Number of Questions 25 **Time:60 min.**

Directions for questions 1 to 25: Select the correct alternative from the given choices.

1. Which component of a vapor compression refrigeration cycle produces the refrigerating/cooling effect?
(A) Expansion valve (B) Condenser
(C) Evaporator (D) Compressor

2. In a vapor compression refrigeration cycle the isenthalpic process takes place in the
(A) Compressor (B) Evaporator
(C) Condensor (D) Expansion device

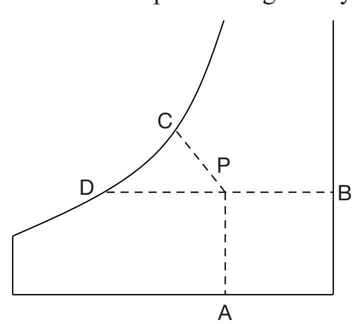
3. Which component of a vapor-compression refrigeration cycle is replaced by an expansion device in the gas-refrigeration cycle?
(A) Compressor (B) Evaporator
(C) Condensor (D) Throttle valve

4. The partial pressures of dry air and water vapor are 98.32 kPa and 1.68 kPa respectively at a given temperature. What is the specific humidity of this mixture?
(A) 58.52380 (B) 0.01063
(C) 36.40180 (D) 0.98937

5. Air at 20°C and 60% relative humidity has a mass of 3 kg, if the specific humidity is 0.00256 kg of vapor/kg of dry air, then the mass of dry air in kg is
(A) 2.9507 (B) 2.9924
(C) 2.8317 (D) 1.7954

6. In chemical dehumidification process
(i) DBT decreases
(ii) Specific humidity decreases
(iii) DBT increases
(iv) Humidity decreases
(A) (i), (iii) and (iv) (B) (i) and (ii)
(C) (ii), (iii) and (iv) (D) (i) and (iv)

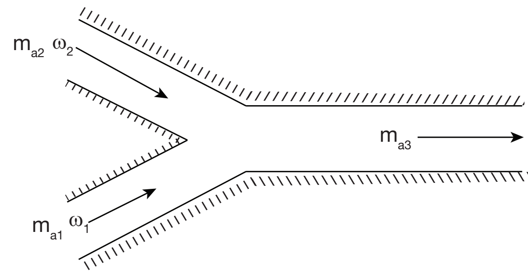
7. A point *P* is plotted on the psychometric chart, the dew point temperature of the point *P* is given by the point



(A) *A* (B) *B*
(C) *C* (D) *D*

8. The wet bulb depression of air at 30°C is found to be 2.35°C. What is the wet bulb temperature of this air-water vapor mixture?
(A) 27.65°C (B) 32.35°C
(C) 28°C (D) 27°C

9. In an adiabatic mixing process of air streams the specific humidity of the final mixture in kg *w.v*/kg *d.a* is



m_a = mass of dry air
m_{a1} = 3 kg
m_{a2} = 2 kg
ω_1 = 0.02 kg *w.v* /kg *d.a*
ω_2 = 0.03 kg *w.v*/kg *d.a*
(*w.v* → water vapor, *d.a* → dry air)
(A) 0.025 (B) 0.024
(C) 0.12 (D) 0.06

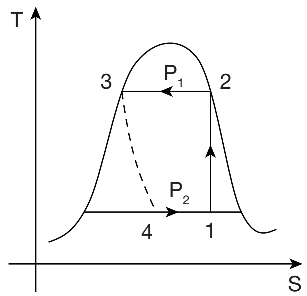
10. A process 1-2 increases the specific humidity of the mixture from ω_1 to ω_2, then which of the following must be true?
(A) DBT increases
(B) DBT decreases
(C) Enthalpy increases
(D) Relative humidity increases
(A) *a*, *c* and *d* (B) *a* and *c*
(C) *c* and *d* (D) *b* and *c*

11. A person working at Hyderabad (room temperature 27°C) got relocated to Bengaluru (room temperature 22°C) because of her promotion. She carried her refrigerator with her to Bengaluru, temperature she maintained in the refrigerator is 7°C. If the refrigerator works according to a reversed Carnot cycle then what is the percentage change in the COP of the refrigerator?
(A) 33.34% (B) 66.67%
(C) 15% (D) 25%

