CHAPTER 9

REFRIGERATION & AIR-CONDITIONING

YEAR 2012 **ONE MARK**

• Common Data For Q.1 and Q.2

A refrigerator operates between 120 kPa and 800 kPa in an ideal vapour compression cycle with R-134a as the refrigerant. The refrigerant enters the compressor as saturated vapour and leaves the condenser as saturated liquid. The mass flow rate of the refrigerant is 0.2 kg/s. Properties for R134a are as follows :

Saturated R-134a					
p(kPa)	T (°C)	h_f(kJ/kg)	h_g(kJ/kg)	s_f(kJ/kgK)	s_g(kJ/kgK)
120	-22.32	22.5	237	0.093	0.95
800	31.31	95.5	267.3	0.354	0.918
Superheated R-134a					
p(kPa)		T (°C)	h (kJ/kg)		s (kJ/kgK)
800		40	276.45		0.95

MCQ 9.1 The rate at which heat is extracted, in kJ/s from the refrigerated space is

(A) 28.3 (B) 42.9

(C) 34.4 (D) 14.6

YEAR 2012 **TWO MARKS**

MCQ 9.2 The power required for the compressor in kW is

(A) 5.94 (B) 1.83

(C) 7.9 (D) 39.5

YEAR 2011 **ONE MARK**

MCQ 9.3 If a mass of moist air in an airtight vessel is heated to a higher temperature, then

Published by: NODIA and COMPANY ISBN: 9788192276250

(A) specific humidity of the air increases

(B) specific humidity of the air decreases

(C) relative humidity of the air increases

(D) relative humidity of the air decreases

YEAR 2010 **ONE MARK**

MCQ 9.4 A moist air sample has dry bulb temperature of $30^\circ C$ and specific humidity of 11.5 g water vapour per kg dry air. Assume molecular weight of air as 28.93. If the saturation vapour pressure of water at $30^\circ C$ is 4.24 kPa and the total pressure is 90 kPa, then the relative humidity (in %) of air sample is

(A) 50.5 (B) 38.5

(C) 56.5 (D) 68.5

YEAR 2009 **ONE MARK**

MCQ 9.5 In an ideal vapour compression refrigeration cycle, the specific enthalpy of refrigerant (in kJ/kg) at the following states is given as:

Inlet of condenser :283

Exit of condenser :116

Exit of evaporator :232

The COP of this cycle is

(A) 2.27 (B) 2.75

(C) 3.27 (D) 3.75

YEAR 2008 **TWO MARKS**

MCQ 9.6 Moist air at a pressure of 100 kPa is compressed to 500 kPa and then cooled to $35^\circ C$ in an aftercooler. The air at the entry to the aftercooler is unsaturated and becomes just saturated at the exit of the aftercooler. The saturation pressure of water at $35^\circ C$ is 5.628 kPa. The partial pressure of water vapour (in kPa) in the moist air entering the compressor is closest to

(A) 0.57 (B) 1.13

(C) 2.26 (D) 4.52

MCQ 9.7 Air (at atmospheric pressure) at a dry bulb temperature of $40^\circ C$ and wet bulb temperature of $20^\circ C$ is humidified in an air washer operating with continuous water recirculation. The wet bulb depression (i.e. the difference between the dry and wet bulb temperature) at the exit is 25% of that at the

Published by: NODIA and COMPANY ISBN: 9788192276250

inlet. The dry bulb temperature at the exit of the air washer is closest to

(A) 10° C (B) 20° C

(C) 25° C (D) 30° C

YEAR 2007 TWO MARKS

MCQ 9.8 A building has to be maintained at 21° C (dry bulb) and 14.5° C (wet bulb). The dew point temperature under these conditions is 10.17° C. The outside temperature is -23°C (dry bulb) and the internal and external surface heat transfer coefficients are 8 W/m^{2}K and 23 W/m^{2}K respectively. If the building wall has a thermal conductivity of 1.2 W/m K, the minimum thickness (in m) of the wall required to prevent condensation is

(A) 0.471 (B) 0.407

(C) 0.321 (D) 0.125

MCQ 9.9 Atmospheric air at a flow rate of 3 kg/s (on dry basis) enters a cooling and dehumidifying coil with an enthalpy of 85 kJ/ kg of dry air and a humidity ratio of19 grams/kg of dry air. The air leaves the coil with an enthalpy of 43 kJ/kg of dry air and a humidity ratio of 8 grams/kg of dry air. If the condensate water leaves the coil with an enthalpy of 67 kJ/kg, the required cooling capacity of the coil in kW is

(A) 75.0 (B) 123.8

(C) 128.2 (D) 159.0

YEAR 2006 ONE MARK

MCQ 9.10 Dew point temperature is the temperature at which condensation begins when the air is cooled at constant

(A) volume (B) entropy

(C) pressure (D) enthalpy

YEAR 2006 TWO MARKS

MCQ 9.11 The statements concern psychrometric chart.

1. Constant relative humidity lines are uphill straight lines to the right
2. Constant wet bulb temperature lines are downhill straight lines to the right
3. Constant specific volume lines are downhill straight lines to the right
4. Constant enthalpy lines are coincident with constant wet bulb temperature lines

Published by: NODIA and COMPANY ISBN: 9788192276250
Visit us at: www.nodia.co.in

Which of the statements are correct ?

(A) 2 and 3
(B) 1 and 2
(C) 1 and 3
(D) 2 and 4

YEAR 2005 ONE MARK

MCQ 9.12 For a typical sample of ambient air (at 35° C, 75% relative humidity and standard atmosphere pressure), the amount of moisture in kg per kg of dry air will be approximately

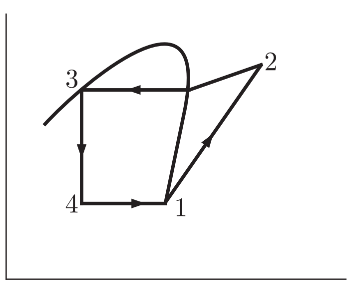
(A) 0.002
(B) 0.027
(C) 0.25
(D) 0.75

MCQ 9.13 Water at 42° C is sprayed into a stream of air at atmospheric pressure, dry bulb temperature of 40° C and a wet bulb temperature of 20° C. The air leaving the spray humidifier is not saturated. Which of the following statements is true ?

