CLASS TEST

Sl.: 02 SPME_HIJKLMNO_111024

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REFRIGERATION & AIR CONDITIONING

MECHANICAL ENGINEERING

Date of Test : 11/10/2024

ANSWER KEY

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

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

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

$n + 1 = 1, n = 0$

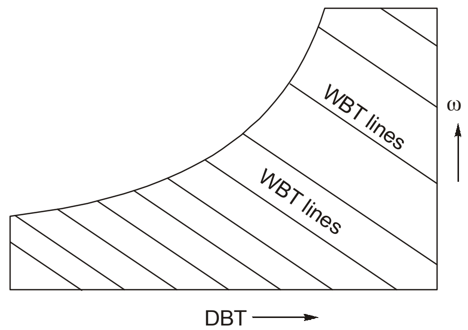
$p = 3$

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

$q = 3$

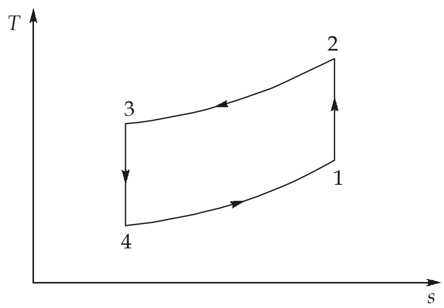
$\therefore \quad R - 113 = C_2H_0F_3Cl_3 = C_2Cl_3F_3$

4. (d)



5. (c)

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



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

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

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

$$\text{COP} = 1.0745$$

6. (c)

$$T_E = 268\text{ K} \qquad T_a = 273 + 25 = 298\text{ K}$$
$$T_G = 373\text{ K}$$
$$(COP)_{max} = \left(\frac{T_E}{T_a - T_E}\right)\times\left(\frac{T_G - T_a}{T_G}\right) = \left(\frac{268}{298-268}\right)\times\left(\frac{373-298}{373}\right) = 1.796$$
$$(COP)_a = \text{Actual COP} = 0.8\,(COP)max$$
$$= 1.437$$
$$\Rightarrow \quad 1.437 = \frac{RE}{W_{in}} = \frac{60}{Q_G}$$
$$\Rightarrow \quad Q_G = 41.75\text{ kW}$$
$$\Rightarrow \quad \dot{m}_s \times 0.95 \times h_{fg} = Q_G = 41.75$$
$$\dot{m}_s = 0.022\text{ kg/s}$$

7. (b)

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

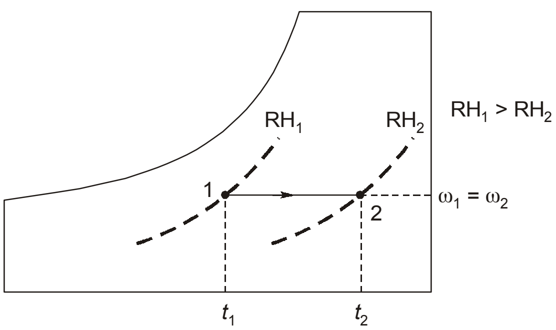
8. (d)

Given: $T = 45°C$,
$p_{vs} = 0.09584$ bar
Relative humidity, $\phi = 30\%$
$p_{atm} = 100\text{ kPa} = 1\text{ bar}$

$$\therefore \quad \phi = \frac{p_v}{p_{vs}}$$
$$p_v = 0.3 \times 0.09584 = 0.028752\text{ bar}$$
$$\text{humidity ratio, } \omega = 0.622 \times \frac{p_v}{p - p_v}$$
$$= 0.622 \times \frac{0.028752}{1 - 0.028752}$$
$$= 0.0184\text{ kg/kg of da}$$

Now
$$\text{enthalpy, } h = 1.005t + \omega(2500 + 1.88t)$$
$$= 1.005 \times 45 + 0.0184(2500 + 1.88 \times 45) = 92.816\text{ kJ/kg of da.}$$

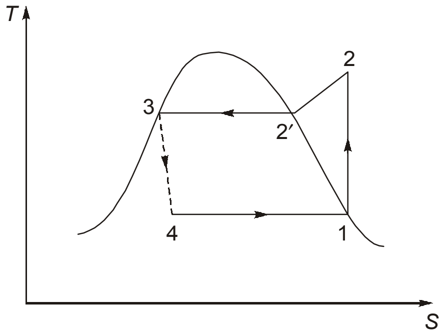
10. (b)



11. (d)

Given: $h_1 = 407.1$ kJ/kg; $h_3 = h_4 = 271.62$ kJ/kg; $S_1 = 1.72$ kJ/kgK; $S_{2'} = 1.7072$ kJ/kgK; $h_{2'} = 423.4$ kJ/kg

