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ESE 2022 : Prelims Exam
CLASSROOM TEST SERIES

MECHANICAL ENGINEERING

Test 2

Section A : Thermodynamics

Section B : Refrigeration & Air-Conditioning

Answer Key

1.	(b)	16.	(b)	31.	(d)	46.	(b)	61.	(b)
2.	(b)	17.	(a)	32.	(d)	47.	(c)	62.	(d)
3.	(d)	18.	(a)	33.	(b)	48.	(c)	63.	(b)
4.	(b)	19.	(b)	34.	(d)	49.	(d)	64.	(b)
5.	(b)	20.	(d)	35.	(b)	50.	(a)	65.	(d)
6.	(b)	21.	(b)	36.	(b)	51.	(d)	66.	(a)
7.	(b)	22.	(c)	37.	(a)	52.	(d)	67.	(b)
8.	(b)	23.	(a)	38.	(b)	53.	(b)	68.	(d)
9.	(c)	24.	(a)	39.	(c)	54.	(c)	69.	(d)
10.	(b)	25.	(c)	40.	(d)	55.	(b)	70.	(b)
11.	(b)	26.	(a)	41.	(c)	56.	(d)	71.	(b)
12.	(b)	27.	(a)	42.	(d)	57.	(d)	72.	(c)
13.	(c)	28.	(b)	43.	(d)	58.	(b)	73.	(c)
14.	(c)	29.	(c)	44.	(d)	59.	(b)	74.	(c)
15.	(b)	30.	(d)	45.	(c)	60.	(a)	75.	(d)*

Q. 75. Answer Key has been updated.

DETAILED EXPLANATIONS

1. (b)

$$\eta_I = \frac{\frac{1}{2}(T_1 - T_2)(S_2 - S_1)}{T_2(S_2 - S_1) + \frac{1}{2}(T_1 - T_2)(S_2 - S_1)}$$

$$= \frac{T_2 - T_1}{T_1 + T_2}$$

$$\eta_{II} = \frac{\frac{1}{2}(T_1 - T_2)(S_2 - S_1)}{T_1(S_2 - S_1)}$$

$$\frac{\eta_I}{\eta_{II}} = \frac{2T_1}{T_1 + T_2}$$

2. (b)

Network $\Rightarrow$ $\Sigma Q = 30 - 50 - 10 + 60 = \Sigma W$

[By Ist law of thermodynamics for a cycle]

$$= 30J$$

Heat supplied $= 30 + 60 = 90J$

$$\eta = \frac{\text{Work}}{Q_{\text{supply}}} = \frac{30}{90} = 33.33\%$$

4. (b)

For gases, $pv = RT$

$\therefore$ $\lim\limits_{p \to 0}(pv) = \lim\limits_{p \to 0}(RT)$

$\Rightarrow$ It depends only on temperature.

5. (b)

Polytropic specific heat,

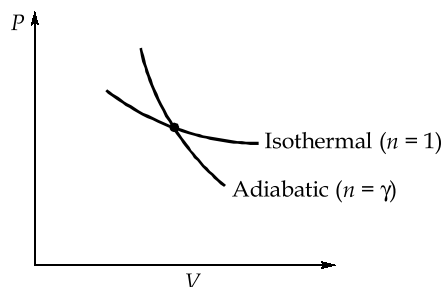$$C_{\text{poly}} = -C_V\left(\frac{\gamma - n}{n - 1}\right)$$

In the polytropic process for which n is in between 1 and γ, the work done by the gas exceeds the heat supplied to the gas. Therefore, even though heat is supplied the temperature of the gas decreases. Since extra work is obtained at the cost of internal energy.
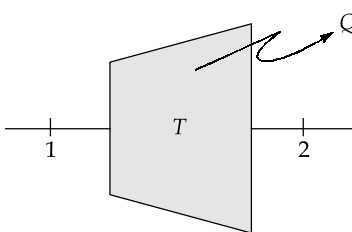
6. (b)

On *P-V* plot

- Slope of an isotherm $= \left(\frac{\partial P}{\partial V}\right)_T = -\left(\frac{P}{V}\right)$

- Slope of an isentrope = $\left(\dfrac{\partial P}{\partial V}\right)_s = -\gamma\left(\dfrac{P}{v}\right) = \gamma\left(\dfrac{\partial P}{\partial V}\right)_T$

7.   (b)

by second law,

$$S_2 - S_1 \;\geq\; \int_1^2 \frac{\delta Q}{T}$$

$\Rightarrow$
$$S_2 - S_1 \;=\; \int_1^2 \frac{\delta Q}{T} + s_{gen}$$

As give entropy associated with heat lost exceeds increase in entropy of stream by friction so, let
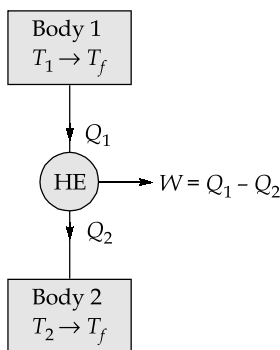
assume $\displaystyle\int_1^2 \frac{\delta Q}{T} = -10$ and $s_{gen} = 5$

$\Rightarrow$ $S_2 - S_1 \;=\; -10 + 5 = -5$

                $S_2 - S_1 \;<\; 0$

$\Rightarrow$ Entropy change for process will be negative.

