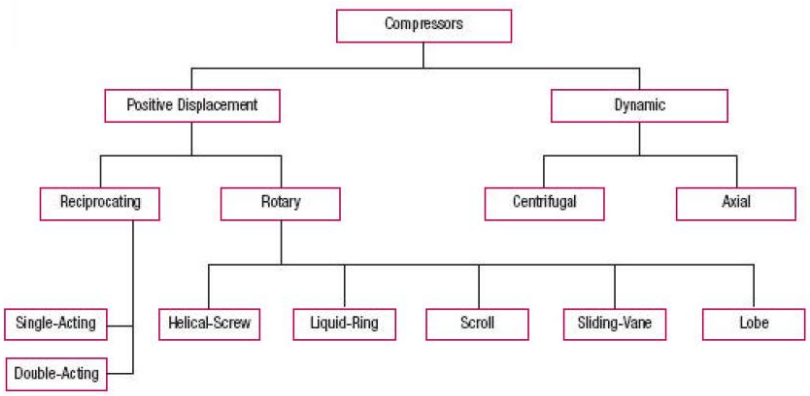
WINTER– 16 EXAMINATION

Model Answer

Subject Code: 17612

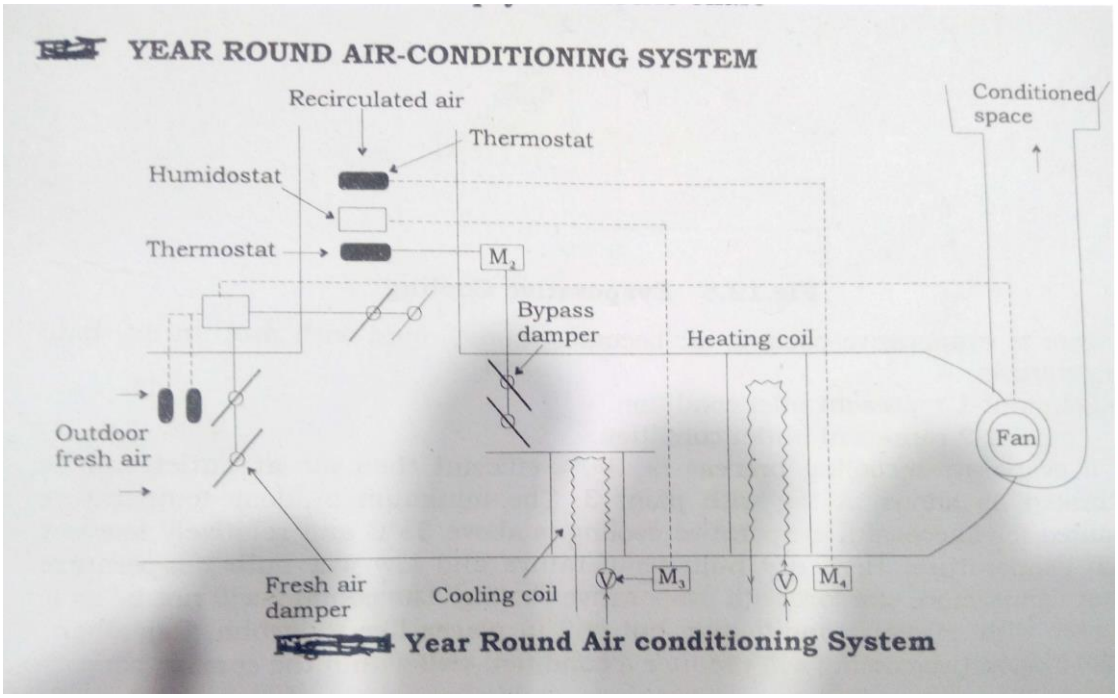
Important Instructions to examiners:

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.

