1237

Code : 20ME52I

Register Number | | | | | | | | | | |

V Semester Diploma Examination, June/July-2023

HEATING VENTILATION AND AIR CONDITIONING – (HVAC)

Time : 3 Hours] **[Max. Marks : 100**

Instructions : (i) Answer one full question from each section.
(ii) Use of Psychrometric chart is allowed.
(iii) Use of E20 form or other form is allowed.

SECTION – I

1. (a) Psychrometric chart is a very important tool used in measuring properties of moist air, on such a psychrometric chart show the following processes. **5**
   (1) Sensible heating
   (2) Sensible cooling
   (3) Humidification
   (4) Dehumidification
   (5) Heating & humidification

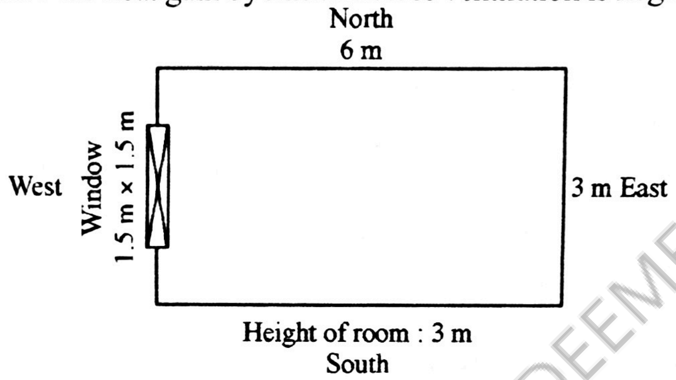
   (b) An air-conditioned room that stands on a well-ventilated basement measures 3 m wide, 3 m high & 6 m deep. One of the two 3 m walls faces west & contains a double-glazed glass window of size 1.5 m by 1.5 m, mounted flush with no external shading. There are no heat gains through the walls other than the one facing west. Calculate the sensible, latent, Total heat gains on the room, room sensible heat factor (SHF) and also calculate the cooling capacity required in T.R. (Tons of refrigeration) from the following information. **15**
   (Use E20 form or any other similar form or any other method.)
   Inside condition : 25 °C dry bulb, 50% RH
   Outside condition : 43 °C dry bulb, 24 °C wet bulb
   U-value for wall : 1.78 w/m^2 K.
   U-value for floor : 1.2 w/m^2 K.
   U-Value for roof : 1.316 w/m^2 K.
   U-value for glass : 3.12 w/m^2 K.
   Effective temperature difference (ETD) for wall : 25 °C
   Effective temperature difference (ETD) for roof : 30 °C
   Solar Heat gain (SHGF max) of glass : 300 w/m^2
   Internal shading co-efficient (SC) of glass : 0.86
   Occupancy 4 people : (90 W sensible heat/person)
   (40 W latent heat/person)

[Turn over

Lighting load : 33 W/m^2 of (floor) area.

Appliance load : 600 W (sensible) 300 W (latent)

Since the room stands on a well-ventilated basement, assume the conditions in the basement to be the same as that of the outside (i.e., 43 °C DBT, 24 °C WBT), also the floor is not exposed to the solar radiation assume the effective temperature difference for the floor is same as temperature difference between the outdoor & indoor. Here the heat gain by infiltration & ventilation is neglected.



2. (a) It is known that sun, earth and its geometrical position & orientations play a very important role in energy engineering, with respect to this discuss the below sun angles : **5**
   (i) Hour angle
   (ii) Angle of incidence

   (b) The following data relates to the office air conditioning plant having maximum seating capacity of 25 occupants. **15**

   Outside design conditions : 34 °C DBT, 28 °C WBT

   Inside design conditions : 24 °C DBT, 50% RH

   Solar heat gain : 120 W

   Sensible heat gain per occupants : 90 W/person

   Latent heat gain per occupants : 105 W/person

   Lighting load : 2300 W

   Sensible heat load from other sources : 11630 W

   Infiltration load : 14 m^3/min.

   Find the sensible heat load. Total heat load & capacity of the plant in TR for this Total heat load. Use psychrometric chart to obtain specific volume & enthalpy.

SECTION – II

3. (a) The refrigeration is a heat carrying medium which absorbs heat from the low temperature system and discharges the heat to the high temperature system. It is the life blood of any HVAC system. As refrigerant is very essential for this thermodynamics cycle it needs to possess certain desirable properties. Discuss the required properties of refrigerants. **12**

