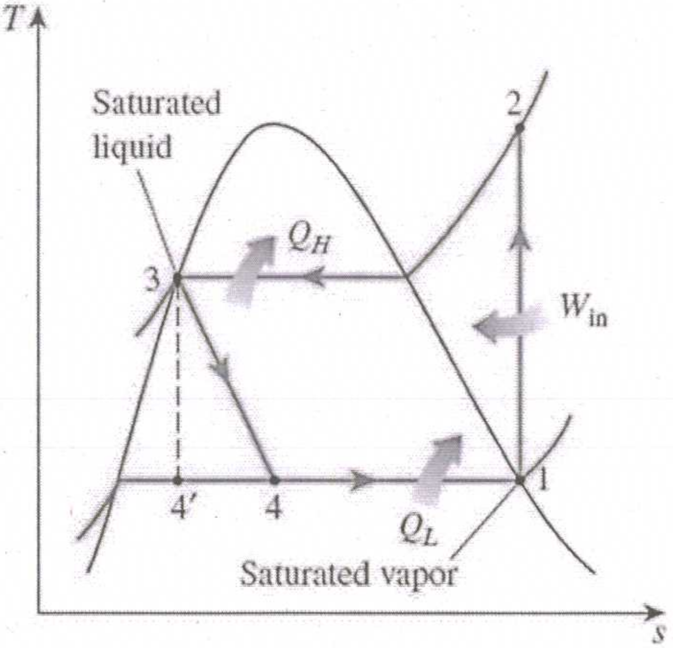
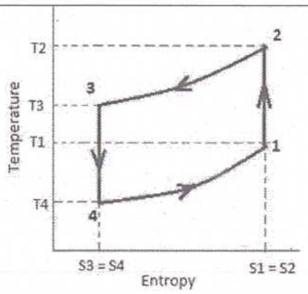
Process 3-4: Isenthalpic expansion of saturated liquid in expansion device

Process 4-1: Isobaric heat extraction in the evaporator 2

The low temperature, low pressure vapour at state 1 is compressed by a compressor to high temperature and pressure vapour at state 2. This vapour is condensed into high pressure liquid at state 3 in the condenser and then passes through the expansion valve. Here, the liquid is throttled down to a low pressure liquid and passed on to an evaporator, where it absorbs heat from the surroundings from the circulating fluid (being refrigerated) and vaporizes into low pressure vapour at state 1. The cycle then repeats. 2



P-h diagram 1

	 T-S diagram	1		
IV.b	 (b) T-S Diagram		7	
	P_1 =1 bar T_1 =10°C =283 K P_2 =5 bar T_3 =15°C =288 K $\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$	1		
	$T_2 = T_1 \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$			
	$= 283 \left(\frac{5}{1}\right)^{\frac{1.4-1}{1.4}}$ =448.22 K	1		

$$\frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\frac{\gamma-1}{\gamma}}$$ 1

$T_4 = \frac{288}{\frac{0.4}{51.4}} = 181.84$ K 1

Heat absorbed = $C_p(T_1 - T_4)$

= 1.005 (283-181.84) = 101.67 kJ/kg.

Heat released = $C_p(T_3 - T_2)$

=1.005(448.22 – 288) = 161.0211 kJ/kg.

