SUMMER – 15 EXAMINATION

Subject Code: **17612 (RAC)** **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 1 A a) **(02 marks each)**

i) COP : Coefficient of Performance of refrigerator is the ratio of heat removed from sink (Refrigerating effect) by the device and work done required.

COP = Refrigerating effect / Work done

The value of COP is always greater than 1

ii) One Ton of refrigeration

A ton of refrigeration is defined as the quantity of heat required to be removed to from one ton of ice at 0 ^{o}C in 24 hours when initial condition of water is 0 ^{o}C

Since the latent heat of ice is 335 kJ/kg, therefore one tonne of refrigeration,

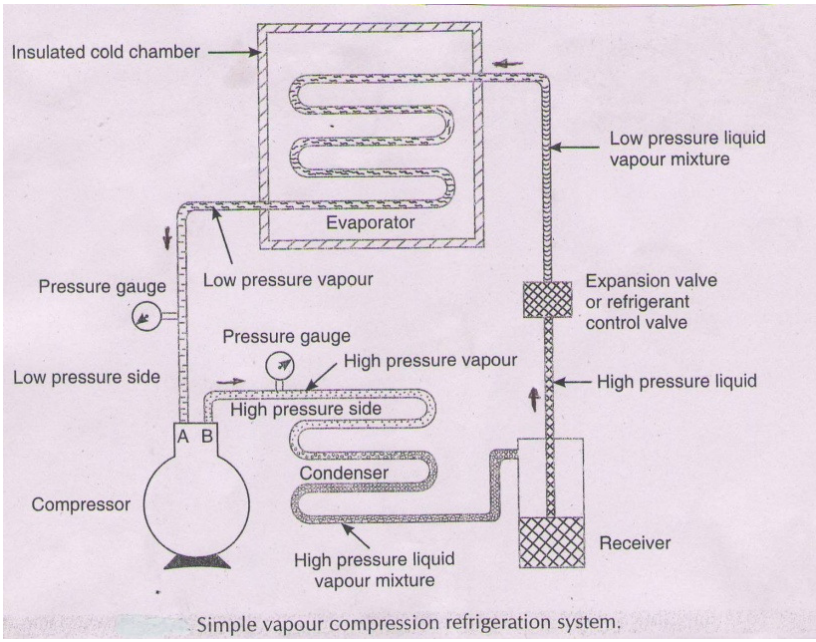
$$1TR = 1000 \times 335 \text{ kJ in 24 hours}$$

$$= \frac{1000 \times 335}{24 \times 60} = 232.6 \text{ kJ/min}$$

In actual practice, one tonne of refrigeration is taken as equivalent to 210 kJ/min or 3.5 kW (*i.e.* 3.5 kJ/s).

1 Ton of refrigeration = 3.517 KJ/Sec or 3.517 kW

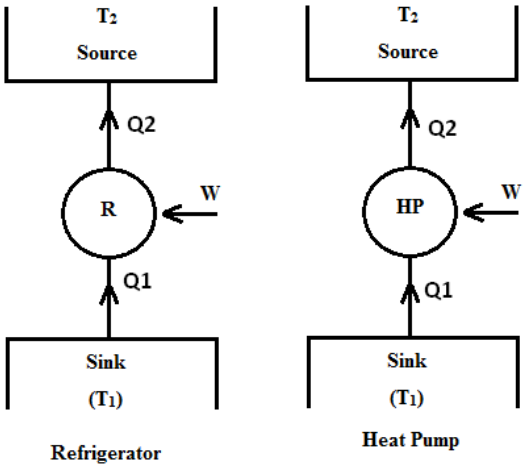
Q 1 A b) Simple vapour compression refrigeration system. (04 marks for correct diagram)



Simple vapour compression refrigeration system.

