MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION
(Autonomous)
(ISO/IEC - 27001 - 2005 Certified)
SUMMER – 16 EXAMINATION

Subject Code : **17612** **Model Answer**

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.

Q. 01 Attempt any five

a) Important properties of insulating material ½ mark each

i) Low thermal conductivity

ii) Adequate structural strength

iii) Light weight.

iv) Odourless

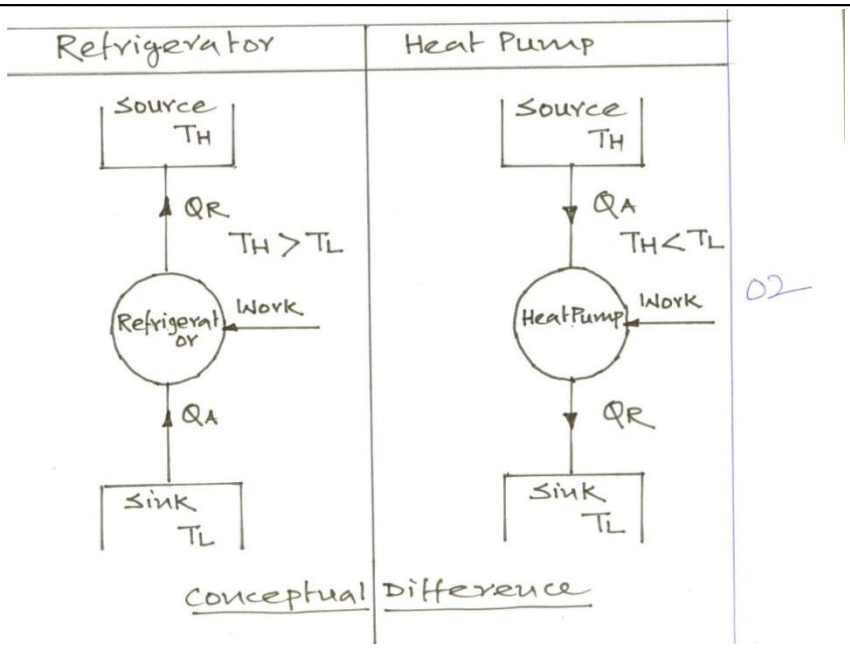
v) Nonflamable

vi) Chemical stability

vii) Moisture resistance

viii) Low cost

b) Differentiation between refrigerator and heat pump



	Refrigerator	Heat Pump	
II)	$COP = \frac{T_L}{T_H - T_L}$	$COP = \frac{T_H}{T_H - T_L}$	1/2
III)	Used in summer	Used in Winter	1/2
IV)	COP is less than COP of heat pump	COP is more than refrigerator by an amount equal to 1 i.e. $(COP)_{HP} = 1 + (COP)_{Ref.}$	01

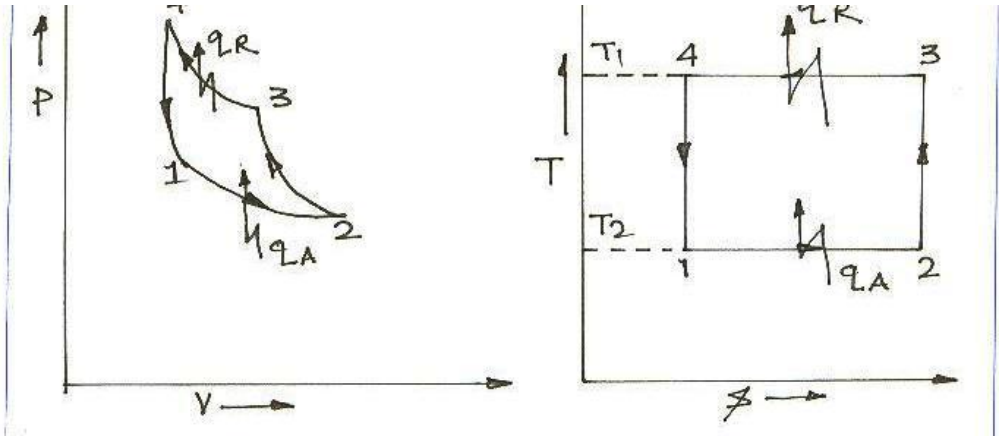
c) Reversed carnot cycle on P-V and T-S plane (2+2 marks)

Processes :-

1-2- Reversible isothermal heat absorption

2-3 -Reversible adiabatic compression.

P –V Plane T –S Plane



3-4 -Reversible isothermal heat rejection.

4-1-Reversible isothermal heat rejection.

Q. 1 d) Classification of Refrigerant (1+2+1 mark)

Refrigerant are classified into two groups

1) Primary Refrigerant

2) Secondary Refrigerant

Primary Refrigerant :- The refrigerant which take part in refrigeration cycle is known as primary refrigerant. They are classified as

i) Halocarbon compounds

e.g R -11 – Trichloromonofluromethane

R - 12

R – 13

R -21 etc.

ii) Azeotropes :- Mixture of different refrigerant

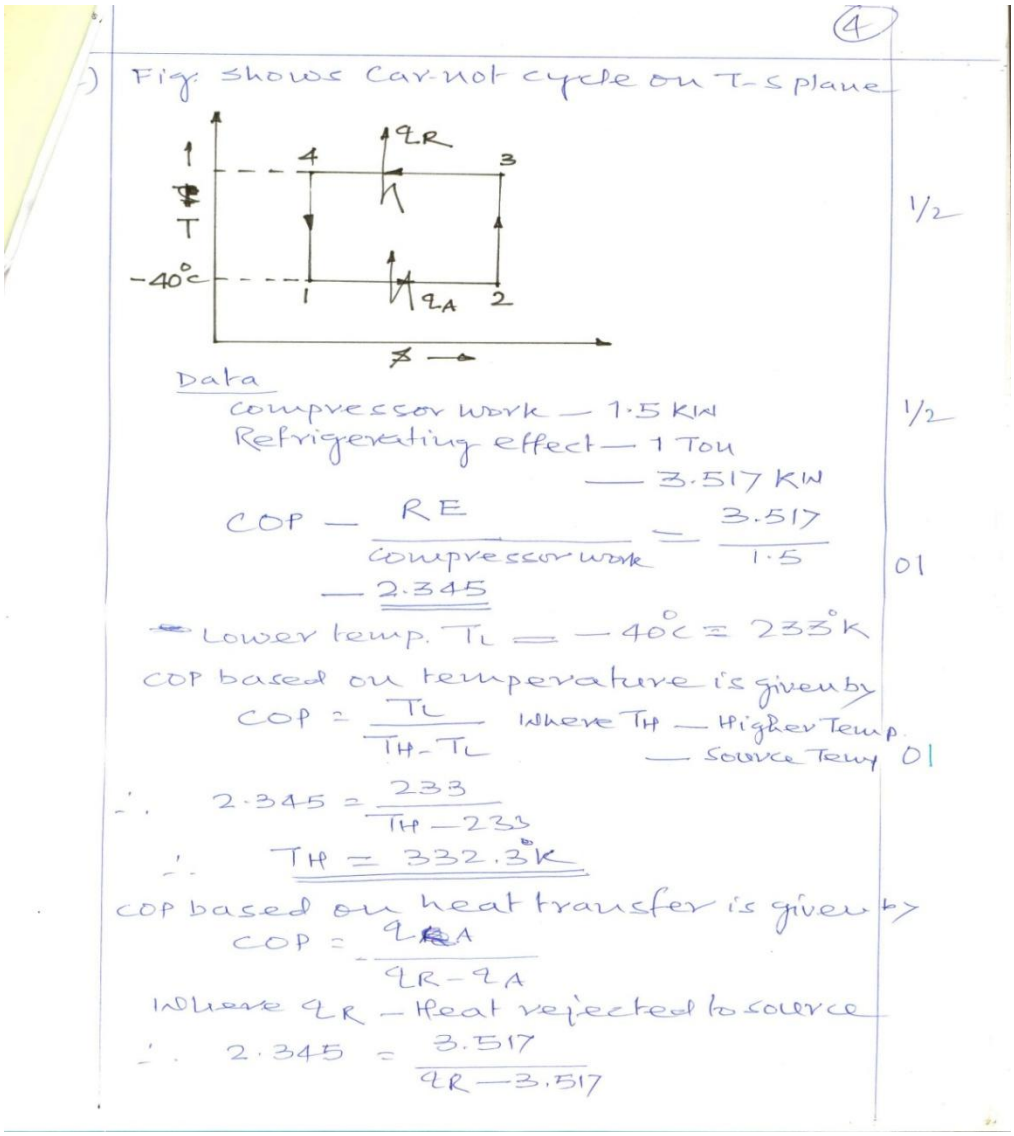
iii) Hydorcarbons :- Methane , Ethane , Propane etc.

iv)Inorganic compounds :- Ammonia, carbon di-oxide , Sulfur di-oxide , Air etc.

v) Unsaturated organic compounds :- Refrigerant with ethylene and propylene base.

