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ESE 2024 : Prelims Exam
CLASSROOM TEST SERIES

MECHANICAL ENGINEERING

Test 2

Section A : Thermodynamics [All Topics]

Section B : Refrigeration and Air-Conditioning [All Topics]

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (d)

Extensive property: It depends on the mass of the system. Example: Entropy, Internal energy.

2. (b)

The closed system is a system of fixed mass. There is no mass transfer across the system boundary. There may be energy transfer into or out of the system. Example: A certain quantity of fluid in a cylinder bounded by a piston constitutes a closed system.

3. (b)

Given: $R_o = 2.3\ \Omega$, $R_{100} = 3.2\ \Omega$

Let the resistance, $R = R_o(1 + \alpha t)$ where, R_o is the resistance at 0°C.

$\therefore \quad R_{100} = 3.2\ \Omega = 2.3 \times (1 + \alpha \times 100)$

$\Rightarrow \quad \alpha = 3.913 \times 10^{-3}\ \Omega/°\text{C}$

So, when, $\quad R = 4.3 = R_o(1 + \alpha t)$

$\Rightarrow \quad 4.3 = 2.3(1 + 3.913 \times 10^{-3} t)$

$\Rightarrow \quad t = 222.22°\text{C}$ **Ans.**

4. (b)

Both heat and work are associated with a process, not on end states only. Unlike properties, heat or work has no meaning at a state.

5. (d)

$$\text{Number of moles} = \frac{\text{Mass}}{\text{Molecular mass}}$$

$$\therefore \quad n_{CO_2} = \frac{22}{44} = 0.5\text{ kmol}$$

$$\therefore \quad n_{N_2} = \frac{28}{28} = 1\text{ kmol}$$

$$\therefore \quad n_{O_2} = \frac{80}{32} = 2.5\text{ kmol}$$

$\therefore$ The total number of moles in the gas mixture

i.e., $\quad n_T = n_{CO_2} + n_{N_2} + n_{O_2}$

i.e., $\quad n_T = 0.5 + 1 + 2.5 = 4$ kmol

$\therefore$ The mole fraction are:

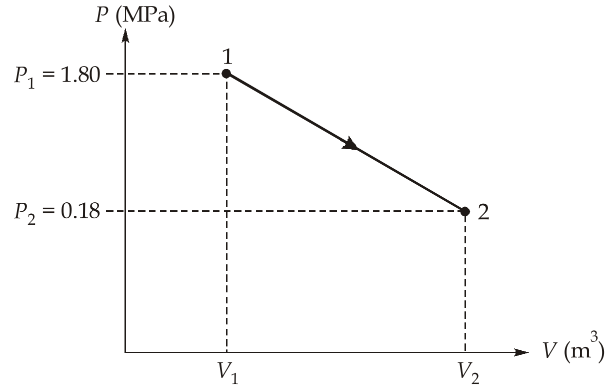
$$\therefore \quad X_{CO_2} = \frac{n_{CO_2}}{n_T} = \frac{0.5}{4} = 0.125$$

$$X_{N_2} = \frac{n_{N_2}}{n_T} = \frac{1}{4} = 0.250$$

$$X_{O_2} = \frac{n_{O_2}}{n_T} = \frac{2.5}{4} = 0.625$$

6. (b)

Given: $A_p = 0.15\ m^2$, $P_1 = 1.8$ MPa, $P_2 = 0.18$ MPa, $\Delta x = 0.45$ m.



Swept volume of piston, $V_s = V_2 - V_1 = A_p \times \Delta x$

$= 0.15 \times 0.45 = 0.0675\ m^3$

∴ Work done by the gas on the piston,

$$W = \frac{1}{2}(P_1 + P_2) \times V_s = \frac{1}{2} \times (1.8 + 0.18) \times 10^3 \times 0.0675 = 66.825 \text{ kJ}$$

7. (d)

- First law of the thermodynamics:

$$Q = W + \Delta U$$

So, for adiabatic processes: $Q = 0 \Rightarrow W = -\Delta U$

- The first law makes no reference to the value of the total energy of a closed system at a state. It simply state that the change in the total energy during an adiabatic process must be equal to the net work done. Therefore, any convenient arbitrary value can be assigned to total energy at a specified state to serve as a reference point.

8. (b)

The storage battery is charged for 5-hours.

