CLASS TEST

Sl.: 01SKME_ABCDEFGHI_200925

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REFRIGERATION & AIR CONDITIONING

MECHANICAL ENGINEERING

Date of Test : 20/09/2025

ANSWER KEY

1.	(c)	7.	(a)	13.	(b)	19.	(b)	25.	(d)
2.	(b)	8.	(a)	14.	(a)	20.	(c)	26.	(a)
3.	(b)	9.	(a)	15.	(b)	21.	(b)	27.	(b)
4.	(d)	10.	(c)	16.	(a)	22.	(a)	28.	(a)
5.	(c)	11.	(b)	17.	(b)	23.	(b)	29.	(c)
6.	(c)	12.	(b)	18.	(c)	24.	(a)	30.	(a)

DETAILED EXPLANATIONS

1. (c)

$$\text{Net heat loss, } Q = 60000 - 4000 = 56000 \text{ kJ/h} = 15.555 \text{ kW}$$

$$\text{COP} = \frac{Q}{W} = 2.5$$

$$\text{Power required, } W = \frac{Q}{2.5} = \frac{15.555}{2.5} = 6.22 \text{ kW}$$

2. (b)

$$\text{COP} = \frac{\text{Refrigeration Effect}}{W_{\text{compressor}} - W_{\text{turbine}}} = \frac{T_1 - T_4'}{(T_2' - T_1) - (T_3 - T_4')}$$

$$= \frac{263 - 197}{(467 - 263) - (313 - 197)} = 0.75$$

5. (c)

The heat rejection ratio is the ratio of heat rejected to the heat absorbed,

$$\text{HRR} = \frac{Q_c}{Q_e} = \frac{Q_e + W_c}{Q_e} = 1 + \frac{1}{COP}$$

For a fixed condenser temperature, as the evaporator temperature increases, the COP increases and the heat rejection ratio decreases.
Thus, option (c) is correct.

6. (c)

To produce ultra-low temperature the compression ratio will increase thereby decreasing the volumetric efficiency.

7. (a)

$$(\text{COP})_{\text{cascade}} = \frac{(COP)_1 \times (COP)_2}{1 + (COP)_1 + (COP)_2} = \frac{3.4 \times 6.1}{1 + 3.4 + 6.1} = 1.975$$

8. (a)

$$\text{Heat rejection ratio (HRR)} = \frac{Q_{\text{condenser}}}{RE}$$

$$\text{HRR} = \frac{h_2 - h_3}{h_1 - h_4} = \frac{200 - 50}{150 - 50} = \frac{150}{100} = 1.5$$

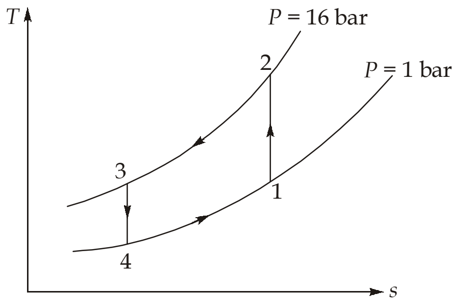
10. (c)

$$\text{CMM} = 10 \times \frac{3}{60} = 0.5 \text{ m}^3/\text{min}$$

$$\Delta T = 20 \text{ K}$$

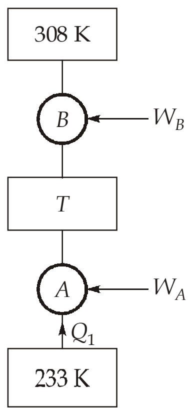
$$\text{SHL} = 0.0204 \times \text{CMM} \times \Delta t = 0.0204 \times 0.5 \times 20 = 0.20 \text{ kW}$$

11. (b)



