CLASS TEST

Sl.: 01 JP_ME_RAC_22082022

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Refrigeration & Air Conditioning

MECHANICAL ENGINEERING

Date of Test : 22/08/2022

ANSWER KEY

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

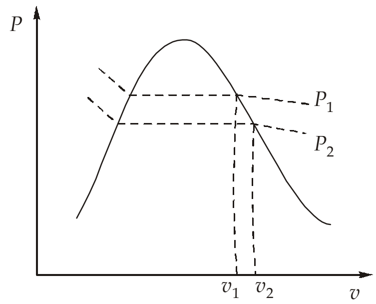
DETAILED EXPLANATIONS

1. (b)

For the same condensing temperature and refrigerating capacity, a vapour compression refrigeration system operating at a low evaporator temperature is more expensive than a system operating at a higher evaporator temperature, because with decrease in evaporator temperature the refrigeration effect of the cycle decreases and specific volume of refrigerant at exit of evaporator increases. So volumetric refrigeration effect decreases. For the same refrigeration capacity if refrigeration effect decreases we have to increase mass flow rate of refrigerant so size of compressor increases.

2. (d)

As suction line pressure decreases, pressure ratio increases and increase in pressure ratio causes increase in discharge temperature. From, Pv diagram as saturation pressure decreases specific volume at suction increases.



4. (a)

HRR is the ratio of heat rejected to the heat absorbed (refrigeration capacity).

For a fixed condenser temperature, as the evaporator temperature decreases the COP decreases and HRR increases. For fixed evaporator temperature as condenser temperature increases the COP decreases hence the heat rejection ratio increases. At a given evaporator and condenser temperatures, the HRR of refrigeration systems using hermetic compressor is higher than that of open compressor system.

5. (a)

$$SHL = mc_p\Delta T$$

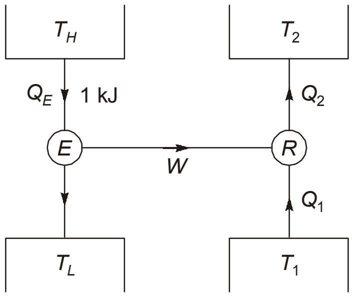
$$0.6 = \frac{(3\times10)}{3600}\times1.2\times1\times\Delta T$$

$$\Delta T = 60\text{ K}$$

6. (b)

Given: $\eta_E = 0.8 = \frac{W}{Q_E} = \frac{W}{1}$

$\Rightarrow$ $W = 0.8$ kJ



$$COP|_R = \frac{Q_2 - W}{W} = 6$$

or $$Q_2 = 5.6 \text{ kJ}$$

7. (a)

Absorption of ammonia in absorber lowers the pressure which helps to draw more ammonia.

8. (c)

For $t_w = t_{WBT}$, the sensible heat transfer from air to water is exactly equal to latent heat transfer from water to air. Hence no external cooling or heating of water is required.

9. (c)

$$NH_3 \rightarrow -33.3°C,\ CO_2 \rightarrow -73.6°C$$
$$CCl_2F_2 \rightarrow -29.8°C,\ CF_4 \rightarrow -127.8°C$$

10. (c)

As $$RSHF = 0.75 = \frac{SH}{100}$$

$\Rightarrow$ $$SH = 75 \text{ kW}$$

$\Rightarrow$ $$LH = 100 - 75 = 25 \text{ kW}$$

$\Rightarrow$ As $$RLH = 50 \text{ cmm } \Delta\omega$$

$\Rightarrow$ $$25 = 50 \times 100 \times (0.01 - \omega_2)$$

$\Rightarrow$ $$\omega_2 = 0.005 \text{ kg/kg dry air}$$

11. (c)

$$RSHF = \frac{SH}{SH + LH}$$

$$0.75 = \frac{75}{75 + LH}$$

$$LH = 25 \text{ kW}$$

Now, latent heat, $LH = 50(\text{cmm}) \times \Delta\omega$

$$\Delta\omega = \frac{25}{50 \times 200} = 0.0025 \text{ kg/kg of dry air}$$

$$\frac{25}{50 \times 200} = (\omega_{room} - \omega_{supply}) = 0.0025$$

$$\omega_{room} = 0.0025 + 0.005$$

$$\omega_{room} = 0.0075 \text{ kg/kg of dry air}$$

12. (d)

Density of water vapour, $\rho_{wv} = \dfrac{P}{RT} = \dfrac{4.62\times10^3}{0.462\times10^3\times300}$

$$\rho_{wv} = 0.0333 \text{ kg/m}^3$$

Now, density of dry air, $\rho_{da} = \dfrac{P_{da}}{RT} = \dfrac{(100-4.62)\times10^3}{0.3\times10^3\times300} = 1.0597 \text{ kg/m}^3$

