CLASS TEST

Sl.: 01 SP_ME_ABCD_15052023

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Refrigeration & Air Conditioning

MECHANICAL ENGINEERING

Date of Test : 15/05/2023

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (b)

For saturated hydrocarbon, refrigerant chemical formula is $C_m\ H_n\ F_p\ Cl_q$

$R - (m - 1)\ (n + 1)p$

where $n + p + q = 2m + 2$

$\therefore\quad m - 1 = 1,\ m = 2$

$n + 1 = 1,\ n = 0$

$p = 3$

$\therefore\quad 0 + 3 + q = 2 \times 2 + 2 = 6$

$q = 3$

$\therefore\quad R - 113 = C_2H_0\,F_3\,Cl_3 = C_2Cl_3F_3$

3. (c)

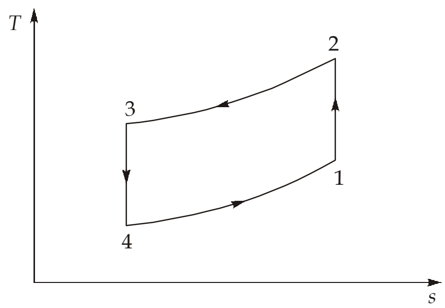
$$r_p = 10 = \frac{P_2}{P_1},\ T_1 = 283\text{ K}$$

$$\Rightarrow \quad \frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{1.4-1/1.4}$$

$$\text{COP} = \frac{1}{r_p^{\gamma-1/\gamma} - 1}$$

$$\text{COP} = \frac{1}{10^{1.4-1/1.4} - 1}$$

$$\text{COP} = 1.0745$$



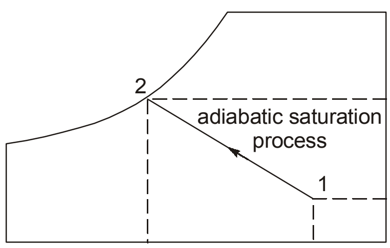
4. (b)

$$(\text{COP}) = \frac{(\text{COP})_1 \times (\text{COP})_2}{1 + (\text{COP})_1 + (\text{COP})_2} = \frac{2.3 \times 1.6}{1 + 2.3 + 1.6} = 0.751$$

7. (b)

As from diagram $\omega_2 > \omega_1$

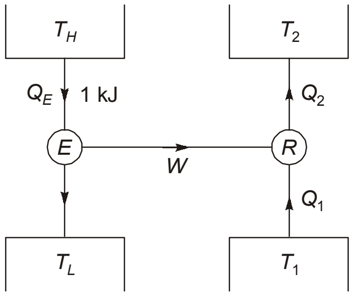
So its a humidification process.



9. (b)

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

$\Rightarrow \quad W = 0.8$ kJ



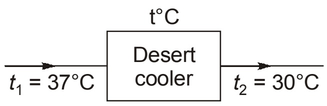
$$\text{COP}\big|_R = \frac{Q_2 - W}{W} = 6$$

or $\quad Q_2 = 5.6$ kJ

10. (a)

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

11. (d)



$$\therefore \quad \eta = 1 - \left(\frac{t_2 - t}{t_1 - t}\right)$$

$$0.7 = 1 - \left(\frac{30 - t}{37 - t}\right)$$

$\therefore \quad t = 27°C$

$\therefore$ (*D*) is the correct answer.

12. (b)

$$RC = \frac{600 \times 10^3}{24 \times 3600} \text{ kJ/sec}$$

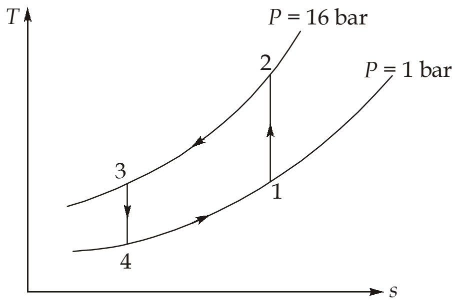
$$RC = 6.944 \text{ kW}$$

$$1\ TR = \frac{6.944}{3.5} = 1.98\ TR$$

13. (a)

Air passing through silica gel – Chemical dehumidification
Summer air conditioning – Cooling and Dehumidification
Winter air conditioning – Heating and humidification
Cooling tower – Adiabatic evaporative cooling

14. (b)



$$T_1 = -5°C = 268 \text{ K}$$
$$T_3 = 30°C = 303 \text{ K}$$
$$\frac{T_2}{T_1} = \frac{T_3}{T_4} = (r_p)^{(\gamma-1)/\gamma} = (16)^{0.4/1.4} = 2.208$$
$$T_2 = 591.74 \text{ K}, T_4 = 137.22 \text{ K}$$
$$\text{Refrigeration effect} = h_1 - h_4 = c_p(T_1 - T_4)$$
$$= 1.005(268 - 137.22)$$
$$= 131.43 \text{ kJ/kg}$$
$$\text{Mass flow rate} = \frac{\text{Refrigeration capacity}}{\text{Refrigeration effect}} = \frac{33.5}{131.43} = 0.2548 \text{ kg/s}$$
$$\dot{V}_{\text{compressor}} = \frac{mRT_1}{P_1} = \frac{0.2548 \times 0.287 \times 268}{100}$$
$$= 0.196 \text{ m}^3/\text{s} = 11.76 \text{ m}^3/\text{min}$$