(A) Air gets cooled and humidified
(B) Air gets heated and humidified
(C) Air gets heated and dehumidified
(D) Air gets cooled and dehumidified

YEAR 2005 TWO MARKS

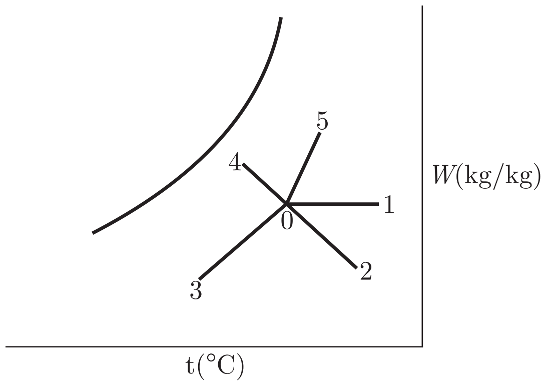
MCQ 9.14 The vapour compression refrigeration cycle is represented as shown in the figure below, with state 1 being the exit of the evaporator. The coordinate system used in this figure is



(A) p-h
(B) T-s
(C) p-s
(D) T-h

MCQ 9.15 Various psychometric processes are shown in the figure below.

Published by: NODIA and COMPANY ISBN: 9788192276250
Visit us at: www.nodia.co.in



	Process in Figure		Name of the process
P.	0 - 1	**(i).**	Chemical dehumidification
Q.	0 - 2	**(ii).**	Sensible heating
R.	0 - 3	**(iii).**	Cooling and dehumidification
S.	0 - 4	**(iv).**	Humidification with steam injection
T.	0 - 5	**(v).**	Humidification with water injection

The matching pairs are

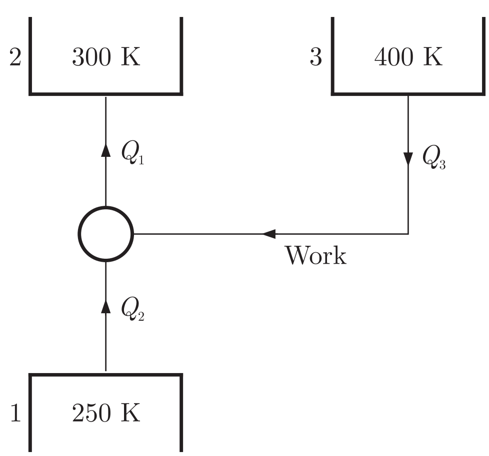
(A) P-(i), Q-(ii), R-(iii), S-(iv), T-(v)

(B) P-(ii), Q-(i), R-(iii), S-(v), T-(iv)

(C) P-(ii), Q-(i), R-(iii), S-(iv), T-(v)

(D) P-(iii), Q-(iv), R-(v), S-(i), T-(ii)

MCQ 9.16 A vapour absorption refrigeration system is a heat pump with three thermal reservoirs as shown in the figure. A refrigeration effect of 100 W is required at 250 K when the heat source available is at 400 K. Heat rejection occurs at 300 K. The minimum value of heat required (in W) is



(A) 167 (B) 100

(C) 80 (D) 20

GATE Previous Year Solved Paper For Mechanical Engineering
Published by: NODIA and COMPANY ISBN: 9788192276250
Visit us at: www.nodia.co.in

YEAR 2004 ONE MARK

MCQ 9.17 In the window air conditioner, the expansion device used is

(A) capillary tube
(B) thermostatic expansion valve
(C) automatic expansion valve
(D) float valve

MCQ 9.18 During the chemical dehumidification process of air

(A) dry bulb temperature and specific humidity decreases
(B) dry bulb temperature increases and specific humidity decreases
(C) dry bulb temperature decreases and specific humidity increases
(D) dry bulb temperature and specific humidity increases

MCQ 9.19 Environment friendly refrigerant R134 is used in the new generation domestic refrigerators. Its chemical formula is

(A) $CHClF_2$
(B) $C_2Cl_3F_3$
(C) $C_2Cl_2F_4$
(D) $C_2H_2F_4$

YEAR 2004 TWO MARKS

MCQ 9.20 A heat engine having an efficiency of 70% is used to drive a refrigerator having a coefficient of performance of 5. The energy absorbed from low temperature reservoir by the refrigerator for each kJ of energy absorbed from high temperature source by the engine is

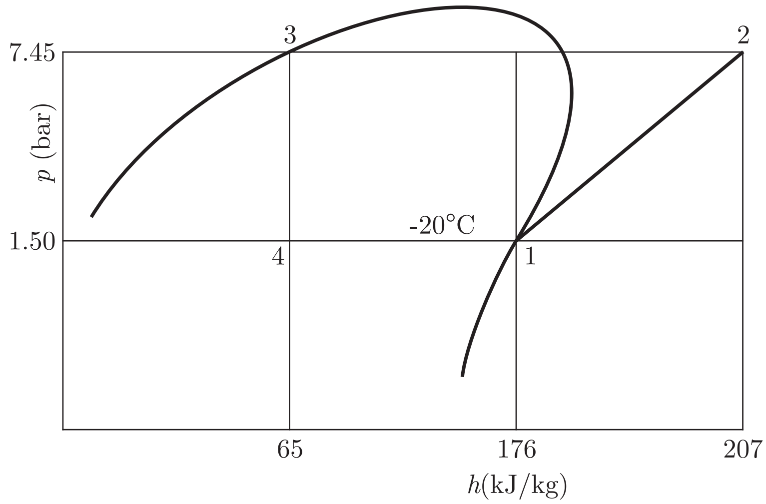
(A) 0.14 kJ
(B) 0.71 kJ
(C) 3.5 kJ
(D) 7.1 kJ

MCQ 9.21 Dew point temperature of air at one atmospheric pressure (1.013 bar) is 18°C. The air dry bulb temperature is 30°C. The saturation pressure of water at 18°C and 30°C are 0.02062 bar and 0.04241 bar respectively. The specific heat of air and water vapour respectively are 1.005 and 1.88 kJ/kg K and the latent heat of vaporization of water at 0°C is 2500 kJ/kg. The specific humidity (kg/kg of dry air) and enthalpy (kJ/kg or dry air) of this moist air respectively, are