2) Secondary Refrigerant: - Refrigerant which does not take part in refrigeration cycle is known as secondary refrigerant e.g water , brines etc.

Q.1 e) Fig . Shows carnot cycle on T-S plane



. ‘. q_R=5.017 kW 1 mark

f) Function of expansion device (2 marks)

i) To reduce the pressure of refrigerant form condenser pressure to evaporator pressure by throttling.

ii) To control mass flow rate of refrigerant in evaporator as per load on evaporator

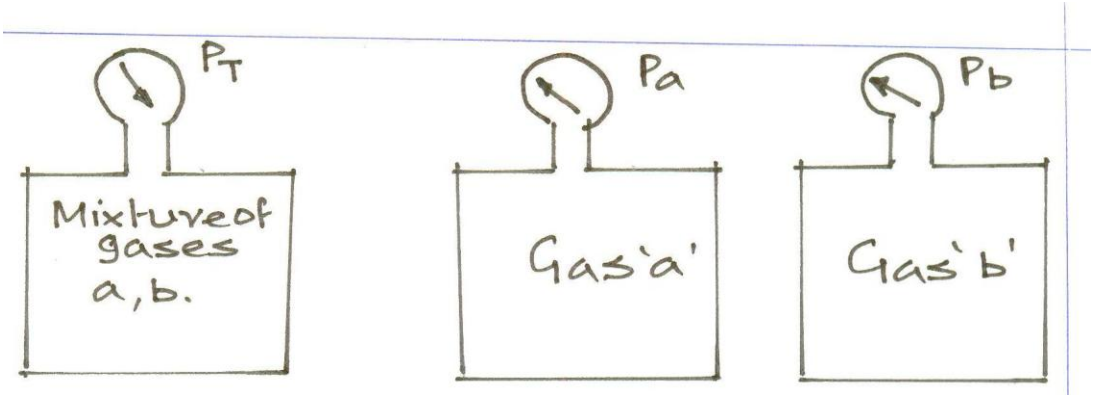
Capillary tube is used as expansion device in all domestic refrigeration. (2 marks)

Q.2 Attempt any four

a) Define- 1) Dalton's partial pressure law – (2 marks)

It states that total pressure of mixture of gases equal to the sum of partial pressures exerted by each gas when it occupies the mixture volume at the temperature of mixture .

Fig Shows explanation of Dalton's partial pressure law.



P_T – Total pressure of the mixture

P_a – Partial pressure of gas 'a'

P_b - partial pressure of gas 'b'

According to Dalton's partial pressure law, we have ·

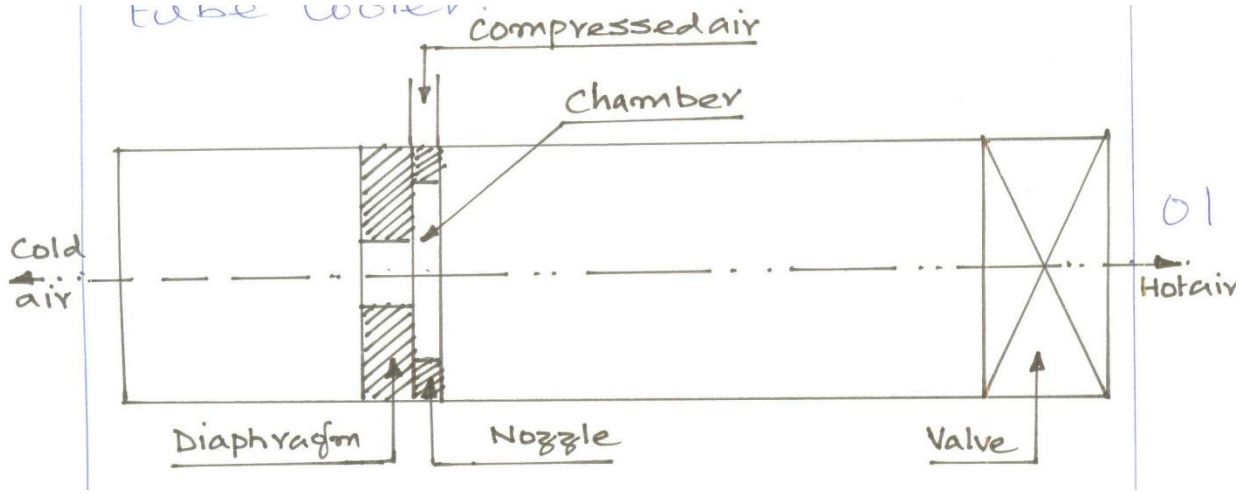
ii) Relative Humidity: - It is a ration of actual partial pressure of water vapour to saturation partial pressure of water vapour . It is denoted by Φ and expressed as percentage

$$\emptyset = \frac{pv}{pvsat} \; X \; 100$$ (2 marks)

b) Vortex Tube Cooler -:(1+2+1 marks)

If the compressed air is supplied through an opening provided circumferentially on the tube than we get hot and cold air supply at its two ends.

Fig. Shows basic construction of vortex tube cooler.



It consists of

Nozzle , Diaphragm, Valve

Working :- Compressed air passed through nozzle. Air expands and acquire high velocity. A vortex flow is created in chamber and air travels in spiral form. Flow is restricted by valve . By partly closing the valve air pressure becomes more than outside. Due to this reversed axial flow set up form high pressure region to low pressure region. During this process energy transfer takes place between reversed stream and forward stream. The air stream through core gets cooled and air stream in forward direction gets heated. The cold stream escaped through diaphragm and not stream through valve. By controlling opening of valve temperature of cold air can be varied.

Application

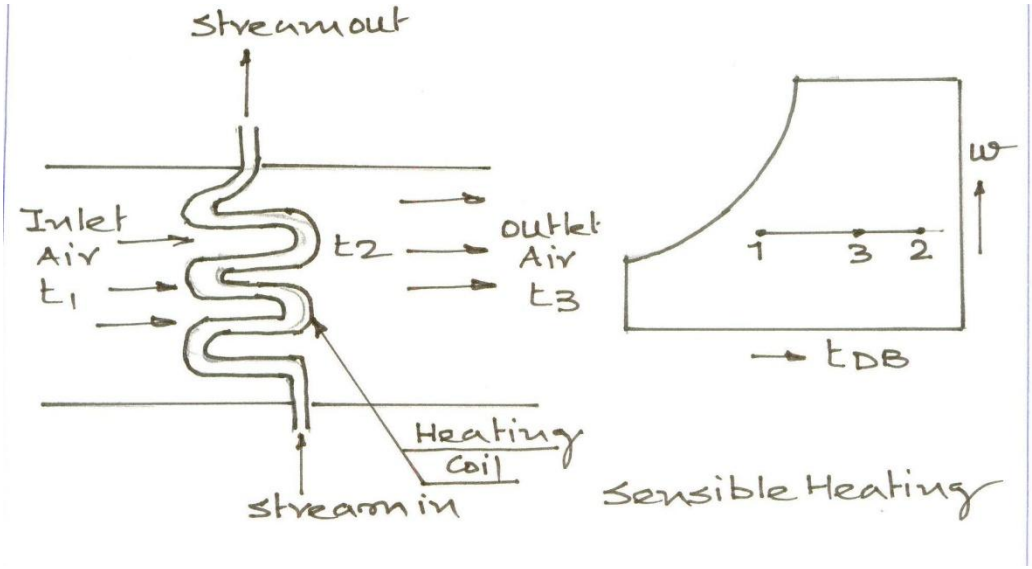
i) Air Suits ii) cooling of aviation cabin iii) cooling of gas turbine blades iv) cutting tool cooling

Q.2 C) By pass factor of heating coil and cooling of coil. (2+2 marks)

When a stream of air passes over a coil , which may be heating or cooling, part of it comes in direct contact with coil surface while remaining just by passes on affected. The amount of air,

which by passed depends upon velocity of flow. This by pass process measured in terms of by- pass factor.