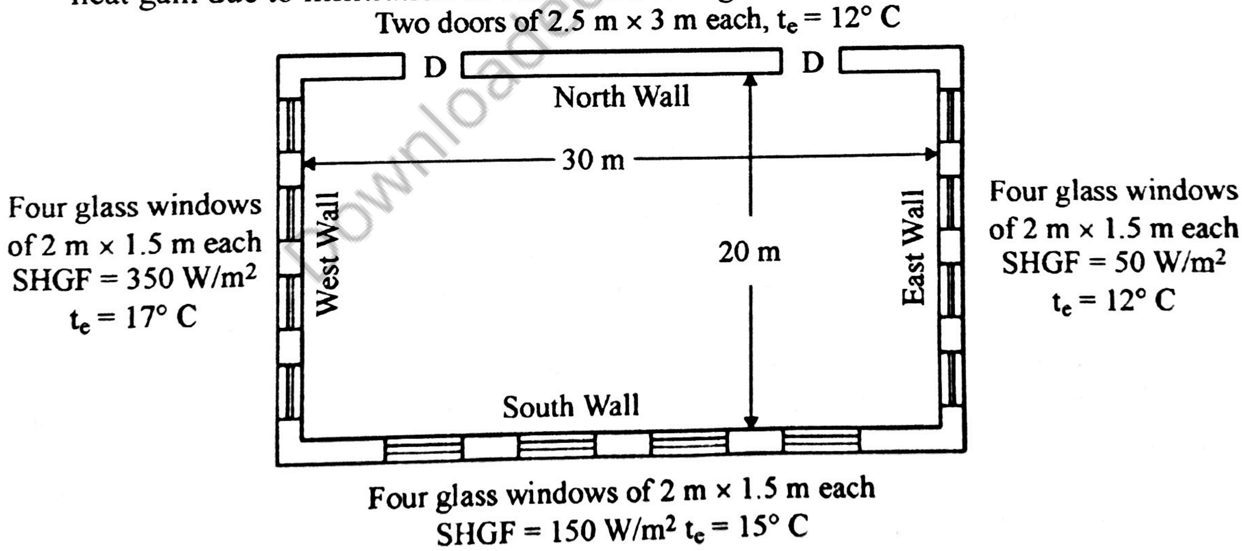
   (b) Residents from a locality were looking for more comfort than they were getting from window air conditioners in the summer and they were tired of installing and store the heavy and bulky units so, they were in need of a ductless HVAC system to resolve this issue. In this context differentiate ducted & ductless air-conditioning system. **8**

4. (a) HVAC systems are equipped with Evaporator, expansion valve and condensers. Brief how do they work in an Air-Conditioning system. **12**

(b) If you are approached by an educational trust which has recognized the need for an integrated air-conditioning solution for one of their polytechnic. The requirements was to provide the most efficient method of cooling mixed use rooms which included offices, classrooms & laboratories. For their requirement highlight any four differences between centralized & non-centralized Air-Conditioning system. **8**

SECTION – III

5. A laboratory measuring 30 m × 20 m × 4 m high as shown in the figure is to be air conditioned. The 30 m wall faces north. The north wall has two doors of 2.5 m × 3 m each. The south wall has four glass windows of 2 m × 1.5 m each. The east and west walls also have four windows of the same size. The lighting load is 15W fluorescent per m^2 floor area. The solar heat gain factor (SHGF) for south glass is 150 W/m^2, east glass is 50 W/m^2 and west glass is 350 W/m^2. The overall heat transfer co-efficients for wall is 2.5 W/m^2 K, roof is 2 W/m^2 K, floor is 3 W/m^2 K, door is 1.5 W/m^2k and window is 6 W/m^2K. The corrected equivalent temperature difference for north wall is 12 °C, south wall is 15 °C east wall is 12 °C, west wall is 17 °C, roof is 20 °C & floor is 2.5 °C. There are 100 persons with sensible heat 75 W/person & latent heat 55 W/person. The outdoor condition is 43 °C DBT & indoor condition is 25 °C DBT. Use a factor of 1.25 for fluorescent light. Determine room sensible heat, room latent heat, room total heat & cooling capacity in T.R. Here the heat gain due to infiltration & ventilation is neglected. **20**



6. (a) The computation of cooling load requirements in HVAC depends on the various sources of heat gain. Heat gain occurs in many ways in a building. Mention any 10 types of heat gains considered in HVAC cooling load calculations. **10**

[Turn over

(b) Psychrometric properties of air are very important in design air-conditioning systems in HVAC. **10**

Define the following Psychrometric properties.

(i) Humidity

(ii) Wet bulb temperature

(iii) Dew point temperature

(iv) Wet bulb depression

(v) Relative humidity

SECTION – IV

7. (a) It is possible to calculate the life cycle assessment of a green building to find out how it will affect the environment through its whole existence from the extraction of raw materials to construction its use, demolition and its disposal. In this context discuss about life cycle assessment with a diagram. **10**

(b) The concept of green building is an eco-friendly segment and it depends on the essential principles : "Reduce", "Reuse", & "Recycle". Brief about Green building & list any five characteristics of sustainable planning in Green buildings. **10**

8. (a) LEED (leadership in energy and environmental design) is the most widely used in green building rating system in the world. LEED certification is a globally recognized symbol of sustainability achievement and leadership. Mention any five requirements that the building should satisfy to obtain LEED certificate and mention any five benefits. **10**

(b) In a study conducted by a private firm in Delhi, it was found that energy consumption (EC) in Tilak Nagar is very different in summer & winter owing to use of AC throughout the area and found to be very high than that during winter. Mention any four design measures that can be taken to reduce head load and improve the energy efficiency of the building. Also recommend any six strategies adopted in HVAC system to meet green building requirements. **10**

SECTION – V

9. (a) A building has living room, kitchen and hall located on the ground floor. While 3 bed rooms & a small living room located upstairs. The upper portion of the house is mostly occupied during the night only. Hence it is required to establish zones in such situation. Discuss zoning & brief with a schematic diagram different zoning adopted in HVAC systems for such case. **10**