(A) 0.01051, 52.64
(B) 0.01291, 63.15
(C) 0.01481, 78.60
(D) 0.01532, 81.40

MCQ 9.22 A R-12 refrigerant reciprocating compressor operates between the condensing temperature of 30°C and evaporator temperature of -20°C. The clearance volume ratio of the compressor is 0.03. Specific heat ratio of the vapour is 1.15 and the specific volume at the suction is 0.1089 m^3/kg. Other properties at various states are given in the figure. To realize 2 tons of refrigeration, the actual volume displacement rate considering the effect of clearance is

ISBN: 9788192276250



(A) $6.35 \times 10^{-3}\,\text{m}^3/\text{s}$
(B) $63.5 \times 10^{-3}\,\text{m}^3/\text{s}$
(C) $635 \times 10^{-3}\,\text{m}^3/\text{s}$
(D) $4.88 \times 10^{-3}\,\text{m}^3/\text{s}$

YEAR 2003 ONE MARK

MCQ 9.23 An industrial heat pump operates between the temperatures of 27°C and -13°C. The rates of heat addition and heat rejection are 750 W and 1000 W, respectively. The COP for the heat pump is

(A) 7.5
(B) 6.5
(C) 4.0
(D) 3.0

MCQ 9.24 For air with a relative humidity of 80%

(A) the dry bulb temperature is less than the wet bulb temperature
(B) the dew point temperature is less than wet bulb temperature
(C) the dew point and wet bulb temperature are equal
(D) the dry bulb and dew point temperature are equal

YEAR 2003 TWO MARKS

• Common Data For Q.25 and Q.26

A refrigerator based on ideal vapour compression cycle operates between the temperature limits of -20°C and 40°C. The refrigerant enters the condenser as saturated vapour and leaves as saturated liquid. The enthalpy and entropy values for saturated liquid and vapour at these temperatures are given in the table below.

T (°C)	h_f (kJ/kg)	h_g (kJ/kg)	s_f (kJ/kg K)	s_g (kJ/kg K)
– 20	20	180	0.07	0.7366
40	80	200	0.3	0.67

MCQ 9.25 If refrigerant circulation rate is 0.025 kg/s, the refrigeration effect is equal to

(A) 2.1 kW (B) 2.5 kW

(C) 3.0 kW (D) 4.0 kW

MCQ 9.26 The COP of the refrigerator is

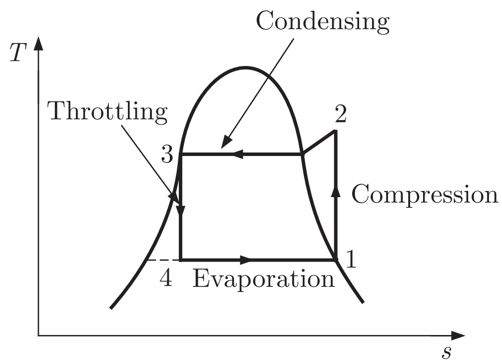
(A) 2.0 (B) 2.33

(C) 5.0 (D) 6.0

****

SOLUTION

SOL 9.1 Option (A) is correct.



T-s diagram for given Refrigeration cycle is given above

Since Heat is extracted in evaporation process.

So rate of heat extracted $= \dot{m}(h_1 - h_4)$

From above diagram $(h_3 = h_4)$ for throttling process, so

$$\text{Heat extracted} = \dot{m}(h_1 - h_3)$$

From given table

$h_1 = h_g$ at 120 kPa, $h_g = 237$ kJ/kg

$h_3 = h_f$ at 120 kPa, $h_f = 95.5$ kJ/kg

Hence $\quad$ Heat extracted $= \dot{m}(h_g - h_f) = 0.2 \times (237 - 95.5) = 28.3$ kJ/s

SOL 9.2 Option (C) is correct.

Since power is required for compressor in refrigeration is in compression cycle (1-2)

Hence, $\quad$ Power required $= \dot{m}(h_2 - h_1) = \dot{m}(h_2 - h_f)$

Since for isentropic compression process.

$$s_1 = s_2 \text{ from figure.} = 0.95$$

For entropy $s = 0.95$ the enthalpy $h = 276.45$ kJ/kg

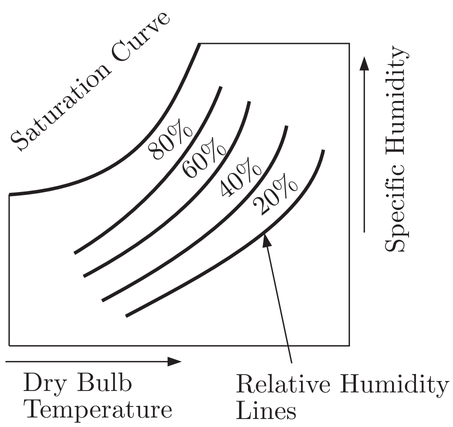
$$h = h_2 = 276.45 \text{ (From table)}$$

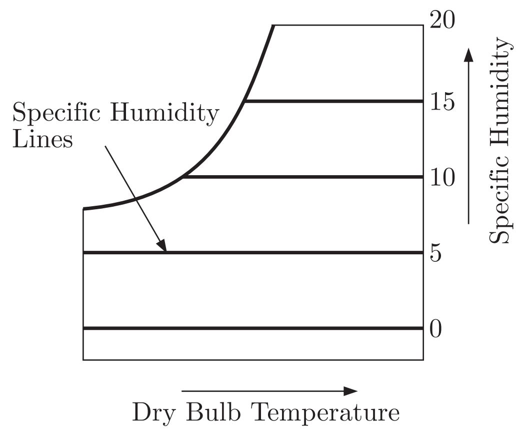
Hence $\quad$ Power $= 0.2(276.45 - 237) = 7.89 \simeq 7.9$ kW

SOL 9.3 Option (D) is correct.

From the given curve, we easily see that relative humidity of air decreases, when temperature of moist air in an airtight vessel increases. So, option (C) is correct. Specific humidity remain constant with temperature increase, so option a & b are incorrect.