By pass factor of heating coil.

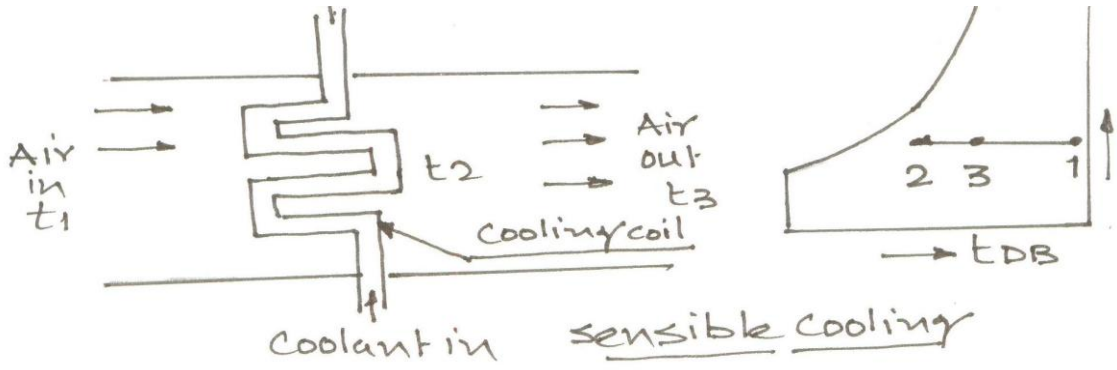


The arrangement for sensible heating is as shown in fig. and process is shown on psychrometric chart.

The process 1-2 is expected how ever the actual process terminates . The process 3-2 does not occur due to by passing of air.

. ' . By Pass factor = $\frac{t_2-t_3}{t_2-t_1}$

By Pass factor of cooling coil



The arrangement for sensible cooling and its psychrometric process is as shown in the fig above

By pass factor of cooling coil - $\frac{t_3-t_2}{t_1-t_2}$

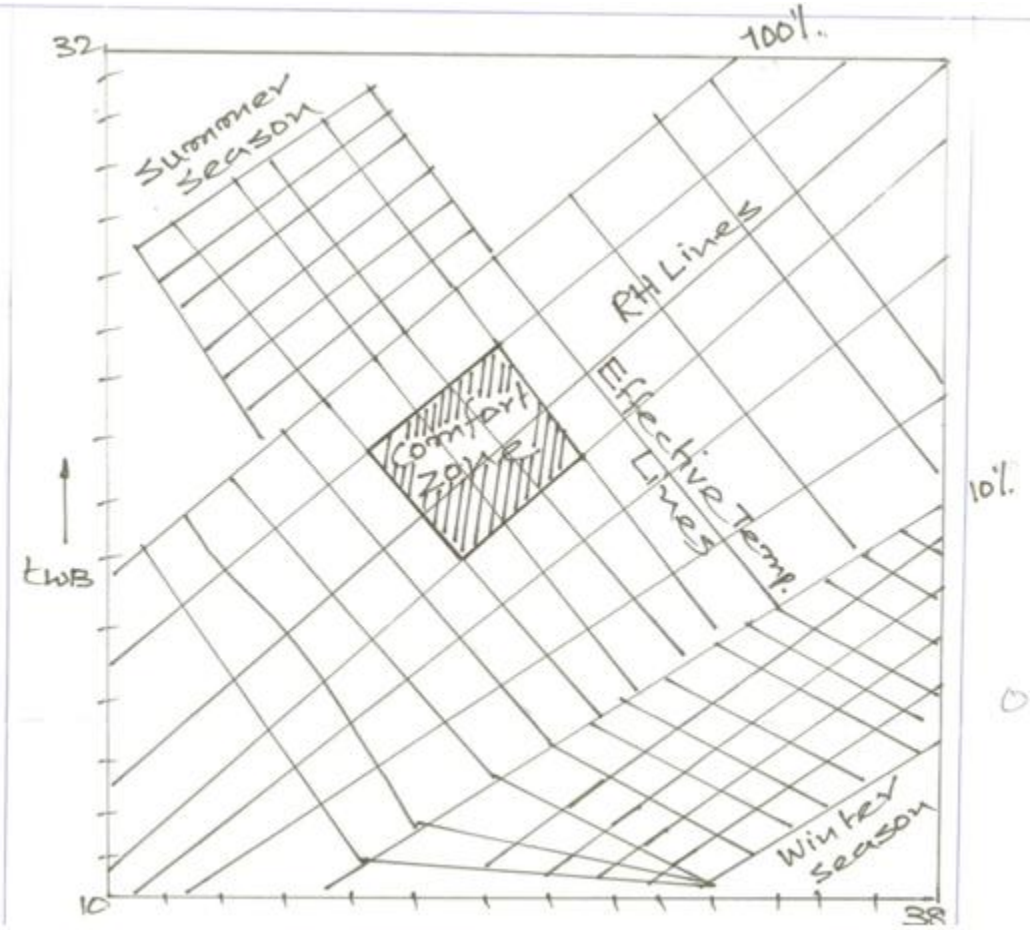
d) Effective Temperature :- It is a concept used for measuring comfort feeling of human being.

The human comfort depends on equilibrium between rate of heat production and rate of heat dissipation. The human comfort for individual varies with temperature, relative humidity, air velocity eating habits age, gender etc.

In order to have a common base, amongst all variables mentioned above on which maximum human being would feel comfort irrespective of season a term Effective Temperature has been used. So effective temperature is that temperature which correlates the combined effects of air temperature, relative humidity and air motion on human body

The practical application of the concept of effective temperature is presented by comfort chart as shown in fig.

The comfort zone shown on the chart is a conditioned space at which maximum percentage of people would feel comfort, with slight change in effective temperature irrespective of season.



Parameters on which effective temperature depends-

1- Temperature

2- Relative Humidity

3- Air velocity

4- Purity

5- Duration of stay

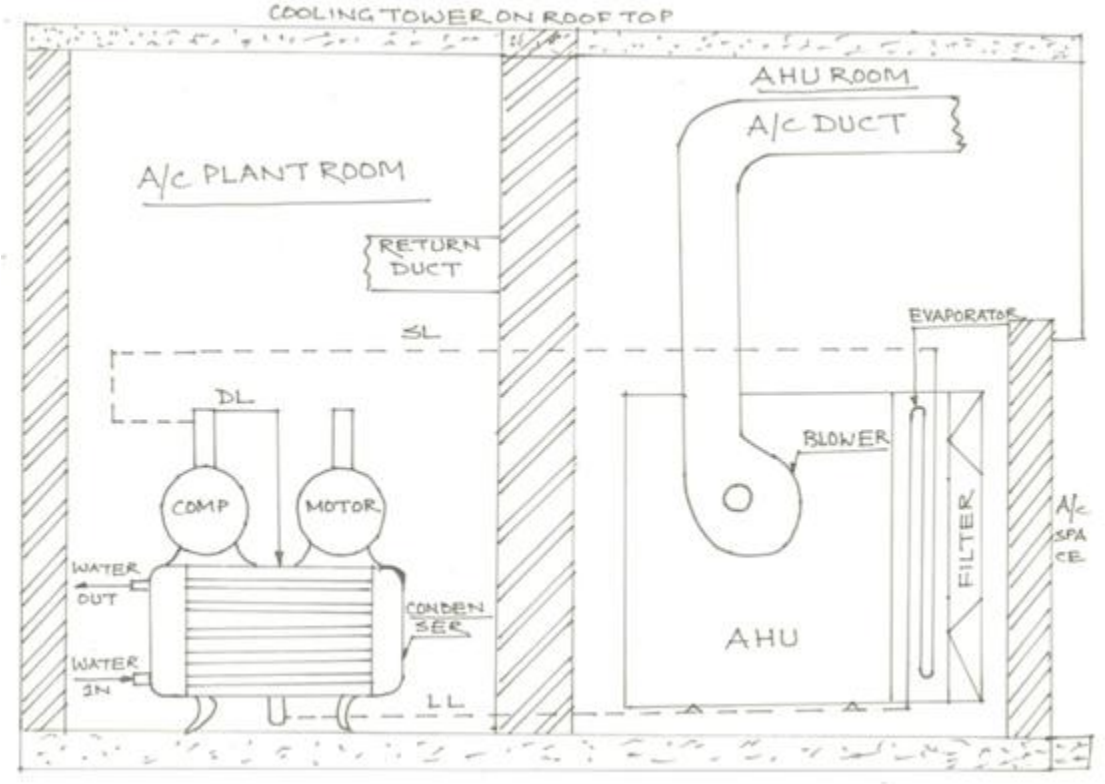
6- Eating habits

7- Ages Gender

8- Types of cloth used

9- Activity of occupant (1+1+2 marks for any four parmeters)