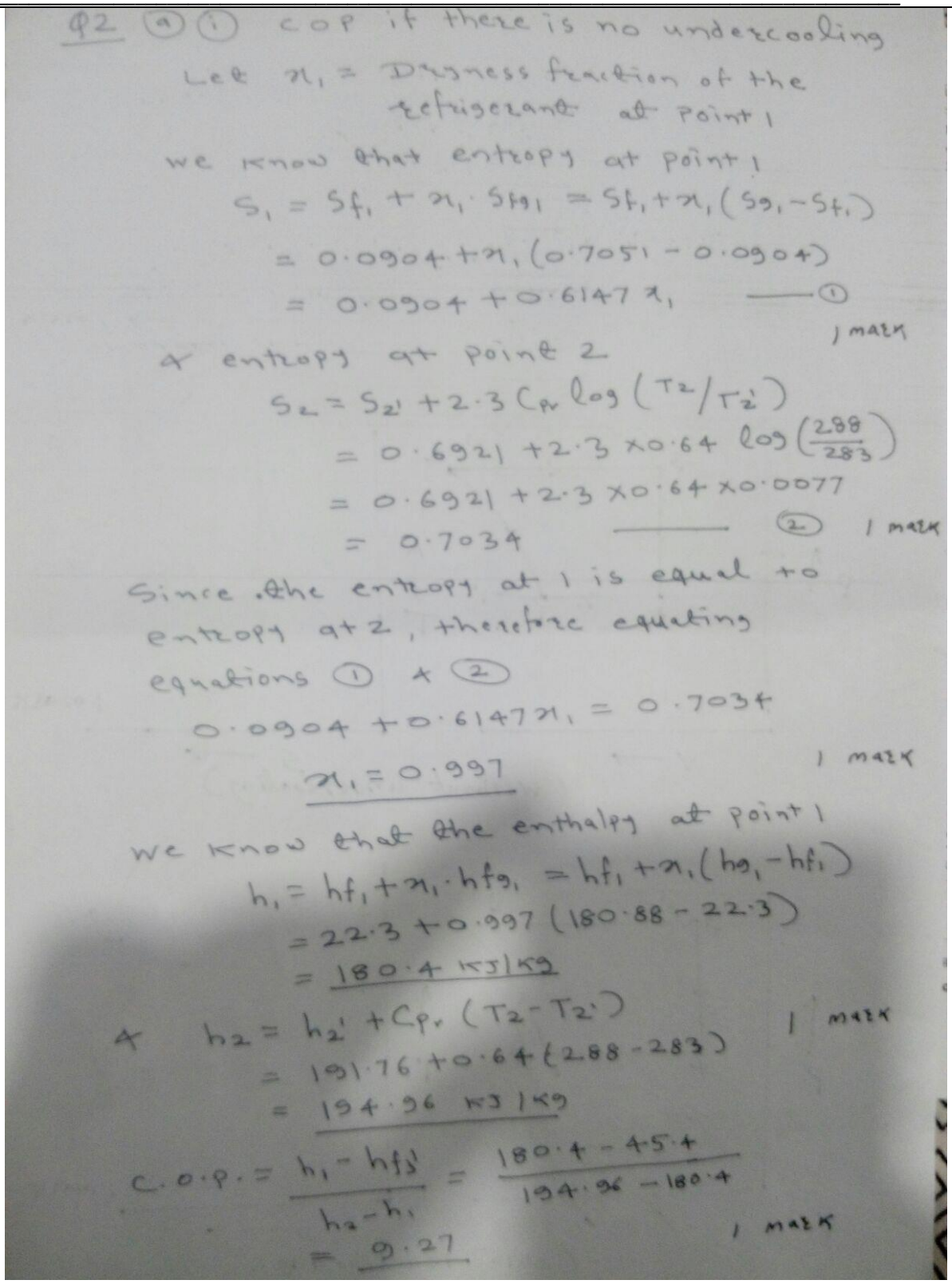
Q. No.	Sub Q. N.	Answer	Marking Scheme
1a	**I**	Refrigeration is related to the Clausius's second law of thermodynamics which states that , heat does not flow from a low temperature region to high temperature region without the aid of external energy. Energy efficiency ratio (EER) is the ratio between the cooling capacity and the power input of the Air conditioners. For example, if a 1 TR (3500 W) AC consumes 1000 watts, then the EER of the Air conditioners is 3.5 W/W. ACs with high EER consume less power.	02 +02
	Ii	COP can be increased by compressing the refrigerant in more stages with intermediate intercooling.	02+02
	Iii	COP can also be increased by subcooling the refrigerant and by removing the flashed vapour. **Compressors are classified as follows**  	04

	iv	1) The dew point depression (often abbreviated to DPD), is the difference between dry bulb temperature and dew-point temperature of air. **(2)** Relative Humidity – It is a measure of the degree of saturation of the air at any DBT. It is defined as the ratio of actual mass of water vapour in a given volume of moist air to the mass of water vapour in the same volume of saturated air at the same temperature and pressure.	02+02
1B	**I**	**Following are the factors affecting human comfort (Any six points)** **i) Effective temperature:** It is the term used for human comfort evaluated by considering the Dry bulb temperature, relative Humidity and Air velocity. **ii) Heat production and regulation in human body**: the rate of heat production depends upon the individual's health, his physical activities and his environment. The rate at which our body produces heat is termed as metabolic rate. **iii) Heat and moisture losses from the human body**: the heat is given off from the human body as either sensible or latent heat or both. **iv) Moisture content of air**: As the moisture content in air increases, it reduces human comfort. **v) Quality and Quantity of air**: Air in an occupied space should at all times, be free from toxic, unhelpful or disagreeable flumes. **vi) Air motion**: Air motion increases human comfort. **vii) Hot and Cold surfaces**: Cold or hot objects in a conditioned space may cause discomfort to the occupants. **viii) Air stratification** : the movement of the air to produce the temperature gradient from floor to ceiling is termed as air stratification.	01 for each
	Ii	Year round air-conditioning system is used for cooling the air I summer and heating the air in winter. Thus, it provides comfort condition throughout the year. Year round air-conditioning system must be capable of maintaining a specified temperature and humidity regardless of outside weather conditions. Such system is more useful as it reduces the capital cost. Problems encountered in year round air-conditioning system are heating and humidifying in winter and cooling and dehumidifying in summer. The arrangement of year round air-conditioning system is shown in fig. below. The amount of outdoor fresh air and recirculated air is controlled by thermostat. These are designed such that when outdoor air temperature is either above or below a certain selected value , the amount of outdoor fresh air is changed by action of damper motor M_1 until a minimum amount as set by the air selector 's' is reached . The temperature of air leaving the cooling coil is controlled by the motor M_2 controlling the movement of bypass damper by signal of thermostat and humidity is controlled	03+03

by separate motor M_3 by operating valve and changing circulation of chilled water in cooling coil.
(Explanation 4 marks Fig. 2 marks)



Year Round Air conditioning System

2	**a**		Marks with solution

Q2 (a) (i) COP if there is no undercooling

Let x_1 = Dryness fraction of the refrigerant at point 1

we know that entropy at point 1

$S_1 = S_{f_1} + x_1 \cdot S_{fg_1} = S_{f_1} + x_1 (S_{g_1} - S_{f_1})$

$= 0.0904 + x_1 (0.7051 - 0.0904)$

$= 0.0904 + 0.6147\, x_1$ ——— (1)