GATE Previous Year Solved Paper For Mechanical Engineering
Published by: NODIA and COMPANY ISBN: 9788192276250
Visit us at: www.nodia.co.in





SOL 9.4 Option (B) is correct.

Given : $t_{DBT} = 30^\circ\text{C}$, $W = 11.5$ g water vapour/kg dry air

$p_s = 4.24\,\text{kPa}$, $p = 90\,\text{kPa}$

Specific humidity, $$W = 0.622\left(\frac{p_v}{p - p_v}\right)$$

Substitute the values, we get

$$11.5 \times 10^{-3} = 0.622\left(\frac{p_v}{90 - p_v}\right)$$

$$18.489 \times 10^{-3} = \frac{p_v}{90 - p_v}$$

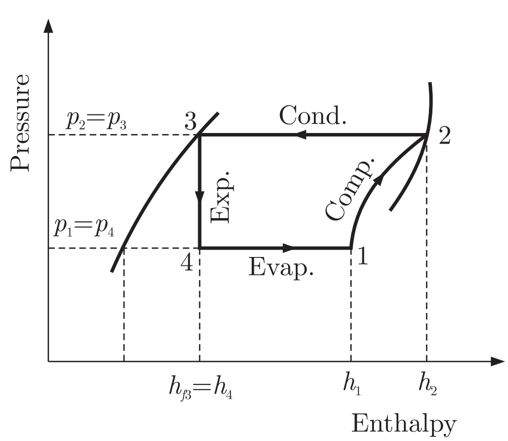
$$(90 \times 18.489 - 18.489 p_v) \times 10^{-3} = p_v \Rightarrow \quad p_v = 1.634\,\text{kPa}$$

Relative humidity $$\phi = \frac{p_v}{p_s} = \frac{1.634}{4.24}$$

$$\phi = 0.3853 = 38.53\% \simeq 38.5\%$$

SOL 9.5 Option (A) is correct.

$p - h$ curve for vapour compression refrigeration cycle is as follows



Published by: NODIA and COMPANY ISBN: 9788192276250
Visit us at: www.nodia.co.in

The given specific enthalpies are

Inlet of condenser $h_2 = 283\,\text{kJ/kg}$

Exit of condenser $h_3 = 116\,\text{kJ/kg} = h_4$ From p-h curve

Exit of evaporator $h_1 = 232\,\text{kJ/kg}$

Now, $$COP = \frac{\text{Refrigerating effect}}{\text{Work done}} = \frac{h_1 - h_4}{h_2 - h_1}$$

Substitute the values, we get

$$COP = \frac{232 - 116}{283 - 232} = \frac{116}{51} = 2.27$$

SOL 9.6 Option (B) is correct.

Given : $p_1 = 100\,\text{kPa}$, $p_2 = 500\,\text{kPa}$, $p_{v1} = ?$

$p_{v2} = 5.628\,\text{kPa}$ (Saturated pressure at 35°C)

We know that,

Specific humidity $W = 0.622\left(\frac{p_v}{p - p_v}\right)$

For case II :

$$W = 0.622\left(\frac{5.628}{500 - 5.628}\right) = 7.08 \times 10^{-3}\ \text{kg/kg of dry air}$$

For saturated air specific humidity remains same. So, for case (I) :

$$W = 0.622\left(\frac{p_{v1}}{p_1 - p_{v1}}\right)$$

On substituting the values, we get

$$7.08 \times 10^{-3} = 0.622\left(\frac{p_{v1}}{100 - p_{v1}}\right)$$

$$11.38 \times 10^{-3}(100 - p_{v1}) = p_{v1}$$

$$1.138 = 1.01138 p_{v1}$$

$$p_{v1} = 1.125\,\text{kPa} \simeq 1.13\,\text{kPa}$$

SOL 9.7 Option (C) is correct.

Given : At inlet $t_{DBT} = 40^\circ\text{C}$, $t_{WBT} = 20^\circ\text{C}$

We know that, wet bulb depression $= t_{DBT} - t_{WBT} = 40 - 20 = 20^\circ\text{C}$

And given wet bulb depression at the exit $= 25\%$ of wet bulb depression at inlet

This process becomes adiabatic saturation and for this process,

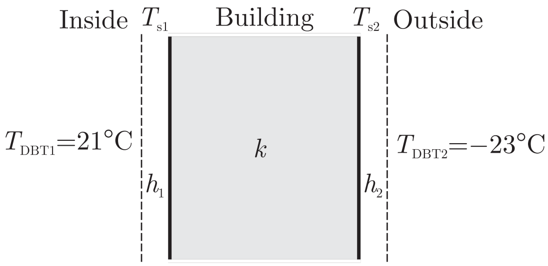
$$t_{WBT(\text{inlet})} = t_{WBT(\text{outlet})}$$

So, $$t_{DBT(\text{exit})} - 20 = 0.25 \times 20$$

$$t_{DBT(\text{exit})} = 20 + 5 = 25^\circ\text{C}$$

Published by: NODIA and COMPANY ISBN: 9788192276250

SOL 9.8 Option (B) is correct.



Let h_1 & h_2 be the internal and external surface heat transfer coefficients respectively and building wall has thermal conductivity k.

Given : $h_1 = 8\text{ W/m}^2\text{ K}$, $h_2 = 23\text{ W/m}^2\text{ K}$, $k = 1.2\text{ W/m K}$, $T_{DPT} = 10.17^\circ\text{ C}$

Now to prevent condensation, temperature of inner wall should be more than or equal to the dew point temperature. It is the limiting condition to prevent condensation

So, $$T_{s1} = 10.17^\circ\text{ C}$$

Here T_{s1} & T_{s2} are internal & external wall surface temperature of building.