Density of atmospheric air, $\rho_{atmospheric} = \rho_{da} + \rho_{wv} = 1.0597 + 0.0333$

$$\rho_{atmospheric} = 1.093 \text{ kg/m}^3$$

13. (b)

Amount of water vapour condensed= $m_{v_i} - m_{v_f}$

$$m_{v_i} = \frac{P_{v_i} V}{R_V \cdot T}$$

$$R_V = \frac{8314}{18}$$

$$m_{v_i} = \frac{0.046368\times10^5\times(8\times16)}{\frac{8314}{18}\times311} = 4.1317 \text{ kg}$$

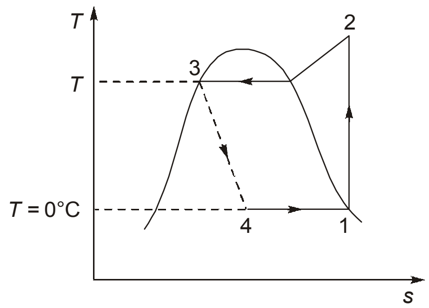
$$m_{v_f} = \frac{0.01227\times10^5\times(8\times16)\times18}{8314\times283} = 1.2015 \text{kg}$$

Amount of water condensed = 2.93 kg

14. (b)

Given:

$$h_2 = 200 \text{ kJ/kg}$$
$$w_c = h_2 - h_1 = 10 \text{ kJ/kg}$$



$\Rightarrow$ $h_1 = 190$ kJ/kg

Cooling load = 15 tons

= 15 × 3.5 kW = 52.5 kW

Cooling load per unit mass flow rate = 52.5 kJ/kg

$\Rightarrow$ $h_1 - h_4 = 52.5$

$\Rightarrow$ $h_4 = h_1 - 52.5 = 190 - 52.5 = 137.5$ kJ/kg

$\Rightarrow$ $h_3 = 137.5$ kJ/kg

h_f at condenser temperature = 137.5 kJ/kg

$\Rightarrow$ Temperature of fluid = 40°C

$\therefore$ Temperature difference required = 10°C

15. (c)

The new value of COP =3.5 and let the change of temperature T. Then, new COP would be

$$\text{COP} = \frac{T_2 + T}{(T_1 - T) - (T_2 + T)}$$

where COP of Carnot refrigerator is increased by decreasing higher temperature and increasing low temperature

where COP = 3.5

$T_2 = -40°\text{C} = (-40 + 273)\text{K} = 233\text{K}$

$T_1 = 40°\text{C} = (40 + 273)\text{K} = 313\text{K}$

$$\therefore \quad 3.5 = \frac{233 + T}{313 - T - 233 - T}$$

or $1095.5 - 3.5T - 815.5 - 3.5T = 233 + T$

or $T = 5.87\text{K}$

$\therefore$ New temperatures,

$T_2' = T_2 + T = 233 + 5.87$

$= 238.87\text{K} = -34.13°\text{C}$ **= – 34°C**

and $T_1' = T_1 - T = 313 - 5.87$

$= 3071.13\text{K} = 34.13°\text{C} \simeq$ **34°C**

16. (b)

DBT = 35°C

Relative humidity : $\phi = 75\% = 0.75$

At 35°C, $p_{vs} = 0.05628$ bar

$$\text{Relative humidity} : \phi = \frac{p_v}{p_{vs}}$$

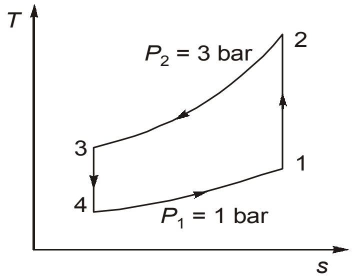
$$0.75 = \frac{p_v}{0.05628}$$

or $p_v = 0.75 \times 0.05628 = 0.04221$ bar

$$\text{Specific humidity} : \omega = \frac{0.622 p_v}{p - p_v}$$

$$= \frac{0.622 \times 0.04221}{1.01325 - 0.04221} = 0.0270 \text{ kg/kg of dry air}$$

17. (c)



$$T_1 = 270\text{ K};\ P_1 = 1 \text{ atm};\ P_2 = 3 \text{ atm}$$

$$\Rightarrow \quad T_2 = T_1 \times \left[\frac{P_2}{P_1}\right]^{\frac{\gamma-1}{\gamma}} = 270 \times (3)^{0.4/1.4} = 370\text{ K}$$

$$\Rightarrow \quad T_3 = 300 \text{ K}$$

$$\Rightarrow \quad T_4 = \frac{T_3}{\left[\frac{P_2}{P_1}\right]^{\frac{\gamma-1}{\gamma}}} = 300/(3)^{0.4/1.4} = 219.35\text{ K}$$

$$\text{Specific volume, } v_1 = \frac{RT_1}{P_1} = \frac{287 \times 270}{1.01 \times 10^5} = 0.765 \text{ m}^3/\text{kg}$$