8.   (b)

$$Q_1 = C_P(T_1 - T_f)$$
$$Q_2 = C_P(T_f - T_2)$$

$$(\Delta S)_{uni} = (\Delta S)_1 + (\Delta S)_2 + \underset{0}{\cancel{(\Delta S)_{engine}}} \geq 0$$

For maximum work, $(\Delta S)_{uni} = 0$

$$\Rightarrow \qquad C_P \ln\left(\frac{T_f}{T_1}\right) + C_P \ln\left(\frac{T_f}{T_2}\right) = 0$$

$$T_f = \sqrt{T_1 \cdot T_2}$$

9. **(c)**

All spontaneous processes are irreversible in nature and they are accompanied by entropy generation.

10. **(b)**

At chemical equilibrium, Gibbs function (G) will be rendered minimum value at constant temperature and pressure.

11. **(b)**

By SFEE

$$\frac{\dot{Q}}{m} = (h_2 - h_1) + \frac{V_2^2 - V_1^2}{2} + g(Z_2 - Z_1)$$

On neglecting PE $(Z_2 - Z_1 = 0)$

$$m = \rho_1 A_1 V_1 = \rho_2 A_2 V_2$$

For solving T_2,

$$T_2 = \frac{P_2}{P_1} \times \frac{\rho_1}{\rho_2} = \frac{P_2}{P_1} \times \frac{A_2 V_2}{A_1 V_1} = \frac{1.5 \times 400}{2 \times 100} \times 300$$

$$T_2 = 900 \text{ K}$$

Now,

$$\frac{\dot{Q}}{m} = 1.005(900 - 300) + \frac{400^2 - 100^2}{2} \times 10^{-3}$$

$$\frac{\dot{Q}}{m} = 1.005 \times 600 + \frac{150000}{2} \times 10^{-3} = 603 + 75$$

$$\frac{\dot{Q}}{m} = 678 \text{ kJ/kg}$$

12. **(b)**

Water is heated through finite temperature difference,

So,

$$(\Delta S)_{water} = \int \frac{\text{đ}Q}{T} = mC \ln\frac{T_{reservoir}}{T_{initial}} = 2 \times 4.18 \times \ln\frac{400}{300}$$
$$= 2 \times 4.18 \times 0.287$$
$$= 2.40 \text{ kJ/K}$$

The reservoir temperature remains constant irrespective of the amount heat withdrawn from it.

$$(\Delta S)_{\text{reservoir}} = -\frac{Q_{rej}}{T_{\text{reservoir}}} = -\frac{2 \times 4.18(400 - 300)}{400}$$

$$= -\frac{2 \times 4.18 \times 100}{400} = -2.09 \text{ kJ/K}$$

$$(\Delta S)_{\text{reservoir}} = (\Delta S)_{\text{water}} + (\Delta S)_{\text{reservoir}} = 2.40 - 2.09$$

$$(\Delta S)_{\text{reservoir}} = 0.31 \text{ kJ/K}$$

13.   (c)

The isobars on mollier diagram diverge from each other. A very wet steam won't turn superheated after throttling and hence cannot be measured by throttling calorimeter.

14.   (c)

As per Clausius-Clapeyran equation,

$$\left(\frac{dP}{dT}\right)_{\text{sat}} = \frac{h_{fg}}{T_{sat} \cdot v_{fg}}$$

$$= \frac{200 - 75}{(40 + 273)(0.02 - 0.8 \times 10^{-3})}$$

$$= 20.8 \text{ kPa/K}$$

15.   (b)

1. Compressibility factor, $Z = 1$ for an ideal gas.
2. As $P \to 0$, or $T \to \infty$, the real gas approaches the ideal gas behaviour.

16.   (b)

Mixing process is irreversible. Hence, entropy will increase.

17.   (a)

$$T_1 = 100 + t; \ T_2 = 0 + t$$

$$\eta = 1 - \frac{Q_r}{Q_s} = 1 - \frac{14}{20} = 0.3$$

$$\eta = \frac{T_1 - T_2}{T_1} = \frac{(100 - t) - (t + 0)}{100 + t}$$

$$= \frac{100}{100 + t} = 0.3$$

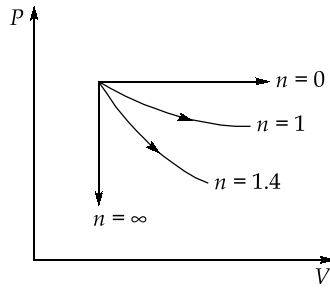$$t = 233.33 \text{ °C}$$

19.   (b)

$$PV^n = \text{Constant}$$

$$W = \int Pdv$$

i.e., $$W = \text{Area under curve on } P\text{-}V \text{ diagram}$$

Clearly from above diagram between *P-V* as the value of *n* decreases the area which represent work increases for particular volume expansion.