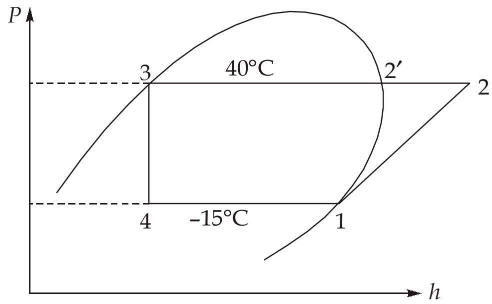
$$T_1 = -5°C = 268\text{ K}$$
$$T_3 = 30°C = 303\text{ K}$$
$$\frac{T_2}{T_1} = \frac{T_3}{T_4} = (r_p)^{(\gamma-1)/\gamma} = (16)^{0.4/1.4} = 2.208$$
$$T_2 = 591.74\text{ K},\ T_4 = 137.22\text{ K}$$
$$\text{Refrigeration effect} = h_1 - h_4 = c_p(T_1 - T_4)$$
$$= 1.005(268 - 137.22)$$
$$= 131.43\text{ kJ/kg}$$
$$\text{Mass flow rate} = \frac{\text{Refrigeration capacity}}{\text{Refrigeration effect}} = \frac{33.5}{131.43} = 0.2548\text{ kg/s}$$
$$\dot{V}_{\text{compressor}} = \frac{\dot{m}RT_1}{P_1} = \frac{0.2548 \times 0.287 \times 268}{100}$$
$$= 0.196\text{ m}^3\text{/s} = 11.76\text{ m}^3\text{/min}$$

12. (b)



$$(\text{COP})_A = (\text{COP})_B$$
$$\frac{T_L}{T - T_L} = \frac{T}{T_H - T}$$
$$T_L T_H - T_L T = T^2 - T_L T$$
$$T^2 = T_L T_H$$
$$T = \sqrt{T_L T_H} = \sqrt{308 \times 233} = 267.88\text{ K}$$
$$(\text{COP})_A = \frac{233}{267.88 - 233} = 6.68$$
$$W_A = \frac{Q_1}{(\text{COP})_A} = \frac{3}{6.68}$$
$$= 0.449\text{ kJ/s} \simeq 0.45\text{ kJ/s}$$

13. (b)



For process 1 - 2,

$$S_1 = S_2$$

$$5.7550 = 5.1558 + 2.1897 \ln\left(\frac{T_2}{40+273}\right)$$

$$T_2 = 411.55 \text{ K}$$

$$h_2 = h_2' + c_{p_v}(T_2 - T_2')$$

$$h_2 = 1473 + 2.1897 [411.55 - (40 + 273)]$$

$$h_2 = 1688.79 \text{ kJ/kg}$$

$$\text{Theoretical COP} = \frac{\text{Desired effect}}{W_{input}} = \frac{h_1 - h_4}{h_2 - h_1} = \frac{1433 - 371.5}{1688.79 - 1433}$$

$$\text{COP} = 4.149 \approx 4.15$$

14. (a)

We know, efficiency of Brayton cycle working with pressure ratio r_p is

$$\eta = 1 - \frac{1}{(r_p)^{\frac{\gamma-1}{\gamma}}} \qquad \text{... (i)}$$

and COP of Bell-Coleman cycle working between same pressure ratio of r_p is,

$$\text{COP} = 1 - \frac{1}{(r_p)^{\frac{\gamma-1}{\gamma}} - 1} \qquad \text{... (ii)}$$

From equation (i), we have,

$$\frac{1}{(r_p)^{\frac{\gamma-1}{\gamma}}} = 1 - \eta$$

$$\Rightarrow \qquad (r_p)^{\frac{\gamma-1}{\gamma}} = \frac{1}{1-\eta}$$

Put value in equation (ii), we get

$$\text{COP} = \frac{1}{\left(\frac{1}{1-\eta}\right) - 1} = \frac{1}{\left(\frac{1-1+\eta}{1-\eta}\right)}$$

$$= \frac{1-\eta}{\eta} = \frac{1}{\eta} - 1$$

$$\Rightarrow \quad \frac{1}{\eta} = 1 + \text{COP}$$

$$\Rightarrow \quad \eta = \frac{1}{1 + COP}$$

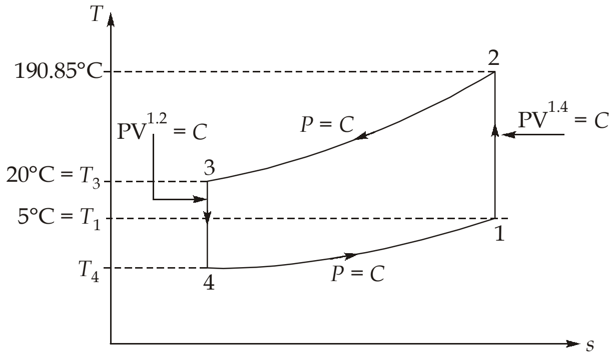
15. (b)