1 mark

& entropy at point 2

$S_2 = S_{2'} + 2.3\, C_{pv} \log (T_2 / T_{2'})$

$= 0.6921 + 2.3 \times 0.64 \log \left(\frac{288}{283}\right)$

$= 0.6921 + 2.3 \times 0.64 \times 0.0077$

$= 0.7034$ ——— (2) 1 mark

Since the entropy at 1 is equal to entropy at 2, therefore equating equations (1) & (2)

$0.0904 + 0.6147\, x_1 = 0.7034$

$x_1 = 0.997$ 1 mark

we know that the enthalpy at point 1

$h_1 = h_{f_1} + x_1 \cdot h_{fg_1} = h_{f_1} + x_1 (h_{g_1} - h_{f_1})$

$= 22.3 + 0.997 (180.88 - 22.3)$

$= 180.4$ KJ/KG

& $h_2 = h_{2'} + C_{pv} (T_2 - T_{2'})$ 1 mark

$= 191.76 + 0.64 (288 - 283)$

$= 194.96$ KJ/KG

$C.O.P. = \frac{h_1 - h_{f_3'}}{h_2 - h_1} = \frac{180.4 - 45.4}{194.96 - 180.4}$

$= 9.27$ 1 mark

(ii) C.O.P. when there is undercooling of 5°c

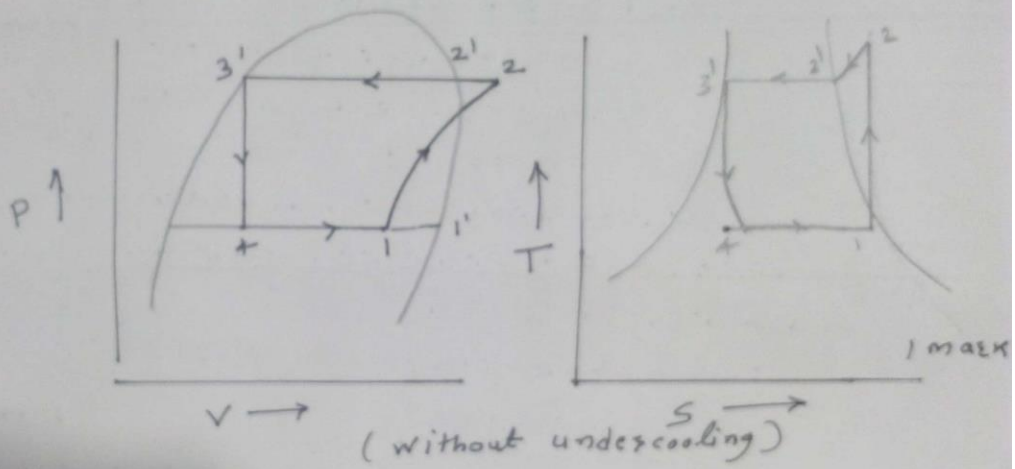
$h_{f3} = h_{f3'} - C_{p_l} \times$ Degree of undercooling

$= 45.4 - 0.94 \times 5$

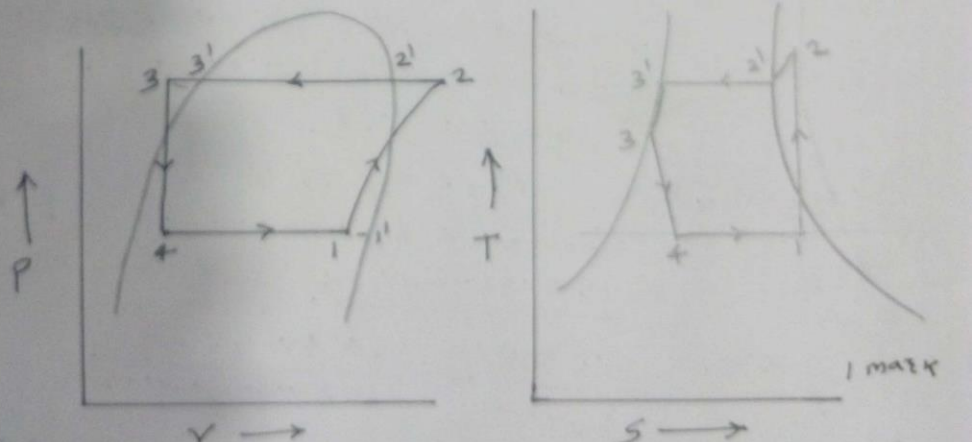
$= 40.7$ kJ/kg

$$C.O.P. = \frac{h_1 - h_{f3}}{h_2 - h_1} = \frac{180.4 - 40.7}{194.96 - 180.4}$$

$= 9.59$ → 1 mark



(without undercooling)