20. (d)

Source temperature, T_s = 2400 K

User temperature, T_a = 600 K

     T_o = 300 K

Heat transfer by solar collector

Q_a = 300 – 60 = 240 kW

$$\eta_I = \frac{Q_a}{Q_s} = \frac{240}{300} = 0.8$$

$$\eta_{II} = \frac{\text{Exergy output}}{\text{Exergy input}}$$

$$= \frac{Q_a\left(1 - \dfrac{T_o}{T_a}\right)}{Q_s\left(1 - \dfrac{T_o}{T_s}\right)} = \eta_I \frac{\left(1 - \dfrac{T_o}{T_a}\right)}{\left(1 - \dfrac{T_o}{T_s}\right)}$$

$$= \frac{0.8 \times \left(1 - \dfrac{300}{600}\right)}{\left(1 - \dfrac{300}{2400}\right)}$$

$$= 0.457$$

21. (b)

Among the given choices the more effective way to increase cycle efficiency is to decrease T_2.

22. (c)

$$S_{\text{gen}} = -\frac{Q}{T_1} + \frac{Q}{T_2}$$

Q_1 = 3000 W

T_1 = 127°C = 400 K

T_2 = ?

$$\Rightarrow \qquad 0.5 \;=\; -\frac{3000}{400} + \frac{3000}{T_2}$$

$$T_2 \;=\; 375.0 \text{ K}$$
$$\;=\; 102°C$$

23.   **(a)**

Since tank is insulated, $Q \;=\; 0$

$$u_f \;=\; h_i$$
$$C_V T_f \;=\; C_P T_i$$
$$T_f \;=\; \gamma T_i$$
$$\;=\; 1.4(23 + 273)$$
$$\;=\; 414.4 \text{ K}$$
$$\;=\; 141.4°C$$

24.   **(a)**

The heat of vapourization ($\Delta H_{\text{vaporization}}$) is only used to determine the amount of heat energy used during the vapourization phase change. It does not indicate any information about the temperature change for a given heat energy input. As heat increases a solutions temperature, the velocity of the solutions molecules will increase.

25.   **(c)**

The first law of thermodynamics requires that energy be conserved during a process, but place no restriction on the direction of a process. Satisfying the first law does not ensure that a process will actually occurred. The inadequacy of the first law to identify whether a process can take place is remedied by introducing the second law of thermodynamics. With the help of a property, called entropy, we can identify if a process violates the second law. So, a process will not occur unless it satisfied both the first and the second law of thermodynamics.

26.   **(a)**

For any substance, if its pressure increases, the volume decreases. Therefore, in any thermodynamic plot in P-V co-ordinate, all process must have $\dfrac{dP}{dV} < 0$.

On the other hand, for a substance if its temperature increases, the disorder of its molecules increases and hence its entropy increases. All processes that have $\dfrac{dT}{dS} > 0$ can only be drawn on T-s diagram.

27.   **(a)**

Slope, $m_2 \;>\; m_1$

$$\frac{R}{P_2} \;>\; \frac{R}{P_1}$$

$$\Rightarrow \qquad P_1 \;>\; P_2$$

28. (b)

Let Q_1 is heat rejected to 500 K reservoir and 30 J rejected to 300 K reservoir.

By first law of thermodynamics

$$200 = W + Q_1 + 30$$
$$W + Q_1 = 170 \qquad \qquad ...(1)$$

By Clausius inequality,

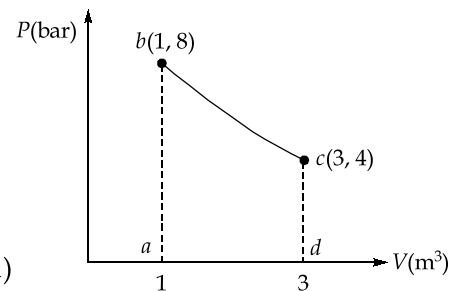$$\frac{200}{1000} - \frac{Q_1}{500} - \frac{30}{300} = 0$$
$$Q_1 = 50 \text{ J}$$

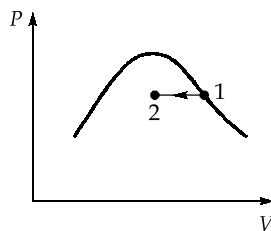$\therefore \qquad \qquad W + 50 = 170$

$\Rightarrow \qquad \qquad W = 120$

$$\eta = \frac{W_{\text{output}}}{Q_{\text{supply}}} = \frac{120}{200} = 0.60$$
$$= 60\%$$

29. (c)

$$P = (-2V + 10) \text{ bar}$$
$$P_{V=1} = 8 \text{ bar} = 800 \text{ kPa}$$
$$P_{V=3} = 4 \text{ bar} = 400 \text{ kPa}$$

$$\text{Work} = \int_1^3 P\,dV = \text{Area } (abcd)$$

$$= \frac{1}{2} \times (800 + 400) \times (3-1)$$
$$= 1200 \text{ kJ}$$

30. (d)

Pressure and temperature are dependent to each other.