Given: P_1 = 1 bar, $C_{P\,air}$ = 1.005 kJ/kgK, P_2 = 6 bar, γ_{air} = 1.4, P_4 = 1 bar, T_1 = 5°C = 278 K, T_3 = 20°C = 293 K

For process 1-2 (Isentropic compression)

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{6}{1}\right)^{\frac{1.4-1}{1.4}}$$

$$T_2 = 463.85 \text{ K}$$



$$W_{compressor} = C_P(T_2 - T_1)$$
$$= 1.005\ (463.85 - 278)$$
$$= 186.78 \text{ kJ/kg}$$

For process 3-4 (Polytropic expansion)

$$\therefore \quad \frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\frac{n-1}{n}} = \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} \quad [\because\ P_3 = P_2 \text{ and } P_4 = P_1]$$

$$\frac{T_3}{T_4} = (6)^{\frac{1.2-1}{1.2}} = 1.348$$

$$T_4 = 217.35 \text{ K}$$

and
$$W_{expander} = \left(\frac{n}{n-1}\right) mR(T_3 - T_4)$$

$$= \left(\frac{1.2}{1.2-1}\right)(1)(0.287)(293 - 217.35) \quad [\because\ m = 1 \text{ kg assumed}]$$

$$= 130.27 \text{ kJ/kg}$$

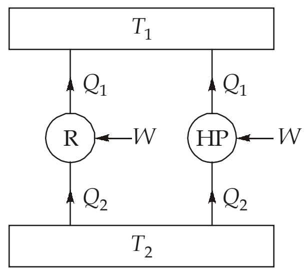
$$\text{Refrigerating effect} = C_P(T_1 - T_4)$$
$$= 1.005\ (278 - 217.35)$$
$$= 60.95 \text{ kJ/kg}$$

$$\therefore \quad \text{COP} = \frac{RE}{W_{input}} = \frac{60.95}{W_C - W_T}$$

$$= \frac{60.95}{186.78 - 130.27} = 1.078$$

16. (a)

Heat delivered by heat pump is the heating effect (Q_1) and heat absorbed by refrigerator is the cooling effect (Q_2).



Given: $(COP)_R = 4; W = 1$ kW

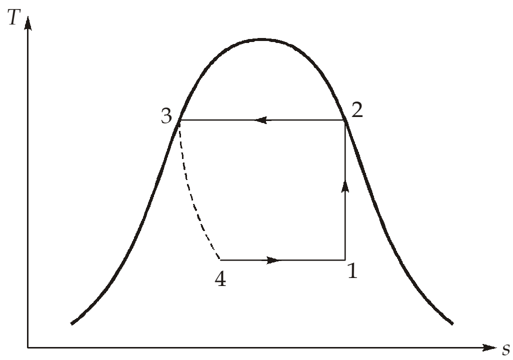
$(COP)_{HP} = (COP)_R + 1$

$(COP)_{HP} = 4 + 1 = 5$

$\Rightarrow \quad \dfrac{Q_1}{W} = 5$

$\Rightarrow \quad Q_1 = 5$ kW

17. (b)



As per given data, $h_2 = h_{f3} + h_{fg}$

$= 81.25 + 121.6 = 202.85$ kJ/kg

$h_3 = h_4 = 81.25$ kJ/kg

$h_1 = h_{f4} + xh_{fg}$

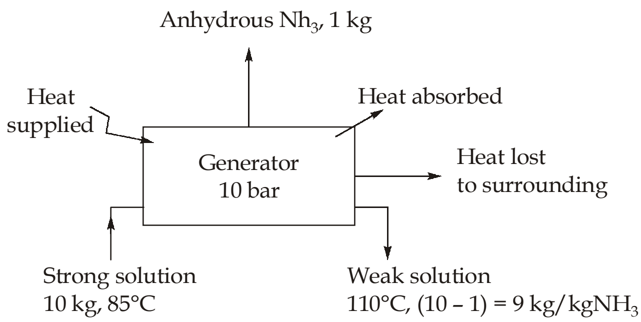
$= -7.53 + 0.6 \times 245.8$

$= 139.95$ kJ/kg

$$\therefore \quad (COP)_{ideal} = \frac{h_1 - h_4}{h_2 - h_1} = \frac{139.95 - 81.25}{202.88 - 139.95} = 0.933$$