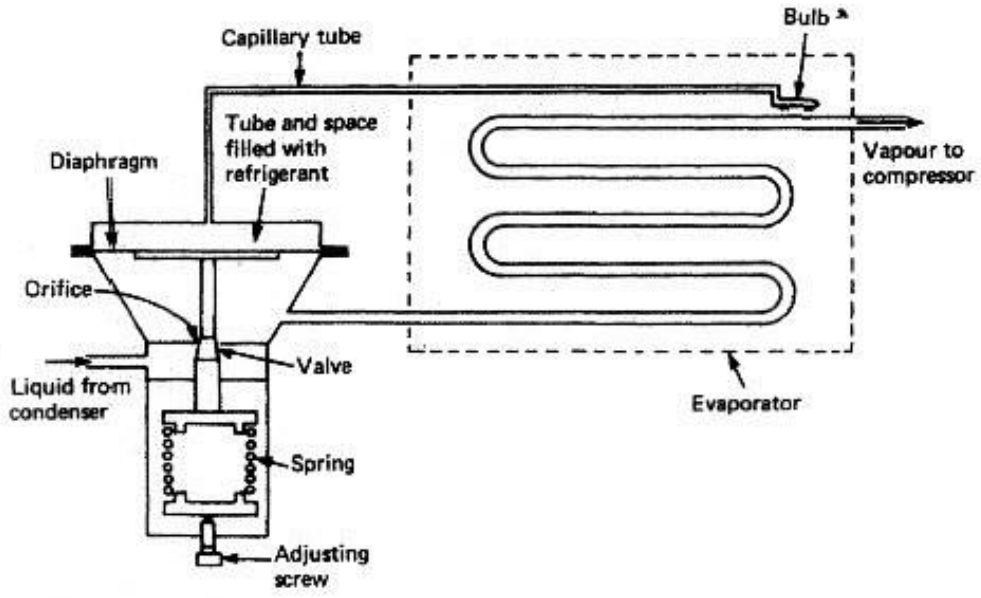


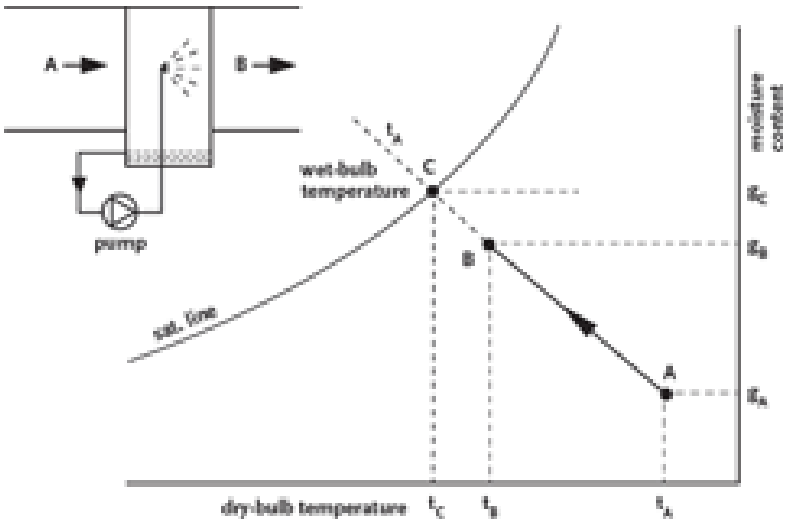
(with undercooling)

Thus in general it is preferable not to use the sin bar for measuring angles greater than 45 ^{o} if high accuracy is required

			½ mark

			each

2	**b**	An **expansion valve** is a component in refrigeration and air conditioning systems that controls the amount of refrigerant flow into the evaporator thereby controlling the superheat at the outlet of the evaporator. **Types of Expansion devices** Thermostatic EV Capillary tube Hand operated EV Automatic or Constant Pressure EV Float expansion **Explanation of Thermostatic expansion valve:**  Thermostatic expansion valve or TEV is one of the most commonly used throttling devices in the refrigerator and air conditioning systems. The thermostatic expansion valve is the automatic valve that maintains proper flow of the refrigerant in the evaporator as per the load inside the evaporator. If the load inside the evaporator is higher it allows the increase in flow of the refrigerant and when the load reduces it allows the reduction in the flow of the refrigerant. This leads to highly efficient working of the compressor and the whole refrigeration and the air conditioning plant. The thermostatic expansion valve also prevents the flooding of the refrigerant to the compressor ensuring that the plant would run safely without any risk of breakage of the compressor due to compression of the liquid. The thermostatic expansion valve does not controls the temperature inside the evaporator and it does not vary the temperature inside the evaporator as its name may suggest.	**02 Marks** **02 Marks** **(2 Marks any four points)** **(2 Marks any four points)**

C		**Various psychrometric processes are as follows** i) sensible cooling and heating ii) Latent heating and cooling iii) cooling and dehumidification iv) cooling and humidification v) heating and humidification vi) chemical dehumidification **The process of Evaporative cooling is shown as below**  It is the process in which cooling is achieved by evaporating water without transfer of heat from or to the surrounding. Thus, enthalpy remains constant during process and process takes place along constant WBT. It is achieved by direct contact of water particles and moving air stream. It can be shown on psychrometric chart as above.	**(4 Marks any four points)** 02+02

3	**a**	**Desirable properties of refrigerant:-** o It should have low boiling and freezing point. o It should have high critical pressure and temperature. o High thermal conductivity. o Non corrosive metal. o Non flammable and non explosive. o Easy to locating leaks by odour or suitable indicator. o Mixes well with oil. o Low specific volume of vapour. o High latent heat of vaporization. o Easily available. o Non toxic. o Low cost	**(4 Marks any four points)**
	b)	**Ozone layer depletion:-** Depletion of ozone layer in atmosphere allows harmful ultra-violet rays from the sun to penetrate through the atmosphere and reach the earth's surface causing skin cancer. It also effect of global warming, which may cause serious changes in environment. **Remedies to save ozone in atmosphere:-** Due to chloro-fluoro-carbon (CFC) refrigerants depletion of ozone layer. So, alter 'CFC' refrigerant by 'HFC' Hydro-fluro- carbon refrigerants. 1) HFC R-123 in place of R-11 2) HFC R-134a in lace of place of R-12	**02+02**
	c)	**Industrial applications of A/C system.** o Laboratories: to make precise measurements o Printing : to control temperature and humidity o Textile manufacture :greatly depends on moisture control o Pharmaceutical: industry needs refrigeration to reduce air borne bacteria and dirt to preserve products	02+02

- Photographic: products deteriorate rapidly at high temperatures and high humidity
- Manufacture of Precision Parts:
- Farm Animals
- Computer Rooms:
- Power Plants