31. (d)

- Bottle filling of gas is a varible flow process.

- $W = \int P\,dV$, this expression is valid when the path followed by the process is quasi-static and other works is neglected.

- Nernst-Simon statement of the third law of thermodynamics, states that the change in entropy which occurs when a homogeneous system undergoes an isothermal reversible process approaches zero as the temperature approaches absolute zero.

- The Joule-Thomson effect refers to a thermodynamic process that occurs when the expansion of fluid takes place from high pressure to low pressure at constant enthalpy.

32.   (d)

$$\Delta S = -\overline{R}(n_1 \ln X_1 + n_2 \ln X_2)$$

$$n_1 = \frac{3}{8} = 0.375, \ n_2 = \frac{5}{8} = 0.625$$

Mole fraction or gas A, $X_1 = \dfrac{n_1}{n_1 + n_2} = 0.375$

Mole fraction of gas B, $X_2 = \dfrac{n_2}{n_1 + n_2} = 1 - X_1 = 0.625$

$\therefore$ $\Delta S = -\overline{R}(0.375 \ln 0.375 + 0.625 \ln 0.625)$

$$= 0.66\overline{R} = 5.49 \ \text{J/K}$$

33.   (b)

In thermodynamic analysis, the concept of reversibility is that, a reversible process is the most efficient process as there is no energy generation during the process and it will not leave any trace on the surrounding that the process took place.

34.   (d)

The equation $TdS = dU + PdV$ hold good for any process reversible or irreversible, undergone by a closed system, since it is a relation among properties which are independent of the path. So, the statement (I) is not correct.

35.   (b)

Entropy is defined as extent of randomness in a system when substance is heated its entropy increases and vice-versa. Thus, entropy of ice lesser than water because of lesser molecular motion in ice. It is true that ice has open cage like structure.

36.   (b)

- Clapeyron's equation can be used to estimate approximately the vapour pressure of a liquid at any arbitrary temperature in conjuction with relation for the latent heat of substance known as Trouton's rule.
- At a given temperature and pressure of the triple point, slope of sublimation curve is more than the slope of vapourization curve.

  As $(I)_{sublimation} > (I)_{vapourization}$ at triple point.
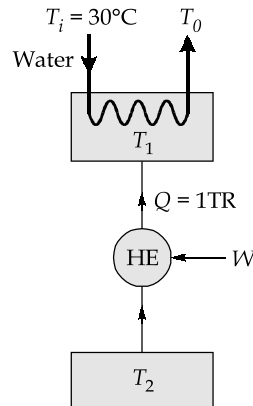
37.   (a)

In steady flow system, the volume of system does not change. Hence, maximum useful work would remains same, i.e., no work done on the atmosphere.

Maximum useful work $(dW_u)_{max} = (dW)_{max} - P_o dV$

$\because$ $dV = 0$

$(dW_u)_{max} = (dW)_{max}$

39. (c)

$$Q = 1 \text{ TR} = 3.5 \text{ kW}$$

and
$$Q = \dot{m}_w C_{Pw}(T_o - T_i)$$

$$\Rightarrow \quad Q = \rho_w \dot{V}_w C_{Pw}(T_o - T_i)$$

$$\Rightarrow \quad Q = 1000 \times \frac{100}{1000 \times 3600} \times 4.2 \times (T_o - 30°C)$$

$$\Rightarrow \quad 3.5 = \frac{1000 \times 100 \times 4.2}{1000 \times 3600} \times (T_o - 30)$$

$$\Rightarrow \quad T_o = 60°C = 333 \text{ K}$$

40. (d)

$$(COP)_R = \frac{T_L}{T_H - T_L} = \frac{248}{62}$$

$$(COP)_R = 4 = \frac{\dot{Q}_R}{\dot{W}}$$

$$\Rightarrow \quad \dot{W} = \frac{10 \text{ TR}}{4} = 2.5 \text{ TR}$$

$$\Rightarrow \quad \dot{W} = 2.5 \times 3.5 \text{ kW}$$

$$\dot{W} = 8.75 \text{ kW}$$

41. (c)

$$\eta_{HE} = \frac{W}{Q_1} \Rightarrow Q_1 = \frac{W}{\eta_{HE}} = \frac{W}{1/2} = 2 \text{ W}$$

$$\Rightarrow \quad (COP)_{HP} = 4 = \frac{Q_C}{W} = 4W \Rightarrow Q_E = Q_C - W \Rightarrow Q_E = 3W$$