(b) Duct work is an essential part of the HVAC system. There are so many duct materials are available in the market & each serves a different purpose. so, what is the purpose of duct, what are the common shape of duct & what are the different duct materials ? **10**

10. (a) Duct design plays a very important role in HVAC, while designing ducts, pressure losses should be considered. What is static pressure, Dynamic pressure & total pressure in ducts ? Also mention any 4 types of ducts. **10**

(b) Fans are most important in regulating the volume flow rate of the air in centralized AC system. Discuss any two fan laws used in its design. **10**

SCHEME OF VALUATION

HVAC - 20ME52I

QUESTION NO		ALLOTMENT OF MARKS	MARKS	REMARKS

SECTION 1

1	a)	1 each x 5	5	
1	b)	Sensible Q_{wall} = 300.38 W - 1 mark Sensible Q_{roof} = 710.6 W - 1 mark Sensible Q_{floor} = 388.8 W - 1 mark Sensible Q_{glass} = 706.9 W - 1 mark Sensible $Q_{occupants}$ = 360 W - 1 mark Latent $Q_{occupants}$ = 160 W- 1 mark Sensible $Q_{lighting}$ = 594 W - 1 mark Sensible $Q_{appliance}$ = 600 W - 1 mark Latent $Q_{applicance}$ = 300 W - 1 makrs RSH or Sensible Q_{total} = 3660.68 W - 1 mark RLH or Latent Q_{total} = 460 W - 1 mark RSHF = 0.889 - 2 mark RTH or Q_{total} = 4120.68 W - 1 mark Cooling capacity in TR = 1.18 TR (14,160 BTU/hr) - 1 mark	15	
2	a)	Defenition - 2.5 each x 2	5	
2	b)	V_{s1} = 0.9 m^3/kg - 1 mark h_1 = 90 KJ/kg - 1 mark h_2 = 48 KJ/kg - 1 mark h_A = 59 KJ/kg - 1 mark m_a or m_1 = 15.56 kg/min - 1 mark SHG through infiltration = 2853 W - 1 mark LHG through infiltration = 8039 W - 1 mark SHG from persons = 2250 W - 1 mark LHG from persons = 2625W - 1 mark RSH or Sensible Q_{total}= 28.153 KW - 1 mark RLH or Latent Q_{total}= 10.664 KW - 1 mark RSHF = 0.725 - 2 mark RTH or Q_{total}= 38.817 KW - 1 mark Cooling load in TR = 11.09 TR (1,33,080 BTU/hr) - 1 mark	15	

SECTION 2

3	a)	Properties -2 each x 6 (List any six properties)	12	
3	b)	2 each x 4 (Any four differences)	8	
4	a)	4 each x 3	12	
4	b)	2 each x 4 (Any four differences)	8	

PTO

SECTION 3

5		Sensible Q_{wall} = 12.13 KW - 2 mark Sensible Q_{roof} = 24 KW - 2 mark Sensible Q_{floor} = 4.5 KW - 2 mark Sensible Q_{door} = 0.270 KW - 2 mark Sensible $Q_{windows}$ = 3.88 KW - 2 mark SHG_{glass} = 6.6 KW - 2 mark Sensible $Q_{persons}$ = 7.5 KW - 1 mark Latent $Q_{persons}$ = 5.5 KW - 1 mark Sensible $Q_{lighting}$ = 11.25 KW - 1 mark RSH or Sensible Q_{total} = 70.138 KW - 1 mark RLH or Latent Q_{total} = 5.5 KW - 1 mark RSHF = 0.92 - 1 mark RTH or Q_{total} = 75.63 KW - 1 mark Cooling capacity in TR = 21.6 TR (2,59,200 BTU/hr)-1 mark	20	
6	a)	1 each x 10 (Any ten heat gians)	10	
6	b)	Defenition - 2 each x 5	10	

SECTION 4

7	a)	Diagram - 4, Explanation - 6	10	
7	b)	Explanation - 5, Characteristics - 1 each x 5	10	
8	a)	Requirements - 1 each x 5, Benefits - 1 each x 5	10	
8	b)	Design measures - 1 each x 4, Strategies - 1 each x 6	10	

SECTION 5

9	a)	Appropriate diagram -3, Highlighting importance -2, Explain -5	10	
9	b)	Purpose - 2, Shapes - 1 each x 3, Materials - 1 each x 5	10	
10	a)	Defenition - 2 each x 3, Types - 1 each x 4	10	
10	b)	Equation - 2 each x 2, Definition - 3 each x 2 (any two)	10	

Model Answers for HVAC (20ME52I)

Instructions: 1) Answer ONE FULL question from each section.
2) Use of Psychrometric chart is allowed, if necessary
3) Use of E20 form or any other similar form is allowed, if necessary