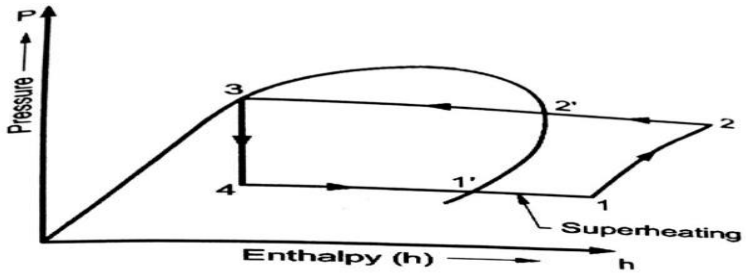
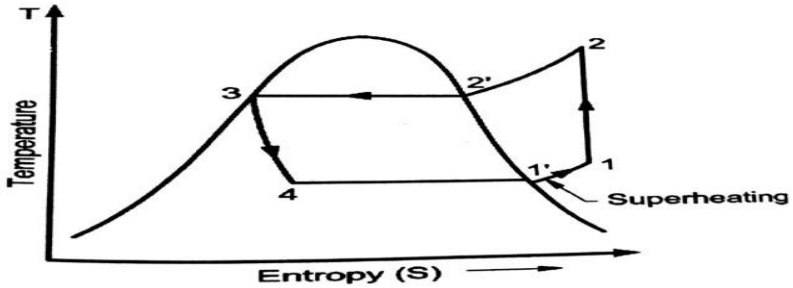
Commercial applications of A/C system.

- Houses and offices: Obtain individual selected temperature.
- Hotels and restaurants: To obtain variable load with high peak.
- Departmental Stores: Zonal air distribution to maintain uniform condition.
- Theatres & Auditoriums: Occupancy & outdoor air used.
- Hospitals:- Remove bacteria outside.

d) Differentiate between 'Central and 'Unitary' air conditioning system. Any four — 01 for each

Sr. no.	Central	Unitary
1	Ton capacity is more than 40 Ton of	Ton capacity is less than 25 Ton of refrigeration
2	Mass flow rate of air handled is around 2000m^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. Unitary air conditioning may be noisy. It is quite in operation if used as split unit. Each room can be maintained at different condition. No duct design and installation is required. Capital cost of unitary air conditioning equipment is more. Maintenance is difficult.

3	**e)**	1) To make precise measurements — 1) Obtain individual selected temperature 2) To control temperature and humidity — 2) To obtain variable load with high peak 3) Greatly depends on moisture control — 3) Zonal air distribution to maintain uniform condition 4) Industry needs refrigeration to reduce air borne bacteria and dirt to preserve products — 4) Occupancy & outdoor air used 5) Products deteriorate rapidly at high temperatures and high humidity — 5) Remove bacteria outside 6) Manufacture of Precision Parts — 6)Providing comfort air	Any four 01 for each

4a)	**i)**	**Effects of super heating on COP** 1) Increases in refrigerating effect from (h'- h4) to (h1-h4). 2) Increase in specific work of compressor from (h2-h1) to (h'2-h1). 3) Superheating increases the R. E. and amount of work supplied to compressor. 4) Increase in specific volume of suction vapour.  **(a) P-h diagram**  **(b) T-S diagram**	**02 Marks**

		Effect of Sub-Cooling on COP 1) It reduces flashing of liquid during expansion & increase refrigerating effect. 2) Although work of compression does not change with sub cooling, the COP is improved & refrigerating effect is higher. 3) Mass flow rate of refrigerant per ton is less 4) Sub-cooling improves condenser performance by increasing its efficiency.	**02 Marks**
4 a)	**ii)**	**Explain concept of SHF & RSHF** **SHF** (Sensible heat factor) The heat added during psychometric process may be split up into sensible heat and latent heat. The ratio of the sensible heat to the latent heat is known as sensible heat factor. Mathematically SHF is given as, SHF= SH/TH =SH/ (SH+LH) Where, SH= Sensible heat LH= Latent heat TH= Total heat **RSHF (**Room Sensible Heat Factor**)** It is defined as the ratio of the room sensible heat to the room total heat. Mathematically RSHF is given as,	**2 Marks** **2 Marks**

RSHF=RSH/RTH= RSH/RSH+RLH

Where,

RSH= Room sensible heat.

RLH= Room latent heat.

RTH= Room total heat.

2 Marks

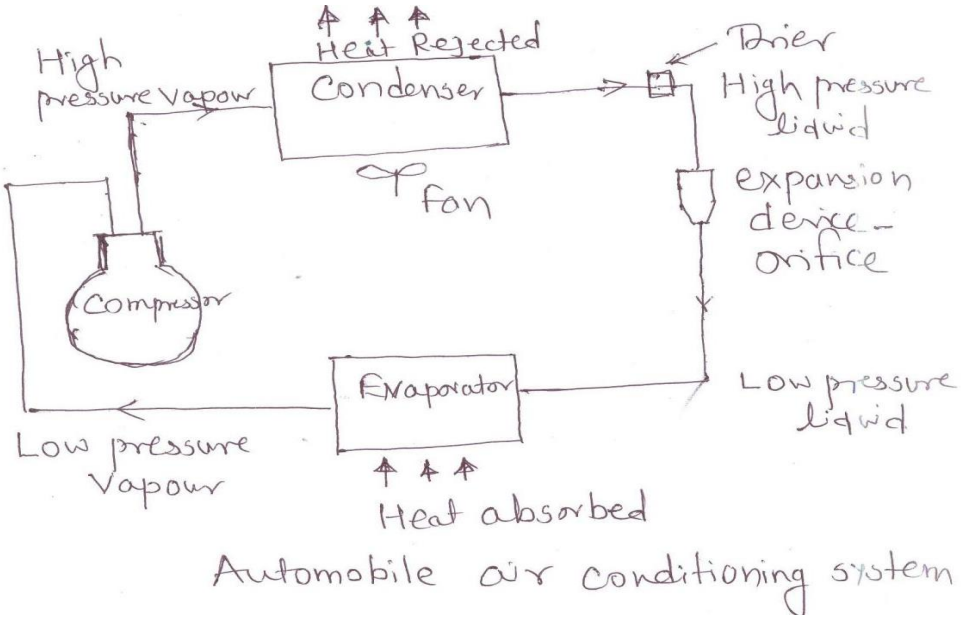
4a) iii) **Automobile air conditioning system**.