Q1A c) (Diagrams 02 marks, proof: 02 marks)

COP (HP) = COP(Ref) + 1



For Refrigerator, COP = Q_1 / W ……..(i)

And for Heat Pump COP = Q_2 / W

But $Q_2 = Q_1 + W$

So, Heat Pump COP = $Q2 / W = (Q_1 + W) / W$

$= (Q_1 / W) + 1 =$ **$COP_{(Ref)} + 1$** Hence Proved

Q1A d i) **(02 marks)**

Sensible Heat Factor

Sensible Heat Factor is defined as ratio of sensible heat to total heat. Total heat is the sum of Latent heat & sensible heat. i.e. SHF = SH / TH = SH / (SH+LH)

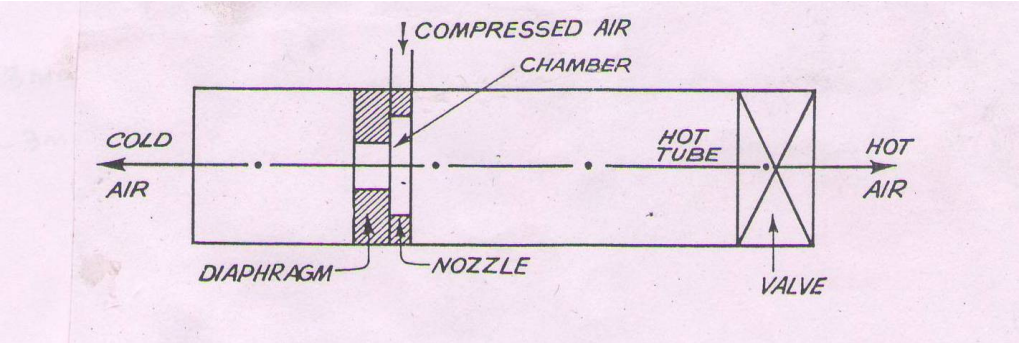
Q1A d ii) **(02 marks)**

Room Sensible Heat Factor

Room Sensible Heat Factor is defined as ratio of room sensible heat to room total heat. Room total heat is the sum of room latent heat & room sensible heat.

i.e. RSHF = RSH / RTH = RSH / (RSH+RLH)

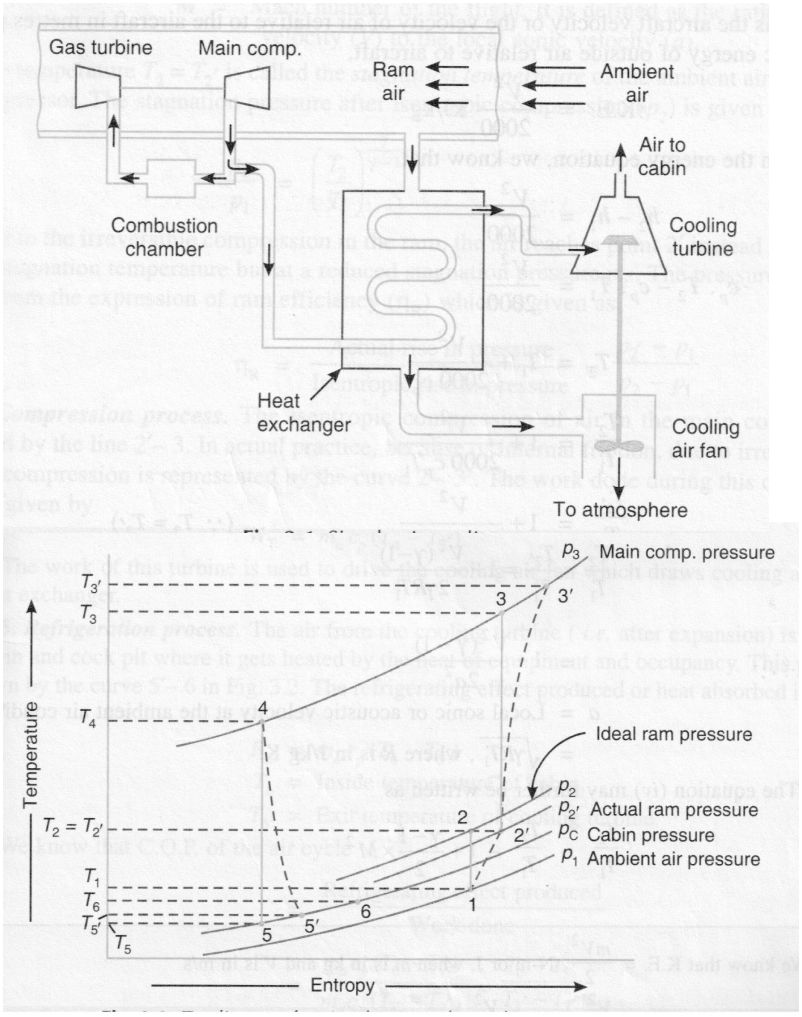
Q. 1 B a) Vortex Tube refrigeration **(Fig: 3 Marks, Explaination:3 marks)**