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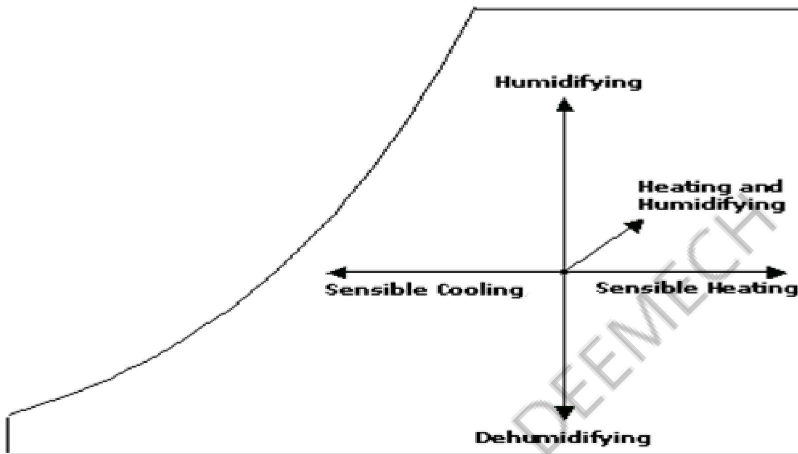
SECTION 1

1. a) Source: RAC - by CP Arora



1. b) Source: Internet- solved problem by IIT, KGP

External loads:

a) Heat transfer rate through the walls: Since only west wall measuring 3m x 3m with a glass windows of 1.5m x 1.5m is exposed; the heat transfer rate through this wall isgiven by:

$$Q_{wall} = U_{wall}A_{wall}ETD_{wall} = 1.78 \times (9-2.25) \times 25 = 300.38 \text{ W (Sensible)}$$

b) Heat transfer rate through roof:

$$Q_{roof} = U_{roof}A_{roof}ETD_{roof} = 1.316 \times 18 \times 30 = 710.6 \text{ W (Sensible)}$$

c) Heat transfer rate through floor: Since the room stands on a well-ventilatedbasement, we can assume the conditions in the basement to be same as that of the outside (i.e., 43°C dry bulb and 24°C wet bulb), since the floor is not exposed to solar radiation, the driving temperature difference for the roof is the temperature differencebetween the outdoor and indoor, hence:

$$Q_{floor} = U_{floor}A_{floor}ETD_{floor} = 1.2 \times 18 \times 18 = 388.8 \text{ W (Sensible)}$$

d) Heat transfer rate through glass: This consists of the radiative as well as conductive components. Since no information is available on the value of CLF, it is taken as 1.0. Hence the total heat transfer rate through the glass window is given by:

$$Q_{glass} = A_{glass}\,[U_{glass}(T_o - T_i) + SHGF_{max}SC] = 2.25[3.12 \times 18 + 300 \times 0.86]$$

$$= 706.9 \text{ W (Sensible)}$$

Internal loads:

a) Load due to occupants: The sensible and latent load due to occupants are:

$$Q_{s,occ} = \text{no.of occupants} \times SHG = 4 \times 90 = 360 \text{ W (Sensible)}$$

$$Q_{l,occ} = \text{no.of occupants} \times LHG = 4 \times 40 = 160 \text{ W (Latent)}$$

b) Load due to lighting: Assuming a CLF value of 1.0, the load due to lighting is:

$$Q_{lights} = 33 \times \text{floor area} = 33 \times 18 = 594 \text{ W (Sensible)}$$

c) Load due to appliance:

$$Q_{s,app} = 600 \text{ W (Sensible)}$$

$$Q_{l,app} = 300 \text{ W (Latent)}$$

Total sensible and latent loads are obtained by summing-up all the sensible and latent load components (both external as well as internal) as:

$$Q_{s,total} = 300.38+710.6+388.8+706.9+360+594+600 = 3660.68 \text{ W (RSH)}$$

$$Q_{l,total} = 160+300 = 460 \text{ W (RLH)}$$

Total load on the building is:

$$Q_{total} = Q_{s,total} + Q_{l,total} = 3660.68 + 460 = 4120.68 \text{ W (RTH)}$$

Room Sensible Heat Factor (RSHF) is given by:

$$RSHF = Q_{s,total}/Q_{total} = 3660.68.68 / 4120.68 = 0.889$$

To calculate the required cooling capacity,

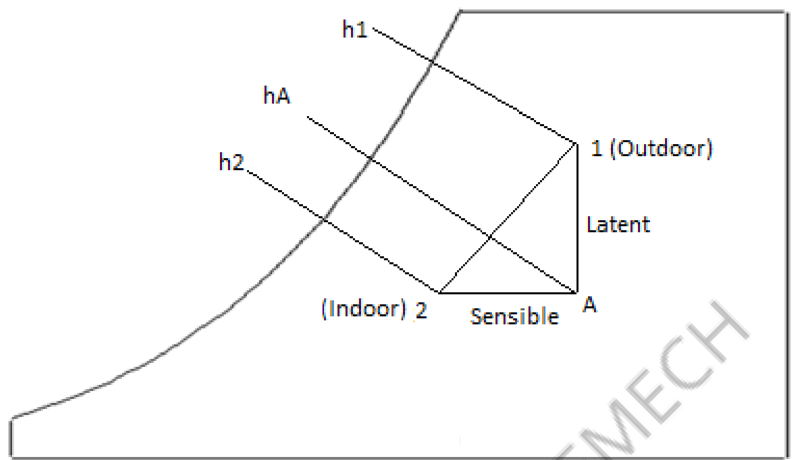
Required cooling capacity = 4.120.68 / 3.5 = 1.18 TR ≈ **1.2 TR (14,160 BTU/hr)**

2.a) Source: Non-conventional energy sources – by AK Sawhaney

Hour angle: The hour angle is the angular displacement of the sun east or west of the local meridian due to rotation of the earth on its axis at 15° per hour with morning being negative and afternoon being positive. For example, at 10:30 a.m. local apparent time the hour angle is −22.5° (15° per hour times 1.5 hours before noon).