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.

2 Marks

For figure



Automobile air conditioning system

		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	
4a)	**iv)**	**Desirable properties of insulating material** • Low thermal conductivity • Adequate structural strength • Light weight. • Odourless • Nonflammable • Chemical stability • Moisture resistance • Low cost	**2 Marks**
		Insulting materials • Fiber Glass • Mineral wool • Cellular glass • Calcium silicate • Organic foams • Corkboard • Kapok • Insulating Papers	**2 Marks**
4b	**i)**	**Losses in ducts** **1) Pressure losses in ducts due to friction** The friction between moving particles of the fluid and interior surfaces of duct gives pressure losses in duct due to friction. **2) Pressure losses due to enlargement in area and static regain** When area is increases velocity decreases with rise in pressure and conversion of	**6 Marks**

velocity head in pressure head. The increase in static pressure as a result of the conversion from velocity pressure is static regain.

3) Pressure losses due to contraction in area

When air is flowing through the duct of such contraction area/ eddies are formed at two places i.e. at shoulders of the large section and beyond entry at smaller section forming a vena-contracta.

4) Pressure loss at suction and discharge of duct

The pressure is loss in case of abrupt suction opening and discharge also the air is accelerated forms vena contracta inside the duct. The area changes from infinity to the duct area.

5) Pressure loss due to an obstruction in duct

The pressure losses also occur due to various obstructions in the path of air flow from the fan to the outlet i.e. air conditioned room. The different obstructions are as:

1) Air heater 2) Air Washer 3) Air fitter 4) Screen grills

4b) ii) Different types of heat load for computer lab.

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

1 Mark

1. Sensible heat load :-

The heat gaining through room structure such as walls, floors, ceilings, doors and windows constitutes the major portion of sensible heat load.

2. Latent heat load :-

The latent heat gain due to moisture in the outside air condensation of moisture from occupants, moisture passing into conditioned space through walls or partitions.

1 Mark for each

3. Occupant load:-

The heat omitted from the bodies of the people also constitutes a major portion of a summer cooling load. The heat quantities given u by the occupants are dependent on activity of persons, sex, age and indoor dry bulb temperature.

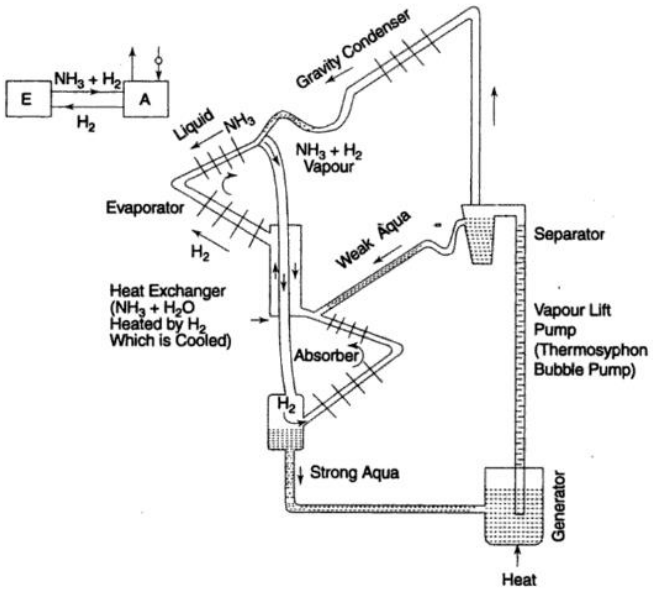
4. Lighting and application load :-

Electric fans, hot plates and lighting equipments generate heat and it is given up in air conditioned space. One of the major loads in many air conditioning systems is the light load.

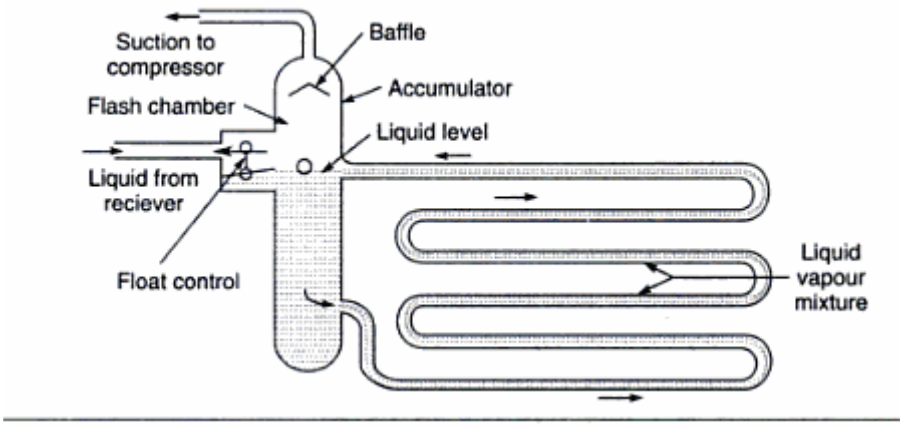
5. Infiltration load:-

The outdoor air enters into the air conditioned space through window cracks and through doors when opened. It is general practices to assume an infiltration factor of $5m^3$ per hour per m^2 of window and door area.

