Model Question Paper

Subject :→ Refrigeration and air Conditioning.

Question :-1 :→ The temperature limits of an ammonia refrigerating system are 25°C and -10°C. If the gas is dry at the end of compression, calculate 1) Draw T.S and P-H diagram and 2) calculate COP of the cycle assuming no undercooling of the liquid ammonia. Use the following table for properties of ammonia

Temperature (°C)	liquid heat (kJ/kg)	Latent heat (kJ/kg)	liquid entropy (kJ/kgK)
25	298.9	1166.94	1.1242
−10	135.37	1297.68	0.5443

Question 2 :→ An aircraft refrigeration plant has to handle a cabin load of 30 tonnes. The atmospheric temperature is 17°C. The atmospheric air is compressed to a pressure of 0.95 bar and temperature of 30°C due to ram action. This air is then further compressed in a compressor to 4.75 bar, cooled in a heat exchanger to 67°C, expanded in a turbine to 1 bar pressure and supplied to the cabin. The air leaves the cabin at a temperature of 27°C. The isentropic efficiencies of both compressor and turbine are 0.9. Calculate the mass of air circulated per minute and COP. for air $c_p = 1.004$ kJ/kgK and $c_p/c_v = 1.4$

Question 3 :→ Derive an expression for COP of an ideal vapour absorption system in terms of temperature T_G at which heat is supplied to the generator. the tempe

T_E at which heat is absorbed in the evaporator and the temperature T_C at which heat is discharged from the condenser and absorber.

Question 4 :→ The humidity ratio of atmospheric air at 28°c dry bulb temp and 760 mm of mercury is 0.016 kg/kg of dry air.

Determine 1) Partial pressure of water vapour

2) Relative humidity

3) Dew point temp

4) Specific enthalpy and

5) Vapour density

Question 5 :→ A small office hall of 25 persons capacity is provided with summer air conditiong with following data

Outside conditions = 34°C DBT and 28°C WBT

Inside conditions = 24°C DBT and 50% RH

Volume of air supplied = 0.4 m^3/min/person

Sensible heat load in room = 125600 kJ/h

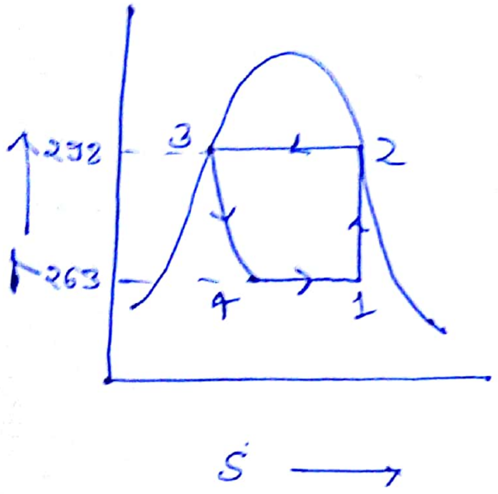
Latent heat load in room = 42000 kJ/h.

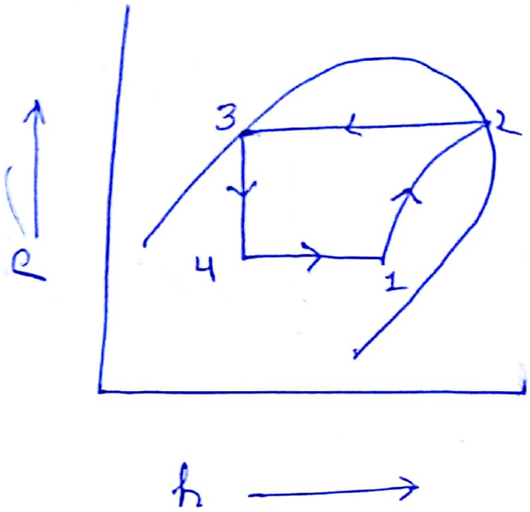
Find sensible heat factor of the plant

Solution of Model Question Paper

Subject :→ Refrigeration and air conditioning

Answer 1 :→ 1) T-s and P-H diagrams are





2) we know that entropy at point 1

$$S_1 = S_{f1} + \frac{x_1 h_{fg1}}{T_1} = 0.5443 + \frac{x_1 \times 1297.68}{263}$$

$$= 0.5443 + 4.934 x_1$$

Similarly at point 2

$$S_2 = S_{f2} + \frac{h_{fg2}}{T_2} = 1.1242 + \frac{1166.94}{298} = 5.04$$

we know $S_1 = S_2$

$$0.5443 + 4.934 x_1 = 5.04 \Rightarrow x_1 = 0.91$$

enthalpy at point 1

$$h_1 = h_{f1} + x_1 h_{fg1} = 135.37 + 0.91 \times 1297.68 = 1316.26 \text{ kJ/kg}$$