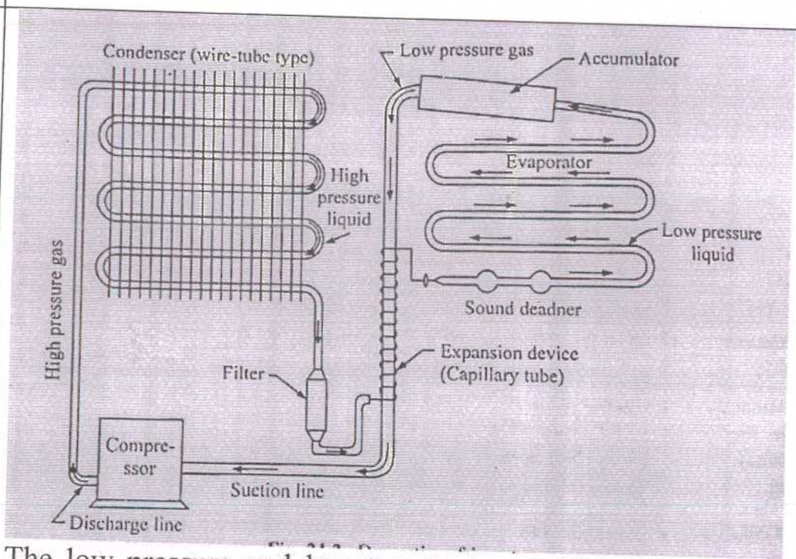
Work input = Heat released - Heat absorbed

=161.0211 -101.67 = 59.35 kJ/kg 2

COP = $\frac{Refrigeration\ effect}{Work\ input}$

$= \frac{101.67}{59.35} = 1.713$ 1

V.a



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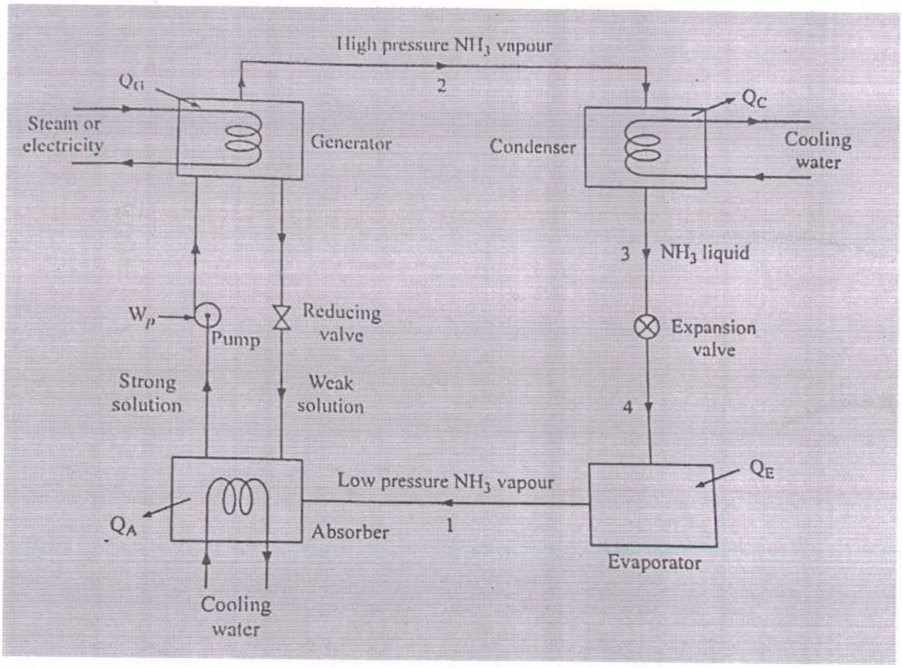
The low pressure and low temperature refrigerant vapour is drawn through the suction line to the compressor. The accumulator provided between the suction line and the evaporator collects liquid refrigerant coming out of the evaporator due to incomplete evaporation, if any, prevents it from entering the compressor. The compressor then compresses the refrigerant vapour to high pressure and high temperature. The compressed vapour flows through the discharge line into condenser. In the condenser the vapour refrigerant at high pressure and at high temperature is condensed to the liquid refrigerant at high pressure and low temperature.The liquid refrigerant then flows through the filter and then enters the capillary tube. The capillary tube expands the liquid refrigerant at high pressure to the liquid refrigerant at low pressure. The refrigerant then enters the evaporator 4