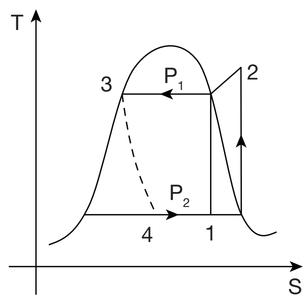
12. The heat received by a reversible pump from a temperature of 5°C, it follows a reversed Carnot cycle, is 94 kW. The heat pump is used to maintain a room at 25°C. What is the amount of work input to the heat pump?
(A) 96.475 kW (B) 6.763 kW
(C) 87.237 kW (D) 100.763 kW

13. In which of the given two vapor compression refrigeration cycles the wear of the compressor is more?

(P)



(Q)



(A) Q (B) P
(C) Both have equal wear (D) Insufficient data

14. Match the following refrigerants with their designation

	List I		List II
P	R134	1	$C\,Cl_2\,F_2$
Q	R22	2	$C_2\,H_2\,F_4$
R	R11	3	$C\,H\,Cl\,F_2$
S	R12	4	$C\,Cl_3\,F$

	P	Q	R	S
(A)	2	3	1	4
(B)	3	2	1	4
(C)	2	3	4	1
(D)	3	2	4	1

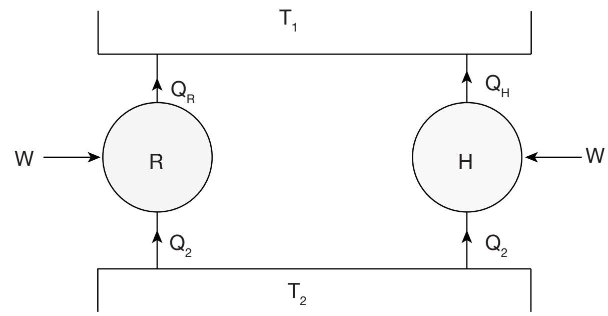
15. Match the refrigerant with the appropriate application

	Refrigerant		Uses
M	R11	1	Transport refrigerant
N	CO_2	2	Food refrigerant
O	NH_3	3	Reciprocating compressors
P	R22	4	Centrifugal compressors

	M	N	O	P
(A)	2	1	4	3
(B)	3	4	1	2
(C)	4	1	2	3
(D)	3	1	2	4

16. A heat pump(H) and a refrigerator(R) are working within the same temperature limits as shown. The heat extracted from the low temperature limit and the work input are same for both. What is the relation between the *COPs* of both?

(A) $(COP)_R > (COP)_H$
(B) $(COP)_H > (COP)_R$
(C) $\dfrac{1}{(COP)_H} - \dfrac{1}{(COP)_R} = W$



(A) Only (A)
(B) Only (B)
(C) (B) and (C)
(D) (A), (B) and (C)

17. A refrigerator maintains the temperature of vegetables at 7°C when the room temperature is 27°C. The COP of the refrigerator is 0.17 times of the Carnot refrigerator. What is the power consumption in (kWhr) if the thermal load of 9000 kJ/day is handled by the refrigerator?

(A) 3781.5 (B) 0.0437
(C) 1.05 (D) 2.62

18. The compressor work of a refrigerator working on a vapor compression refrigeration cycle is 300 W with an efficiency of 75%. The heat flow to the atmosphere is 600 kJ/hr from the condenser and the compressor works only for 20% of the time. What is the COP of the system?

(A) 2.7 (B) 0.73
(C) 0.37 (D) 1.7

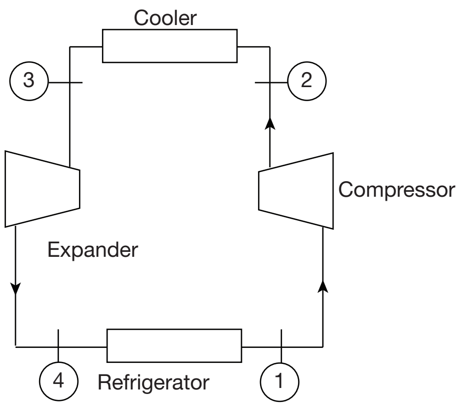
19. The efficiencies of three Carnot engines are 0.4, 0.35 and 0.5 respectively. When the cycles are reversed the *COP*'s are x, y and z respectively. What is the relation between x, y and z.