For the isentropic process $1 \rightarrow 2$:



$$S_1 = S_2 = S_{2'} + C_P \frac{T_2}{T_{2'}}$$

$$1.72 = 1.7072 + 1.3 \ln \frac{T_2}{(273+50)}$$

$$T_2 = (273+50)\exp\left[\frac{1.72 - 1.7072}{1.3}\right]$$

$$T_2 = 326.2 \text{ K}$$

$$\text{Enthalpy at discharge, } h_2 = h_{2'} + c_P(T_2 - T_{2'})$$

$$h_2 = 423.4 + 1.3(326.2 - 323)$$

$$= 427.56 \text{ kJ/kg}$$

12. (a)

$$\text{Relative humidity, } \phi = \frac{P_v}{P_s}$$

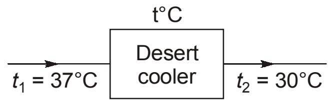
$$P_v = 0.048 \times 0.65 = 0.0312 \text{ bar}$$

$$\text{Degree of saturation, } \mu = \frac{\omega}{\omega_s} = \frac{P_v(P - P_s)}{P_s(P - P_v)}$$

$$= \frac{0.0312(1.0132 - 0.048)}{0.048(1.0132 - 0.0312)}$$

$$= \frac{0.03011424}{0.047136} = 0.63888$$

13. (d)



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

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

$$\therefore \quad t = 27°\text{C}$$

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

14. (a)

Mass of dry air/unit mass of moist air:

$$m_{a_1} = \frac{1}{1+\omega_1}\text{kg} = \frac{1}{1+0.0035} = 0.9955\,\text{kg}$$

Mass of dry air/two unit mass of moist air:

$$m_{a_2} = \frac{2}{1+\omega_2}\text{kg} = \frac{2}{1+0.0076} = 1.9849\text{ kg}$$

For the mixture, $\omega = \dfrac{m_{a_1}\omega_1 + m_{a_2}\omega_2}{m_{a_1} + m_{a_2}}$

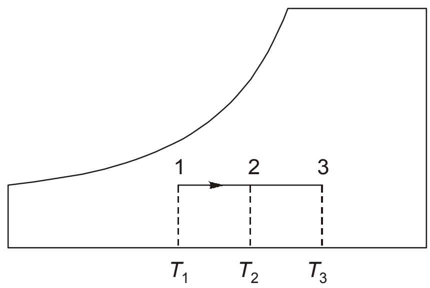
$$= \frac{0.9955 \times 0.0035 + 1.9849 \times 0.0076}{0.9955 + 1.9849}$$

$= 0.00623$ kg w.v./kg d.a

15. (d)

$T_1 = 15°\text{C}, \quad T_2 = 25°\text{C}, \quad T_3 = 34°\text{C}$

$$\text{BPF} = \frac{T_3 - T_2}{T_3 - T_1} = \frac{34-25}{34-15} = \frac{9}{19} = 0.474$$



16. (b)

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

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

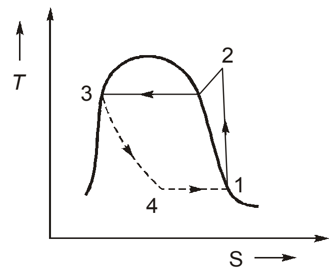
$$R_V = \frac{8314}{18}$$

$$m_{v_i} = \frac{0.046368 \times 10^5 \times (8 \times 16)}{\frac{8314}{18} \times 311} = 4.1317\text{ kg}$$

$$m_{v_f} = \frac{0.01227 \times 10^5 \times (8 \times 16) \times 18}{8314 \times 283} = 1.2015\,\text{kg}$$

Amount of water condensed = 2.93 kg

18. (a)



Given,

$$h_1 = 230 \text{ kJ/kg}$$
$$h_2 = 295 \text{ kJ/kg}$$
$$h_3 = 120 \text{ kJ/kg} = h_4 \qquad \text{(Isenthalpic process)}$$

$$\therefore \quad \text{COP} = \frac{R_E}{W_{input}} = \frac{h_1 - h_4}{h_2 - h_1} = \frac{230 - 120}{295 - 230}$$

$$\text{COP} = 1.692$$

20. (b)

For a two-stage cascade system working on Carnot cycle, the optimum cascade temperature at which the COP will be maximum, $T_{cc,\,opt}$ is given by:

$$T_{cc,\,opt} = \sqrt{T_e \cdot T_c}$$

where T_e and T_c are the evaporator temperature of low temperature cascade and condenser temperature of high temp. cascade, respectively.

$$T_e = -90°C = -90 + 273 = 183 \text{ K}$$
$$T_c = 50°C = 50 + 273 = 323 \text{ K}$$
$$T_{cc,\,opt} = \sqrt{183 \times 323} = 243.123 \text{ K} \text{ or } -29.87°C \approx -30°C$$

Note: Limitation of multi-stage vapour compression refrigeration (VCR) system are overcome by using cascade refrigeration system. In a cascade system, a series of refrigerants with progressively lower boiling points are used in a series of single stage units. The condenser of lower stage system is coupled to the evaporator of the next higher stage system and so on.

