CLASS TEST

S.No. : 01SP_ME_D+E_130522

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REFRIGERATION & AIR CONDITIONING

MECHANICAL ENGINEERING

Date of Test : 13/05/2022

ANSWER KEY

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

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

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

$p = 3$

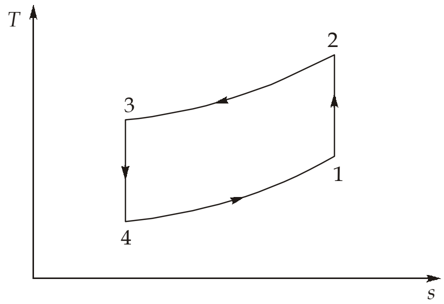
$\therefore\ 0 + 3 + q = 2 \times 2 + 2 = 6$

$q = 3$

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

5. (c)

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



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

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

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

$$\text{COP} = 1.0745$$

6. (c)

$$T_E = 268\text{ K} \qquad T_a = 273 + 25 = 298\text{ K}$$

$$T_G = 373\text{ K}$$

$$(\text{COP})_{max} = \left(\frac{T_E}{T_a - T_E}\right)\times\left(\frac{T_G - T_a}{T_G}\right) = \left(\frac{268}{298-268}\right)\times\left(\frac{373-298}{373}\right) = 1.796$$

$(\text{COP})_a$ = Actual COP = 0.8 (COP)max

$= 1.437$

$$\Rightarrow 1.437 = \frac{RE}{W_{in}} = \frac{60}{Q_G}$$

$$\Rightarrow Q_G = 41.75\text{ kW}$$

$$\Rightarrow \dot{m}_s \times 0.95 \times h_{fg} = Q_G = 41.75$$

$$\dot{m}_s = 0.022\text{ kg/s}$$

7. (b)

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

8. (d)

Given: $T = 45°\text{C}$,

$p_{vs} = 0.09584$ bar

Relative humidity, $\phi = 30\%$

$p_{atm} = 100$ kPa = 1 bar

$$\therefore \quad \phi = \frac{p_v}{p_{vs}}$$

$$p_v = 0.3 \times 0.09584 = 0.028752 \text{ bar}$$

$$\text{humidity ratio, } \omega = 0.622\times\frac{p_v}{p-p_v}$$

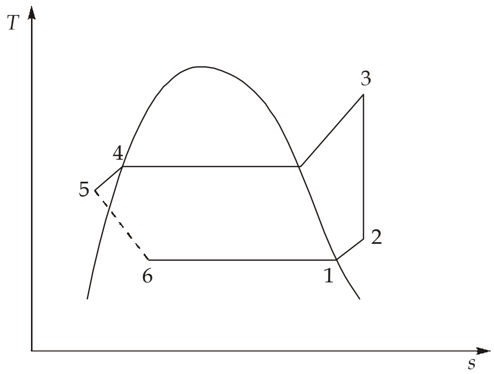
$$= 0.622\times\frac{0.028752}{1-0.028752}$$

$$= 0.0184 \text{ kg/kg of da}$$

Now 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)



Degree of superheat at suction $t_2 - t_1 = 15 - (-15) = 30\text{K}$

By interpolating for superheated vapour

$$h_2 = 193.2+\frac{30-20}{20}\times(205.7-193.2)$$

$$h_2 = 199.45 \text{ kJ/kg}$$

Now, $h_2 - h_1 = h_4 - h_5$

$$199.45 - 181 = 69.5 - h_5$$

$$h_5 = 51.05 \text{ kJ/kg}$$

11. (b)

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

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

12. (b)

$$W_{net/kg} = \text{Work done on compressor – work done by expander}$$

$$= \frac{n_1}{n_1-1}R(T_2-T_1) - \frac{n_2}{n_2-1}R(T_3-T_4)$$

$$= \frac{n_1}{n_1-1}RT_1\left[\left(\frac{P_2}{P_1}\right)^{n_1-1/n_1}-1\right] - \frac{n_2}{n_2-1}RT_4\left[\left(\frac{P_3}{P_4}\right)^{n_2-1/n_2}-1\right]$$

where $n_1 = 1.2,\ R = 0.287$ kJ/kgK

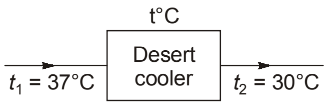
$T_1 = 263$ K, $n_2 = 1.35$, $T_3 = 273 + 30 = 303$ K

$$T_4 = \frac{T_3}{\left(\frac{P_2}{P_1}\right)^{\frac{1.35-1}{1.35}}} = \frac{303}{(6.5)^{0.35/1.35}} = 186.5\,\text{K}$$

$$\therefore W_{net}/\text{kg} = \left(\frac{1.2}{1.2-1}\times 0.287\times 263\times\left((6.5)^{0.2/1.2}-1\right)\right) - \left(\frac{1.35}{1.35-1}\times 0.287\times 186.5\left((6.5)^{0.35/1.35}-1\right)\right)$$

$$= 165.75 - 129.03 = 36.72\ \text{kJ/kg}$$

13. (d)