Hence, heat flux per unit area inside the building,

$$q_i = \frac{Q}{A} = h_1(T_{DBT1} - T_{s1})$$

$$q_i = 8(21 - 10.17) = 8 \times 10.83 = 86.64\text{ W/m}^2 \qquad ...(i)$$

& Heat flux per unit area outside the building is

$$q_0 = h_2(T_{s2} - T_{DBT2}) = 23(T_{s2} + 23) \qquad ...(ii)$$

Heat flow will be same at inside & outside the building. So from equation (i) & (ii)

$$q_i = q_0$$

$$86.64 = 23(T_{s2} + 23)$$

$$T_{s2} + 23 = 3.767$$

$$T_{s2} = 3.767 - 23 = -19.23^\circ\text{ C}$$

For minimum thickness of the wall, use the fourier's law of conduction for the building. Heat flux through wall,

$$q = \frac{k(T_{s1} - T_{s2})}{x} = \frac{1.2 \times (10.17 + 19.23)}{x}$$

Substitute the value of q_i from equation (i), we get

$$86.64 = \frac{1.2 \times 29.4}{x}$$

$$x = \frac{35.28}{86.64} = 0.407\text{ m}$$

Note :- Same result is obtained with the value of q_o

Published by: NODIA and COMPANY ISBN: 9788192276250

SOL 9.9 Option (C) is correct.

Given : $\dot{m}_a = 3$ kg/sec,

Using subscript 1 and 2 for the inlet and outlet of the coil respectively.

$h_1 = 85$ kJ/kg of dry air, $W_1 = 19$ grams/kg of dry air $= 19 \times 10^{-3}$ kg/kg of dry air

$h_2 = 43$ kJ/kg of dry air, $W_2 = 8$ grams/kg of dry air $= 8 \times 10^{-3}$ kg/kg of dry air

$h_3 = 67$ kJ/kg

Mass flow rate of water vapour at the inlet of the coil is,

$$\dot{m}_{v1} = W_1 \times \dot{m}_a \qquad W = \frac{\dot{m}_v}{\dot{m}_a}$$

$$\dot{m}_{v1} = 19 \times 10^{-3} \times 3 = 57 \times 10^{-3}\text{ kg/sec}$$

And mass flow rate of water vapour at the outlet of coil is,

$$\dot{m}_{v2} = W_2 \times \dot{m}_a$$

$$= 8 \times 10^{-3} \times 3 = 24 \times 10^{-3}\text{ kg/sec}$$

So, mass of water vapour condensed in the coil is,

$$\dot{m}_v = \dot{m}_{v1} - \dot{m}_{v2}$$

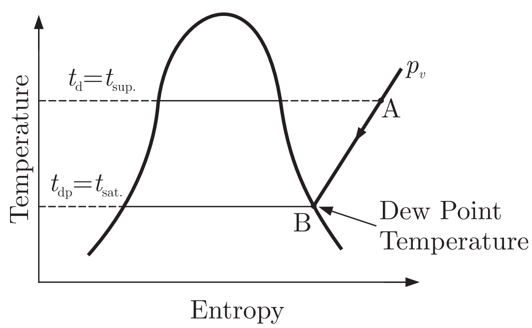
$$= (57 - 24) \times 10^{-3} = 33 \times 10^{-3}\text{ kg/sec}$$

Therefore, required cooling capacity of the coil = change in enthalpy of dry air + change in enthalpy of condensed water

$$= (85 - 43) \times 3 + 67 \times 33 \times 10^{-3}$$

$$= 128.211\text{ kW}$$

SOL 9.10 Option (C) is correct.

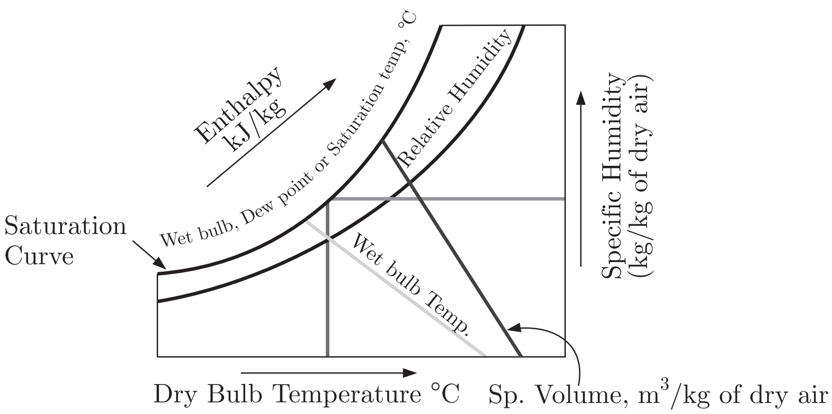


It is the temperature of air recorded by a thermometer, when the moisture (water vapour) present in it begins to condense.

If a sample of unsaturated air, containing superheated water vapour, is cooled at constant pressure, the partial pressure (p_v) of each constituent remains constant until the water vapour reaches the saturated state as shown by point B. At this point B the first drop of dew will be formed and hence the temperature at point B is called dew point temperature.

Published by: NODIA and COMPANY ISBN: 9788192276250

SOL 9.11 Option (A) is correct.



Hence, the statement 2 & 3 are correct.

SOL 9.12 Option (B) is correct.

From steam table, saturated air pressure corresponding to dry bulb temperature of 35° C is $p_s = 0.05628\text{ bar}$.

Relative humidity,

$$\phi = \frac{p_v}{p_s} = 0.75$$

$$p_v = 0.75 \times p_s$$

$$= 0.75 \times 0.05628 = 0.04221\text{ bar}$$

Now the amount of moisture in kg/kg of dry air, (Specific Humidity) is

$$W = 0.622 \times \frac{p_v}{p_b - p_v} \qquad p_b = p_{atm} = 1.01\text{ bar}$$

$$= 0.622 \times \frac{0.04221}{1.01 - 0.04221}$$

$$= 0.622 \times 0.04362$$

$$= 0.0271\text{ kg/kg of dry air}$$

SOL 9.13 Option (B) is correct.

Given : $t_{sp} = 42^\circ$ C, $t_{db} = 40^\circ$ C, $t_{wb} = 20^\circ$ C

Here we see that $t_{sp} > t_{db}$

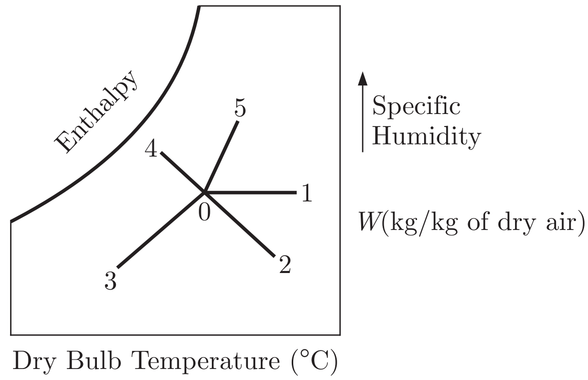
Hence air gets heated, Also water is added to it, so it gets humidified.