$\therefore \quad (COP)_{act} = 0.7 \times 0.933 = 0.65$

18. (c)



Energy balance: Heat of strong ammonia-aqua + Heat from heating source = Heat of anhydrous NH_3 vapour + Heat of weak solution + heat absorbed + heat lost to surrounding.

$10 \times [200 + 4.8(85 - (-50))] + Q_s = 1910 + 9 \times [200 + 4.8 \times (110 - (-50))] + 479.1 + 100$

$Q_s = 2721.1$ kJ/kgNH_3

19. **(b)**

As per given data, P = 85 kPa, DBT = 30°C, P_{vs} = 4.24 kPa, ϕ = 0.55

$$\therefore \quad \phi = \frac{P_v}{P_{vs}} \Rightarrow 0.55 = \frac{P_v}{4.24}$$

$$\therefore \quad P_v = 2.332 \text{ kPa}$$

$$\therefore \quad \text{Humidity ratio, } \omega = \frac{0.622 P_v}{P - P_v} = \frac{0.622 \times 2.332 \times 1000}{85 - 2.332}$$

$$= 17.54 \text{ g/kgd.a.}$$

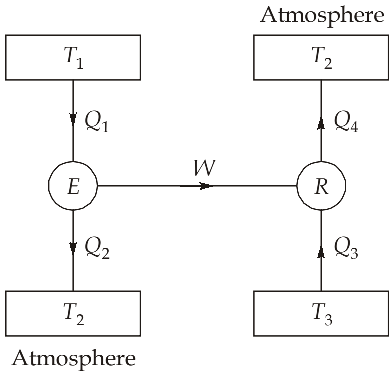
20. **(c)**

Given: $Q_3 = 40 \times 3.5 = 140$ kW

$$(\text{COP})_{act} = 0.7(\text{COP})_{ideal}$$

$$(\eta_E)_{act} = 0.5(\eta_E)_{ideal}$$

$$T_1 = 1273 \text{ K}, T_2 = 303 \text{ K}, T_3 = 263 \text{ K}$$



Heat supplied 'Q_1' is given by

$$Q_1 = \frac{Q_3}{(\text{COP})_{act} \times (\eta_E)_{act}} = \frac{140}{0.7\left(\frac{T_3}{T_2 - T_3}\right) \times 0.5\left(\frac{T_1 - T_2}{T_1}\right)}$$

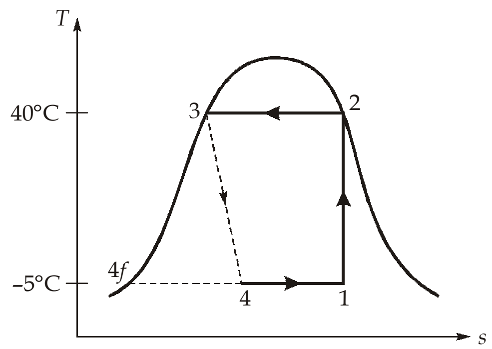
$$= \frac{140 \times 1273 \times (303 - 263)}{0.7 \times 0.5 \times 263(1273 - 303)} = 79.84 \text{ kW}$$

$$\therefore \quad (\text{COP})_{overall} = \frac{Q_3}{Q_1} = \frac{140}{79.84} = 1.75$$