(A) $x = y = z$
(B) $x > y > z$
(C) $z > y > x$
(D) $y > x > z$

20. A gas-refrigeration cycle with isentropic compression and expansion employs air as the working fluid. If the compressor pressures are 0.1 MPa and 0.3 MPa then what is the *COP* of the refrigerator?

(A) 0.24 (B) 0.36
(C) 0.63 (D) 0.58

21. The enthalpies of the gas at different stages of a refrigeration system are given as shown in the figure. What is the *COP* of the system?



$h_1 = 500$ kJ/kg
$h_2 = 700$ kJ/kg
$h_3 = 300$ kJ/kg
$h_4 = 200$ kJ/kg

(A) 3 (B) 4
(C) 2 (D) 1

22. When the degree of saturation of an air-water vapor mixture is one, the relative humidity of the mixture is

(A) 25% (B) 50%
(C) 100% (D) 75%

23. A unsaturated air-water vapor mixture is cooled at constant pressure until the water vapor reaches the saturated state. What happens upon further cooling?

(A) Sublimation (B) Evaporation
(C) Freezing (D) Condensation

24. The partial pressure and the saturation pressure of water vapor in a mixture at a dew point temperature of 15°C are 1707.5 Pa and 25.86 kPa respectively. What is the degree of saturation of the mixture?

(A) 0.05 (B) 0.06
(C) 0.09 (D) 0.025

25. Match the processes with the effects.

Process		Effect	
T	Humidification	**1**	DBT decreases
U	Heating and dehumidification	**2**	Enthalpy increases
V	Cooling and dehumidification	**3**	Specific humidity decreases

	T	*U*	*V*
(A)	2	1	3
(B)	3	1	2
(C)	3	2	1
(D)	2	3	1

Answer Keys

1. C	**2.** D	**3.** D	**4.** B	**5.** B	**6.** C	**7.** D	**8.** A	**9.** B	**10.** C
11. A	**12.** B	**13.** B	**14.** C	**15.** C	**16.** B	**17.** C	**18.** A	**19.** D	**20.** C
21. C	**22.** C	**23.** D	**24.** A	**25.** D					

Hints and Explanations

1. In a vapor compression refrigeration cycle the refrigerant expands in the evaporator by a constant pressure reversible process. The refrigerant entering the evaporator has the saturation temperature below the saturation temperature of the surrounding, thus heat flows from the surroundings, which is cooled.

Choice (C)

2. Choice (D)

3. The throttle valve does not provide a good temperature drop while using a real gas. Therefore, a expander is used in gas-refrigeration cycle. Choice (D)

4. Specific humidity = ω

$$= 0.622.\frac{P_v}{P_a}\ (P_v = 1.68 \text{ kPa and } P_a = 98.32 \text{ kPa})$$

$$\therefore \quad \omega = 0.622 \times \frac{1.68}{98.32} = 0.01063$$ Choice (B)

5. Mass of air = 3 kg = $m_v + m_a$

m_v = mass of vapor

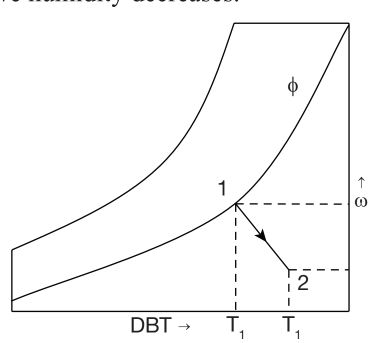
m_a = mass of dry air

$\therefore$ specific humidity = ω

$$= \frac{m_v}{m_a} = \frac{3 - m_a}{m_a} = 0.00256$$

$\Rightarrow \quad m_a = 2.9924$ kg Choice (B)

6. The process 1–2 is a chemical dehumidification process in which DBT increases, specific humidity decreases and relative humidity decreases.