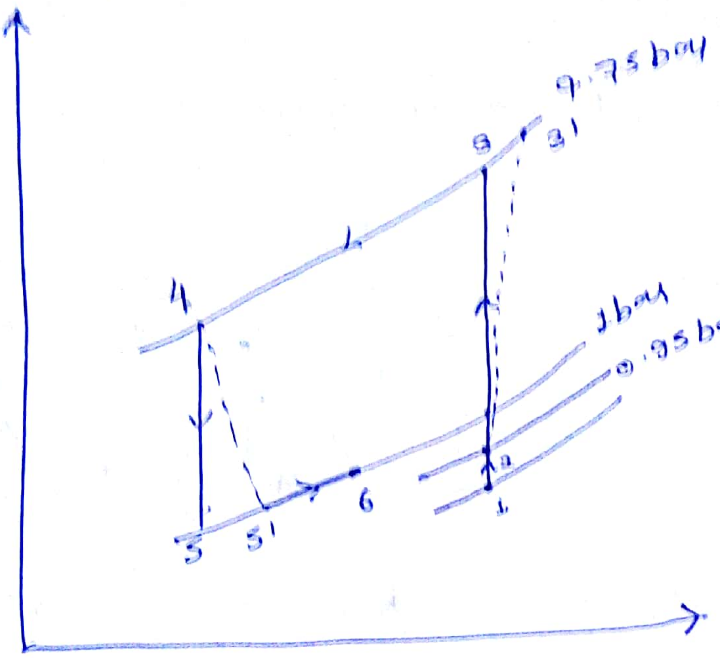
$$h_2 = h_{f2} + h_{fg2} = 298.9 + 1166.94 = 1465.84 \text{ kJ/kg}$$

$$COP = \frac{h_1 - h_{f3}}{h_2 - h_1}$$

$$= \frac{1316.26 - 298.9}{1465.84 - 1316.26} = 6.8$$

$$\boxed{COP = 6.8}$$

Solution 2 :- The T-S diagram for simple air conditioning is



T_3 = Temp^r of the air after isentropic compression in the compressor

T_3' = Actual temp^r of the air leaving the compressor

T_5 = Temp^r of the air leaving the turbine after isentropic expansion

T_5' = Actual temp^r of air leaving the turbine

isentropic compression in process 2-3

$$\frac{T_3}{T_2} = \left(\frac{P_3}{P_2}\right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{4.75}{0.95}\right)^{\frac{1.4-1}{1.4}} = 1.584$$

$$T_3 = T_2 \times 1.584 = 303 \times 1.584 = 480K.$$

and effeciency of compressor

$$\eta_c = \frac{\text{Isentropic increase in temp}^r}{\text{Actual increase in temp}^r} = \frac{T_3 - T_2}{T_3' - T_2}$$

$$0.9 = \frac{480 - 303}{T_3' - 303} = \frac{177}{T_3' - 303}$$

$$T_3' = 499.7 \text{ K}.$$

efficiency of turbine

$$\eta_T = \frac{\text{Actual increase in temp}^r}{\text{Isentropic increase in temp}^r} = \frac{T_4 - T_5'}{T_4 - T_5}$$

isentropic Expansion in process 4-5

$$\frac{T_4}{T_5} = \left(\frac{P_4}{P_5}\right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{4.75}{1}\right)^{\frac{1.4-1}{1.4}} = 1.561$$

$$T_5 = 340/1.561 = 217.8K.$$

$$\eta_T = \frac{T_4 - T_5'}{T_4 - T_5} \Rightarrow 0.9 = \frac{340 - T_5'}{340 - 217.8}$$

$$T_5' = 230K$$

mass of air circulated

$$m_a = \frac{210Q}{C_p(T_6 - T_5)} = \frac{210 \times 30}{1.004(300 - 230)} = 89.64 \text{ kg/min}$$

$$COP = \frac{210Q}{m_a C_p(T_3' - T_2)} = \frac{210 \times 30}{89.64 \times 1.004(499.7 - 303)} = 0.356$$

Solution 3 : → Given

T_G = Temp^r at which heat is supplied to generator

T_E = Temp^r at which heat is absorbed in evaporator

T_C = Temp^r at which head is discharged from condensor and absorber

we know that

$$Q_C = Q_G + Q_E$$

and we know that initial entropy is equal to the entropy after change in condition.

$$\frac{Q_G}{T_G} + \frac{Q_E}{T_c} = \frac{Q_c}{T_c}$$

$$= \frac{Q_G + Q_E}{T_c}$$

$$\frac{Q_G}{T_G} - \frac{Q_G}{T_c} = \frac{Q_E}{T_c} - \frac{Q_E}{T_E}$$

$$Q_G\left(\frac{T_c - T_G}{T_G \times T_c}\right) = Q_E\left(\frac{T_E - T_c}{T_E \times T_c}\right)$$

$$Q_G = Q_E\left[\frac{T_E - T_c}{T_c \times T_E}\right]\left[\frac{T_G \times T_c}{T_c - T_G}\right]$$

$$= Q_E\left(\frac{T_c - T_E}{T_E}\right)\left(\frac{T_G}{T_G - T_c}\right)$$

$$(COP)_{max} = \frac{Q_E}{Q_G} = \frac{Q_E}{Q_E\left(\frac{T_c - T_E}{T_E}\right)\left(\frac{T_G}{T_G - T_c}\right)}$$

$$\boxed{(COP)_{max} = \left(\frac{T_E}{T_c - T_E}\right)\left(\frac{T_G - T_c}{T_G}\right)}$$