SOL 9.14 Option (A) is correct.

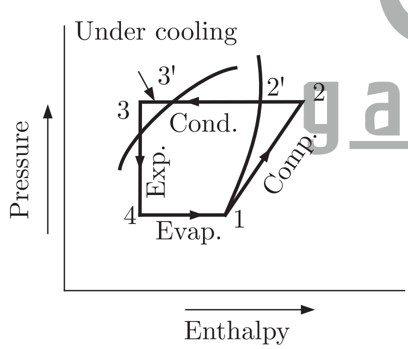
Given curve is the theoretical p-h curve for vapour compression refrigeration cycle.

GATE Previous Year Solved Paper For Mechanical Engineering
Published by: NODIA and COMPANY ISBN: 9788192276250
Visit us at: www.nodia.co.in

SOL 9.15 Option (B) is correct.



Process	Process Name	t_{DBT}	W
0-1	Sensible Heating	Increase	Constant
0-2	Chemical dehumidification	Increase	Decrease
0-3	Cooling and dehumidification	Decrease	Decrease
0-4	Humidification with water injection	Decrease	Increase
0-5	Humidification with steam injection	Increase	Increase



Hence, curve given in question is a ideal $p-h$ curve for vapour compression refrigeration cycle.

SOL 9.16 Option (C) is correct.

$$(COP)_{ref.} = \frac{\text{Refrigeration Effect}}{\text{Work done}} = \frac{T_1}{T_2 - T_1}$$

$$\frac{100}{W} = \frac{250}{300-250}$$

$$W = \frac{100}{250} \times 50 = 20 \text{ Watt}$$

For supply this work, heat is taken from reservoir 3 & rejected to sink 2. So efficiency,

$$\eta = \frac{W}{Q_3} = \frac{T_3 - T_2}{T_3}$$ It works as a heat engine.

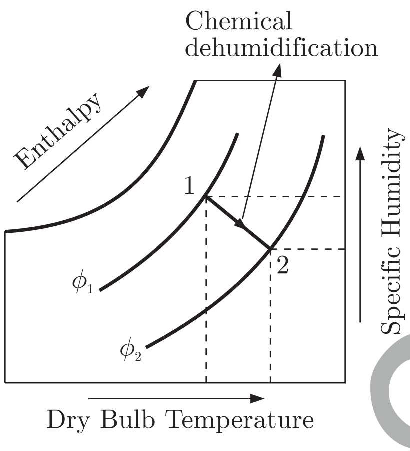
Published by: NODIA and COMPANY ISBN: 9788192276250
Visit us at: www.nodia.co.in

$$\frac{20}{Q_3} = \frac{400 - 300}{400} \qquad \Rightarrow Q_3 = 80 \text{ Watt}$$

SOL 9.17 Option (A) is correct.

Air conditioner mounted in a window or through the wall are self-contained units of small capacity of 1 TR to 3 TR. The capillary tube is used as an expansion device in small capacity refrigeration units.

SOL 9.18 Option (B) is correct.



In the process of chemical dehumidification of air , the air is passed over chemicals which have an affinity for moisture and the moisture of air gets condensed out and gives up its latent heat. Due to the condensation, the specific humidity decreases and the heat of condensation supplies sensible heat for heating the air and thus increasing its dry bulb temperature.

So chemical dehumidification increase dry bulb temperature & decreases specific humidity.

SOL 9.19 Option (D) is correct.

If a refrigerant is written in the from of $Rabc$.

The first digit on the right (c) is the number of fluorine (F) atoms, the second digit from the right (b) is one more than the number of hydrogen (H) atoms required & third digit from the right (a) is one less than the Number of carbon (C) atoms in the refrigerant. So, For R134

$$\text{First digit from the Right} = 4 = \text{Number of Fluorine atoms}$$

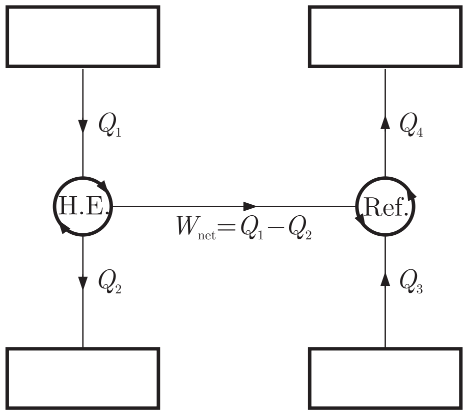
$$\text{Second digit from the right} = 3 - 1 = 2 = \text{Number of hydrogen atoms}$$

$$\text{Third digit from the right} = 1 + 1 = 2 = \text{Number of carbon atoms}$$

Hence, Chemical formula is $C_2H_2F_4$

GATE Previous Year Solved Paper For Mechanical Engineering
Published by: NODIA and COMPANY ISBN: 9788192276250
Visit us at: www.nodia.co.in

SOL 9.20 Option (C) is correct.



Given : $(COP)_{refrigerator} = 5$, $(\eta)_{H.E} = 70\% = 0.7$

$$(COP)_{ref.} = \frac{Q_3}{W} = 5 \qquad ...(i)$$

$$(\eta)_{H.E.} = \frac{W}{Q_1} = 0.7 \qquad ...(ii)$$

By multiplying equation (i) & (ii),

$$\frac{Q_3}{W} \times \frac{W}{Q_1} = 5 \times 0.7 \qquad \Rightarrow \frac{Q_3}{Q_1} = 3.5$$

Hence, Energy absorbed (Q_3) from low temperature reservoir by the refrigerator for each kJ of energy absorbed (Q_1) from high temperature source by the engine = 3.5 kJ

SOL 9.21 Option (B) is correct.

Given : $t_{dp} = 18^\circ\,\text{C} = (273 + 18)\,\text{K} = 291\,\text{K}$, $p = p_{atm} = 1.013$ bar

$t_{db} = 30^\circ\,\text{C} = (273 + 30)\,\text{K} = 303\,\text{K}$

$p_v = 0.02062$ bar (for water vapour at dew point).