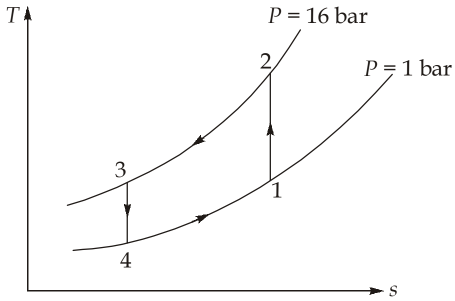
21. (b)

$$P_a = 90 \text{ kPa}$$
$$P_s = 4.2469 \text{ kPa}$$
$$\phi = 0.75$$
$$V = 40 \text{ m}^3$$
$$P_v = \phi P_s = 0.75 \times 4.2469 = 3.185 \text{ kPa}$$
$$P_a = P - P_v = 90 - 3.185 = 86.815 \text{ kPa}$$
$$m_a = \frac{P_a V}{RT} = \frac{(86.815) \times 10^3 \times 40}{287 \times 303} = 39.93 \text{ kg}$$

22. (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

23. (b)



$$T_1 = -5°C = 268\ K$$
$$T_3 = 30°C = 303\ K$$
$$\frac{T_2}{T_1} = \frac{T_3}{T_4} = (r_p)^{(\gamma-1)/\gamma} = (16)^{0.4/1.4} = 2.208$$
$$T_2 = 591.74\ K,\ T_4 = 137.22\ K$$

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

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

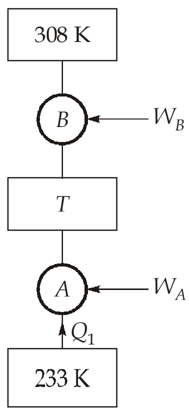
$$\dot{V}_{compressor} = \frac{mRT_1}{P_1} = \frac{0.2548 \times 0.287 \times 268}{100}$$
$$= 0.196\ m^3/s = 11.76\ m^3/min$$

24. (b)

The use of hermetic compressors is ideal in smaller refrigeration systems, which use capillary tubes as expansion devices and are critically charged systems. Hermetic compressors are normally not serviceable. They are not flexible as it is difficult to vary their speed to control the cooling capacity.

25. (b)

$$(COP)_A = (COP)_B$$
$$\frac{T_L}{T - T_L} = \frac{T}{T_H - T}$$
$$T_L T_H - T_L T = T^2 - T_L T$$
$$T^2 = T_L T_H$$
$$T = \sqrt{T_L T_H} = \sqrt{308 \times 233} = 267.88\ K$$
$$(COP)_A = \frac{233}{267.88 - 233} = 6.68$$



$$W_A = \frac{Q_1}{(\text{COP})_A} = \frac{3}{6.68}$$
$$= 0.449 \text{ kJ/s} \simeq 0.45 \text{ kJ/s}$$

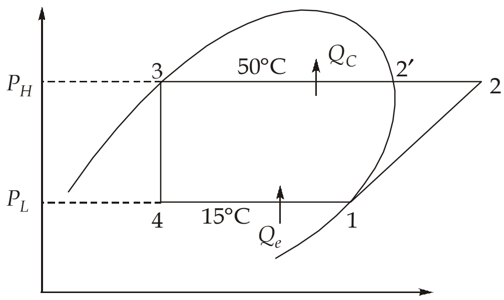
26. (a)

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,

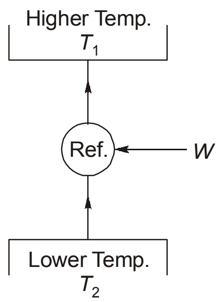
$$\dot{V} = \dot{m}v_1 = 0.178 \times 0.04185$$
$$= 7.455 \times 10^{-3} \text{ m}^3/\text{s}$$

28. (a)

$$\text{COP} = 3.6 = \frac{T_2 + T}{(T_1 - T) - (T_2 + T)}$$

Given,

$$T_2 = -40°\text{C} = -40 + 273 = 233 \text{ K}$$
$$T_1 = 30°\text{C} = 30 + 273 = 303 \text{ K}$$



$$3.6 = \frac{233 + T}{(303 - T) - (233 + T)}$$
$$3.6 = \frac{233 + T}{70 - 2T}$$
$$233 + T = 252 - 7.2\,T$$
$$T + 7.2T = 252 - 233$$
$$T = \frac{19}{8.2} = 2.317 \text{ K} \approx 2.32 \text{ K}$$

New temperature are,

$$T_{2'} = T_2 + T = 233 + 2.32 = 235.32 \text{ K or } -37.68°\text{C}$$
$$T_{1'} = T_1 - T = 303 - 2.32 = 300.68 \text{ K or } 27.68°\text{C}$$

29. **(c)**

Given data:

$$(DBT)_i = 38°C$$
$$(WBT)_i = 21°C$$
$$(WBD)_i = (DBT)_i - (WBT)_i$$
$$= 38 - 21 = 17°C$$

Web bulb depression at output,

$$(WBD)_o = (DBT)_0 - (WBT)_o$$
$$(WBD)_o = 25\% \ (WBD)_i$$
$$(DBT)_o - (WBT)_o = 0.25 \times 17$$
$$(DBT)_o = 4.25°C + 21°C$$
$$(DBT)_o = 25.25°C$$

30. **(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,

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

$$\phi_2 = 40.16\%$$

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