15. (b)

$$\eta_v = 1 - c\left[\left(\frac{P_2}{P_1}\right)^{\frac{1}{n}} - 1\right]$$
$$\eta_v = 1 - c\left[(r_p)^{\frac{1}{n}} - 1\right]$$

For $(r_p)_{\max}$, $\eta_v = 0$

$$1 - c\left[(r_p)^{\frac{1}{n}}_{\max} - 1\right] = 0$$
$$(r_p)_{max} = \left[1 + \frac{1}{c}\right]^n = \left[1 + \frac{1}{0.05}\right]^{1.25}$$
$$= 44.95 \simeq 45$$

16. (b)

At inlet, $\phi_1 = 100\%$

$$\left(\frac{p_v}{p_{vs}}\right)_1 = 1$$
$$p_v = p_{vs} = 1.7057 \text{ kPa}$$

Since there is no pressure losses,

$$(p_v)_1 = (p_v)_2 = 1.7057 \text{ kPa}$$

Relative humidity at output,

$$\phi_2 = \left(\frac{p_v}{p_{vs}}\right)_2 = \frac{1.7057}{4.2469}$$

$$\phi_2 = 40.16\%$$

17. (a)

$$\text{COP} = \frac{T_H}{T_H - T_l} = \frac{Q_s}{W_{in}}$$

$$T_H = 273 + 74 = 374 \text{ K}$$

$$T_L = 273 - 4 = 269 \text{ K}$$

$$\Rightarrow \quad \frac{347}{347 - 269} = \frac{\frac{2000 \times 10^6}{24 \times 3600}}{W_{in}}$$

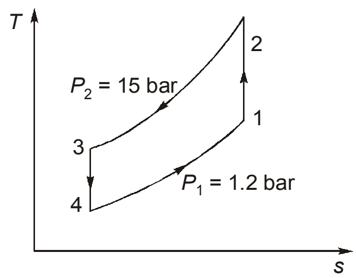
$$\Rightarrow \quad 4.4487 = \frac{23148}{W_{in}}$$

$$\Rightarrow \quad W_{in} = 5203 \text{ W} = 5.2 \text{ kW}$$

18. (b)

The discharge pressure at a given condenser temperature should be as small as possible to allow lightweight construction of compressor, condenser etc.

19. (c)



Given:

$$T_1 = 10°\text{C} = 283 \text{ K}$$

$$T_3 = 25°\text{C} = 298 \text{ K}$$

$$\frac{T_4}{T_3} = \left(\frac{P_1}{P_2}\right)^{\frac{\gamma-1}{\gamma}}$$

$$\Rightarrow \quad \frac{T_4}{298} = \left(\frac{1.2}{15}\right)^{\frac{0.4}{1.4}}$$

$$\Rightarrow \quad T_4 = 144.81\text{ K}$$

$$\text{Cooling load} = \dot{m}c_p(T_1 - T_4)$$

$$\Rightarrow \quad 50 = \dot{m} \times 1.005 \times (283 - 144.81)$$

$$\dot{m} = 0.36\text{ kg/s}$$

Volume handled by the compressor, $\dot{V}_c = \dfrac{\dot{m}RT_1}{P_1} = 0.24\text{ m}^3\text{/s}$

Volume handled by the expander, $\dot{V}_e = \dfrac{\dot{m}RT_4}{P_1} = 0.12\text{ m}^3\text{/s}$

20. (c)

Since a temperature difference of 7K is required for heat transfer, the CO_2 evaporator and NH_3 condenser temperature are given by:

$$T_{e,\,CO_2} = -36 - 7 = -43°C = 230\text{ K}$$

$$T_{c,\,NH_3} = 43 + 7 = 50°C = 323\text{ K}$$

In the cascade condenser

$$T_{c,\,CO_2} = T_{e,\,NH_3} + 7$$

Also;

$$\left(T_{c,\,CO_2} - T_{e,CO_2}\right) = \left(T_{c,\,NH_3} - T_{e,NH_3}\right)$$

$$T_{c,\,CO_2} = 280\text{ K}$$

$$T_{e,NH_3} = 273\text{ K}$$

$$(COP)_{CO_2} = \frac{T_{e,CO_2}}{T_{c,CO_2} - T_{e,CO_2}} = \frac{230}{280 - 230}$$

$$(COP)_{CO_2} = 4.6$$

$$(COP)_{NH_3} = \frac{T_{e,NH_3}}{T_{c,NH_3} - T_{e,NH_3}} = \frac{273}{323 - 273} = 5.46$$