Solution 4:→

Given :→ $t_d = 28°C$ $P_b = 760$ mm of Hg $W = 0.016$ kg/kg of air

1) Partial Pressure of water vapour

P_v = Partial p^r of water vapour

we know humidity Ratio (W)

$$W = \frac{0.622 P_v}{P_b - P_v} \Rightarrow 0.016 = \frac{0.622 P_v}{760 - P_v}$$

$P_v = 19.06$ mm of Hg

$= 2540.6\ N/m^2$

2) Relative humidity

From steam table, we find that the saturation p^r of vapour corresponding to dry bulb temp^r of 28°C is

$P_s = 0.03778$ bar $= 3778\ N/m^2$

Relative humidity

$$\phi = \frac{P_v}{P_s} = \frac{2540.6}{3776} = 0.672 = 67.2\%$$

3) Dew point temp^r

from steam table for $P_v = 2540.6$

$t_{dp} = 21.1°C$

4) Specific enthalpy

from steam table $h_{dp} = 21.1°C$

$h_{fgdp} = 2451.76$ kJ/kg

$h = 1.022\, t_d + W(h_{fgdp} + 2.3\, t_{dp})$

$= 1.022 \times 28 + 0.016\,(2451.76 + 2.3 \times 21.1)$

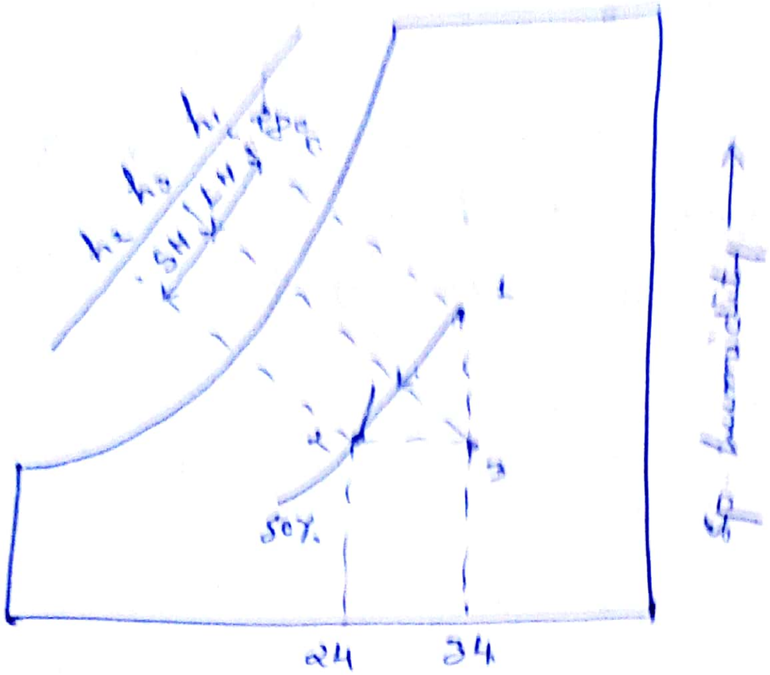
$= 68.62$ kJ/kg of dry air

5) Vapour density

$$\rho_v = \frac{W\,(P_b - P_v)}{R_a T_d} = \frac{0.016\,(760 - 19.06)\,133.3}{287\,(273 + 28)}$$

$= 0.0183$ kg/m3 of dry air

Solution 5 :→



from the psychrometric chart

V_{s1} (specific Volume) = 0.9 m^3/kg of dry air

h_1 (Enthalpy at 1) = 90 kJ/kg of dry air

h_2 (" " 2) = 48 kJ/kg " "

h_3 (" " 3) = 58 kJ/kg " "

mass of air supplied

$$m_a = \frac{V_1}{V_{s1}} = \frac{10}{0.9} = 11.1 \text{ kg/min}$$

Sensible heat removed from the air

$$= m_a(h_3 - h_2) = 11.1(58 - 48)$$

$$= 111 \text{ kJ/min} = 6660 \text{ kJ/h}$$

Total sensible heat of room

$$SH = 6660 + 125600$$

$$= 132260\ kJ/h.$$

Latent heat from air

$$= m_a (h_1 - h_2)$$

$$= 11.1 (90 - 58)$$

$$= 355\ kJ/min = 21300\ kJ/h.$$

Total latent heat

$$LH = 21300 + 42000$$

$$= 63300\ kJ/H$$

Sensible heat factor

$$SHF = \frac{SH}{SH + LH} = \frac{132260}{132260 + 63300}$$

$$\boxed{SHF = 0.676}$$