5	a	Electrolux principle works on *3-fluid system*. There is no solution circulation pump. Total pressure is the same throughout the system. The third fluid remains mainly in the evaporator thus reducing partial pressure of refrigerant to enable it to evaporate at low pressure and hence low temperature. The schematic diagram of the Electrolux Refrigeration system working on NH_3–H_2O system with H_2 as the third fluid is shown in Fig. Liquid NH_3 evaporates in the evaporator in the presence of H_2. Hydrogen is chosen as it is non-corrosive and insoluble in water. A *thermosyphon bubble pump* is used to lift the weak aqua from the generator to the separator. The discharge tube from the generator is extended down below the liquid level in the generator. The bubbles rise and carry slugs of weak NH_3-H_2O solution into the separator. Two *U-bends* are provided as *vapour-locks* to prevent H_2 from getting into the high side or solution circuit.	Neat labeled sketch 04 marks, Explanation 04 marks



b Flooded type of evaporator:-



Neat labeled sketch 03 marks, Explanation 03 marks Applications 02 marks

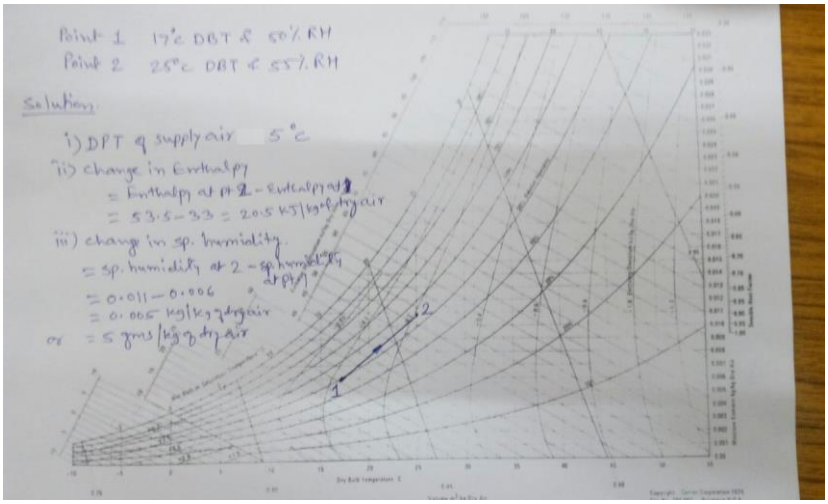
Flooded type of evaporator feeds excess of liquid refrigerant so that the exit of evaporator will be mixture of liquid and vapour refrigerant. In flooded type of evaporator coil remains completely filled with liquid refrigerant as shown in figure. The level of liquid refrigerant is maintained constant 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.

Applications of flooded type evaporator:- This type of evaporator are used for

1) Large installations, where refrigerating capacity is high.

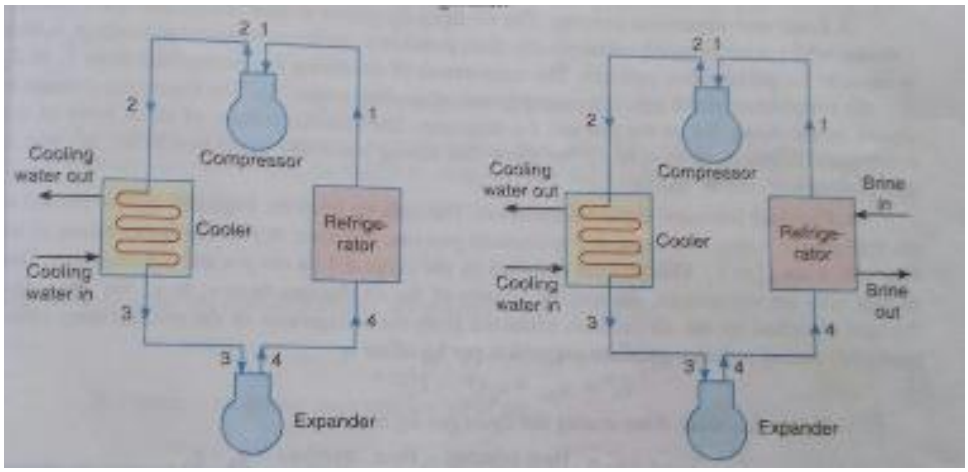
2) In a refrigeration system where load fluctuation are higher.
3) For multi evaporator system.

c



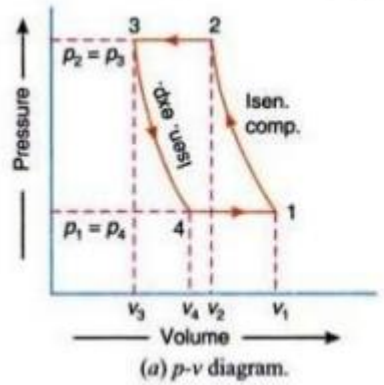
Correct solution 03 marks
Psycrometric chart 03 marks
Representation on chart 02 marks

6 **a** Bell coleman cycle of refrigeration:

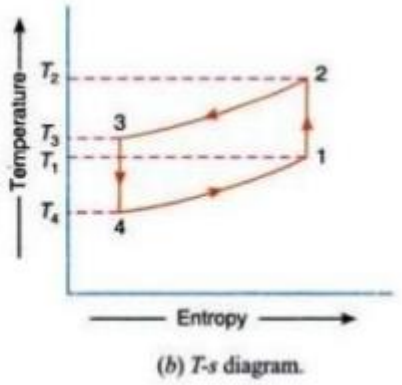


Neat labeled diagram 02 marks

PV & TS diagram 01 mark each



(a) p-v diagram.