Vortex Tube

Vortex tube is simple device of producing cold. A compressed air is passed tangentially through nozzle. Here air velocity increases due to expansion and particular shape of nozzle. A vortex flow is created in the chamber and air flows in spiral motion along periphery of hot side. This flow is restricted by valve. If the pressure of air near valve is increased by partly closing of valve, a reversed axial flow through the core of hot side starts from high pressure to low pressure region. During this process, energy transfer takes place between reversed stream and forward stream through the core gets cooled below the inlet temperature of the air in the vortex tube while air stream in forward direction gets heated. The cold stream is escaped through the diaphragm hole into the cold side, while hot stream is passed through the opening valve.

Q. 1 B b) Simple Air-craft cooling system (Fig: 3 Marks, T-s Dig:3 marks)

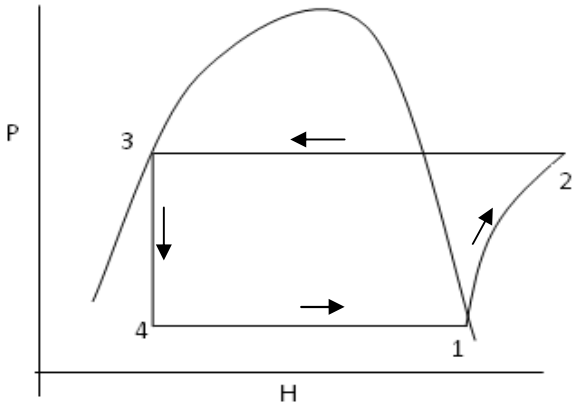


Q. 2 a) Solution :

Given Load = 10 tones.

= 10 × 3.517

= 35.17 KJ/sec. **(01 mark)**



Assume, there is no under cooling.

Total refrigeration effect.

$$N = m_{ref.} (H_1 - H_4)$$

$$35.17 = m_{ref.} (185\text{-}70)$$

$$\therefore mref = \frac{35.17}{115} = 0.3058 \frac{Kg}{sec}. \quad \textbf{(02 mark)}$$

Total Power $= m_{ref} (H_2 - H_1)$

$= 0.3058 (206\text{-}185)$

$= 6.4218$ KJ/sec.

= 6.4218 KW **(02 mark)**

$$COP = \frac{N}{W} = \frac{35.17}{6.4218} = 5.476$$ **(02 mark) (01 mark for appropriate fig.)**

Q 2 b) Heat Load for MQC(MRC) Lab (04 Heat sources with explanation: 02 marks each)

MQC lab has mainly M.S./C.I. instruments which has more thermal conductivity and take much heat whenever the air conditioning unit is off . Other heat load coming is as follows

a) Conduction: due to sunlight, the wall gets heated in day hours. Due to hot walls heat is received from outside

b) Radiation: as the lab is packed with glass windows and curtains, the amount of heat infiltrated is not much more some heat may leak in from window /door frame gaps.

c) Occupants load:- The occupants are staff, students in batches .so the heat load coming on lab during practical hours is more.

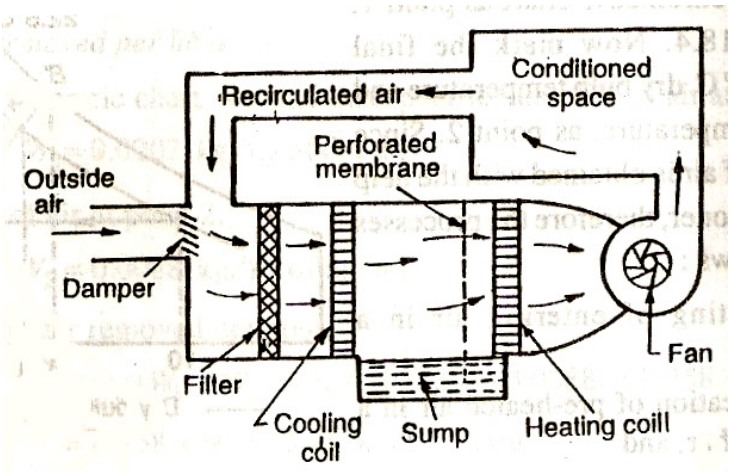
d) Equipments: the main equipments in lab are tubes, A/c equipments, bulbs etc.