Now,
$$\frac{Q_1}{Q_E} = \frac{2W}{3W} = \frac{2}{3}$$

42.　(d)

Statement 1 :　　　　　$(COP)_R = \dfrac{T_L \uparrow}{(T_H - T_L) \leftarrow \text{Same}} \Rightarrow COP \uparrow$ (correct statement)

Statement 2 :　　　　　$(COP)_R = \dfrac{T_L \downarrow}{(T_H - T_L) \leftarrow \text{Same}} \Rightarrow COP \downarrow$ (correct statement)

Statement 3 :　　　　　$(COP)_R = \dfrac{T_L \uparrow}{(T_H - T_L) \downarrow} \Rightarrow COP \uparrow$ (incorrect statement)

Statement 4 :　　　　　$(COP)_R = \dfrac{T_L \downarrow}{(T_H - T_L) \uparrow} \Rightarrow COP \downarrow$ (incorrect statement)

43.　(d)

$$(COP)_{CC} = \frac{COP_1 \times COP_2}{1 + COP_1 + COP_2} = \frac{5 \times 4}{1 + 5 + 4}$$

$$(COP)_{CC} = \frac{20}{10} = 2$$

$$(COP)_{CC} = \frac{\dot{Q}_{Ref}}{W_{required}} = 2$$

$$\frac{1TR}{\dot{W}} = 2$$

$\Rightarrow$　　　　　　　　$\dot{W} = \dfrac{1}{2} TR$　　　　$\left[\because 1TR = 3.51 \text{ kW}\right]$

$\Rightarrow$　　　　　　　　$\dot{W} = \dfrac{3.5}{2} = 1.75 \text{ kW}$

44.　(d)

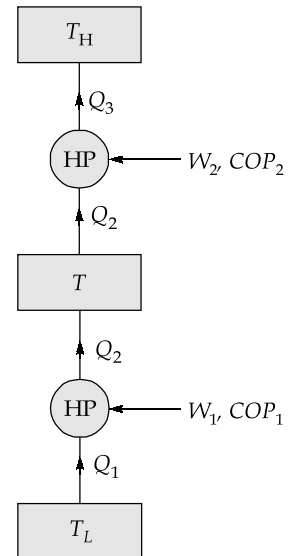$[(COP)_{CC}]_{HP} = \dfrac{Q_3}{W_1 + W_2}$

$\Rightarrow$　　　　$COP_2 = \dfrac{Q_3}{W_2}$

$\Rightarrow$　　　　$COP_1 = \dfrac{Q_2}{W_1}$

$[(COP)_{CC}]_{HP} = \dfrac{Q_3}{\dfrac{Q_2}{COP_1} + \dfrac{Q_3}{COP_2}}$ and $Q_3 = Q_2 + W_2$

So,　　　$[(COP)_{CC}]_{HP} = \dfrac{Q_3}{\dfrac{Q_3 - W_2}{COP_1} + \dfrac{Q_3}{COP_2}}$

$[(COP)_{CC}]_{HP} = \dfrac{Q_3}{\dfrac{Q_3 - \left(\dfrac{Q_2}{COP_2}\right)}{COP_1} + \dfrac{Q_3}{COP_2}}$

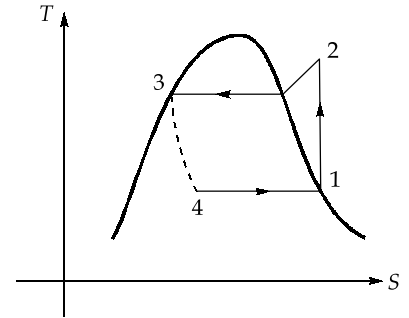$$[(COP)_{CC}]_{HP} = \frac{COP_1 * COP_2}{COP_1 + COP_2 - 1}$$
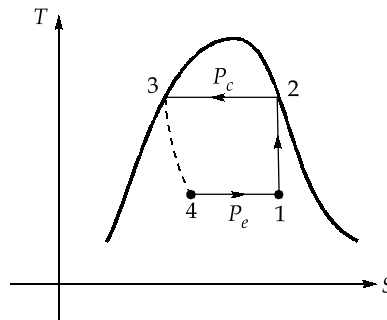
45. **(c)**

$$h_1 = 120 \text{ kJ/kg}$$
$$h_2 = 150 \text{ kJ/kg}$$
$$h_4 = 60 \text{ kJ/kg}$$