Q.No.2 e):



Central air conditioning system layout (DX system)

Q. 3 a) Working of Flooded type evaporator. **(For sketch 2 Marks and working 2 Marks)**

This is typically used in large ammonia systems. The refrigerant enters a surge drum through a float type expansion valve. The compressor directly draws the flash vapour formed during expansion. This vapour does not take part in refrigeration hence its removal makes the evaporator more compact and pressured drop due to this is also avoided. The liquid refrigerant enters the evaporator from the bottom of the surge drum. This boils inside the tubes as heat is absorbed. The mixture of liquid and vapour bubbles rises up along the evaporator tubes. The vapour is separated as it enters the surge drum. The remaining unevaporated liquid circulates again in the tubes along with the constant supply of liquid refrigerant from the expansion valve. The mass flow rate through the evaporator is three times that through the compressor.

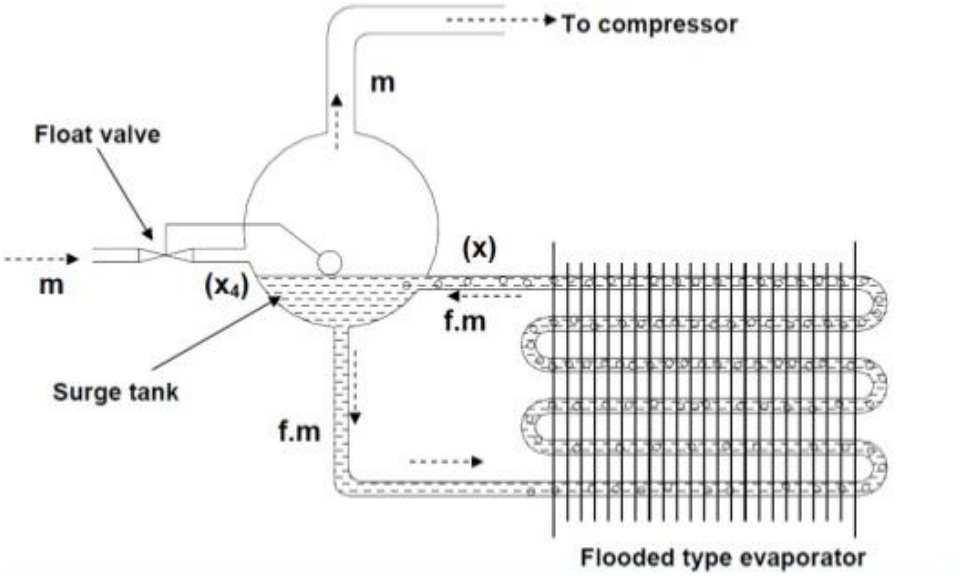


Fig. no3.a

Since, liquid refrigerant is in contact with whole of evaporator surface, the refrigerant side heat transfer coefficient will be very high. The lubricating oil tends to accumulate in the flooded evaporator hence an effective oil separator must be used immediately after the compressor.

Q.3 b) Open type compressors. **(2 Marks for Four points)**

- most common problem is failure of shaft seal assembly and leakage of refrigerant.
- Due to leakage of refrigerant , the recurring cost for open type compressor is quite high.
- Motors used for Open compressors are air-cooled.
- Reduces the efficiency and reliability of the motors.
- Motors of Open compressors have to be erected and assembled at site. This requires precise alignment of the motor and compressor
- Motors of Open compressors reject heat in the plant room
- Open type compressor requires heavy foundations and grouting to be done at site.
- simple construction
- Application for capacity of plants ex. Cold storage .central air conditioning

Hermetically sealed type compressors. **(2 Marks for Four points)**

- Do not need any shaft seal assembly, because the compressor and the motor are mounted on a common shaft and in a common housing.
- there is no chance of leakage of costly refrigerant gas through the seals is less costly
- Semi-hermetic compressor motors are refrigerant gas cooled.
- high efficiency and reliability of the compressor motor
- Motor is enclosed under shell. Problem does not arise in case of hermetic compressors.
- The motor heat is rejected directly into the cooling tower.
- Hermetic compressors are factory assembled and mounted on the structure / skid and do not require any foundation or grouting.
- With many redundant safety features built in the system like overheat and overload protection, hermetic motors do not face serious problems.
- Application for smaller capacity plant like refrigerator ,air conditioning unit

Q.3 c) Classify ducts used in air-conditioning system **(Each point ½ Marks)**

The ducts may be classified as follows:

1. Supply duct – conditioned air from the air conditioning equipment to the space to be conditioned
2. Return air duct- carry the recirculating air from the conditioning space back to the air conditioning equipment.
3. Fresh air duct – carry the outside air
4. Low pressure duct- static pressure in the duct is less than 50mm of water gauge
5. Medium pressure duct- static pressure in the duct is upto 150mm of water gauge
6. High pressure duct- static pressure in the duct is from 150 to 250mm of water gauge
7. Low velocity duct-velocity of air in the duct is upto 600 m/min
8. High velocity duct- velocity of air in the duct is more than 600m/min

Q.3 d) Industrial applications of refrigeration (2 Marks any four points)

- Air-conditioning for comfort of workers
- For textile industries for production of quality textile products.
- For manufacturing process in photographic industry.

- In printing industries for quality printing.
- In paper industries for production of paper.
- For preservation of food in food industries.

Industrial applications of A/C system. (2 Marks any four points)

- Laboratories: to make precise measurements
- Printing : to control temperature and humidity
- Textile manufacture :greatly depends on moisture control
- Pharmaceutical: industry needs refrigeration to reduce air borne bacteria and dirt to preserve products
- Photographic: products deteriorate rapidly at high temperatures and high humidity
- Manufacture of Precision Parts:
- Farm Animals
- Computer Rooms:
- Power Plants

Q. 3 e) Automobile air conditioning system. **(For sketch 2 and working 2 Marks)**

Air conditioners work on the principle that "liquids absorb heat when they become a vapour (evaporate). Low pressure R134a vapor entering the compressor is compressed to become high pressure/temperature R134a vapor. This is then circulated along with lubricant oil to the condenser. As the high pressure/temperature vapor travels through the condenser, heat is released to the cooler ambient air passing over the condenser tubes condensing the vapor into a liquid. This high pressure/temperature liquid then travels through the filter drier onto the expansion valve where a small variable orifice provides a restriction against which compressor pushes.

Suction from the compressor pulls the high pressure/temperature liquid R134a through small variable orifice of the TX valve and into the low-pressure side of the A/C system. The R134a is now under low pressure/temperature vapor where heat from the cabin being blown over the evaporator coil surface is absorbed into the colder low pressure refrigerant The R134a is then pulled through the evaporator and into the compressor.