21. **(b)**

Refrigerating effect, R-E $= h_1 - h_4 = (h_1 - h_{4f}) - (h_4 - h_{4f})$

$= T(S_1 - S_{4f}) - (h_3 - h_{4f})$ $\quad [\because \; h_3 = h_4]$



Here, $S_1 - S_{4f} = (S_1 - S_3) + (S_3 - S_{4f})$

$$S_1 - S_{4f} = \left(\frac{h_{fg}}{T}\right)_{40°C} + c_p \ln\left(\frac{T_3}{T_{4f}}\right) \qquad [\because S_1 = S_2]$$

$$= \left(\frac{203.2}{273+40}\right) + 0.963 \ln\left(\frac{273+40}{273-5}\right)$$

$$= 0.649 + 0.149 = 0.798$$

and $h_3 - h_{4f} = C_{pl}(T_3 - T_{4f})$

$\therefore$ R.E. $= 268 \times 0.798 - 0.963 \times (313 - 268)$

$= 170.53$ kJ/kg

22. (a)

Given : $t = 28°C$; $p = 1$ bar; $\phi = 67\%$; $P_{vs} = 3.778$ kPa

$$\phi = \frac{P_v}{P_{vs}}$$

$$\Rightarrow \quad 0.67 = \frac{P_v}{3.778}$$

$$\Rightarrow \quad P_v = 2.53126 \text{ kPa}$$

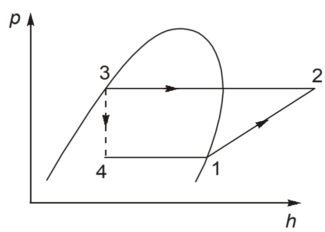
$$\omega = \frac{0.622 P_v}{p - p_v} = \frac{0.622 \times 2.53126}{100 - 2.53126} = 0.016 \text{ kg/kg of dry air}$$

$$h = 1.005t + \omega(2500 + 1.88t)$$

$$= 1.005 \times 28 + 0.016(2500 + 1.88 \times 28)$$

$$= 68.98 \text{ kJ/kg}$$

23. (b)



Given: $h_1 = 1200$ kJ/kg, $h_2 = 1700$ kJ/kg, $h_4 = h_3 = 400$ kJ/kg

$$\text{Compressor work} = \dot{m}[h_2 - h_1]$$

$$\Rightarrow \quad \dot{m} = \frac{W_c}{h_2 - h_1} = \frac{50 \times 1000}{(1700 - 1200) \times 1000} = 0.1 \text{ kg/s}$$

$$\text{Capacity of plant} = \frac{\dot{m}(h_1 - h_4)}{3.5} \text{ Tons}$$

$$= \frac{0.1(1200 - 400)}{3.5} = 22.86 \text{ Tons}$$

24. (a)

Given data: Total pressure, $p = 736$ mm Hg, Saturation pressure, $p_{vs} = 18$ mm Hg,

Relative humidity, $\phi = \frac{p_v}{p_{vs}} = 0.68$

$$0.68 = \frac{p_v}{18}$$

Partial pressure of water vapour, p_v = 12.24 mm Hg

We know that humidity ratio,

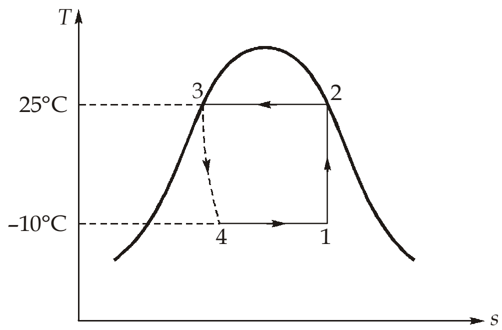
$$\omega = \frac{0.622 p_v}{p - p_v} \text{ kg}_{\text{W.V.}}/\text{kg of d.a.}$$

$$= \frac{0.622 \times 12.24}{736 - 12.24} = 0.01052 \text{ kg}_{\text{W.V.}}/\text{kg of d.a.}$$

$$= 10.52 \; g_{\text{W.V.}}/\text{kg d.a.}$$

25. (d)

Given: P_2 = 10 bar, P_1 = 3 bar, $\dot{m}$ = 6 kg/min



$$s_2 = (s_g)_{25°C} = 5.0391 \text{ kJ/kgK}$$

$$s_2 = s_1 = (s_g)_{-10°C} + x(s_{fg})_{-10°C}$$

$$5.0391 = 0.5443 + x(5.4770 - 0.5443)$$

$$x = 0.9112$$

So, $h_1 = (h_f)_{-10°C} + x(h_{fg})_{-10°C}$

$$= (130.37) + 0.9112\,(1380.50 - 130.37)$$

$$h_1 = 1269.51 \text{ kJ/kg}$$

$$h_2 = (h_g)_{25°C} = 1450.80 \text{ kJ/kg}$$

$$h_3 = (h_f)_{25°C} = 285.98 \text{ kJ/kg} \quad (\because \text{ Process 3-4 is Isenthalpic})$$