The lab dimensions are about 18^I x 30^I. To have complete maintenance of temperature about 20 ^oC, RH about 60 % with apparatus bypass factor of 0.15,
Requirement; 4 split air conditioners of 1.5 capacity each is suggested.

(This is for particular Institute. Answer may differ)

Q. 2 c) Summer Air conditioning System (Fig: 04 marks, Explanation: 04 marks)

This system is used in summer air conditioning applications. In this system air is cooled and generally dehumidified. Schematic diagram is shown in figure. The outside air flows through damper and mixes up with recirculated air .which is obtained from air conditioned space. The mixed air passes through a filter to remove dirt, dust and other impurities. The air now passes through cooling coil. The coil has a temperature much less than required dry bulb temperature of the air in the conditioned space. The cooled air passes through a perforated membrane and loses its moisture in the condensed form which is collected in a sump. Air now passes through a heating coil which heats up the air slightly, in order to bring air to requisite DBT and relative humidity. Now conditioned air passes to conditioned space by a fan. From the conditioned space the part of air is exhausted to atmosphere by exhaust fans or ventilators. The remaining part of the used air or recirculated air is again conditioned as shown in the figure. The outside air is sucked and made to mix with recirculated air in order to make up for the loss of conditioned or used air through exhaust fans or ventilators from conditioned space.



. Summer air conditioning system.

Q 3 a) Difference between Heat Pump & Refrigerator (4 points: 01 mark for each point)

Basis	Heat Pump	Refrigerator
Def of COP	COP is the ratio of heat delivered to source to work done	COP is the ratio of heat removed from sink to work done
COP values	More than COP of Ref	More than 1
Important function	Amount of heat supplied to source is important	Amount of heat removed from sink is important
Application	For space/ room heating	For space cooling / refrigeration

Q3 b) (04 marks for proper classification)

Classification of condensers

i. Air-cooled
   a) Natural circulation air cooled condensers,
   b) Force circulation air cooled condensers

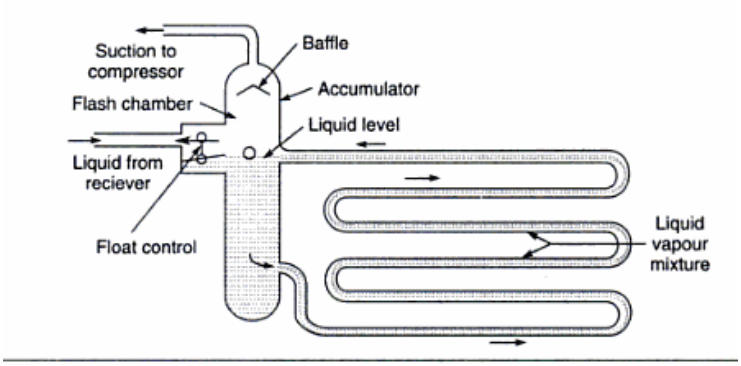
ii. water cooled
   a) Double tube type
   b) Shell and coil condensers
   c) Shell and tube condensers

iii) Evaporative condensers

Q 3 c) Function of Evaporator (01 mark for function 01 for explanation, 02 marks for figure)

Def: Function of evaporator is to absorb the heat from the space or surrounding medium which is to be cooled by means of refrigeration**.**

Flooded type evaporator.



Flooded type of evaporator feeds excess of liquid refrigerant so that the exit of evaporator will be mixture of liquid and vapour refrigerant.

