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Refregeration & Air Conditioning

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CLASS TEST 2019-2020

MECHANICAL ENGINEERING

Date of Test : 15/09/2019

ANSWER KEY ➤ Refregeration & Air Conditioning

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

DETAILED EXPLANATIONS

1. (b)

Since the cycle shown is anti-clockwise

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

3. (b)

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

4. (a)

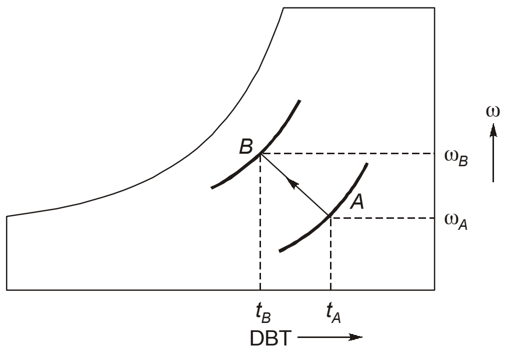
Air passing through silica gel – Chemical dehumidification

Summer air conditioning – Cooling and Dehumidification

Winter air conditioning – Heating and humidification

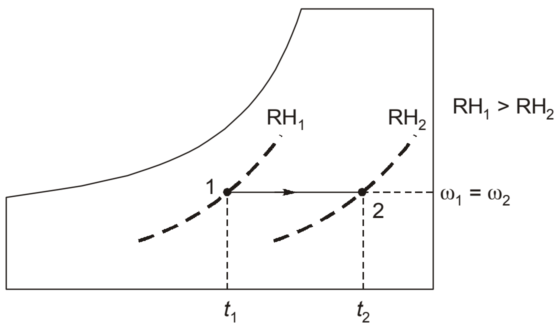
Cooling tower – Adiabatic evaporative cooling

5. (b)



We can see that $t_A > t_B$ and $\omega_B > \omega_A$. Therefore, correct answer is (b).

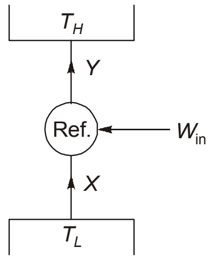
6. (b)



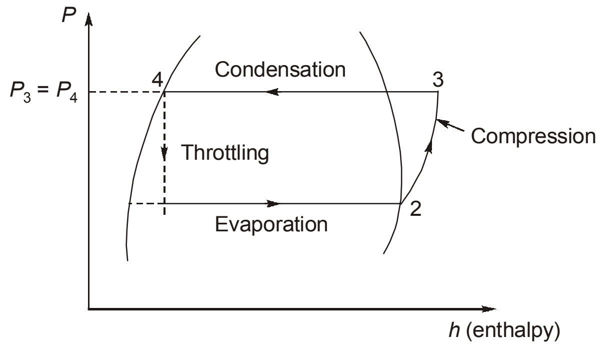
7. (a)

$$\text{COP} = \frac{\text{Heat extracted}}{\text{Work input}}$$

$$= \frac{X}{Y - X}$$



8. (b)



11. (b)
At very low evaporator temperature, the COP becomes very low and also the size of the compressor becomes large (due to small volumetric refrigeration effect).

13. (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

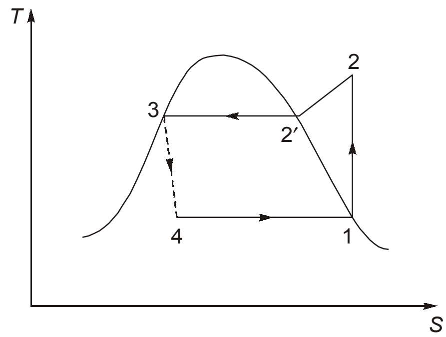
For the isentropic process $1 \to 2$:

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

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

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

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



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

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

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

14. (a)

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

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

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

$$= \frac{0.0312(1.0132 - 0.048)}{0.048(1.0132 - 0.0312)} = \frac{0.03011424}{0.047136} = 0.63888$$