ϕ/Relative Humidity
ω – specific humidity
DBT – Dry blub temperature Choice (C)

7. Choice (D)

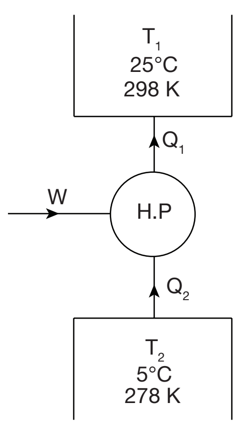
8. Wet bulb depression = *DBT* – *WBT*
$\therefore$ 2.35 = 30 – *WBT*
$\Rightarrow$ *WBT* = 27.65°C Choice (A)

9. In adiabatic mixing of two air streams.
$m_{a3} = m_{a1} + m_{a2} = 3 + 2 = 5$ kg
By moisture balance,
$m_{a1}\,\omega_1 + m_{a2}\,\omega_2 = m_{a3}\,\omega_3$
$\Rightarrow$ $\omega_3 = (m_{a1}\,\omega_1 + m_{a2}\,\omega_2)/m_{a3}$
$\omega_3 = [(3 \times 0.02) + (2 \times 0.03)]/5$
$\omega_3 = 0.024$ kg *w.v*/kg *d.a* Choice (B)

10. In humidification, there can be a constant *DBT* humidification but the relative humidity and the enthalpy will always increase. Choice (C)

11. Hyderabad, $T_1 = 27°C = 300$ K
$T_2 = 7°C = 280$ K
$$(COP)_H = \frac{T_2}{T_1 - T_2} = \frac{280}{300 - 280} = 14$$
Bengaluru, $T_1 = 22°C = 295$ K
$T_2 = 7°C = 280$ K
$$(COP)_B = \frac{T_2}{T_1 - T_2} = \frac{280}{295 - 280} = 18.67$$
$$\%\text{ change in } COP = \frac{(COP)_B - (COP)_H}{(COP)_H} = \frac{18.67 - 14}{14}$$
= 0.3334 = 33.34% Choice (A)

12. $$(COP)_{HP} = \frac{T_1}{T_1 - T_2} = \frac{298}{298 - 278} = 14.9$$
But, $$(COP)_{HP} = \frac{Q_1}{Q_1 - Q_2}$$



Q_1 = heat supplied to the room
Q_2 = 94 kW
W = work input = $Q_1 - Q_2$

$$\therefore \quad \frac{Q_1}{Q_1 - Q_2} = 14.9 \Rightarrow \frac{Q_1}{Q_1 - 94} = 14.9$$
$\Rightarrow$ $Q_1 = 100.763$ kW
Work input = $Q_1 - Q_2$ = 100.763 – 94 = 6.763 kW
Choice (B)

13. The compression in cycle *P* is a wet compression in which the input to the compressor is a mixture of gas and liquid. Wet compression results in accelerated wear due to the wash away of lubricating oil from the walls of the cylinder. Choice (B)

14. The designation of refrigerants is:
$R(m - 1)(n + 1)p = C_m H_n F_p Cl_q$
and $2m + 2 = n + p + q$
$\therefore$ $R134 = C_2 H_2 F_4$ (2)
$R22 = CHClF_2$ (3)
$R11 = CCl3F$ (4)
$R12 = CCl_2F_2$ (1) Choice (C)

15. Choice (C)

16. $$(COP)_R = \frac{Q_2}{Q_R - Q_2} \ (COP \text{ of refrigerant})$$
$$(COP)_H = \frac{Q_H}{Q_H - Q_2} \ (COP \text{ of heat pump})$$
$Q_H - Q_2 = Q_R - Q_2 = \mathrm{W} \Rightarrow Q_R = Q_H$
$$\therefore \quad (COP)_R = \frac{Q_2}{W} \text{ and } (COP)_H = \frac{Q_H}{W}$$
$\because$ $Q_H > Q_2 \Rightarrow (COP)_H > (COP)_R$
$$\frac{1}{(COP)_H} - \frac{1}{(COP)_R} = \frac{Q_H - Q_2}{Q_H} - \frac{Q_R - Q_2}{Q_2}$$
$$= \frac{Q_H^2 - 2Q_2\,Q_H + Q_2^2}{Q_H\,Q_2}$$
$$\therefore \frac{1}{(COP)_H} - \frac{1}{(COP)_R} \neq W$$ Choice (B)