∴ $W = 4.2 \times 5 = 21$ kWh

$Q = -0.42 \times 5 = 2.1$ kWh

∴ The total amount of energy stored in the battery in five-hour operation,

$$\Delta E = 21 - 2.1 = 18.9 \text{ kWh}$$

9. (c)

The rate of change of energy of the motor,

$$\frac{dE}{dt} = \dot{Q} - \dot{W} = \dot{Q} - (\dot{W}_{shaft} + \dot{W}_{electric})$$

$$\dot{W}_{electric} = -2.7 \text{ kW}$$

$$\dot{W}_{shaft} = 20 \times 120 \times 10^{-3} = 2.4 \text{ kW}$$

$$\Rightarrow \quad \frac{dE}{dt} = -0.3 \times (1 - e^{-0.75t}) - (2.4 - 2.7)$$

$$= -0.3 + 0.3 \times e^{-0.75t} - 2.4 + 2.7 = 0.3 \times e^{-0.75t} \text{ kW}$$

10. (d)

$$Q_{PQR} = 92 \text{ kJ}, W_{PQR} = 36 \text{ kJ}$$

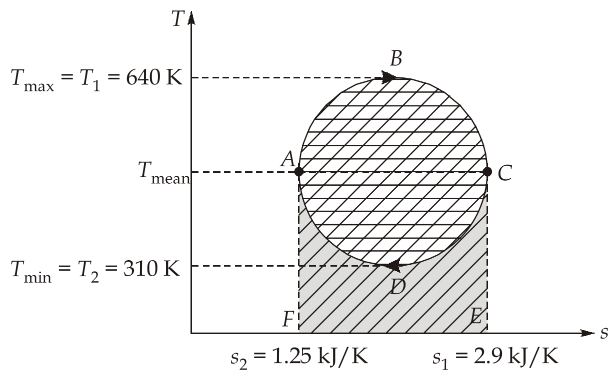
$\therefore$
$$Q_{PQR} = (U_R - U_P) + W_{PQR}$$

$\Rightarrow$
$$U_R - U_P = 92 - 36 = 56 \text{ kJ}$$

For process PSR:

$$Q_{PSR} = (U_R - U_P) + W_{PSR} = 56 + 13 = 69 \text{ kJ}$$ **Ans.**

11. (a)



$$T_{mean} = \frac{T_1 + T_2}{2} = \frac{640 + 310}{2} = 475 \text{ K}$$

Net work done, W_{net} = Area of the circle ABCD

$$= \frac{\pi}{4} \times (AC) \times (BD) = \frac{\pi}{4} \times (640 - 310) \times (2.90 - 1.25)$$

$$= 427.65 \text{ kJ}$$

Heat supplied to the cycle = Area under the curve ABC,

$$Q_s = \frac{\text{Area of circle ABCD}}{2} + \text{Area of rectangle ACEF}$$

$$= \frac{427.65}{2} + T_{mean}(s_1 - s_2)$$

$$= 213.824 + 475 \times (2.90 - 1.25) = 997.57 \text{ kJ}$$

$\therefore$ Efficiency of the reversible cycle, $\eta = \dfrac{W_{net}}{Q_s} = \dfrac{427.65}{997.57} = 0.4287 \text{ or } 42.87\%$

12. (b)

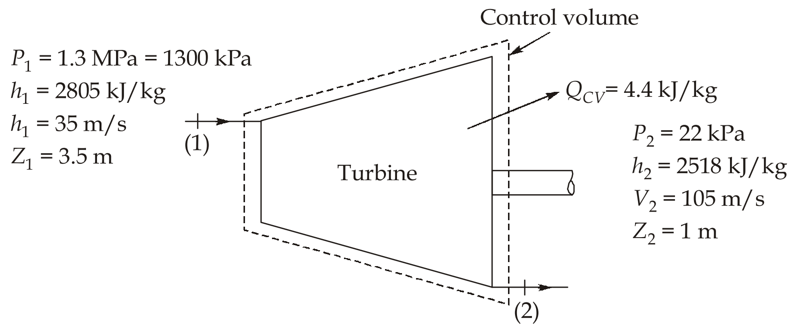
$$\eta_I = \frac{\frac{1}{2} \times (T_1 - T_2) \times (s_1 - s_2)}{\frac{1}{2} \times (T_1 - T_2) \times (s_1 - s_2) + T_2(s_1 - s_2)}$$

$$= \frac{(T_1 - T_2)}{T_1 - T_2 + 2T_2} = \frac{(T_1 - T_2)}{(T_1 + T_2)}$$

$$\eta_{II} = \frac{\frac{1}{2} \times (T_1 - T_2) \times (s_1 - s_2)}{T_1(s_1 - s_2)} = \frac{(T_1 - T_2)}{2T_1}$$

$$\therefore \qquad \frac{\eta_I}{\eta_{II}} = \frac{(T_1 - T_2)/(T_1 + T_2)}{(T_1 - T_2)/2T_1} = \frac{2T_1}{(T_1 + T_2)}$$