<table>
<tr><td></td><td>and absorbs heat from the surroundings</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>V.b</td><td>The ammonia vapour leaving the evaporator is readily absorbed in the low temperature hot solution in the absorber, releasing the latent heat of condensation. The temperature of the solution tends to rise, while the absorber is cooled by the circulating water. Strong solution is pumped to the generator where heat is supplied from an external source .The high pressure ammonia vapour goes to condenser where it is condensed to high pressure liquid ammonia .The weak solution returns to the absorber through a pressure reducing valve. The liquid ammonia from the condenser is throttled by the expansion valve and then enters to the evaporator. In the evaporator, the liquid ammonia absorbs heat from the surrounding and become ammonia vapour.



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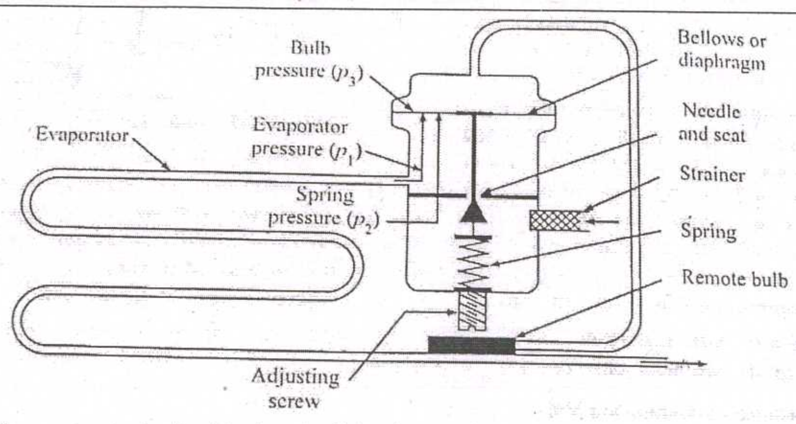
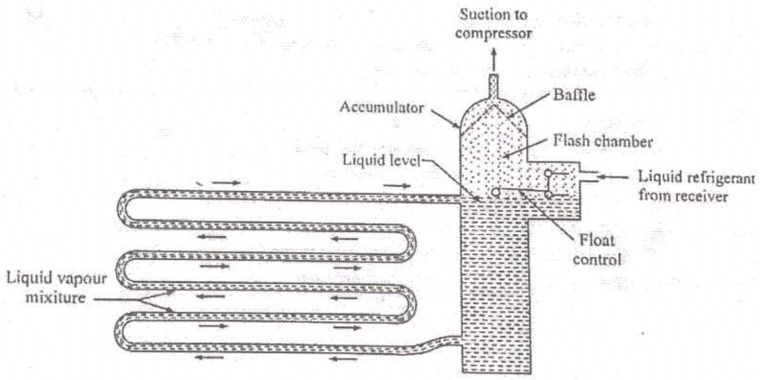
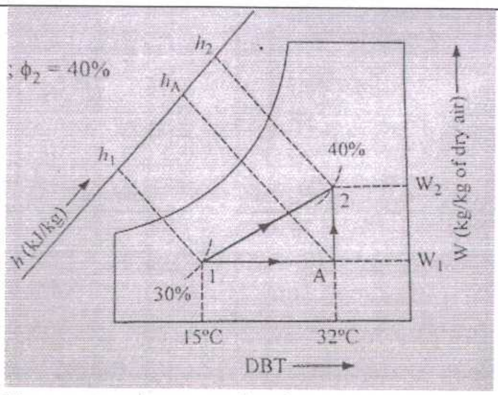
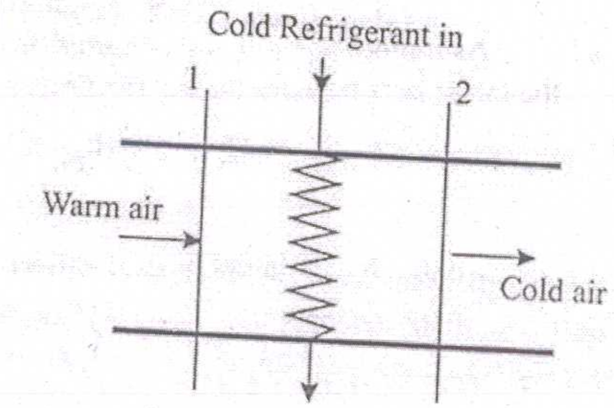
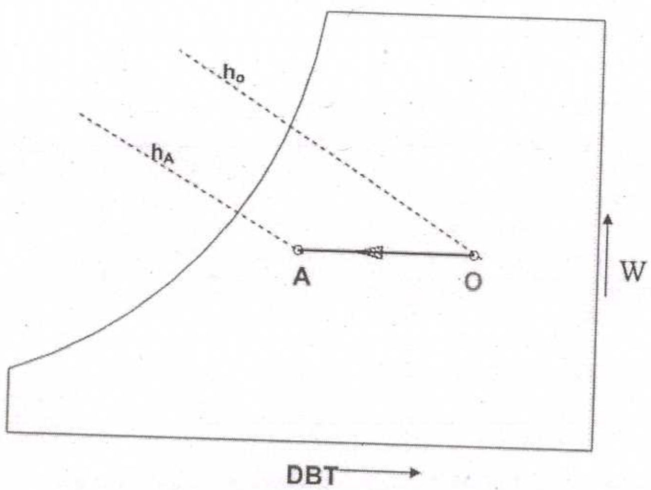
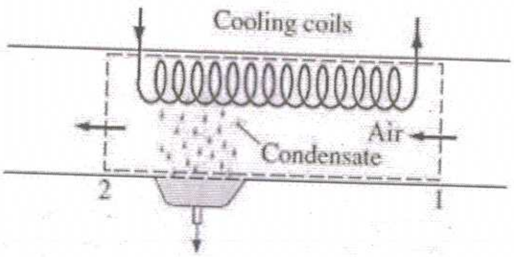
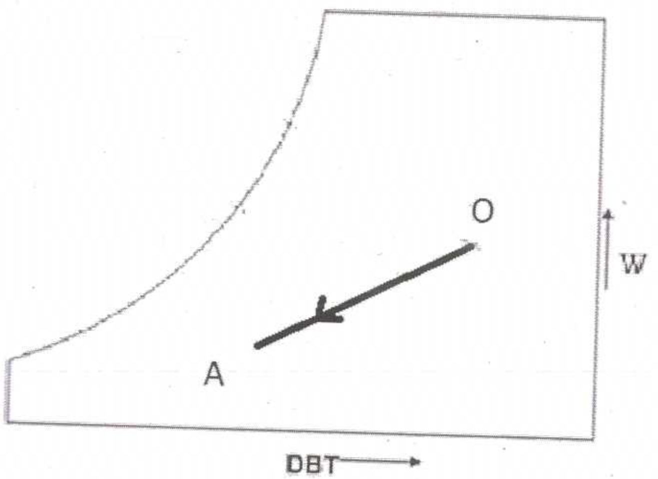
4</td><td>7</td><td></td></tr>
<tr><td>VI.a</td><td>