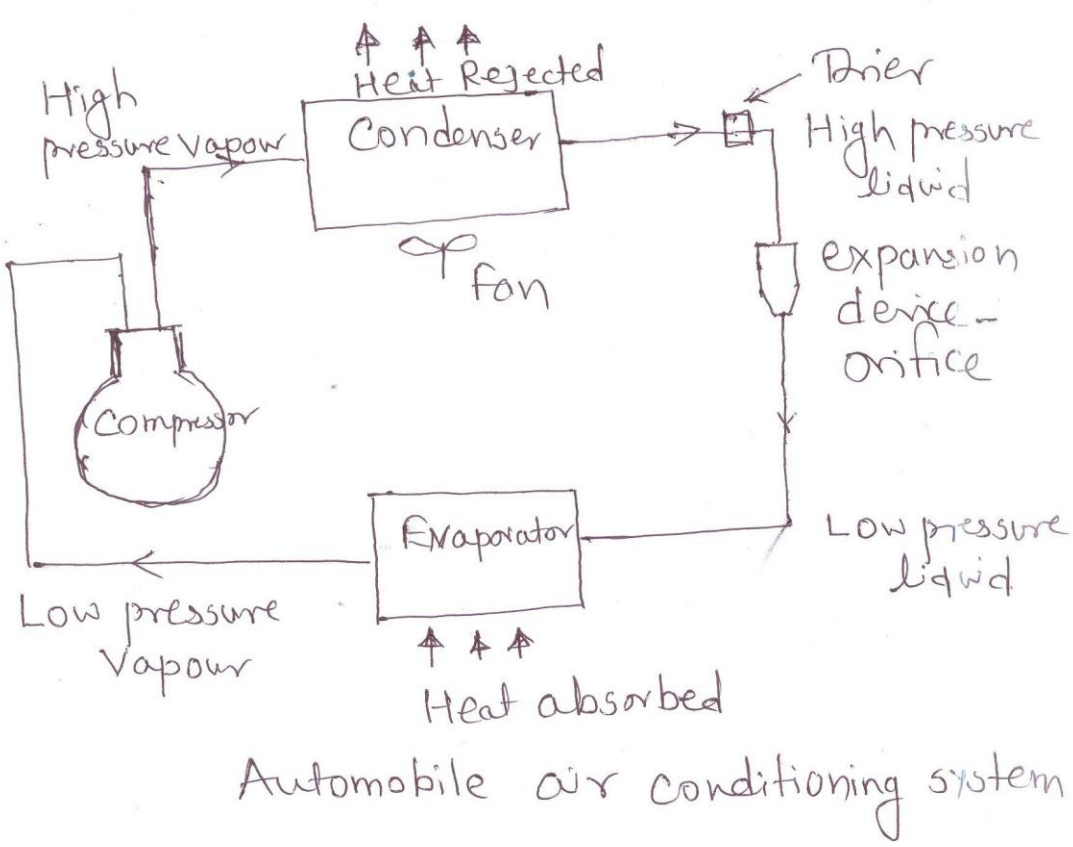


Fig no 3.e

The A/C cycle begins again as the R134a vapor is compressed and discharged under pressure. Heat transfer R134a in the LOW-PRESSURE side is COLD and can absorb large quantities of heat from the air moving over the evaporator . R134a in HIGH-PRESSURE side is HOT and the cooler ambient air moving over the condenser can absorb the heat from it.

Q.4 a) Given data

$T_2=T_3 = 298K$
$T_1=T_4= 268$ K
$X_1= 0.6$ $hf_3=hf_2= 164.77$ KJ /kg $hf_1=h4= 72.57$KJ/kg
$Sf_2=0.5978$ KJ/kg K

T-s and P-h diagrams
(2 Marks)
Find the dryness fraction at point 2 = x_2

Entropy at point 1 $s_1= s_{f1} + x_1 h_{fg1}/ T_1$

$= 0.2862 + 0.6 \times 248.76 /268 = 0.8431$KJ/kg K **(1 Mark)**

Entropy at point 2

$S_2 = s_{f2} + x_2\, h_{fg2}/ T_2 = 0.5978 + (x_2)(117.46)/298$

$= 0.5978 + 0.3941\, x_2$

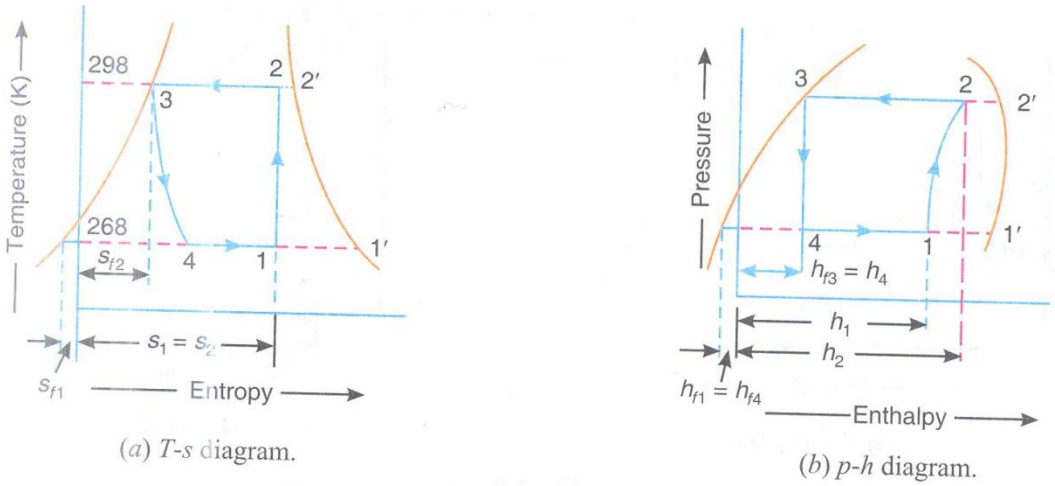


Fig. no 4.a

Entropy at point 1 S1 = Entropy at point 2 s2

$0.8431 = 0.5978 + 0.3941.\, x_2$

$x_2 = 0.622$ **(1 Mark)**

Enthalpy at point 1

$h_1 = hf_1 + x_1 hfg_1 = 72.57 + 0.6 \times 248.76 = 221.83$ KJ/kg **(1 Mark)**

Enthalpy at point 2

$h_2 = hf_2 + x_2 hfg_2 = 164.77 + 0.622 \times 117.46 = 237.83$ KJ/kg **(1 Mark)**

$COP = h_1 - hf_3 / h_2 - h_1 = 221.83 - 164.77 / 237.83 - 221.83 = 3.57$ **(2 Marks)**

Q.4 b) working of Lithium Bromide Absorption refrigeration system

It consists of conventional component of vapour absorption system like absorber, generator, heat exchanger, condenser, and evaporator. In evaporator refrigerant water evaporates absorbing latent heat from water to be chilled. The water vapors are drawn in absorber. In absorber weak solution of lithium bromide is spread which absorbs water vapour and gets converted in to strong solution. To increase the affinity for water vapour

cooling coil is placed in absorber. Strong solution of lithium bromide is pumped to generator through heat exchanger. The function of heat exchanger is to transfer heat from weak solution to strong solution. In generator strong solution is heated by means of heating coil to realize water vapour. By realizing water vapour in strong solution converts in weak solution which is passed to absorber through heat exchanger. The generated water vapour from generator is further passed to condenser where it is condensed by condensing water supplied externally. This condensed water refrigerant is passed to evaporator to compensate the refrigerant evaporated in evaporator and cycle is completed. . **(For sketch 4 Marks and working 4 Marks)**