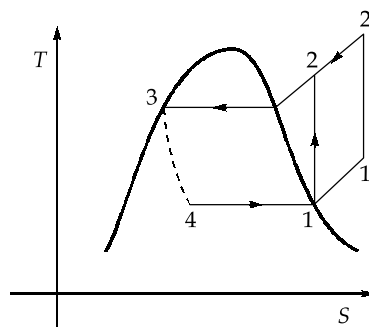$$[COP]_{VCRS} = \frac{h_1 - h_4}{h_2 - h_1} = \frac{120 - 60}{150 - 120} = 2$$

46. **(b)**

$$COP = \frac{RE}{W_{in}}$$

- Increasing P_{cond} (P_c) = RE $\downarrow$, W_{in} $\uparrow$ $\Rightarrow$ COP$\downarrow$
- Increasing P_{evap} (P_e) = RE $\uparrow$, W_{in} $\downarrow$ $\Rightarrow$ COP$\uparrow$
- Increasing P_c and decreasing P_e = RE $\downarrow$, W_{in} $\uparrow$ $\Rightarrow$ COP$\downarrow$
- Only carnot cycle between given temperature limits has maximum COP.

47. **(c)**

Effect of superheating of suction vapour:

$$RE' = \{h_1 - h_4\} + \{h_1' - h_1\} > RE$$

$$W_{IP}' = f(T_1') \qquad\qquad\qquad \text{[For Ideal gas]}$$

$$\Rightarrow \qquad\qquad\qquad T_1' \;>\; T_1$$

$$\Rightarrow \qquad\qquad\qquad W_{I/P}' \;>\; W_{I/P}$$

Since, both refrigerating effect and compressor work are increasing then COP may increase, decrease or remain constant.

$\Rightarrow \qquad\qquad$ For R12 and R134a $\Rightarrow$ COP increases

$\Rightarrow \qquad\qquad$ For R22 and $NH_3 \Rightarrow$ COP decreases

48. (c)

$$\begin{aligned}
W_{\text{net}} &= [W_C]_{\text{actual}} - [W_E] \\
&= 1.30 \times [W_C]_{\text{theoretical}} - [W_E] \\
&= 1.30 \times (120) - 40 = 116 \text{ kW} \\
\text{RE} &= 174 \text{ kW}
\end{aligned}$$

$$\text{COP} \;=\; \frac{174}{116} = 1.5$$

49. (d)

$$(\text{COP})_{RB} \;=\; \cfrac{1}{\left(r_p\right)^{\frac{\gamma-1}{\gamma}} - 1} = \cfrac{1}{\left\{(8)^{\frac{1.5-1}{1.5}}\right\} - 1}$$

$$(\text{COP})_{RB} \;=\; \frac{1}{2-1} = 1 = \frac{\dot{Q}_{rej}}{\dot{W}_{net}}$$

So, $\qquad\qquad \dot{W}_{net} \;=\; 1 \times 1\text{TR} = 1\text{TR} = 3.5 \text{ kW}$

50. (a)

Ideal absorbent
- Should remain in liquid condition under operating condition.
- Heat liberated should be minimum when refrigerant is absorbed by absorbent.
- Absorbent should have greater affinity for refrigerant.
- Lithium bromide solution has strong affinity for water vapour because of its very low vapour pressure so, that the water and LiBr solution are placed adjacent to each other in a closed evacuated system, the water will evaporate.

52. (d)
- $\qquad\qquad$ Completely miscible = R-11, R-12
- $\qquad\qquad$ Completely immiscible = NH_3, CO_2
- $\qquad\qquad$ Partially miscible = R-22

53. (b)

Soap bubble : Hydrocarbons

Halide torch : Freons

54. (c)

CO_2 refrigerant :

- It has high power requirement, the kW power required per tonne of refrigeration using CO_2 is nearly twice than any other commonly used refrigeration.
- It is immiscible in oil.
- Non-toxic
- Non-flammable
- Non-poisonous but causes death due to suffocation when present in large quantities.

55. (b)

For reciprocating compressor,

$$\eta_{vol.} = \frac{\dot{m}_{ref}\, v_{entry}}{\underbrace{\left(\frac{\pi}{4}D^2 L\right)\left(\frac{N}{60} \times K\right)}_{\leftarrow\ V_s\ \rightarrow}}$$

$$0.80 = \frac{\dot{m}_{ref} \times 0.08}{\left(400 \times 10^{-6}\right)\left(\frac{800}{60} \times 2\right)}$$

$$\dot{m}_{ref} = 106.67 \text{ g/s}$$

56. (d)

Expansion valves are devices used to control the refrigerant flow in a refrigeration system. They remove pressure from the liquid refrigerant to allow expansion or change of state from a liquid to a vapour in the evaporator.