13. (c)



Applying steady flow energy equation on the control volume, we get,

$$\dot{m}\left[h_1 + \frac{V_1^2}{2} + gZ_1 + Q_{cv}\right] = \dot{m}\left[h_2 + \frac{V_2^2}{2} + gZ_2\right] + \dot{W}_{cv}$$

$$\Rightarrow \dot{m}\left[(h_1 - h_2) + \frac{V_1^2 - V_2^2}{2} + g(Z_1 - Z_2) + Q_{cv}\right] = \dot{W}_{cv}$$

$$\Rightarrow 0.5 \times \left[(2805 - 2518) + \frac{35^2 - 105^2}{2 \times 1000} + \frac{9.81(3.5 - 1)}{1000} - 4.4\right] = \dot{W}_{cv}$$

$$\Rightarrow \qquad \dot{W}_{cv} = 138.86 \text{ kW}$$ **Ans.**

14. (d)

By first law of thermodynamics, $Q = \Delta U + W$

$\because \qquad \Delta U = 0$

$\Rightarrow \qquad W = Q = 350 \text{ kJ}$ **Ans.**

15. (c)

Usually, the substance refer as superheated vapor at temperature above the critical temperature and as compressed liquid at temperatures below the critical temperature.

16. (c)

The deviation of a gas from ideal gas behaviour is greatest in the vicinity of the critical point.

17. (b)

$$\gamma = \frac{C_P}{C_V} = 1.28$$

For acetylene (C_2H_2):

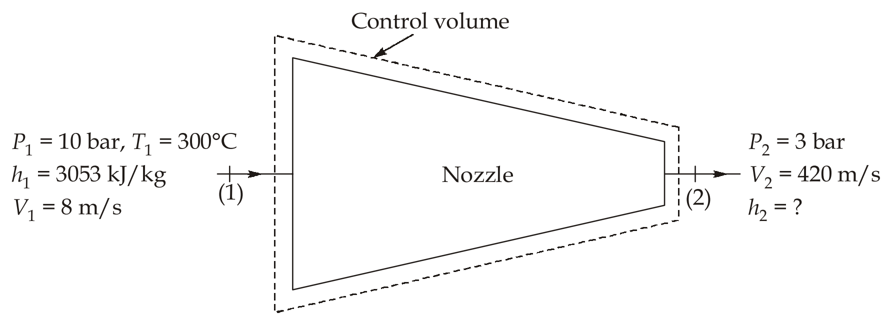
Molecular mass, $M = 2 \times 12 + 2 \times 1 = 26$

$$\text{Gas constant, } R = \frac{\bar{R}}{M} = \frac{8.314}{26} = 0.31977 \text{ kJ/kgK}$$

$$\Rightarrow \qquad C_P - C_V = R$$

$$\Rightarrow \quad 1.28 \times C_V - C_V = 0.31977$$
$$\Rightarrow \quad 0.28 \times C_V = 0.31977$$
$$\Rightarrow \quad C_V = 1.142 \text{ kJ/kgK}$$
$$\therefore \quad C_P = 1.28 \times C_V = 1.28 \times 1.142$$
$$= 1.462 \text{ kJ/kgK}$$

18. (a)



Applying steady flow energy equation on the control volume,

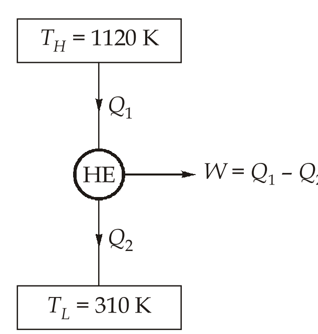
$$h_1 + \frac{V_1^2}{2} + \cancel{gZ_1}^{0} + \cancel{Q_{CV}}^{0} = h_2 + \frac{V_2^2}{2} + \cancel{gZ_2}^{0} + \cancel{W_{CV}}^{0}$$

$$\Rightarrow \quad h_2 = h_1 + \frac{V_1^2 - V_2^2}{2} = 3053 + \frac{8^2 - 420^2}{2000}$$
$$= 2964.83 \text{ kJ/kg} \simeq 2965 \text{ kJ/kg}$$

19. (b)

- A reversible process should not leave any trace behind to show that the process had occurred.
- If the time allowed for a process to occur is infinitely large, then even though the gradient is finite, the process becomes reversible.