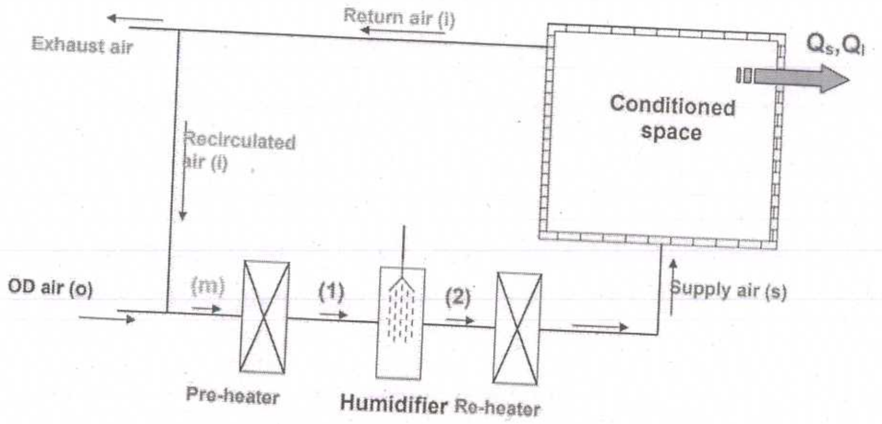
The remote bulb (feeler bulb) charged with refrigerant which is open on one side of the diaphragm through a capillary tube is clamped firmly to the evaporator</td><td>4</td><td>8</td><td></td></tr>
</table>