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

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

$$\therefore \quad t = 27°\text{C}$$

∴ (*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,
$$\omega = \frac{m_{a_1}\omega_1 + m_{a_2}\omega_2}{m_{a_1}+m_{a_2}}$$

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

$$= 0.00623\ \text{kg w.v./kg d.a}$$

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

17. (c)

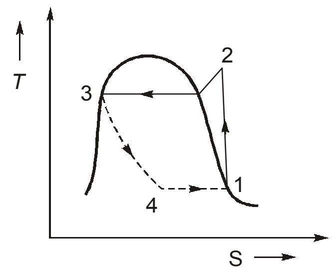
$$\omega = 0.622 \frac{p_v}{p_a} = 0.622 \frac{p_v}{p_t - p_v}$$

$$0.0085 = 0.622 \frac{p_v}{1.01325 - p_v}$$

$$\Rightarrow \quad p_v = 0.01366$$

$$\phi = \frac{0.01366}{0.0234} = 0.5837$$

18. (a)



Given, $h_1 = 230$ kJ/kg

$h_2 = 295$ kJ/kg

$h_3 = 120$ kJ/kg $= h_4$ (Isenthalpic process)

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

$$COP = 1.692$$

19. (b)

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

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

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

20. **(b)**

Since the cycle shown is anti-clockwise

∴ It is work-absorbing device cycle. Hence, it will be used in air-refrigeration. The cycle shown is a reverse Brayton cycle.

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)**

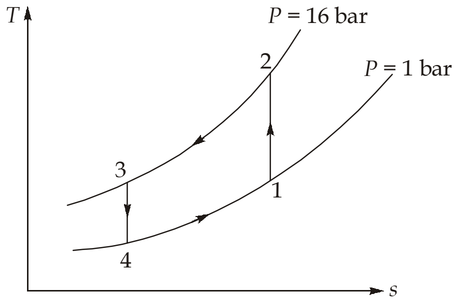
Air passing through silica gel – Chemical dehumidification

Summer air conditioning – Cooling and Dehumidification

Winter air conditioning – Heating and humidification

Cooling tower – Adiabatic evaporative cooling

23. **(b)**



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

24. (a)

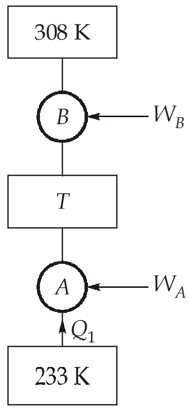
COP for Bell-Coleman cycle is given by,

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

where, P_1 = 1.05 bar, P_2 = 8.5 bar

$$\therefore \quad \text{COP} = \frac{1}{\left(\frac{8.5}{1.05}\right)^{\frac{0.4}{1.4}} - 1} = 1.22$$

25. (b)



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

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

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

$$T^2 = T_L T_H$$

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

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

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

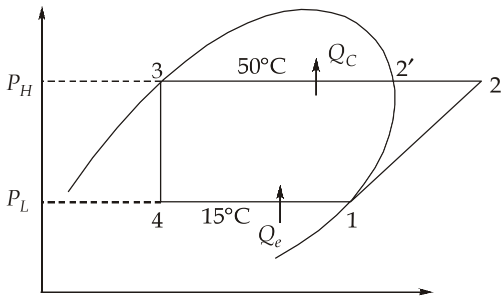
$$= 0.449\text{ kJ/s} \simeq 0.45\text{ kJ/s}$$

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)

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

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

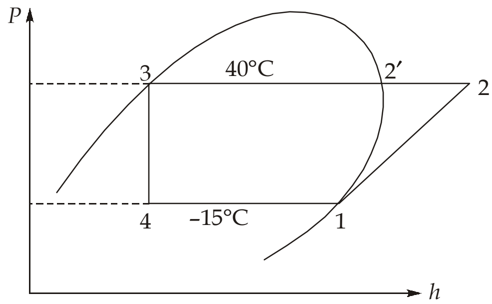
For $(r_p)_{max}$, $\eta_v = 0$

$$1 - c\left[(r_p)_{max}^{\frac{1}{n}} - 1\right] = 0$$

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

$$= 44.95 \simeq 45$$

28. (b)



For process 1 - 2,

$$S_1 = S_2$$

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

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

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

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

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

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

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

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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