Angle of Incidence: The angle between the normal to the plane on which the Sun is shining and the line from the surface passing through the centre of the solar disc.

2.b) Source: RAC - by RS Khurmi and JK Guptha (Problem 19.2, page 619)



From the psychrometric chart, we find that specific volume of air at point 1,

$$v_{s1} = 0.9 \text{ m}^3\text{/kg of dry air}$$

Enthalpy of air at point 1,

$$h_1 = 90 \text{ kJ/kg of dry air}$$

Enthalpy of air at point 2,

$$h_2 = 48 \text{ kJ/kg of dry air}$$

and enthalpy of air at point A,

$$h_A = 59 \text{ kJ/kg of dry air}$$

We know that mass of infiltrated air at point 1,

$$m_1 = \frac{v_1}{v_{s1}} = \frac{14}{0.9} = 15.56 \text{ kg / min}$$

∴ Sensible heat gain due to infiltration air

$$= m_1 (h_A - h_2) = 15.56 (59 - 48) = 171.16 \text{ kJ/min}$$
$$= 171.16 / 60 = 2.853 \text{ kW} = 2853 \text{ W}$$

and latent heat gain due to infiltration air

$$= m_1 (h_1 - h_A) = 15.56 (90 - 59) = 482.36 \text{ kJ/min}$$
$$= 482.36 / 60 = 8.039 \text{ kW} = 8039 \text{ W}$$

Total sensible heat gain from occupants

$$= Q_S \text{ per occupant} \times \text{No. of occupants}$$
$$= 90 \times 25 = 2250 \text{ W}$$

Total latent heat gain from occupants

$$= Q_L \text{ per occupant} \times \text{No. of occupants}$$
$$= 105 \times 25 = 2625 \text{ W}$$

$\therefore$ Total sensible heat gain in the room,

RSH = Solar heat gain + Sensible heat gain due to infiltration air + Sensible heat gain from occupants + Sensible heat gain due to lightening + Sensible heat gain from other sources

$$= 9120 + 2853 + 2250 + 2300 + 11\,630 = 28\,153 \text{ W}$$
$$= 28.153 \text{ kW}$$

and total latent heat gain in the room,

RLH = Latent heat gain due to infiltration air + Latent heat gain from occupants

$$= 8039 + 2625 = 10\,664 \text{ W} = 10.664 \text{ kW}$$

We know that room sensible heat factor,

$$RSHF = \frac{RSH}{RSH + RLH} = \frac{28.153}{28.153 + 10.664} = 0.725$$

Room Total heat (RTH) = RSH+ RLH = 28.153+10.644 = 38.817 KW

It is know that 1TR = 3.5 KW, also 1TR = 12000 BTU/hr

Cooling load TR = RTH / 3.5 = 38.817 / 3.5 = 11.09 TR (1,33,080 BTU/hr)

SECTION 2

3. a) Source: RAC - by RS Khurmi and JK Guptha

Desirable properties of Refrigerant:(Any 12 properties)

1) Low boiling point
2) Low freezing point
3) High latent heat of vapourization
4) High critical pressure and temperature
5) Low specific volume of vapour
6) High thermal conductivity
7) Non-corrosive
8) Non-flammable
9) Non-explosive
10) Non-toxic
11) Low cost
12) Easy availability
13) Easy to liquify at moderate temperature
14) Ease of leak detection by odour or suitable indication
15) Mixes well with oil.
16) High COP
17) Ozone friendly (Environmental friendly)
18) Low specific heat of liquid and high specific heat of vapour

3.b Source: www.quora.com

(Any 8 only)

	Ductless(Window or Split AC)	Duct AC
1)	Small size	Big size
2)	Versatile zoning	Uniform zoning
3)	Simple installation	Installation needs expertise
4)	More Energy efficient	Less energy efficient
5)	Low initial cost	High initial cost
6)	Lesser number of components	More number of components
7)	Low maintenance cost	High maintenance cost
8)	Less pressure losses	More pressure losses in duct
9)	Duct is not required	Duct is required
10)	False ceiling is not needed	False ceiling may be needed

4.a) Source: RAC - by RS Khurmi and JK Guptha

Evaporator: Evaporator is an important device used in the low pressure side of the refrigeration system. The liquid refrigerant from the expansion valve enters into the evaporator where it boils and changes into vapour. It means here the heat exchange is done with the room. It consists of tubes which expose to the conditioned space and absorbs the heat flowing over its tubes their by cooling the space with the help of the refrigerant which acts as working medium.