57. (d)

$$RTH = 75 \text{ kW}$$

$$RSHF = 0.8 = \frac{RSH}{RTH}$$

$\Rightarrow$
$$RSH = 0.8 \times 75 = 60 \text{ kW}$$
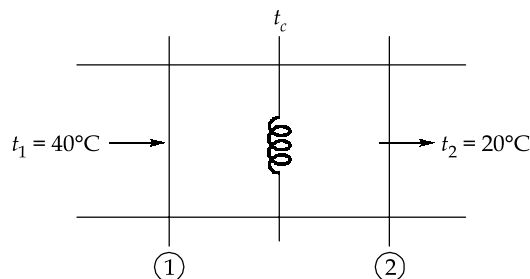$$RLH = RTH - RSH = 75 - 60 = 15 \text{ kW}$$

Also,
$$RLH = 50 \text{ (cmm) } (\omega_1 - \omega_2)$$
$$15 = 50\,(50)\,(0.01 - \omega_2)$$
$$\omega_2 = 0.004 \text{ kg/kg of d.a.}$$

58. (b)

$$\text{BPF} \;=\; \frac{20 - t_c}{40 - t_c} = 0.2$$

$\Rightarrow$ $\qquad\qquad\qquad 20 - t_c \;=\; 8 - 0.2 t_c$

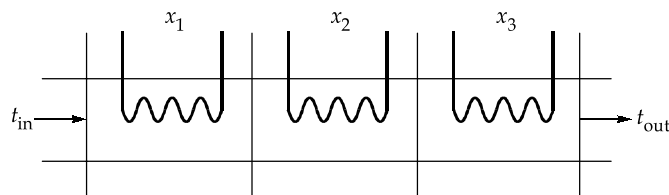$\Rightarrow$ $\qquad\qquad\qquad\qquad t_c \;=\; 15°C$

59. **(b)**

$$\text{LHF} \;=\; \frac{h_1 - h_3}{h_1 - h_2} = \frac{457 - 313}{457 - 217} = 0.6$$

60. **(a)**

$$\text{BPF} \;=\; \frac{t_2 - t_{ADP}}{t_1 - t_{ADP}} \simeq \frac{h_2 - h_{ADP}}{h_1 - h_{ADP}}$$

$$\text{BPF} \;=\; \frac{52 - 37}{97 - 37} = \frac{15}{60} = 0.25$$
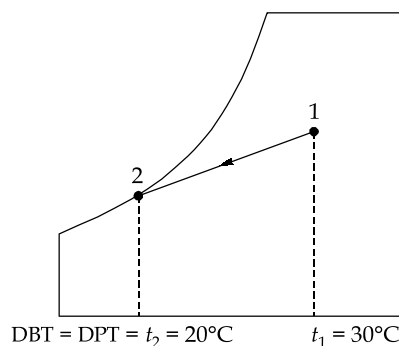
61. **(b)**

$x_1 \;=\; 0.25$

$x_2 \;=\; 0.15$

$x_3 \;=\; 0.17$

$x_e \;=\; x_1 \times x_2 \times x_3 = 0.25 \times 0.15 \times 0.17$

$x_e \;=\; 6.375 \times 10^{-3}$

$\Rightarrow$ $\qquad\qquad x_e \;=\; 0.6375\%$

63. **(b)**

At dew point temperature (20°C),

$$P_V \;=\; P_{VS} = 0.01325 \text{ bar}$$

$$P_t \;=\; P_{atm} = 1.01325 \text{ bar}$$

$$w_2 = \frac{0.622 \times 0.01325}{1.01325 - 0.01325} = 8.24 \times 10^{-3}$$

$$w_2 = 8.24 \text{ g/kg of d.a.}$$

64. (b)

$$\phi = \frac{P_v}{P_{vs}} = \frac{P_v}{4} \qquad \qquad \dots(i)$$

$$w = \frac{0.622 P_v}{(100 - P_v)} = \frac{m_v}{m_a} = \frac{1}{50}$$

$$\Rightarrow \qquad P_v = \frac{2}{0.642} \text{ kPa}$$

and from equation (i),

$$\phi = \frac{\left(\dfrac{2}{0.642}\right)}{4} = 77.88\%$$

65. (d)

1. $\omega = \dfrac{0.622 P_v}{P_t - P_v}$

2. $\mu = \phi\left(\dfrac{P - P_{vs}}{P - P_v}\right)$

3. $\phi = \dfrac{P_v}{P_{vs}}$

4. $\mu = \dfrac{\omega}{\omega_s}$

66. (a)

$$\text{Evaporation of water} = w_2 - w_1$$
$$= 0.032 - 0.0035$$
$$= 0.0285 = 28.5 \text{ g/kg of d.a.}$$

67. (b)

According to Gibbs phase rule,
$$F + P = C + 2$$

For moist air,

$$C = 2 \text{ (air + water vapour)}$$
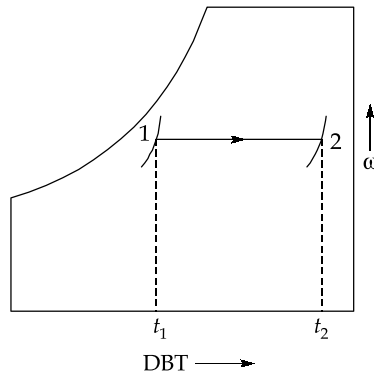$$P = 1 \text{ (vapour)}$$
$$F + 1 = C + 2$$
$$\Rightarrow \qquad F = 3$$