15. (b)

$$\text{Specific humidity, } \omega = 0.0186 \text{ kg vapour/kg of dry air}$$

$$\omega = 0.622\frac{P_v}{P-P_v} \quad \text{(where } P_v \text{ is vapour pressure)}$$

$$0.0186 = 0.622\left(\frac{P_v}{1.0132-P_v}\right)$$

$$1.0132 \times 0.0186 - 0.0186\,P_v = 0.622\,P_v$$

$$P_v = \frac{1.0132 \times 0.0186}{0.6406}$$

$$P_v = 0.0294 \text{ bar}$$

$$\text{Relative humidity, } \phi = \frac{P_v}{P_s} = \frac{0.0294}{0.0563} = 0.5222 \text{ or } 52.22\%$$

16. (c)

$$(\text{COP})_1 = 5,\ (\text{COP})_2 = 5.5$$

$$\text{Combined COP} = \frac{(\text{COP})_1 \times (\text{COP})_2}{1+(\text{COP})_1+(\text{COP})_2}$$

$$= \frac{5 \times 5.5}{1+5+5.5} = \frac{27.5}{11.5} = 2.39$$

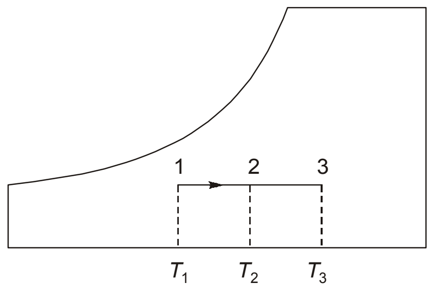
17. (d)

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

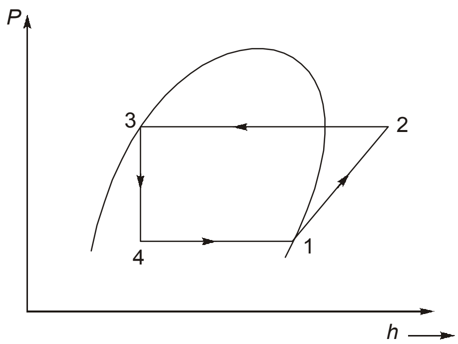
$$\text{BPF} = \frac{T_3 - T_2}{T_3 - T_1}$$

$$= \frac{34-25}{34-15}$$

$$= \frac{9}{19} = 0.474$$



18. (b)



$$h_1 = 210 \text{ kJ/kg}$$

$$h_3 = h_4 = 74 \text{ kJ/kg}$$

$$\text{mass flow rate, } \dot{m} = 1 \text{ kg/s}$$

$$\text{Cooling load, } Q = \dot{m}(h_1 - h_4)$$

$$= 1(210-74)$$

$$= 136 \text{ kW}$$

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.

$$T_e = -90°\text{C} = -90 + 273 = 183 \text{ K}$$

$$T_c = 50°C = 50 + 273 = 323 \text{ K}$$

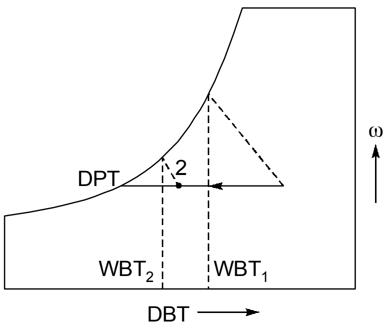
$$T_{cc,\,opt} = \sqrt{183 \times 323} = 243.123 \text{ K or } -29.87°C \approx -30°C$$

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)

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.

22. (b)



We can see that

DPT = constant

$WBT_2 < WBT_1$

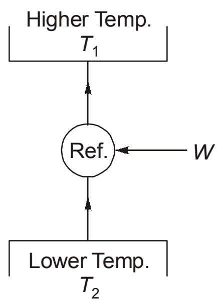
$DBT_1 > DBT_2$

23. (b)

Based on Gibbs' phase rule, the thermodynamic state of moist air is uniquely fixed if the barometric pressure and two other independent properties are known. So, statement 4 is correct (not 3).