17. Thermal load = Q_2 = 9000 kJ/day
$$\text{Carnot } COP = \frac{T_2}{T_1 - T_2} = \frac{280}{300 - 280} = 14$$
COP of refrigerator = 0.17 × 14 = 2.38
$$\therefore \quad \frac{Q_2}{W} = \frac{9000}{W} = 2.38 \Rightarrow \quad W = 3781.51 \text{ kJ/day}$$
W = 0.0437 kW(for 1 day = 24 hours)
$\therefore$ W = 0.0437 × 24 = 1.05 kWhr Choice (C)

18. Compressor work = 300 × 0.75 = 225 W
For 1 hour,
Condenser heat flow = 600 kJ
Compressor work = 225 × 0.2 × (60 × 60) = 162000 J
$$\therefore \quad \text{COP of the system} = \frac{600 - 162}{162} = 2.7$$ Choice (A)

19.

For engine 1,	For engine 2,	For engine 3,
$\eta = \frac{T_1 - T_2}{T_1}$ $= 0.4$ $\Rightarrow T_2 = 0.6T_1$ When reversed, the $\text{COP} = \frac{T_2}{T_1 - T_2}$ $= \frac{0.6T_1}{T_1 - 0.6T_1}$ $\text{COP} = \frac{0.6}{0.4} = 1.5$ $\therefore$ $x = 1.5$	$\eta = \frac{T_1 - T_2}{T_1}$ $= 0.35$ $\Rightarrow T_2 = 0.65T_1$ Similarly, $\text{COP} = \frac{T_2}{T_1 - T_2}$ $= \frac{0.65}{0.35}$ COP = 1.86 $\therefore y = 1.86$	$\eta = \frac{T_1 - T_2}{T_1}$ $= 0.5$ $T_2 = 0.5T_1$ Similarly, $\text{COP} = \frac{0.5}{0.5} = 1$ $z = 1$

$\therefore \quad y > x > z$ Choice (D)

20. $P_2 = 0.1$ MPa and $P_1 = 0.3$ MPa
$\gamma = 1.4$ for air

$$COP = \frac{1}{\left(\frac{P_1}{P_2}\right)^{\frac{8-1}{8}} - 1}$$

$$\therefore \quad COP = \frac{1}{3^{\frac{0.4}{1.4}} - 1} = \frac{1}{3^{0.285} - 1} = 0.6312$$ Choice (C)

21. The refrigeration effect $= h_1 - h_4$
The net work $= (h_2 - h_1) - (h_3 - h_4)$

$$\therefore \quad COP = \frac{h_1 - h_4}{(h_2 - h_1) - (h_3 - h_4)} = \frac{500 - 300}{(700 - 500) - (300 - 200)}$$

$$COP = \frac{200}{200 - 100} = 2$$ Choice (C)

22. Degree of saturation $= \mu = \frac{P_w}{P_s} \cdot \frac{P - P_s}{P - P_w}$

Relative humidity $= \phi = \frac{P_w}{P_s}$

Where, P_w = partial pressure of water vapor
P_s = Saturation pressure of water vapor at a given temperature.
P = atmospheric pressure.
When $\mu = 1$

$$\Rightarrow \quad 1 = \frac{P_w}{P_s} \cdot \frac{P - P_s}{P - P_w}$$

$$\Rightarrow \quad \frac{P_s}{P_w} = \frac{P - P_s}{P - P_w}$$

$\Rightarrow \quad P_s = P_w$
$\Rightarrow \quad \phi = 1$ i.e., 100% Choice (C)

23. The temperature at which, by cooling the air-water vapor mixture, the water vapor condenses is called dew point temperature. (Constant pressure is maintained) Choice (D)

24. $P_v = 1707.5$, $P_a = 1.7075$ kPa
$P_s = 25.86$ kPa

Degree of saturation $= \mu = \frac{P_v}{P_s} \cdot \frac{(P - P_s)}{(P - P_v)}$

P = atmospheric pressure = 101.325 kPa

$$\therefore \quad \mu = \frac{1.7075}{25.86} \times \left(\frac{101.325 - 25.86}{101.325 - 1.7075}\right) = 0.05$$

Choice (A)

25. Choice (D)