For psychrometric chart,

$$P = \text{Fixed (i.e. } P_{atm})$$
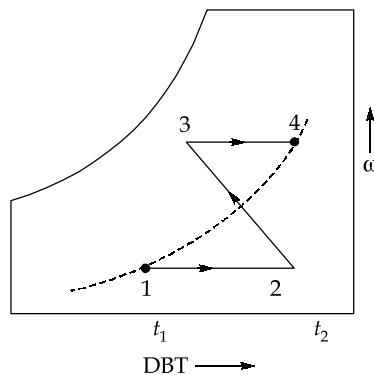$$\text{So,} \qquad F^* = 3 - 1 = 2$$

68. (d)

When a well sealed container is heated,

1. $\phi \downarrow$
2. w = constant
3. WBT $\uparrow$
4. DBT $\uparrow$

69. (d)

For winter air conditioning,

70. (b)

1. Generally 1% evaporation of water takes place in flash chamber.
2. No moving parts, vibration free, reliable and less maintenance required.
3. Double of the heat must be removed in the condenser per ton of refrigeration compared with VCRS.

71. (b)

$$\phi = \frac{P_v}{P_{vs}}$$
$$\Rightarrow \quad \phi \propto P_v$$
$$\Rightarrow \quad \frac{\phi_2}{\phi_1} = \frac{P_{v_2}}{P_{v_1}}$$

$$\Rightarrow \qquad P_{v_1}V_1 \;=\; RT_1$$

$$\Rightarrow \qquad \frac{P_{v_2}}{P_{v_1}} \;=\; \frac{V_1}{V_2}=2 \qquad \left[\because \text{For isothermal process, } \frac{P_2}{P_1}=\frac{V_1}{V_2}=2\right]$$
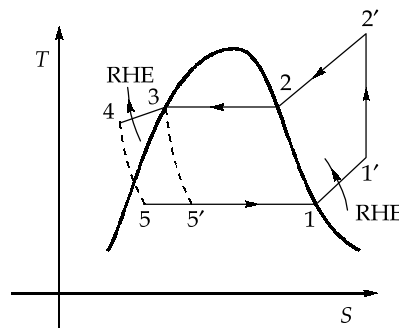
So,

$$\frac{\phi_2}{\phi_1} \;=\; \frac{P_{v_2}}{P_{v_1}}=2$$

$$\Rightarrow \qquad \phi_2 \;=\; 2\phi_1$$
$$= 2 \times 0.4 = 0.8$$
$$\phi_2 \;=\; 80\%$$

72. (c)
VCRS with RHE,

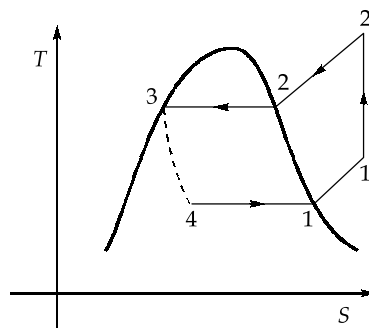(1) Refrigerating effect without RHE,

$$\text{RE} \;=\; h_1 - h_5'$$

Refrigerating effect with RHE,

$$\text{RE}' \;=\; h_1 - h_5$$

Since, $RE' > RE$, statement (I) is correct.

(2) Superheating in evaporator,

$$\text{RE}'' \;=\; h_1' - h_4$$
$$\text{RE}'' \;>\; RE$$

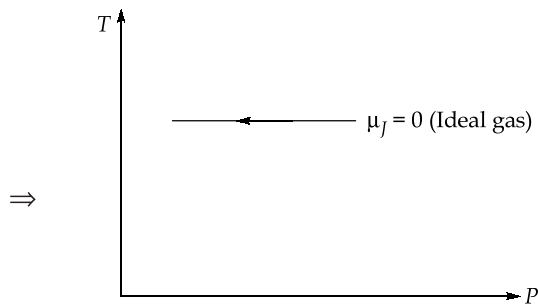$\Rightarrow$ Statement (II) is incorrect.

73.   (c)

Statement (I) is correct.

Statement (II) is incorrect.

•   Isentropic expander is used because for air (ideal gas), $\mu_J = 0$, so no temperature drop in throttling process.

$$\mu_J = \left(\frac{dT}{dP}\right)_h$$

⇒

74.   (c)

Statement (I) is correct.

Statement (II) is incorrect.

•   For $LiBr \cdot H_2O$

H_2O is an refrigerant

$LiBr$ is an absorbent

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