20. (c)



$$T_H = 847°\text{C} = 847 + 273 = 1120 \text{ K}$$
$$T_L = 37°\text{C} = 37 + 273 = 310 \text{ K}$$

For a reversible engine, the rate of the heat rejection will be minimum.

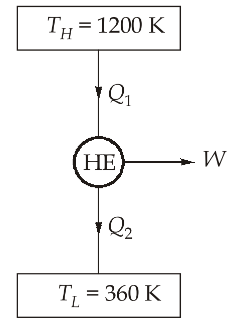
$$\eta_{\text{max}} = \eta_{\text{rev}} = 1 - \frac{T_L}{T_H} = 1 - \frac{310}{1120} = 0.7232$$

Also, $$\eta_{\text{max}} = \frac{W_{net}}{Q_1} \Rightarrow Q_1 = \frac{1}{0.7232}$$

$$\Rightarrow \quad Q_1 = 1.383 \text{ kW}$$
$$\therefore \quad Q_2 = Q_1 - W_{\text{net}} = 1.383 - 1 = 0.383 \text{ kW}$$

21. (c)

For Carnot heat engine, we have



$$\Rightarrow \quad -\frac{Q_1}{T_H}+\frac{Q_2}{T_L} = 0$$

$$\Rightarrow \quad \frac{40}{1200} = \frac{Q_2}{360}$$

$$\Rightarrow \quad Q_2 = 360\times\frac{40}{1200} = 12\text{ kW}$$

22. (d)

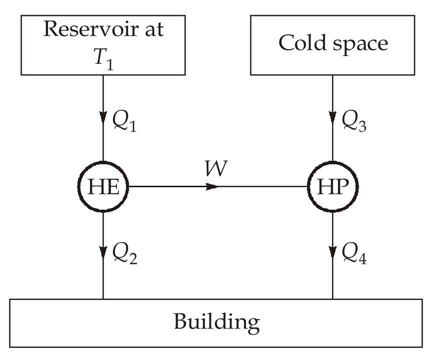
- The efficiencies of all reversible heat engines operating between the same two reservoirs are the same.
- The efficiency of a reversible heat engine is always more than the efficiency of an irreversible one operating between the same two reservoirs.

23. (a)

The thermal efficiency of actual heat engines can be maximized by supplying heat to the engine at the highest possible temperature (limited by material strength) and rejecting heat from the engine at the lowest possible temperature (limited by the temperature of the cooling medium such as river, lakes or the atmosphere).

24. (b)

Given: η_{HE} = 40%, $(COP)_{HP}$ = 5



$$\eta_{HE} = 0.40 \Rightarrow \frac{W}{Q_1} = 0.40 \Rightarrow W = 0.40\times Q_1 \quad \text{...(i)}$$

Also,
$$\frac{W}{Q_2+W} = 0.4 \Rightarrow \frac{W+Q_2}{W} = 2.5 \Rightarrow 1+\frac{Q_2}{W} = 2.5$$

$$\frac{Q_2}{W} = 1.5 \Rightarrow Q_2 = 1.5\times W = 1.5\times 0.4\times Q_1 = 0.6\times Q_1 \quad \text{...(ii)}$$

$$(COP)_{HP} = 5 \Rightarrow \frac{Q_4}{W} = 5 \Rightarrow Q_4 = 5\times W = 5\times 0.4\,Q_1$$

$$Q_4 = 2\times Q_1 \quad \text{...(iii)}$$

$$\text{Total heat rejected to building}, Q = Q_2 + Q_4$$

$$Q = 0.6Q_1 + 2 \times Q_1 = 2.6\,Q_1$$

$$\therefore \quad \frac{\text{Heat transfer to building}}{\text{Heat transfer to heat engine}} = \frac{2.6 \times Q_1}{Q_1} = 2.6$$

25. (c)

- Third law of thermodynamics states that it is impossible by any procedure, no matter how idealized, to reduce any system to the absolute zero of temperature in a finite number of operation.
- The heat transferred isothermally between the given adiabatics decreases as the temperature decreases. Conversely, the smaller the value of $Q\left[T = 273.16 \times \dfrac{Q}{Q_1}\right]$, the smaller the value of T.