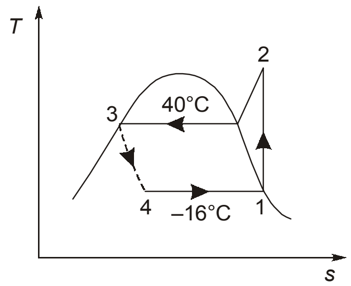
$$\text{Mass flow rate, } \dot{m} = \frac{\dot{V}}{v_1} = \frac{1.5}{0.765} = 1.96 \text{ kg/s}$$

$$\text{Net power input} = \dot{m}c_p\left[(T_2 - T_1) - (T_3 - T_4)\right]$$

$$= 1.96 \times 1.005[(370 - 270) - (300 - 219.35)] = 38.11 \text{ kW}$$

18. (a)

Given data: $h_1 = 389.02$ kJ/kg



$h_3 = 256.41 \text{ kJ/kg} = h_4$

$s_1 = 1.7379 \text{ kJ/kgK} = s_2$

To calculate discharge temperature of compressor,

$\Rightarrow$ $$s_2 = s_{g\,40°C} + c_p \ln\frac{T_2}{T_g} = s_1$$

$\Rightarrow$ $$1.711 + 1.145 \ln\frac{T_2}{313} = 1.7379$$

On solving,

$\Rightarrow$ $$T_2 = 320.5 \text{ K}$$

Now, $$h_2 = h_{g\,@40°C} + C_p[T_2 - T_3]$$
$$= 419.43 + 1.145[320.5 - 313] = 427.92 \text{ kJ/kg}$$

Now, $$\text{COP} = \frac{h_1 - h_4}{h_2 - h_1} = \frac{389.04 - 256.41}{427.92 - 389.04} = 3.41$$

19. (a)

Inlet conditions denoted by subscript 1.

Outlet conditions denoted by subscript 2.

$$P_{s1} = 4.246 \text{ kPa}$$
$$\phi_1 = 0.5$$
$$P_{v1} = \phi_1 P_{s1} = 0.5 \times 4.246 = 2.123 \text{ kPa}$$
$$P_{s2} = 1.7051 \text{ kPa}$$
$$\phi_2 = 0.8$$
$$P_{v2} = \phi_2 P_{s2} = 0.8 \times 1.7051 = 1.3641 \text{ kPa}$$

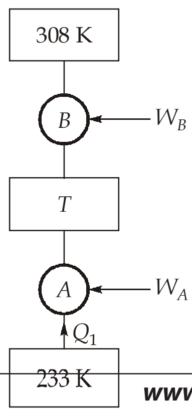
Specific humidities are:

$$\omega_1 = 0.622 \times \frac{P_{v1}}{P - P_{v1}}$$
$$= 0.622 \times \frac{2.123}{101.325 - 2.123} = 0.01331 \text{ kg/kg da}$$
$$\omega_2 = 0.622 \times \frac{P_{v2}}{P - P_{v2}}$$
$$= 0.622 \times \frac{1.3641}{101.325 - 1.3641} = 0.00849 \text{ kg/kg da}$$

$$\text{Moisture removed} = \omega_1 - \omega_2$$
$$= 0.01331 - 0.00849 = 0.00482 \text{ kg/kg da}$$

20. (b)

$$(\text{COP})_A = (\text{COP})_B$$
$$\frac{T_L}{T - T_L} = \frac{T}{T_H - T}$$
$$T_L T_H - T_L T = T^2 - T_L T$$
$$T^2 = T_L T_H$$
$$T = \sqrt{T_L T_H} = \sqrt{308 \times 233} = 267.88 \text{ K}$$



$$(COP)_A = \frac{233}{267.88 - 233} = 6.68$$

$$W_A = \frac{Q_1}{(COP)_A} = \frac{3}{6.68}$$

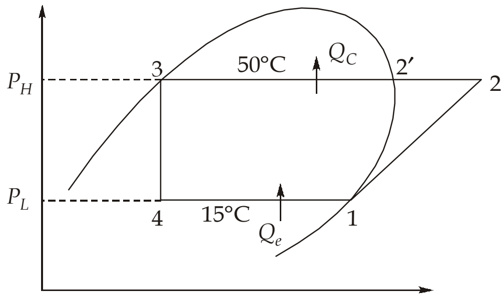
$$= 0.449 \text{ kJ/s} \simeq 0.45 \text{ kJ/s}$$

21. (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,

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

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

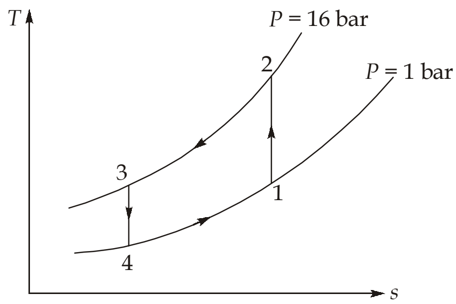
Mass flow rate of refrigerant, $\dot{m} = 0.178 \text{ kg/s}$