In flooded type of evaporator coil remains completely filled with liquid refrigerant as shown in figure. The level of liquid refrigerant is maintained constant in surge chamber by using float control. The liquid refrigerant enters into evaporator coil from surge chamber. In evaporator coil part of liquid refrigerant boils and converts into vapour. The vapour formed is collected at the top of surge chamber and remaining liquid refrigerant is returned to surge chamber. From top of surge chamber refrigerant vapours are drawn in suction line of compressor. In flooded type evaporator rate of heat transfer is very high as whole evaporator coil remains in contact with liquid refrigerant but this type of refrigerant requires large amount of refrigerant.

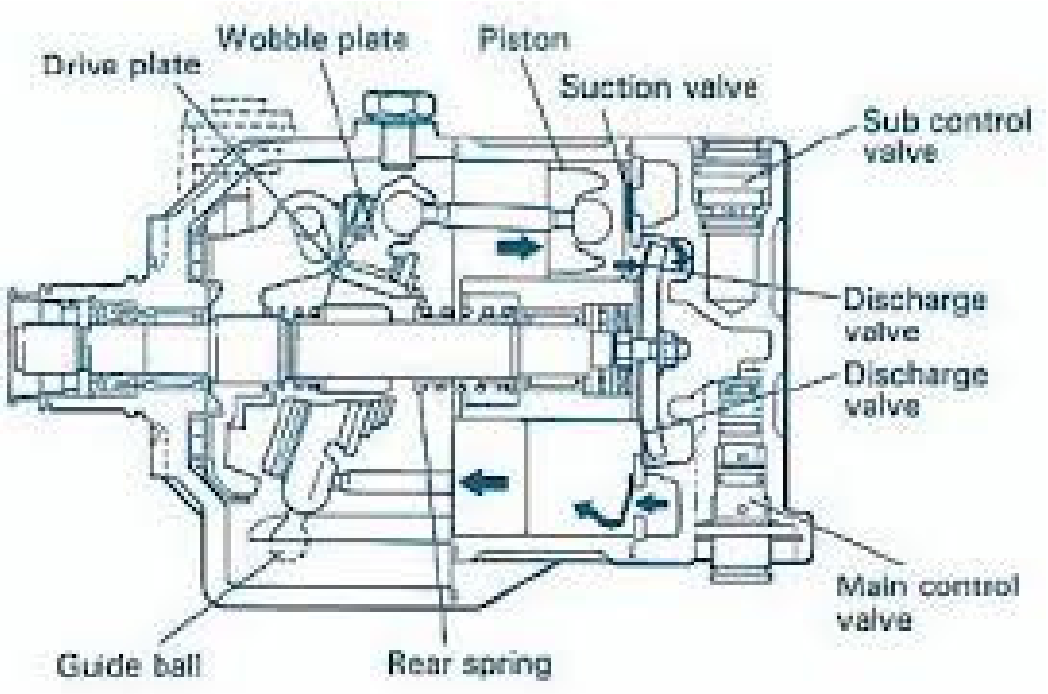
Q 3 d) Advantages of multi-staging in vapor compression system: (Any 4 points 04 Marks)

Advantages of multi-staging in vapor compression system are :

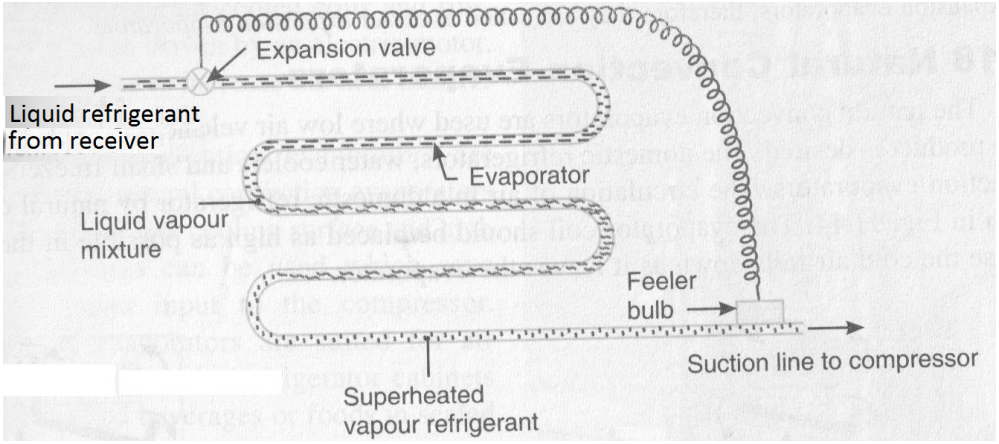
1. Work done per kg of refrigerant is reduces by using an intercooler
2. Volumetric efficiency of compressor increases
3. It reduces leakage of refrigerant
4. It gives uniform torque therefore smaller flywheel may be used
5. Effective lubrication can be done
6. Cost of compressor reduces