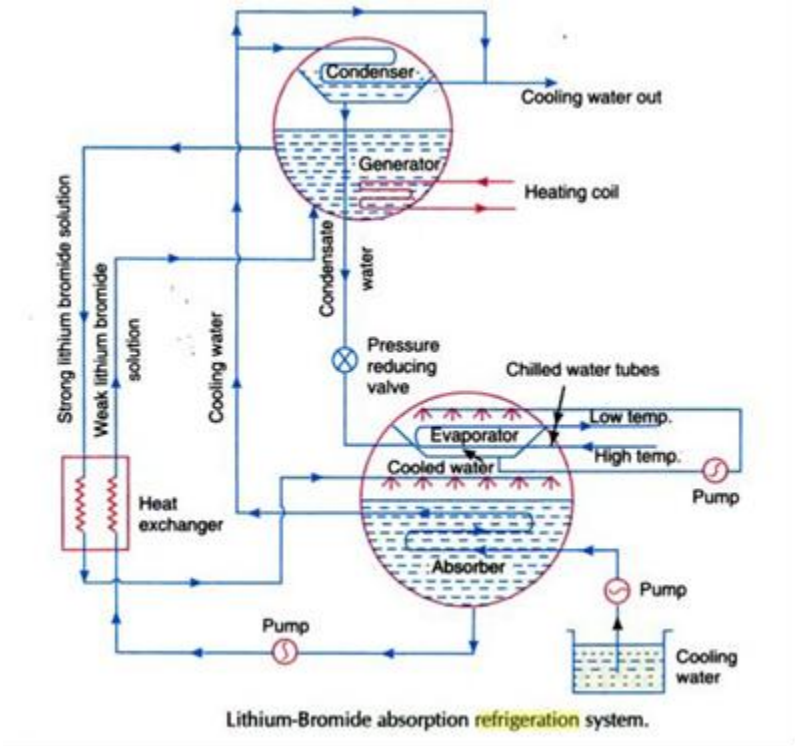


Fig.no.4.b

Q.4 (c) Simple air cooling' system used for aircrafts.
(For sketch 2 Marks, working 2 Marks, T-S diagram 2 Marks and COP 2Marks)

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 are consist of this system:

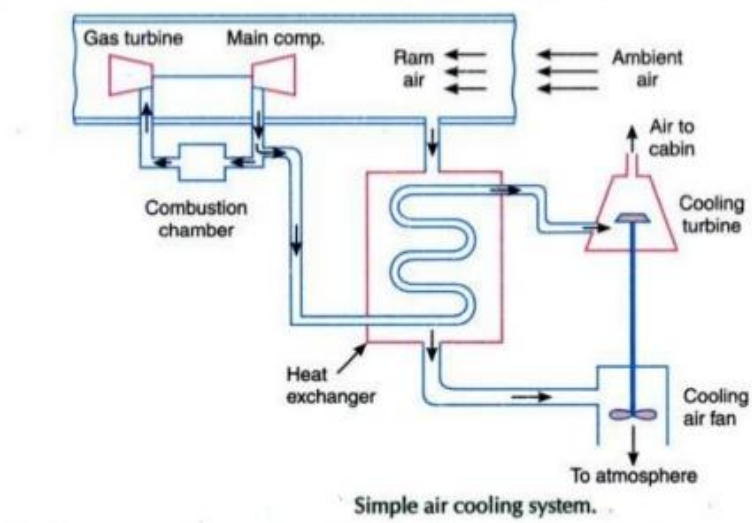


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Fig. no.4.c.1

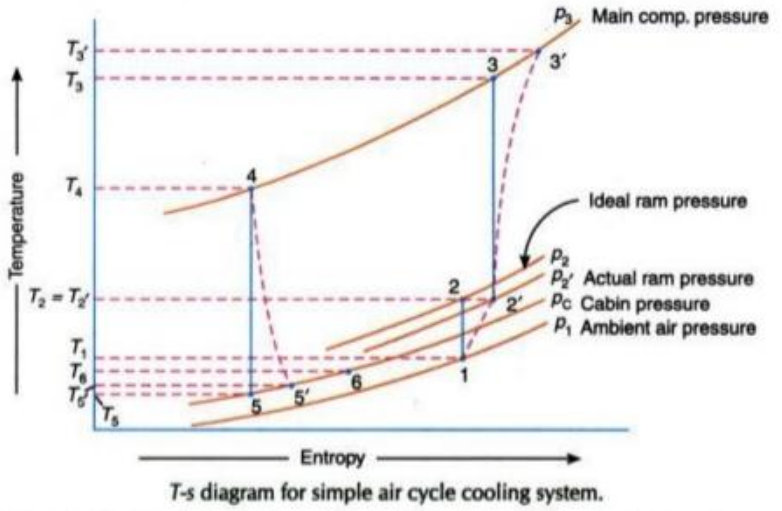
Ramming process: ideal ramming action is shown by vertical line 1-2 & actual ramming process 1-2’

Compression: isentropic compression by line 2’-3

Cooling process: shown by curves 3’-4

Expansion process: isentropically expanded in the cooling turbine shown by curve 4-5

Refrigeration process: cooling effects curves 5’-6’



T-s diagram for simple air cycle cooling system.

Fig. no.4.c.2

COP = Refrigerating effect produced / work done

$= m_a Cp(T_6-T_5') / m_a. Cp(T_3'-T_2')$

$=(T_6-T_5') /(T_3'-T_2')$

In terms of Q tonnes of refrigeration are the cooing load in the cabin

$COP = 210 Q / ma Cp (T_3' - T_2') = 210 Q / P$

P= power required for the refrigeration system

Q. 5 Attempt any TWO of the following:

a) Enlist various types of heat load to be considered while designing air conditioning system for particular room/lab. How room sensible heat factor is calculated?

Ans- Types:

1. Sensible heat load, 2. Latent heat load, 3. Occupant load
4. Lighting and appliance load, 5. Infiltration load

How room sensible heat factor is calculated?

As we know sensible heat factor is defined as the ratio of total sensible heat to total sensible and latent heat load. It is given by,

$$SHF = H_S / (H_S + H_L)$$

And Room sensible heat factor is the ratio of room sensible heat to room total heat. The point joining indoor condition and supply air condition is known as room sensible factor line. From fig. it can be seen that cold and dry air is supplied to the room and the air that leaves the conditioned space. The room sensible cooling load ($Q_{s,r}$), room latent cooling load ($Q_{I,r}$) and Room total cooling load($Q_{t,r}$) ,are given by:

$$Q_{s,r} = m_s C_{pm}(t_i - t_s)$$

$$Q_{I,r} = m_s hfg(W_i - W_s)$$

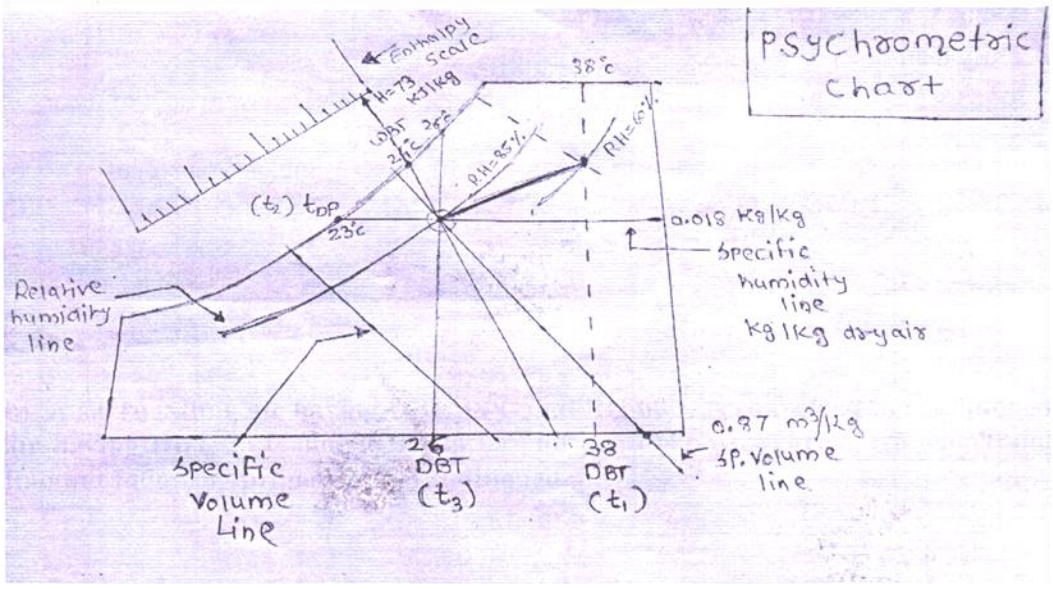
$$Q_{t,r} = Q_{s,r} + Q_{I,r} = m_s (h_i - h_s)$$

From cooling load calculation, the sensible, latent and total cooling load on the room can be obtained. Hence one can find the room sensible heat factor (RSHF) from the equation:

$$RSHF = (Q_{s,r}) / (Q_{s,r} + Q_{I,r}) = (Q_{s,r}) / (Q_{t,r})$$

(4marks for types and 4marks for explanation)

b) A surrounding air having DBT 38^{0}C and RH 60% is converted to conditioned air having DBT 26^{0}C and WBT 24^{0}C. Plot process on psychrometric chart and find out following properties of conditioned air.