24. (a)

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



Given,

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

$$T_1 = 30°C = 30 + 273 = 303 \text{ K}$$

$$3.6 = \frac{233 + T}{(303 - T) - (233 + T)}$$

$$3.6 = \frac{233 + T}{70 - 2T}$$

$$233 + T = 252 - 7.2\,T$$

$$T + 7.2T = 252 - 233$$

$$T = \frac{19}{8.2} = 2.317 \text{ K} \approx 2.32 \text{ K}$$

New temperature are,

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

$$T_{1'} = T_1 - T = 303 - 2.32 = 300.68 \text{ K or } 27.68°C$$

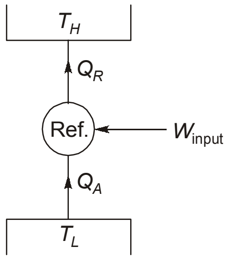
26. (b)

$$\text{COP} = \frac{Q_A}{W_{in}} = \frac{Q_A}{Q_R - Q_A}$$

$$Q_R - Q_A = \frac{Q_A}{\text{COP}}$$

$$= \frac{9}{3.5} = 2.57 \text{ kJ}$$

$$Q_R = 9 + 2.57 = 11.57 \text{ kJ}$$



28. (a)

$$\text{COP} = \frac{1}{(r_p)^{\frac{\gamma-1}{\gamma}} - 1} = \frac{1}{(5)^{\frac{0.4}{1.4}} - 1} = 1.713$$

29. (d)

$$\omega = 0.015 \text{ kg w.v/kg d.a.}$$

$$P = 740 \text{ mm of Hg}$$

$$\omega = 0.622\left(\frac{P_v}{P - P_v}\right)$$

Where P_v = partial pressure of water vapour

$$0.015 = 0.622\left(\frac{P_v}{740 - P_v}\right)$$

$$0.015 \times 740 - 0.015\, P_v = 0.622\, P_v$$

$$P_v = \frac{0.015 \times 740}{(0.622 + 0.015)} = 17.42 \text{ mm Hg}$$

Partial pressure of given air sample, $P_a = P - P_v = 740 - 17.42 = 722.58$ mm Hg

$$\text{Specific volume of air, } v_a = \frac{R_a T}{P_a} = \frac{287 \times (273 + 21)}{\frac{722.58}{1000} \times 13.6 \times 1000 \times 9.81} = 0.8752 \text{ m}^3\text{/kg.d.a}$$

30. (a)

Given: h_1 = 190 kJ/kg; h_2 = 215 kJ/kg; $h_3 = h_4$ = 75 kJ/kg

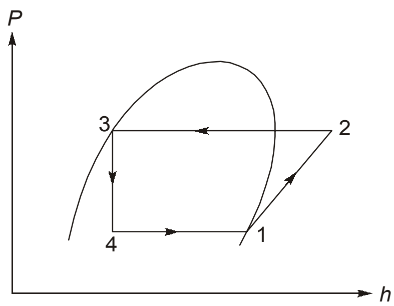
$$\text{Refrigerant flow, } \dot{m} = \frac{Q}{q_0}$$

$$\text{Refrigerant effect, } q_0 = h_1 - h_4$$

$$= 190 - 75 = 115 \text{ kJ/kg}$$

$$Q = 12 \times 3.5 \text{ kJ/s}$$

$$\dot{m} = \frac{12 \times 3.5}{115} = 0.3652 \text{ kg/s}$$



$$\text{Power consumption} = \dot{m}(h_2 - h_1) = 0.3652\,(215 - 190) = 9.13 \text{ kW}$$

$$\text{Horse power/ton of refrigeration} = \frac{9.13 \times 1000}{746 \times 12} = 1.02 \text{ HP/TR}$$

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