$c_{air} = 1.005\,\text{kJ/kg K}$, $c_{water} = 1.88\,\text{kJ/kg K}$

Latent heat of vaporization of water at 0° C.

$$h_{fgdp} = 2500\,\text{kJ/kg}$$

Specific humidity,
$$W = \frac{0.622 \times p_v}{p - p_v} = \frac{0.622 \times 0.02062}{1.013 - 0.02062}$$
$$= \frac{0.01282}{0.99238} = 0.01291\,\text{kg/kg of dry air}$$

Enthalpy of moist air is given by,

$$h = 1.022 t_{db} + W(h_{fgdp} + 2.3 t_{dp})\,\text{kJ/kg}$$
$$= 1.022 \times 30 + 0.01291\,[2500 + 2.3 \times 18]$$
$$= 30.66 + 0.01291 \times 2541.4 = 63.46\,\text{kJ/kg} \simeq 63.15\,\text{kJ/kg}$$

Published by: NODIA and COMPANY ISBN: 9788192276250
Visit us at: www.nodia.co.in

SOL 9.22 Option (A) is correct.

Given : $C = 0.03$, $n = 1.15$, Specific volume at suction $= 0.1089\,\text{m}^3/\text{kg}$

Net refrigeration effect $= 2$ ton $\qquad 1\,\text{TR} = 1000 \times 335$ kJ in 24 hr

$$= \frac{2 \times 1000 \times 335}{24 \times 60 \times 60} = 7.75\,\text{kJ/sec}$$

Let net mass flow rate $= \dot{m}$

Net refrigeration effect $= \dot{m}(h_1 - h_4)$

Substitute the values from equation (i), and from the p-h curve,

$$7.75 = \dot{m}(176 - 65)$$

$$m = \frac{7.75}{111} = 0.06981\,\text{kg/sec}$$

Specific volume, $\qquad \frac{\nu}{\dot{m}} = 0.1089$

$$\nu = 0.1089 \times 0.06981 = 0.00760 = 7.60 \times 10^{-3}\,\text{m}^3/\text{sec}$$

We know that volumetric efficiency,

$$\eta_v = 1 + C - C\left(\frac{p_2}{p_1}\right)^{\frac{1}{n}}$$

Where, p_1 is the suction pressure and p_2 is the discharge pressure.

$$= 1 + 0.03 - 0.03 \times \left(\frac{7.45}{1.50}\right)^{\frac{1}{1.15}}$$

$$= 1.03 - 0.12089 = 0.909$$

Now actual volume displacement rate is,

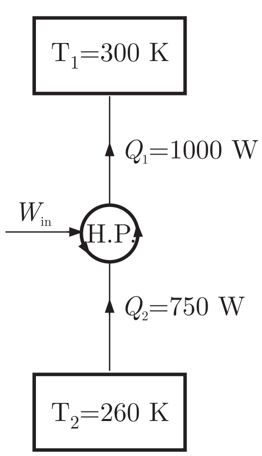
$$\nu_{actual} = \nu \times \eta_v = 7.60 \times 10^{-3} \times 0.909$$

$$= 6.90 \times 10^{-3} \simeq 6.35 \times 10^{-3}\,\text{m}^3/\text{sec}$$

SOL 9.23 Option (C) is correct.

Given : $T_1 = 27^\circ\text{C} = (27 + 273)\,\text{K} = 300\,\text{K}$,

$T_2 = -13^\circ\text{C} = (-13 + 273)\,\text{K} = 260\,\text{K}$, $Q_1 = 1000\,\text{W}$, $Q_2 = 750\,\text{W}$



GATE Previous Year Solved Paper For Mechanical Engineering
Published by: NODIA and COMPANY ISBN: 9788192276250
Visit us at: www.nodia.co.in

So, $$(COP)_{H.P.} = \frac{Q_1}{Q_1 - Q_2} = \frac{1000}{1000 - 750} = 4$$

Alternate Method :

From energy balance

$$W_{in} + Q_2 = Q_1$$

$$W_{in} = Q_1 - Q_2 = 1000 - 750 = 250 \text{ W}$$

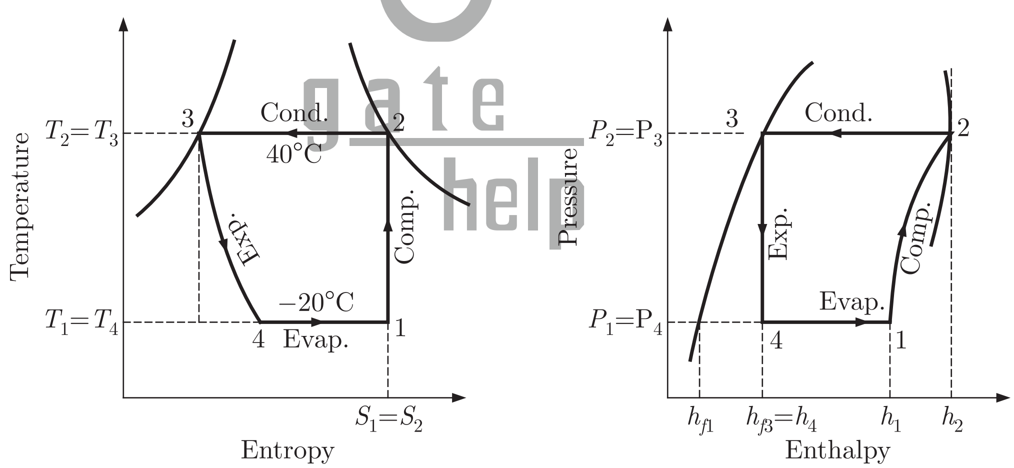
And $$(COP)_{H.P.} = \frac{\text{Desired effect}}{W_{in}} = \frac{Q_1}{W_{in}} = \frac{1000}{250} = 4$$

SOL 9.24 Option (B) is correct.

We know that for saturated air, the relative humidity is 100% and the dry bulb temperature, wet bulb temperature and dew point temperature is same. But when air is not saturated, dew point temperature is always less than the wet bulb temperature.

$$\text{DPT} < \text{WBT}$$

SOL 9.25 Option (A) is correct.