Expansion valve: Expansion valve is also known as metering device or throttling device. It is an important device that divides the high pressure side and low pressure side of HVAC system, it is connected between the condenser (containing liquid refrigerant at high pressure) and evaporator (containing liquid refrigerant at high pressure).

Condenser: The condenser is an important device used in high pressure side of any HVAC system, its function is to remove heat from hot vapour refrigerant discharged from compressor. The heat from the hot vapour refrigerant in the condenser is removed first by transferring it to the walls of the condenser tube ant then from the tubes to the condensing or cooling medium, either air or water. A fan may be used to blows air across the coils, hich point it's sent back inside to start the process over again.

4.b) Source:www.quora.com

(Any 8 only)

	Non- Centralized AC	Centralized AC
1)	False ceiling is not needed	False ceiling may be needed
2)	Simple installation	Installation needs expertise
3)	Smaller in size	Bigger in size
4)	Non-uniform (Independent) zoning	Uniform zoning
5)	Energy efficiency is more	Energy efficiency is less
6)	Duct is not required	Duct is required
7)	Lesser number of components	More number of components
8)	Low maintenance cost	High maintenance cost
9)	Less pressure losses	More pressure losses in duct
10)	Low initial cost	High initial cost

SECTION 3

5 Source: RAC - by RS Khurmi and JK Guptha (Prob19.7, page 635)

Area of one door = $2.5 \times 3 = 7.5$ m^2

Area of one window = $2 \times 1.5 = 3$ m^2

Source	*Overall heat transfer coefficient* (U) $W/m^2\,K$	*Area (A)* m^2	*Equivalent temperature difference* (t_e)°C	*Sensible heat gain* $= U.A.\,t_e$ W
1. North wall	2.5	$30 \times 4 - 2 \times 7.5 = 105$	12	$2.5 \times 105 \times 12 = 3150$
2. South wall	2.5	$30 \times 4 - 4 \times 3 = 108$	15	$2.5 \times 108 \times 15 = 4050$
3. East wall	2.5	$20 \times 4 - 4 \times 3 = 68$	12	$2.5 \times 68 \times 12 = 2040$
4. West wall	2.5	$20 \times 4 - 4 \times 3 = 68$	17	$2.5 \times 68 \times 17 = 2890$
5. Roof	2	$30 \times 20 = 600$	20	$2 \times 600 \times 20 = 24\,000$
6. Floor	3	$30 \times 20 = 600$	2.5	$3 \times 600 \times 2.5 = 4500$
7. Doors (2 Nos.) in north wall	1.5	$2 \times 7.5 = 15$	12 (Same as north wall)	$1.5 \times 15 \times 12 = 270$
8. Windows				
(*a*) South wall (4 Nos)	6	$3 \times 4 = 12$	*18	$6 \times 12 \times 18 = 1296$
(*b*) East wall (4 Nos)	6	$3 \times 4 = 12$	18	$6 \times 12 \times 18 = 1296$
(*c*) West wall (4 Nos)	6	$3 \times 4 = 12$	18	$6 \times 12 \times 18 = 1296$
				Total = 44 788 W = 44.788 kW

12.13 KW

24 KW
4.5 KW
0.27 KW

3.88 KW

Solar heat gain through south glass

= Area of four glass windows × *SHGF* for south glass

= $(3 \times 4)\,150 = 1800$ W

Similarly, solar heat gain through east glass

= Area of four glass windows × *SHGF* for east glass

= $(3 \times 4)\,50 = 600$ W

and solar heat gain through west glass

= Area of four glass windows × *SHGF* for west glass

= $(3 \times 4)\,350 = 4200$ W

6.6 KW

Total solar heat gain (sensible) through south, east and west glasses

= $1800 + 600 + 4200 = 6600$ W = 6.6 kW

Total sensible heat gain from persons

= Q_S per person × No. of persons

= $75 \times 100 = 7500$ W = 7.5 kW

Total latent heat gain from persons

= Q_L per person × No. of persons

= $55 \times 100 = 5500$ W = 5.5 kW

Sensible heat gain due to lighting

$$= \text{Total wattage of lights} \times \text{Use factor} \times \text{Allowance factor}$$

$$= 15\,(30 \times 20) \times 1 \times 1.25 = 11\,250 \text{ W} = 11.25 \text{ kW}$$

$$\ldots (\because \text{Use factor} = 1)$$

RSH or Total Sensible heat = 12.13 + 24 + 4.5 + 0.27 + 3.88 + 6.6 + 7.5 + 11.25 = 70.138 KW

RLH or Total Latent heat = 5.5 KW

RSHF = RSH / (RSH+RTH) = 70.318 / (70.318 + 5.5) = 0.92

RTH = RSH + RLH = 70.138 + 5.5 = 75.63 KW

To calculate the required cooling capacity,

Required cooling capacity = 75. 63 / 3.5 = 21.6 TR (2,59,200 BTU/hr)

6.a) Source: RAC - by RS Khurmi and JK Guptha

Sources of Heat gain for cooling load calculations: (Any 10 only)

1) Heat gain through Building structures by conduction (walls, floor, roof and ceiling)
2) Heat gain from solar radiation
3) Solar heat gain through outside walls and roofs
4) Sol Air temperature effect
5) Solar heat gain through glass
6) Heat gain due to infiltration
7) Heat grain due to ventilation
8) Heat gain from occupants
9) Heat gain from appliances
10) Heat gain from products
11) Heat gain from lighting equipment
12) Heat gain from power equipment
13) Heat gain from ducts