Power input to CO_2 compressor $= W_{c,CO_2} = \dfrac{Q_{e,CO_2}}{(COP)_{CO_2}}$

$$= \frac{10 \times 3.517}{4.6} = 7.65\text{ kW}$$

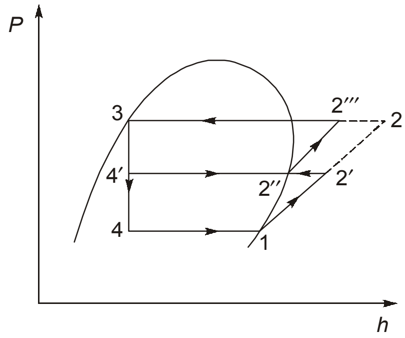
$$Q_{e,NH_3} = Q_{c,CO_2} = Q_{e,CO_2} + W_{c,CO_2}$$

$$= 35.17 + 7.65 = 42.82\text{ kW}$$

Power input to NH_3 compressor $= \dfrac{Q_{e,NH_3}}{(COP)_{NH_3}} = \dfrac{42.82}{5.46} = 7.84\text{ kW}$

21. (d)

Two stage system:



Mass flow rate through first compressor, $\dot{m}_{r1} = \dfrac{Q_e}{(h_1 - h_4)}$

$$\dot{m}_{r1} = \frac{100}{392.7 - 248.4}$$

$$\dot{m}_{r1} = 0.693 \text{ kg/s}$$

Energy balance across intercooler

$$\dot{m}_{r2} h_{1'} = \dot{m}_{r1} h_{2'} + (\dot{m}_{r2} - \dot{m}_{r1}) h_{4'} \qquad (h_{4'} = h_3 = 248.4)$$

$$\Rightarrow \quad \dot{m}_{r2}(407.2) = 0.693 \times 424.4 + (\dot{m}_{r2} - 0.693) \times 248.4$$

$$\Rightarrow \quad \dot{m}_{r2} = 0.768 \text{ kg/s}$$

$$\frac{\dot{m}_{r1}}{\dot{m}_{r2}} = 0.902$$

22. (b)

$$V = 0.1 \text{ m}^3/\text{s}$$

$$v = \frac{R_a T}{P_a} = \frac{R_a T}{P_t - P_v}$$

$$P_v = 0.8 \times P_{vs} = 1.3 \text{ kPa}$$

$$T = 15 + 273 = 288 \text{ K}$$

$$\Rightarrow \quad v = \frac{0.287 \times 288}{100 - 1.3} = 0.84 \text{ m}^3/\text{kg d.a.}$$

$$\Rightarrow \quad \dot{m}_a = \frac{V}{v} = \frac{0.1}{0.84} = 0.12 \text{ kg/s}$$

23. (b)

$$\dot{m}_a = 19 \text{ kg/s}$$

Humidity ratio at inlet, ω_i = 0.0143 kg w.a./kg d.a.

Humidity ratio at outlet, ω_o = 0.0203 kg w.a./kg d.a.

Amount of make up water required = $m_a(\omega_o - \omega_i)$

$$= 19 \times (0.0203 - 0.0143) = 114 \text{ g/s}$$

24. (c)

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

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

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

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

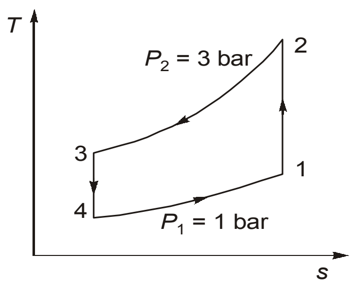
$$\Delta\omega = \frac{25}{50 \times 200} = 0.0025 \text{ kg/kg of dry air}$$

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

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

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

25. (c)



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

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

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

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

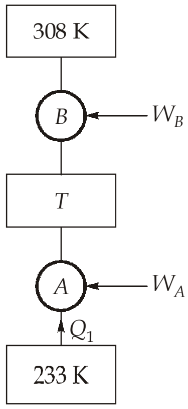
$$\text{Specific volume, } v_1 = \frac{RT_1}{P_1} = \frac{287 \times 270}{1.01 \times 10^5} = 0.765 \text{ m}^3/\text{kg}$$

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

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

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

26. (b)



$$(\text{COP})_A = (\text{COP})_B$$

$$\frac{T_L}{T - T_L} = \frac{T}{T_H - T}$$

$$T_L T_H - T_L T = T^2 - T_L T$$

$$T^2 = T_L T_H$$

$$T = \sqrt{T_L T_H} = \sqrt{308 \times 233} = 267.88 \text{ K}$$

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

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

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

27. (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

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

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

30. (a)

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

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