(A) T-S Diagram (B) p-h Diagram

Given : $T_1 = T_4 = -20^\circ \text{C} = (-20 + 273) \text{ K} = 253 \text{ K}$, $\dot{m} = 0.025 \text{ kg/sec}$

$T_2 - T_3 = 40^\circ \text{C} = (40 + 273) \text{ K} = 313 \text{ K}$

From the given table,

At, $T_2 = 40^\circ \text{C}$, $h_2 = 200 \text{ kJ/kg}$

And $h_3 = h_4 = 80 \text{ kJ/kg}$

From the given T-s curve

$$s_1 = s_2$$

$$s_2 = s_f + x s_{fg} \qquad x = \text{Dryness fraction}$$

$\{s_2$ is taken 0.67 because s_2 at the temperature 40°C & at 2 high temperature

Published by: NODIA and COMPANY ISBN: 9788192276250

and pressure vapour refrigerant exist.}

$$0.67 = 0.07 + x(0.7366 - 0.07) \qquad s_{fg} = s_g - s_f$$

$$0.67 - 0.07 = x \times 0.6666$$

$$0.6 = x \times 0.6666$$

$$x = \frac{0.6}{0.6666} = 0.90$$

And Enthalpy at point 1 is,

$$h_1 = h_f + xh_{fg} = h_f + x(h_g - h_f)$$

$$= 20 + 0.90(180 - 20) = 164 \text{ kJ/kg}$$

Now refrigeration effect is produce in the evaporator.

Heat extracted from the evaporator or refrigerating effect,

$$R_E = \dot{m}(h_1 - h_4) = 0.025(164 - 80) = 2.1 \text{ kW}$$

SOL 9.26 Option (B) is correct.

$$(COP)_{refrigerator} = \frac{h_1 - h_4}{h_2 - h_1} = \frac{\text{Refrigerating effect}}{\text{Work done}}$$

$$= \frac{164 - 80}{200 - 164} = \frac{84}{36} = 2.33$$

****

GATE Multiple Choice Questions
For Mechanical Engineering

By NODIA and Company

Available in Three Volumes

Features:

- The book is categorized into chapter and the chapter are sub-divided into units
- Unit organization for each chapter is very constructive and covers the complete syllabus
- Each unit contains an average of 40 questions
- The questions match to the level of GATE examination
- Solutions are well-explained, tricky and consume less time. Solutions are presented in such a way that it enhances you fundamentals and problem solving skills
- There are a variety of problems on each topic
- Engineering Mathematics is also included in the book

Contents

2.5 Transformation of stress and strain
2.6 Design of beams and shafts
2.7 Deflection of beams and shafts
2.8 Column
2.9 Energy methods

UNIT 3. Machine Design

3.1 Design for static and dynamic loading
3.2 Design of joints
3.3 Design of shaft and shaft components
3.4 Design of spur gears
3.5 Design of bearings
3.6 Design of clutch and brakes

UNIT 4. Theory of Machine

4.1 Analysis of plane mechanism
4.2 Velocity and acceleration
4.3 Dynamic analysis of slider-crank and cams
4.4 Gear-trains
4.5 Flywheel
4.6 vibration

VOLUME-2 Fluid Mechanics and Thermal Sciences

UNIT 5. Fluid Mechanics

5.1 Basic concepts and properties of fluids
5.2 Pressure and fluid statics
5.3 Fluid kinematics and Bernoulli Equation
5.4 Flow analysis using control volume
5.5 Flow analysis using differential method
5.6 Internal flow
5.7 External flow
5.8 Open channel flow
5.9 Turbomachinary

UNIT 6. Heat Transfer

6.1 Basic concepts and modes of Heat transfer
6.2 Fundamentals of conduction
6.3 Steady heat conduction
6.4 Transient heat conduction
6.5 Fundamentals of convection
6.6 Free convection
6.7 Forced convection
6.8 Fundamentals of thermal radiation
6.9 Radiation Heat transfer
6.10 Heat exchangers.

UNIT 7. Thermodynamics

7.1 Basic concepts and Energy analysis
7.2 Properties of pure substances
7.3 Energy analysis of closed system
7.4 Mass and energy analysis of control volume
7.5 Second law of thermodynamics
7.6 Entropy
7.7 Gas power cycles
7.8 Vapour and combined power cycles
7.9 Refrigeration and air conditioning

VOLUME-3 Manufacturing and Industrial Engineering

UNIT 8. Engineering Materials

8.1 Structure and properties of engineering materials, heat treatment, stress-strain diagrams for engineering materials

UNIT 9. Metal Casting:

Design of patterns, moulds and cores; solidification and cooling; riser and gating design, design considerations.

UNIT 10. Forming:

Plastic deformation and yield criteria; fundamentals of hot and cold working processes; load estimation for bulk (forging, rolling, extrusion, drawing) and sheet (shearing, deep drawing, bending) metal forming processes; principles of powder metallurgy.

UNIT 11. Joining:

Physics of welding, brazing and soldering; adhesive bonding; design considerations in welding.

UNIT 12. Machining and Machine Tool Operations:

Mechanics of machining, single and multi-point cutting tools, tool geometry and materials, tool life and wear; economics of machining; principles of non-traditional machining processes; principles of work holding, principles of design of jigs and fixtures

UNIT 13. Metrology and Inspection:

Limits, fits and tolerances; linear and angular measurements; comparators; gauge design; interferometry; form and finish measurement; alignment and testing methods; tolerance analysis in manufacturing and assembly.

UNIT 14. Computer Integrated Manufacturing:

Basic concepts of CAD/CAM and their integration tools.

UNIT 15. Production Planning and Control:

Forecasting models, aggregate production planning, scheduling, materials requirement planning

UNIT 16. Inventory Control:

Deterministic and probabilistic models; safety stock inventory control systems.

UNIT 17. Operations Research:

Linear programming, simplex and duplex method, transportation, assignment, network flow models, simple queuing models, PERT and CPM.

UNIT 18. Engineering Mathematics:

18.1 Linear Algebra
18.2 Differential Calculus
18.3 Integral Calculus
18.4 Differential Equation
18.5 Complex Variable
18.6 Probability & Statistics
18.7 Numerical Methods