Q3 e) Wobble plate compressor

(fig: 04 Marks)



Q.4 A a) **(fig: 02 marks, explanation : 02 marks)**

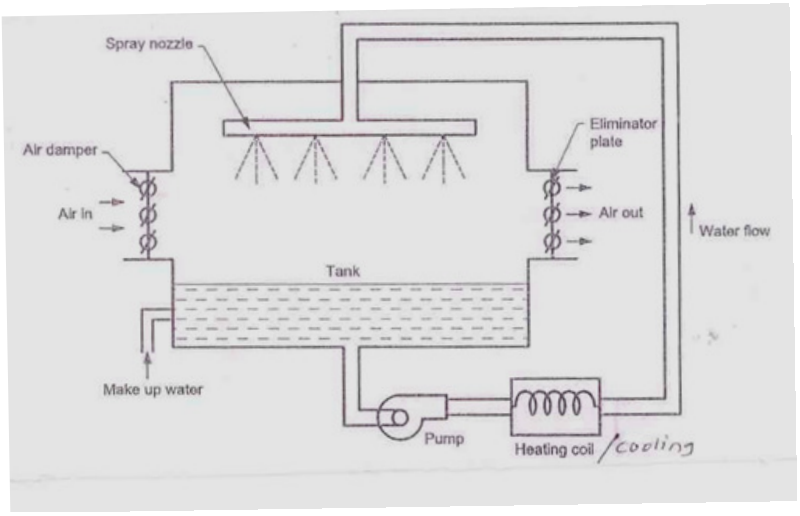


Dry expansion type chiller: This type of chiller, though named as dry expansion, is not dry in actual practice. System consists of relatively less amount of refrigerant as compared flooded type of coolers but the coil volume is kept same. The dry expansion type chiller has usually one forth to one third coil filled with liquid refrigerant.

In dry expansion process, the liquid refrigerant from the receiver is fed by the expansion valve to the evaporator coil. The importance of expansion valve is to control rate of flow of liquid refrigerant such that all liquid form refrigerant gets vaporized until it reaches end of evaporator coil i.e. at the start of compressor suction line. The rate at which liquid refrigerant taken into evaporator coil depend upon rate of vaporization. It varies according to the load on chiller. When the load is higher, the quantity of liquid refrigerant entering into coil is relatively high and vice versa. Performance of dry expansion chiller depends upon following factors:

1. Diameter of coil
2. Quantity of refrigerant in the coil
3. Velocity of liquid refrigerant within coil

Q.4 A b) Humidification by Air Washing **(fig: 02 marks, explanation : 02 marks)**



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 & get humidified. The complete process is known as Humidification by air washing.

Q.4 A c) Bypass factor and its formula (02 marks +02 marks)

When air passes over the coil, part of it comes in direct contact with the oil surface whereas the remaining part of the air just bypasses unaffected. The amount or air which bypasses depends upon velocity of flow. BPF depends upon following factors:

i. No. of fins provided per unit length of the coil

ii. No of rows in a coil in the direction of flow

iii. Velocity of flow of air

Let t_1 as DBT of air passing over cooling coil at DBT $t_2$and t_3 is DBT of leaving air

By pass Factor of the cooling coil is given by:

$$BPF = (t_{3-} t_{2)} \quad / \quad (t_{1-} t_{2)}$$

Q.4 A d) (02 marks +02 marks)

Ozone Layer Depletion & its effects on Global warming

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".