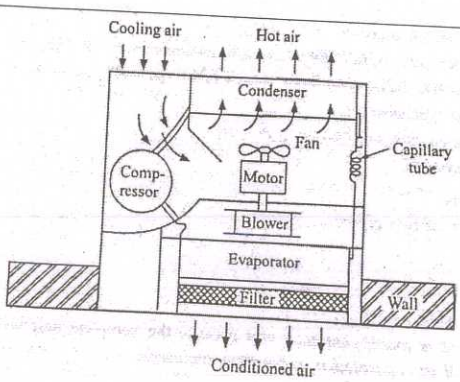
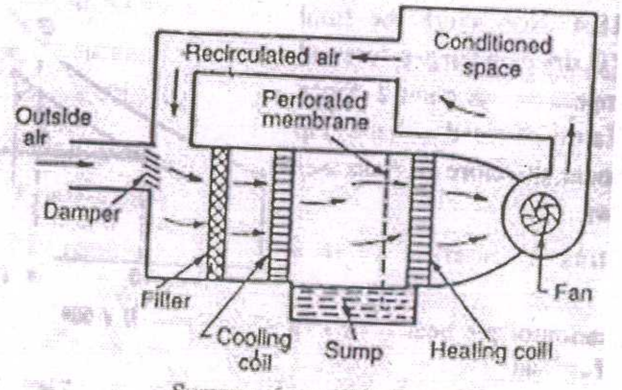
	outlet. The pressure of the liquid in the bulb tends to open the valve. This pressure is balanced by pressure due to spring and pressure in the evaporator.When the cooling load increases, the refrigerant evaporates at a faster rate in the evaporator than the compressor can suck. As a result the pressure and degree of superheat in the evaporator increases.This causes the valve to open more and allows more refrigerant to enter the evaporator.when the cooling load decreases,the refrigerant evaporates at a slower rate than the compressor can suck. As a result,the evaporator pressure drops and the degree of superheat decreases. The valve tends to close and the refrigerant supply decreases.	4		
VI.b	 A flooded type evaporator is one wherein the amount of liquid refrigerant circulated through the evaporator is considerably in excess of that which can be vaporised. A float valve is used as the throttling device which maintains a constant liquid level in the evaporator. Refrigerant absorbs heat and gets vaporised. So the liquid level falls down. The float valve opens to admit more liquid and thus maintains a constant liquid level. As a result the evaporator is always filled with liquid to the level determined by the float adjustment.	4 3	7	
VII .a	 From psychrometric chart	1	8	

	$h_1 = 22.7$ kJ/kg	1	
	$h_2 = 62.3$ kJ/kg	1	
	$h_A = 40$ kJ/kg	1	
	$W_1 = 0.003$ kg/kg of dry air.	1	
	$W_2 = 0.0171$ kg/kg of dry air.	1	
	Heat added to air $= h_2 - h_1 = 62.3 - 22.7 = 39.6$ kJ/kg	1	
	Moisture added to air $= W_2 - W_1 = 0.0171 - 0.003 = 0.0088$ kg/kg of dry air.	1	
VII.b	**Sensible cooling**		
		1	7
	In this process, air is passed through a cooling coil whose surface temperature is kept greater than the dew point temperature of the air. During this process, the moisture content of air remains constant but its temperature decreases as it flows over a cooling coil.	1	
		1	