The following properties of conditioned air are obtained from psychrometric chart:

1. RH = 85%

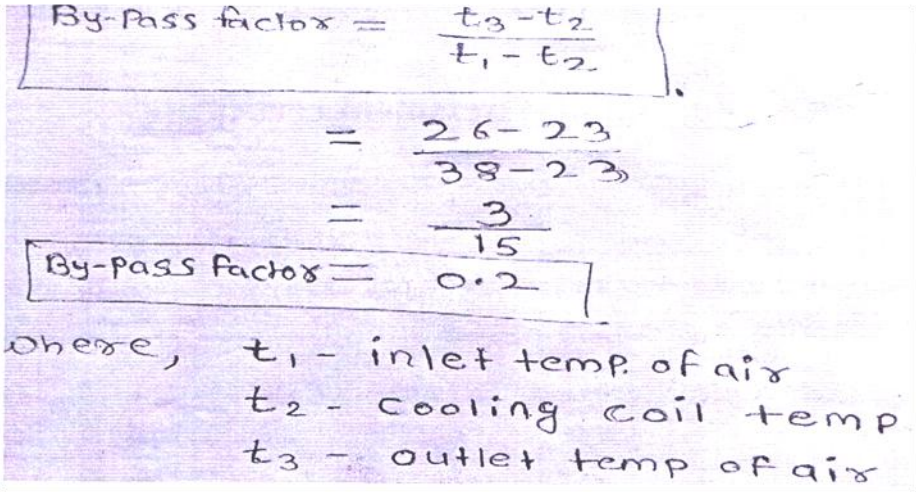
2. Specific humidity = 0.018 kg/kg

3. Enthalpy = 73 kJ/kg

4. Specific volume = 0.87 m^3/kg

5. By pass factor of cooling coil = 0.2

6. Apparatus dew point temperature = 23^0C

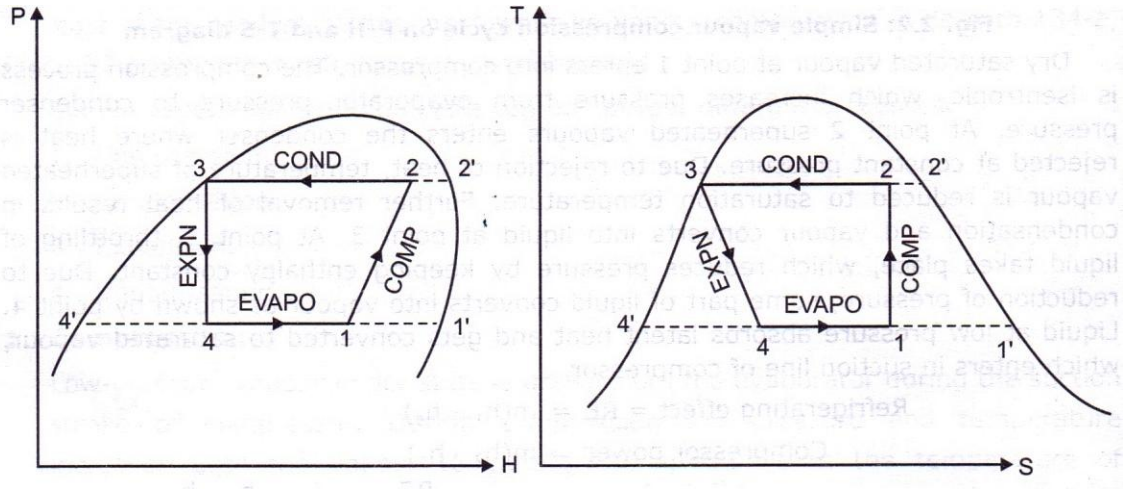


(2marks for psychrometric chart & each correct value of property 1mark)

c) Represent a neat labeled T-S & P-H diagram for the following:

i) Wet refrigerant at the end of compression:
ii) Dry and saturated refrigerant at the end of compression, also write C.O.P. equation for both conditions.

Ans- i) Wet refrigerant at the end of compression:



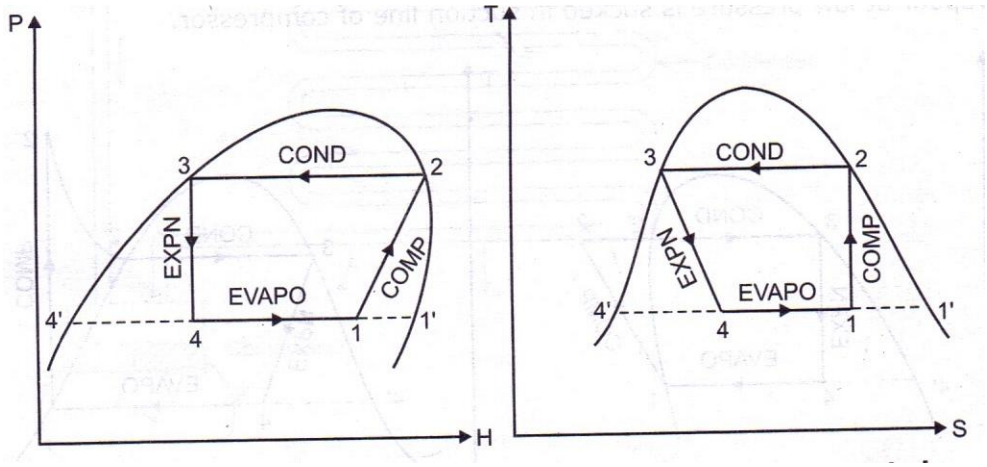
$$COP = \frac{h_1 - h_4}{h_2 - h_1}$$

$$COP = \frac{[h_4' + x_1(h_1 - h_4')] - h_4}{[h_3 + x_2(h_2' - h_3)] - [h_4' + x_1(h_1' - h_4')]}$$

where, • $h_1 = h_4' + x_1(h_1' - h_4')$

• $h_2 = h_3 + x_2(h_2' - h_3)$

ii) Dry and saturated refrigerant at the end of compression:



$$COP = \frac{h_1 - h_4}{h_2 - h_1}$$

$$COP = \frac{[h_4' + x_1(h_1 - h_4')] - h_4}{h_2 - [h_4' + x_1(h_1' - h_4')]}$$

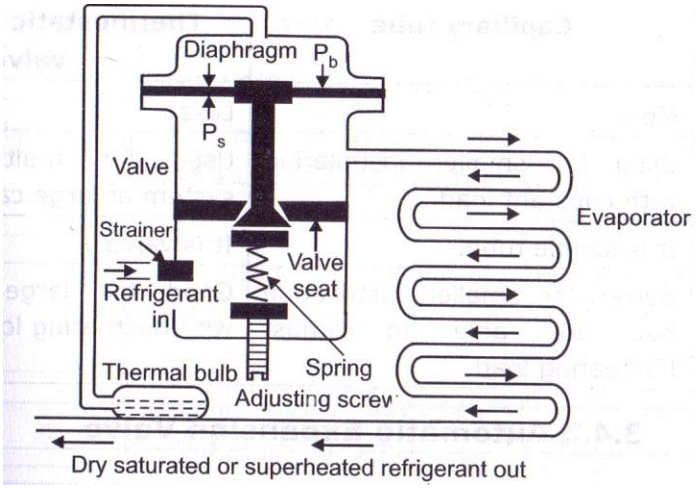
where, $h_1 = h_4' + x_1(h_1' - h_4')$

(4marks each)

Q. 6 Attempt any FOUR of the following:

(a) Explain working of 'Thermostatic Expansion Valve' with neat sketch.