$\Rightarrow$ $h_3 = h_4 = 285.98$ kJ/kg

Now, Refrigeration capacity = $\dot{m}(h_1 - h_4) = 6(1269.51 - 285.98)$

$$\text{RC} = 5901.23 \text{ kJ/min}$$

$$\text{RC} = 98.35 \text{ kW}$$

26. (a)

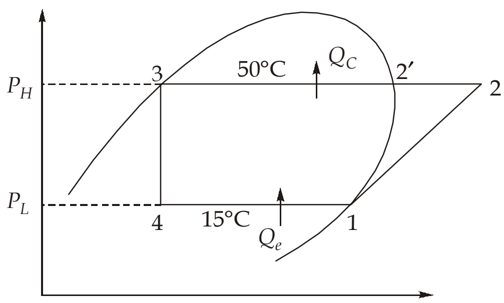
For discharge temperature, $s_1 = s_2 = s_2' + c_{p_v} \ln\left(\frac{T_2}{T_2'}\right)$

$$1.72 = 1.7072 + 1.246 \ln\left(\frac{T_2}{273 + 50}\right)$$

$$T_2 = 326.33 \text{ K}$$

Enthalpy at discharge, $h_2 = h_2' + c_{p_v}(T_2 - T_2')$

$$h_2 = 423.4 + 1.246\,(326.33 - 323)$$



$$= 427.55 \text{ kJ/kg}$$

Heat rejection in condenser,

$$Q_C = \dot{m}(h_2 - h_3)$$

$$\frac{100000}{3600} = \dot{m}(427.55 - 271.62)$$

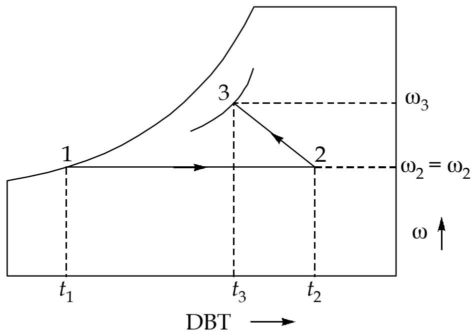
Mass flow rate of refrigerant, $\dot{m} = 0.178 \text{ kg/s}$

Theoretical piston displacement of compressor,

$$\dot{V} = \dot{m}v_1 = 0.178 \times 0.04185$$

$$= 7.455 \times 10^{-3} \text{ m}^3/\text{s}$$

27. (b)



At state 3, $t_3 = 12°\text{C}$

$$[P_{sat}]_{12°C} = 2.34 \text{ kPa}$$

$$\phi = 0.5$$

So, $P_{v3} = \phi P_{sat} = 0.5(2.34) = 1.17 \text{ kPa}$

So, $$\omega_3 = 0.622\frac{P_{v3}}{P_{atm} - P_{v3}} = 0.622\frac{1.17}{101.3 - 1.17}$$

$$\omega_3 = 7.267 \times 10^{-3} \text{ kg/kg of d.a.}$$

At state 1, $t_1 = 2°\text{C}$

$$\phi = 100\% \text{ (Saturated air)}$$

$$P_{v1} = [P_{sat}]_{at\ 2°C} = 0.7156 \text{ kPa}$$

Now, $$\omega_1 = 0.622\frac{P_{v1}}{P_{atm} - P_{v1}} = 0.622\frac{1.7156}{101.3 - 0.7156}$$