	Cooling & dehumidification.		
		1	
	In this process, the air is passed through a cooling coil having surface temperature less than the dew point temperature of air.	1	
	The moisture in the air begins to condense as it comes in contact with the cooling coil. During this process	1	
	both dry bulb temperature and humidity of air decreases.		
		1	
VIII.a	From psychrometric chart		
	$h_1 = 35.4$ kJ/kg	1	
	$h_2 = 45.2$ kJ/kg	1	
	$\upsilon_1 = 0.8267\ m^3/kg$	1	
	RH of heated air =41%	1	
	WBT of heated air = 16.1°C	1	7
	Heat added to air =m $(h_2 - h_1)$	1	

	$=200(45.2 - 35.4)$ $= 1960$ kJ	1		
VIII.b	Applications of cryogenics **Space** • Rocket propulsion • Cooling of IR sensor • Space simulation **Medicine** • Cryosurgery • Cell preservation • Food preservation **Gas Industry** • Liquefaction • Separation • Storage **Mechanical** • Magnetic Separation • Manufacturing • Heat treatment • Recycling **High Energy Physics** • ITER • CERN **Superconductivity** • NMR, MRI • Maglev Locomotion • SC Transformer & Generator Any 8 application from 4 areas	8	8	
IX.a	• Air supplied to the conditioned space is heated and humidified in the winter air conditioning system to the required level of temperature and moisture content. • The mixed air (mixture of return and outdoor air) is first pre-heated (m-1) in the pre-heater, then humidified using a humidifier or an air washer (1-2) and then finally reheated in the reheater (2-s).	1 2		

	• Pre-heating of air is advantageous as it ensures that water in the humidifier/air washer does not freeze.	1	8	
		4		
IX.b	Cooling load is the rate at which sensible and latent heat must be removed from the space to maintain a constant space dry-bulb air temperature and humidity. For air-conditioning, the cooling load can be classified as follows	2	7	
	1.Room load – which falls on the room directly 2.Total load- Which falls on the air-conditioning apparatus.	1		
	<u>Room load</u> <u>Room sensible heat</u> 1.Solar and transmission heat gain through walls, roof , glass etc. 2.Infiltration 3.Internal heat gain from people, power, lights, appliances etc 4.supply duct heat gain, supply duct leakage loss and fan power	1		
	<u>Room Latent Heat</u> 1.Infiltration 2.Internal heat from people, steam, appliances 3.Vapour transmission	1		
	<u>Grand total load</u> (a) Sensible heat : 1. Effective room sensible heat 2. Sensible heat of the outside air that is not by-passed	1		

	3. Return duct heat gain, return duct leakage gain (b)Latent heat 1.effective room latent heat 2.latent heat of outside air which is not by-passed 3.return duct leakage gain	1	
X.a	 A window type air-conditioner is basically designed for cooling of room where it is installed. The entire system consists of following subassemblies. **1.system assembly**: evaporator, capillary tube, condenser, strainer, compressor. **2.Motor, fan and blower assembly**: fan, blower motor, motor mounting brackets. **3. Cabinet and grill assembly** : cabinet, grill **4.switch board panel** : selector switch, relay, thermostat, fan motor capacitor	5 2	7
X.b	 . Summer air conditioning system. Recirculated air from the conditioned space mixes with the outside air and flows	4	8

	through the filter. The filter removes dust and other impurities from air. The air then passes through the cooling coil whose temperature is lower than the dew point temperature of air. The moisture in the air begins to condense. The perforated membrane separates the water droplets from air. The water droplets are collected in a sump. The air is the heated to the required temperature using a heating coil. The air is then supplied to the conditioned space using a fan	4		