Ans- Thermostatic expansion valve consist of diaphragm valve, valve seat, spring, adjusting screw and thermal bulb. Thermostat expansion is fitted in liquid line just ahead of evaporator in direction of arrow provided on it and thermal bulb is clamped with exit line of evaporator. When there is load on evaporator, superheated vapours are coming at exit of evaporator, which transfer its heat to thermal bulb. Due to this, refrigerant filled in thermal bulb vaporizes and increases the bulb pressure to open up valve allowing more liquid refrigerant into evaporator.
When there is decrease in load on evaporator, vapour at the exit of evaporator absorb heat from thermal bulb and reduced the pressure on diaphragm to reduce opening of valve resulting in reduction in mass flow rate of refrigerant entering in evaporator.



(2marks for diagram and 2marks for explanation)

(b) Differentiate between 'air cooled' and 'water cooled' condenser.

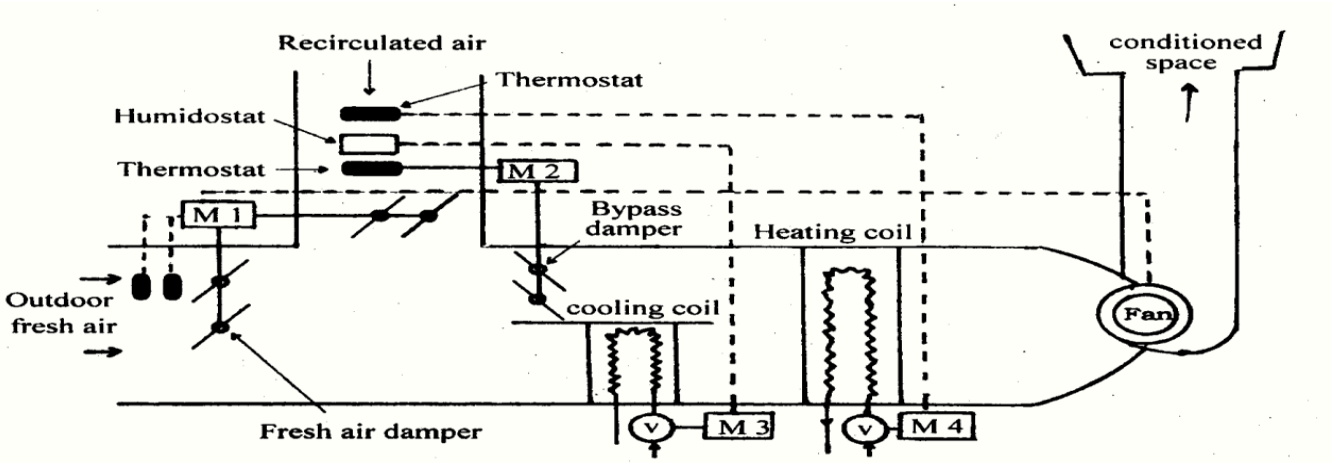
Ans- (Any four point 4marks)

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

7	Low heat transfer capacity.	High heat transfer.
8	Shorter compressor life.	Longer compressor life.

(c) Explain working of 'year round air conditioning'.

Ans-



The arrangement of year round air conditioning system is as shown in fig. The amount of outdoor fresh air and recirculated air is controlled by motor. The air conditioner designed such that when outdoor air temperature is either above or below a certain selected value, it assume the season as summer or winter respectively.

In summer season, by pass damper is almost closed and most of air passes through cooling coil. The cooling coil may be evaporator of refrigeration system or coil through which chilled water is passed. All air is passed through heating coil. In winter season, by pass damper is in almost open position. Most of the air is directly passed to heating coil by passing cooling coil.

(2marks for diagram and 2marks for explanation)

(d) Differentiate between 'Central and 'Unitary' air conditioning system.

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

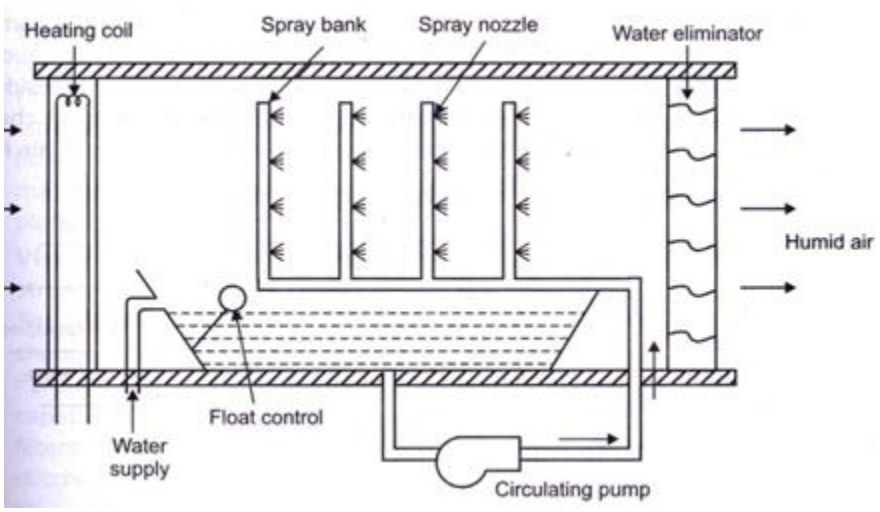
	components are located outside.	is quite in operation if used as split unit.
5	All the rooms are required to be maintained at more or less similar condition.	Each room can be maintained at different condition.
6	It requires duct design and installation.	No duct design and installation is required.
7	Capital cost of central air conditioning equipment is less.	Capital cost of unitary air conditioning equipment is more.
8	Maintenance is convenient and easy.	Maintenance is difficult.

(Any four point 4marks)

e) Explain any one Humidifier with neat sketch.

Ans-Humidification by air washing:

System consists of components like water tank, pump, heating/cooling coil, spray pipe & nozzles, air damper for air in-flow and eliminator plate. Humidification can be achieved by spraying water in the stream of air. The air washer has a chamber in which water is sprayed through the nozzles from the top. Air enters into the chamber through air dampers and it flows through the sprays of water. While flowing, it absorbs the water particles & gets humidified. The complete process is known as Humidification by air washing.

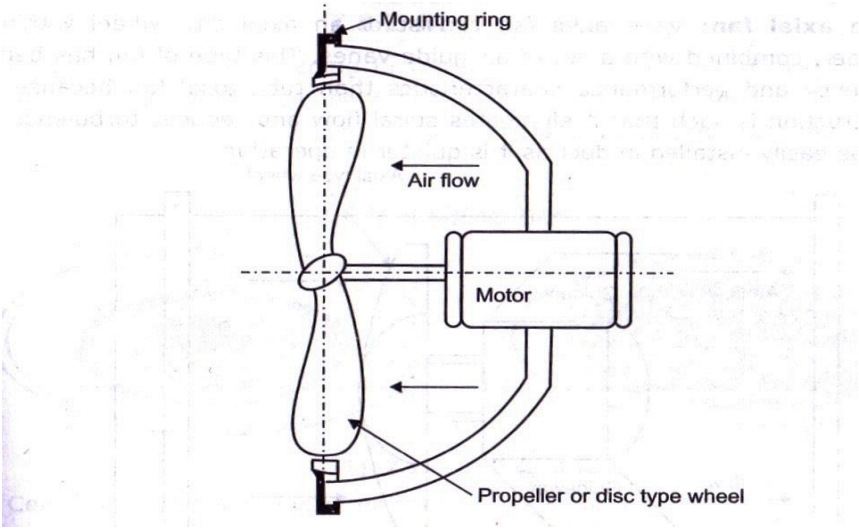


(2marks for diagram and 2marks for explanation)

f) Enlist different types of fan used in air conditioning system. Explain any one with sketch.
Ans- Types:-

1. **Centrifugal fan:**
   i) Forward blade Centrifugal fan
   ii) Radial blade Centrifugal fan
   iii) Backward blade Centrifugal fan
2. **Axial flow fan:**
   i) Propeller fan
   ii) Tube axial fan
3. **Vane axial fan.**

Propeller fan- A propeller fan consists of propeller, which work with mounting ring. Propeller fan is low pressure high capacity fan which require less power than centrifugal fan. These fans are used only when resistance to air moment is small. Example, for ventilation of space, removal of gases and vapours from kitchens, ventilation of laboratories and many other application where duct is not required.



(2marks for types and 2marks for explanation)