(b) T-s diagram.

b

Classification of refrigerants:-

Refrigerants are broadly classified as

1. Primary refrigerants 2. Secondary refrigerants

Primary refrigerants further classified into four groups

1. Hallo-carbon or organic refrigerants
   e.g. R-11, R-12,R-13,R-22 R134a etc.
2. Azeotropes refrigerants
   e.g. R-500, R-502,R-503,R-504 etc.
3. In organic refrigerants
   R-717, R-729,R-744,R-764 etc.
4. Hydro-carbon refrigerants
   R-170, R-290,R-600,R-600a, R-1130, R-1150,R-1270 etc.

Classification 02 marks

Refrigerant name 02 marks

C

Need of multistaging:-

In case of a Refrigeration system very low pressure refrigerant vapors (Evaporator pressure) are to be compressed to very high pressure refrigerant vapors (Condenser pressure). As this pressure ratio is very high the size and work done required in case of single stage is more, thus COP decreases TO increase COP and reduce work done multistaging is needed.

Advantages of multistage vapor compression system:

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

Limitations of multistage vapor compression system:

1. More than one compression is used

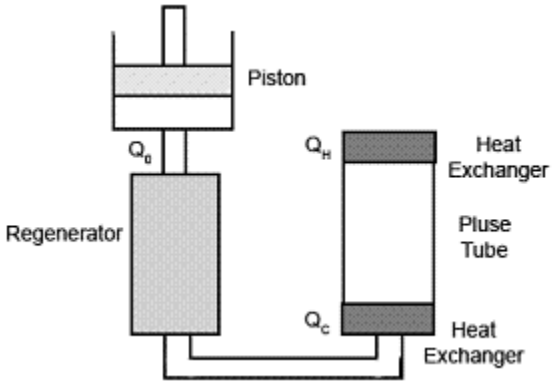
Need

Advantages

Limitations 04 marks

2. Inter-cooling system is required
3. System is complicated

d Explain the concept of pulse tube Refrigeration.



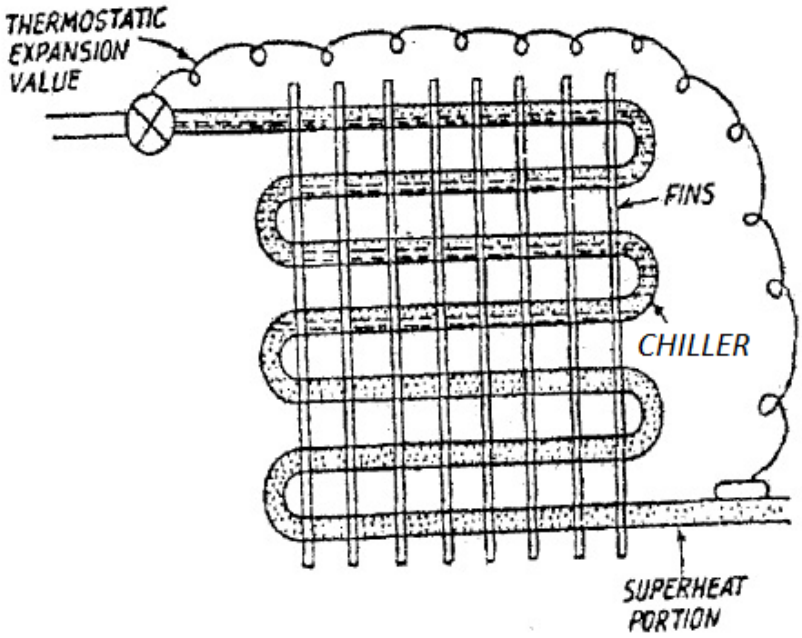
Neat labeled sketch 02marksExplanation 02 marks

The first pulse tube was built in 1963 by Gifford and Longsworth. [2] Its basic components include a pulse tube, a regenerator, a pressure wave generator, and two heat exchangers as shown in Fig. 1. The pulse tube is a simple tube with one open end and one closed end. The closed end is the hot end and is capped with a heat exchanger that cools it to the ambient temperature. The open end is the cold end. It is connected to the regenerator and a cold stage by a second heat exchanger. The regenerator is a periodic flow heat exchanger. It absorbs heat from gas pumped into the pulse tube precooling it, and stores the heat for half a cycle then transfers it back to outgoing cold gas in the second half of the cycle cooling the regenerator. The interior of the regenerator tube is filled with either
stacked fine mesh screens or packed spheres to increase its heat capacity. A piston, compressor or similar pressure wave generator is attached to the warm end of the regenerator and provides the pressure oscillations that drive the refrigeration. Helium is used as the working gas due to its monotonic ideal gas properties and low condensation temperature. In systems with a base temperature below 2K the He3 isotope is used.

e **Dry expansion chiller:-**

Dry expansion chiller is a simple tube type chiller. In dry expansion chiller the liquid refrigerant from the receiver is fed by expansion valve to the chiller. The expansion valve controls the rate of flow of liquid refrigerant in such a way that all the liquid refrigerant is vaporized by the time it reaches at the end of the chiller coil or the suction line of the compressor. The vapor is also superheated to some extent. The rate of refrigerant flow depends on load, it increases when

load increases and vice versa.



DRY EXPANSION CHILLER

Neat labeled sketch 02marksExplanation 02 marks