$$\omega_1 = 4.425 \times 10^{-3} \text{ kg/kg of d.a.}$$

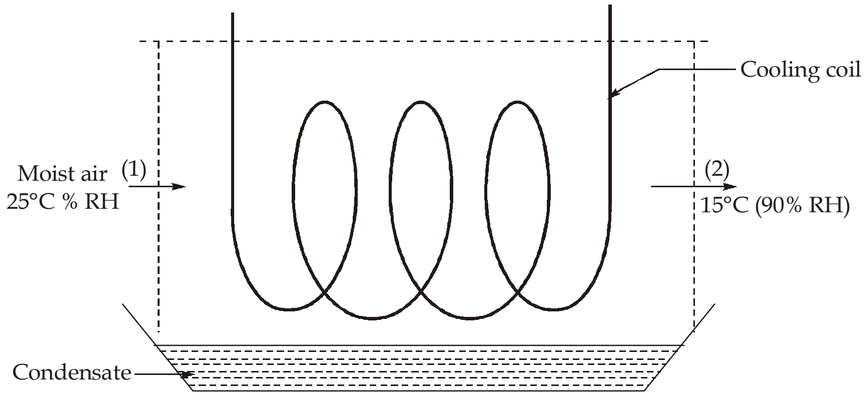
Specific volume of dry air at room temperature,

$$v_3 = \frac{RT_3}{(P_{air})_3} = \frac{0.287(273+12)}{(101.3 - 1.17)} = 0.816 \text{ m}^3/\text{kg}$$

$$\text{Spray water} = \frac{(\Delta\omega)}{v_3} = \frac{(7.267 - 4.425)}{0.816} \times 10^{-3} \text{ kg/m}^3$$

$$= 3.482 \text{ g/m}^3$$

28. (a)



By continuity equation for moisture balance.

$$\dot{m}_{water} = \dot{m}_{air} \times (\omega_1 - \omega_2)$$

Here, For ω_1 and ω_2,

$$P_{v_1} = \theta_1 P_{S1} = 0.50 \times 4.246 = 2.123 \text{ kPa}$$

$$P_{v_2} = 0.8 \times (1.7051) = 1.3641 \text{ kPa}$$

So,

$$\omega_1 = 0.622 \times \frac{P_{v_1}}{P_{atm} - P_{v_1}} = 0.622 \times \left(\frac{2.123}{101.325 - 2.123}\right)$$

$$= 0.01331 \text{ kg/kg da}$$

and

$$\omega_2 = \frac{0.622 \times 1.3641}{101.325 - 1.3641} = 0.00849 \text{ kg/ kgda}$$

So, amount of moisture condensed per kg of d.a.

$$\dot{m}_{water} = \omega_1 - \omega_2$$

$$= 0.01331 - 0.00849$$

$$= 4.82 \times 10^{-3} \text{ kg/kgda}$$

29. (c)

The refrigerator operates on ideal Carnot cycle

$$COP = \frac{T_L}{T_H - T_L} = \frac{-8 + 273}{28} = 9.464$$

Amount of cooling or heat extracted from the refrigerant space,

$$Q_L = COP \times W_{in} = 9.464 \times 15 = 141.96 \text{ kJ}$$

Amount of refrigerant that vaporizes during heat absorption is

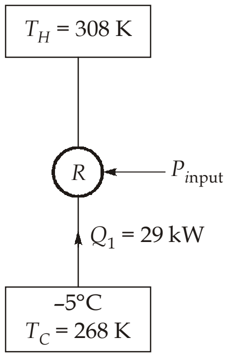
$$m_{evap} \times h_{fg} = Q_L$$

$$\Rightarrow \quad m_{evap} \times 204.52 = 141.96 \text{ kJ}$$

$$\Rightarrow \quad m_{evap} = 0.694 \text{ kg}$$

Fraction of mass that vaporises $= \dfrac{m_{evap}}{m_{total}} = \dfrac{0.694}{0.8} = 0.868 \simeq 0.87$

30. (a)



$$\text{Actual COP} = \frac{1}{3}\times\text{ideal COP} = \frac{1}{3}\times\left(\frac{T_C}{T_H - T_C}\right) = \frac{1}{3}\left(\frac{268}{308-268}\right)$$

$$(\text{COP})_{\text{actual}} = 2.23$$

$$(\text{COP})_{\text{actual}} = \frac{\text{Desired effect}}{P_{\text{input}}}$$

$$P_{\text{input}} = \frac{29}{2.23} = 13.00 \text{ kW}$$

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