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

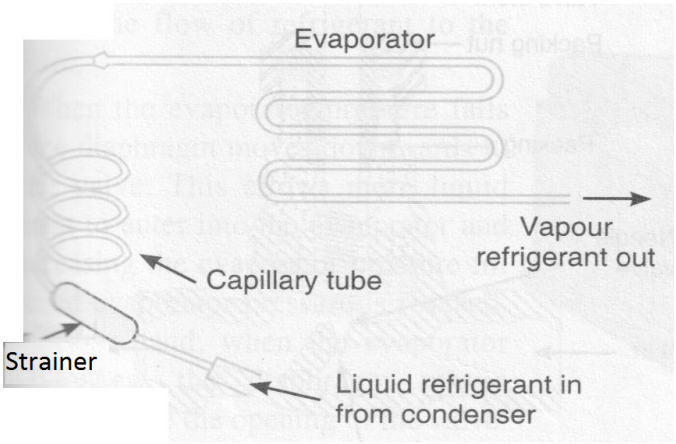
Depletion of Ozone layer leads to formation of "Ozone Holes" in the Ozone layer and through these ozone holes Harmful Ultra Violet rays enters into the atmosphere endangering the earth's biolife.

Due to "Ozone Layer Depletion" **t**he 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.**

Q.4 B a) **(02 mark for fig +02 marks for explanation and 02 mark for advantages)**

Capillary tube :



It is an expansion device used for refrigeration plants up to 3 ton capacity**.**

Its purpose is to reduce high side pressure to low side pressure so that liquid evaporate and it absorbs heat. Actually restriction in the liquid line ahead of evaporator is sufficient to satisfy this function. Capillary tube is a sufficient long metallic tube of diameter 1 /16 to 1/8 inches. Usually copper material is used. Small diameter of the tube reduces condensing pressure to evaporator pressure. The pressure drop depends upon internal diameter of the tube. Therefore it is necessary to select critically two parameters i. e. internal diameter and length of the tube.

Advantages:

1. The cost of Capillary tube is less than all other expansion devices
2. When the compressor stops, the refrigerant continues to flow into the evaporator and equalizes the pressure between the high side and low side of the system; this decreases the starting load on the compressor.
3. Since the refrigerant charge in a capillary system is critical, therefore no receiver is necessary.
4. Rough handling of appliances does not affect working of expansion device.

Q.4 B b)

Losses in Ducts **(02 marks for each)**

Losses in Ducts: Following are the losses in duct :

1. Loss due to enlargement: When section of the duct enlarges, eddies are produced between annular space t the corners. This causes loss of head. To reduce the effect of loss due to enlargement between small and large duct there is provision of transformation piece.

2. Loss due to sudden contraction: when section of the duct suddenly contracts, air entering smaller section of the duct contracts up to vena contracta. Then air expands to fill the duct. The eddies are produced in the annular space at the corners. To reduce the effect of loss due to contraction between large and small duct there is provision of transformation piece.

3. Friction loss: The pressure is lost due to friction between moving particles of the air and interior surface of the duct. When this kind of loss occurs in a straight duct it is known as friction loss. The pressure loss due to friction is calculated by using the formula as below

$$h_f = f L v^2 \ / \ 2 g D$$

Q 5 a) **(Two marks for data from psychrometric chart, 02 for m_a and 04 for H)**