6.b) Source: RAC - by RS Khurmi and JK Guptha

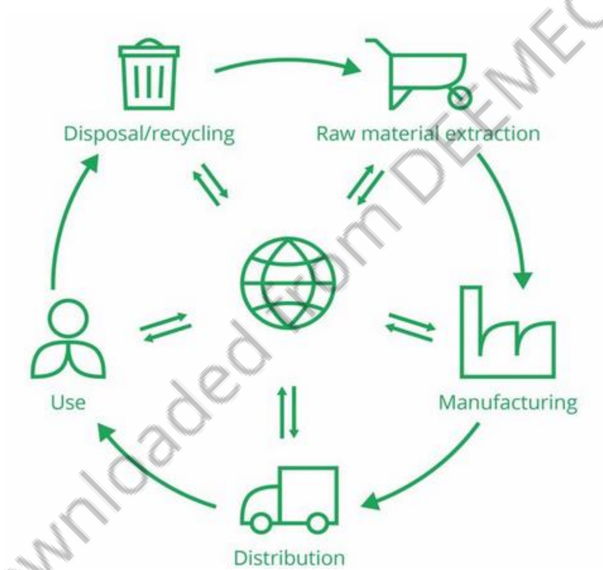
1) Humidity (Specific humidity): It is the mass of water vapour present in 1 kg of dry air.
2) Wet bulb temperature: It is temperature of recorded by a thermometer when its bulb is surrounded by a wet cloth exposed to air.
3) Dew point temperature: It is temperature of air recorded when the moisture in air begins to condense.
4) Wet bulb depression: It is the difference between the dry bulb temperature and wet bulb temperature at any given point.

5) Relative humidity: It is the ratio of actual mass of water vapour in a given volume of moist air to the mass of water vapour in the same mass of saturated air at same temperature and pressure.

SECTION 4

7.a) *Source: https://pre-sustainability.com/articles/life-cycle-assessment-lca-basics/*

Life cycle assessment (LCA), sometimes referred to as life cycle analysis, measures the impacts on the environment associated with the life cycle of a product, process, or service. Every part of a product's life cycle – extraction of materials from the environment, the production of the product, the use phase and what happens to the product after it is no longer used – can have an impact on the environment in many ways. These parts of a product's life cycle are called life cycle stages. With LCA, you can evaluate the environmental impacts of your product or service from the very first life cycle stage to the very last or to any life cycle stage in between. It can be demonstrated with the below diagram.



7. b) https://www.iberdrola.com/sustainability/sustainable-green-buildings

A green or sustainable building is a building that, because of its construction and features, can maintain or improve the quality of life of the environment in which it is located. To do this, it is essential to achieve a high level of efficiency: reducing the consumption of energy, water and other resources minimises pollution**.** The construction of buildings and other infrastructures using sustainable technologies and materials is key to this type of initiative.

Characteristics of Green buildings (Any 5 only)

1) Location and transport.
2) Sustainable sites.
3) Efficient use of water.
4) Energy and atmosphere.
5) Materials and resources.
6) Indoor environmental quality.
7) Design innovation.
8) Regional priority.

8.a) *Source :https://eartheclipse.com/environment/advantages, https://www.usgbc.org › leed › benefits-leed*

LEED certification requires the following details: (Any 5 only)

1. Site sustainability.
2. Water efficiency.
3. Energy consumption.
4. Greenhouse gas emissions.
5. Materials and natural resources.
6. Indoor environmental quality.
7. Overall carbon footprint.

Benefits of LEED certification: (Any 5 only)

1) Improved indoor air quality
2) Promotes better health
3) Improved workforce
4) Foster public relations
5) Money savings
6) Faster to obtain green goals
7) Reduce carbon emission
8) Energy and waste
9) Conserve water
10) Prioritize safer materials
11) Lower our exposure to toxins.

8.b) Source: Syllabus copy

Design Measures to reduce Heat Load & increase energy efficiency of thebuilding: (Any 4 only)

1) Solar passive techniques
2) Building orientation
3) Proper Shading
4) Window Wall Ratio
5) Building Envelope

Strategies adopted in the HVAC system tomeet green building requirements: (Any 6 only)