Theoretical piston displacement of compressor,

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

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

22. (b)



$$T_1 = -5°C = 268 \text{ K}$$

$$T_3 = 30°C = 303 \text{ K}$$

$$\frac{T_2}{T_1} = \frac{T_3}{T_4} = (r_p)^{(\gamma-1)/\gamma} = (16)^{0.4/1.4} = 2.208$$

$$T_2 = 591.74 \text{ K},\ T_4 = 137.22 \text{ K}$$

$$\text{Refrigeration effect} = h_1 - h_4 = c_p\,(T_1 - T_4)$$
$$= 1.005(268 - 137.22)$$
$$= 131.43 \text{ kJ/kg}$$

$$\text{Mass flow rate} = \frac{\text{Refrigeration capacity}}{\text{Refrigeration effect}} = \frac{33.5}{131.43} = 0.2548 \text{ kg/s}$$

$$\dot{V}_{\text{compressor}} = \frac{mRT_1}{P_1} = \frac{0.2548 \times 0.287 \times 268}{100}$$
$$= 0.196 \text{ m}^3\text{/s} = 11.76 \text{ m}^3\text{/min}$$

23. (d)

$$\dot{Q}_L = 4 \text{ kW}$$
$$T_L = 24 + 273 = 297 \text{ K}$$
$$T_H = 35°\text{C} = 35 + 273 = 308 \text{ K}$$

COP of carnot refrigerator

$$\text{COP} = \frac{T_L}{T_H - T_L} = \frac{297}{308 - 297} = 27$$

Lower limit of power input required

$$\text{COP} = \frac{\text{Desired effect}}{\text{Power input}}$$

$$\text{Power input} = \frac{4}{27} = 0.148 \approx 0.15 \text{ kW}$$

24. (b)

$$BPF = \frac{t_3 - t_2}{t_3 - t_1} = \frac{45 - 40}{45 - 20} = \frac{5}{25} = 0.20$$

25. (d)

$$\text{Cooling capacity} = 128 \text{ kW}$$
$$m_a = 3 \text{ kg/s}$$
$$h_1 = 85 \text{ kJ/kg}$$
$$\omega_1 = 20 \text{ g/kg of d.a}$$
$$h_2 = 43 \text{ kJ/kg}$$
$$\omega_2 = 10 \text{ g/kg of d.a}$$
$$h_3 = \text{enthalpy of condensate leaving the coil?}$$

Inlet mass of water vapour

$$m_{v_1} = m_a \times \omega_1$$
$$= 3 \times 20 \times 10^{-3} = 60 \times 10^{-3} \text{ kg}$$

Outlet mass of water vapour

$$m_{v_2} = m_a \times \omega_2$$
$$= 3 \times 10 \times 10^{-3}$$
$$= 30 \times 10^{-3} \text{ kg}$$

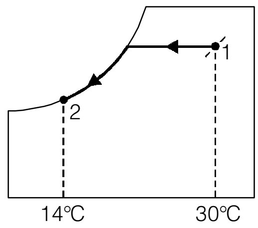
Required cooling capacity = Enthalpy of inlet air – Enthalpy of outlet air + Enthalpy of condensate water

$\Rightarrow \quad Q_c = (m_a h_1 - m_a h_2) + m_v h_3$

$\Rightarrow \quad 128 = 3[85 - 43] + 30 \times 10^{-3} \times h_3$

$\Rightarrow \quad h_3 = 66.67$ kJ/kg

28. (d)

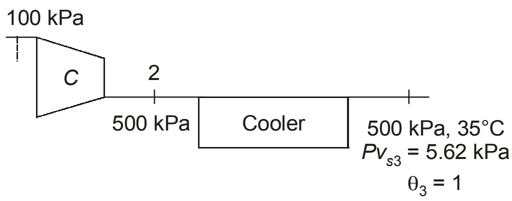


In this case, air is cooled and dehumidified by window a/c. It is a steady flow process where dry air quantity remains constant. Condensate removal takes place during the process. So, all three are applicable.

29. (a)

As the flash chamber reduces the mass flow of refrigerant through the evaporator, it helps in reduction of size of evaporator.

30. (b)



$$\theta_3 = \frac{Pv_3}{Pv_{s_3}}$$

$$Pv_3 = 5.628 \text{ kPa}$$

$$Pv_2 = Pv_3 = 5.628 \text{ kPa}$$

$$Pt_2 = sPt_1$$

$$\therefore \quad Pv_2 = \frac{Pv_2}{s} = 1.1256 \text{ kPa}$$

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