From psychrometric chart at DBT 15 ^{O} C and RH 80 %

$h_1 = 36.6$ kJ/kg of dry air

$Vs_1 = 0.875$ kJ/kg of dry air

$h_2 = 44$ kJ/kg of dry air

Amount of air supplied = $m_a = (V_1 / Vs_1) = 100 / 0.875 = 114.28$ m^3 / min

Heat added $H = ma (h_2 - h_1) = 845.6$ kJ/min

Q 5 b) Comparison of VCR & VAR **(Any four, 2 marks each point)**

	Vapour compression system		Vapour absorption system
(1)	The system has more wear and tear and noise due to moving parts of the compressor.	(1)	The system is quiet in operation as it has minimum number of moving parts i.e. pump.
(2)	Energy supplied is mechanical energy i.e. high grade energy.	(2)	Energy input is mainly heat i.e. low grade energy.
(3)	Energy supplied is low. It is only ⅓ to ¼ of the R.E.	(3)	Energy supplied is high. It is about 1½ times the R.E.
(4)	The system has a poor performance at partial load.	(4)	Performance of the system is not affected by load variation.
(5)	There are more chances of leakage of refrigerant from the system.	(5)	There is no compressor or any reciprocating component to cause leakage.
(6)	Liquid traces in suction line may damage the compressor.	(6)	Liquid traces of refrigerant present in piping at exit of evaporator constitute no danger.
(7)	C.O.P. is higher than vapour absorption system.	(7)	C.O.P. is lower than vapour compression system.
(8)	Charging of refrigerant is quite simple.	(8)	Charging of refrigerant is difficult.

Q 5 c) **(02 marks for each)**

i. Absorber : The function of absorber is to absorb the weak solution of ammonia vapors and convert them into strong solution

ii. Rectifier: Vapors leaving analyzer contains some water particles. Rectifier is a cooling coil provided to remove moisture so that all water particles will be removed and only dehydrated ammonia vapors go to condenser.

iii. Analyser : It is provided to remove unwanted water particles present with ammonia vapors before going to condenser. Removal of water particles is essential because they may enter into expansion valve where freezing and chocking problems may occur.

iv. Heat exchanger: The strong solution entering into generator must be heated and weak solution coming from generator must be cooled to increase COP of system. Both these heating and cooling process is achieved in the device called as heat exchanger.

Q 6 a) **(02 for definition and 02 for significance)**

Effective temperature: in order to evaluate combined effect of DBT, RH and Air Velocity, the term used is known as effective temperature. It is defined as index which co relates combined effects of DBT, RH and Air Velocity on human body.

Significance of effective temperature:

i. It is important practically for comfort chart
ii. It gives wide range of result considering environmental temperature and RH
iii. It gives analysis of men and women comfort temperature over different regions.
iv. It gives information about different RH values

Q 6 b) **Grills and resisters** **(any 04, 01 for each figure)**

Q 6 c) **(04 marks for appropriate explanation)**

Automobile Air conditioning: the system used for automobile air conditioning works on the similar principles that other air conditioning being used. The major problem associated with automobile air conditioning is running speed of compressor. Usually ground AC systems are given electrical input to the compressor whereas in automobile, it is driven by engine shaft. While installing AC in the automobile, the compressor is mounted above the engine and it is driven by belt drive powered from front end of the engine. The condenser is mounted ahead of car radiator. The cooling coil and the blower are usually located under dashboard. Capacity of automobile AC varies from 1 ton to 4 ton.

Q 6 d) **(Any four , 01 mark each)**

Desirable properties of insulating material**:**

A) Thermal properties

1. Low thermal conductivity: Thermal conductivity of insulating material should be as low as possible to reduce the thickness of material.
2. High permanence: Materials may disintegrate as a result of internal chemical activity. Resistance to above activity is permanence. It should be high

B) Mechanical Properties:

1) It should have high strength in compression tension shear and impact as it is carrying some loads
2) It should be light weight.

C) Physical properties :

1) It should be odorless
2) It should be fire proof.
3) It should be chemically inert.

Q 6 e) **(02 marks for each)**

i. Photographic industry : in this case there is a requirement of accurate control over temperature and humidity from process point of view. Photographic film is made of cellulose easter, coated with silver salt emulsion. Photographic paper used for the films is manufactured by supplying emulsion coating on a particular highly pure wood pulp paper. All these process are carried under controlled conditions because they are sensitive to surrounding temperature and humidity. So there is a measure of significance of air conditioning system in the field of photographic industry.

ii. Textile industry: Air conditioning plays an important role in textile industry also. It is essential for production of quality textile products and reduction in the waste. The industry producing cotton, silk, rayon, wool and nylon require controlled humidity during manufacturing process. The produced goods like soft fibres are durable under controlled conditions

iii. Machine tool industry: modern technology machines like CNC, Automats, hydraulic and pneumatic computer controlled machines requires controlled atmosphere to carry out different machining operations. To maintain dimensional quality on the jobs as well as to maintain and increase life of sensitive electronics components incorporated in the machines, it is essential to have air conditioning systems.