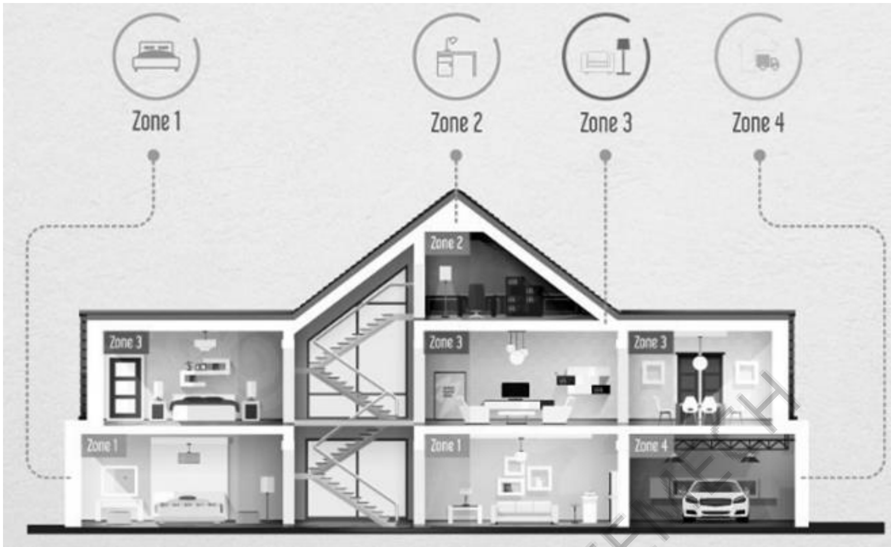
1) Selection of Chiller
2) Variable Speed Drives for Pumps
3) Fans and Compressors
4) Dedicated Outdoor Air Systems
5) Supply Air System Control
6) Demand Control Ventilation
7) Air to Air Heat Recovery System
8) Thermal Storage System for Cooling
9) Gas Fired Chillers

SECTION 5

9.a) Source: https://www.cielowigle.com/blog/what-is-an-hvac-zoning-system/

In a home, the heating or cooling preferences of the family members always differ. Similarly, different rooms in a building have different temperature requirements. Some children might want it a bit cooler, while parents may want it a bit hotter. These are examples of heating and cooling challenges that a standard HVAC can't always handle, thus necessitating HVAC zoning systems.

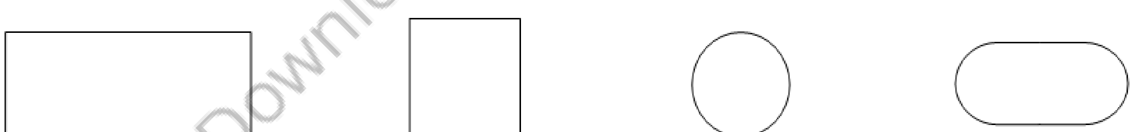
Take for example, a two-story house with the living room, kitchen, and hallway located on the ground floor, while 3 bedrooms, and a smaller living room are located upstairs. The upper portion of the house is mostly occupied during the night only. It makes sense then to establish zones in such a situation. Considering this scenario, the living room, kitchen, and hallway can be turned into one zone; the upper portion can be a whole different zone. The first zone is in continuous use throughout the day, hence a user can set its temperature as desired, while the other two zones can be switched off for the major duration of the day since they are not in use. They will only be turned on when it gets closer to bedtime in the evening. In this manner, you utilize air conditioning only when you require, and not throughout the whole day. This prevents unnecessary usage and ends up saving energy.



9.b) Source:RAC-by Er. R K Rajputh, RAC-by Manohar Prasad, RAC-by Khurmi

Duct Purpose: The main purpose of the duct is to supply the conditioned air from the central cooling coil to required space and to return the warm air from those spaces to the cooling coil.

Duct Shapes: Ducts may be of different shapes like Rectangular, square, circular or oval as shown in the diagrams below. Rectangular ducts selected should be as nearly square as possible.



Rectangular duct | Square duct | Circular duct | Oval duct

Duct material: Galvanized iron, Aluminium sheet, black steel, resin bonded glass fibre, asbestos, wood

10.a) Source: RAC-by Er. RK Rajput

Pressures in ducts:

Static pressure: It is the pressure in the duct which is independent of air movement. It is also known as stationary pressure

Dynamic pressure: It is the drop in static pressure necessary to produce a given velocity of flow. It is also known as velocity pressures

Total pressure: It is the sum of static pressure and dynamic pressure

Types of Duct: (Any 4 only)

1) Supply air duct
2) Return air duct
3) Fresh air duct
4) low pressure duct
5) Medium pressure duct
6) High pressure duct
7) High velocity duct and
8) Low velocity duct.

10.b) Source: https://eldridgeusa.com/blog/understanding-and-applying-the-3-basic-fan-laws/

Fan laws: (Any 2 only)

The 3 Basic Fan Laws provide us the means by which we can correlate the relationship between fan air flow rate, static pressure, speed and horsepower

FAN LAW 1

$$CFM_2 = CFM_1 \times \left(\frac{RPM_2}{RPM_1}\right)$$

FAN LAW 2

$$SP_2 = SP_1 \times \left(\frac{RPM_2}{RPM_1}\right)^2$$

FAN LAW 3

$$HP_2 = HP_1 \times \left(\frac{RPM_2}{RPM_1}\right)^3$$

Fan Law 1 tells us that the change in air flow rate of a fan is proportional to the change in speed of the propeller. If the propeller speed is increased by 10%, the air flow rate will also increase by 10%.

Fan Law 2 tells us that the change in total static pressure of the ventilation system will increase by the square of the change in propeller speed of the fan. If the propeller speed is increased by 10%, the total static pressure will increase 21%.

Fan Law 3 tells us that the change in horsepower required by the fan to turn the propeller will increase by the cube of the change in propeller speed of the fan. If the propeller speed is increased by 10%, the horsepower required to turn the propeller will increase 33.1%.