  The smallest possible value of Q is zero, and the corresponding T is zero. Thus, if a system undergoes a reversible isothermal process without transfer of heat, the temperature at which this process takes place is called absolute zero. In other words, at absolute zero, an isotherm and an adiabatic are identical.

26. (d)

The entropy of an isolated system can never decrease. It always increases and remains constant only when the process is reversible. This is known as the **principle of increase of entropy.**

27. (c)

- **Kelvin-Planck statement** of the second law states that it is impossible for a heat engine to produce net work in a complete cycle if it exchanges heat only with a body at a single fixed temperature.
- **Clausius statement** of the second law states that it is impossible to construct a device which is operating in a cycle will produce no effect other than the transfer of heat from a cooler to a hotter body.
- Heat cannot flow of itself from a body at a lower temperature to a body at a higher temperature, some work must be needed to achieve this.

28. (c)

$$\text{The rate of entropy generation, } \dot{S}_{gen} = \int_1^2 \dot{m}ds = \int \dot{m}R\frac{dP}{P} = \dot{m}R\ln\left(\frac{P_1}{P_2}\right)$$

$$= -\dot{m}R\ln\left(1 - \frac{\Delta P}{P_1}\right) = -\dot{m}R\left(-\frac{\Delta P}{P_1}\right)$$

$$\Delta \dot{S}_{gen} = \dot{m} R \frac{\Delta P}{P_1}$$

$$\therefore \quad \Delta \dot{S}_{gen} = \dot{m} R \frac{\Delta P}{P_1} = 2.5 \times 0.287 \times \frac{0.20 \times P_1}{P_1}$$

$$= \frac{5}{2} \times 0.287 \times \frac{0.20 \times P_1}{P_1} = 0.1435 \text{ kW/K}$$

$\therefore$ Rate of exergy loss, $\dot{I} = T_o \times \dot{S}_{gen} = (273 + 32) \times 0.1435$

$= 43.77$ kW **Ans.**

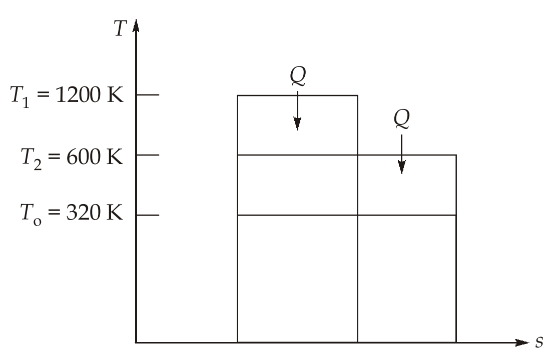
Note: $$\ln\left(1 - \frac{\Delta P}{P_1}\right) = -\frac{\Delta P}{P_1}$$

As we know: $$\ln(1 - x) = -x - \frac{x^3}{3} - \frac{x^5}{5} - \ldots\ldots\ldots\ldots = -x$$

where, $x < 1$, with higher terms being neglected

29. (a)

Given: $Q = 800$ kW; $T_1 = 1200$ K, $T_2 = 600$ K, $T_o = 320$ K



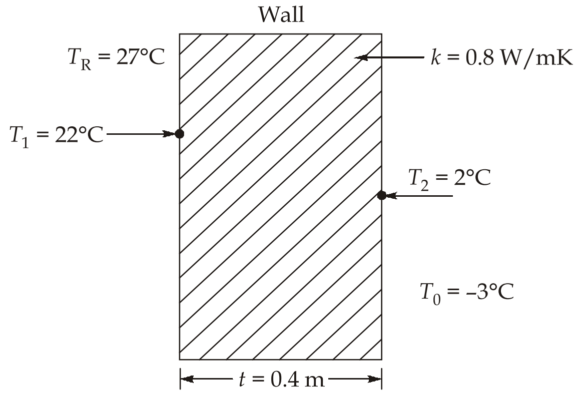
$\therefore$ Loss of available energy, $I = T_o\,(\Delta S)_{uni}$

$I = T_o(\Delta S_{sys} + \Delta S_{surr})$ $\quad [\because \Delta S_{surr} = 0]$

$$= T_o \times \Delta S_{sys} = T_o \times \left[-\frac{Q}{T_1} + \frac{Q}{T_2}\right] = 320\left[-\frac{800}{1200} + \frac{800}{600}\right]$$

$$= 320 \times 800 \times \frac{(1200 - 600)}{1200 \times 600} = 213.33 \text{ kW}$$

32. (b)



Cross-section area, A = $6 \times 5 = 30\ m^2$

∴ The rate of heat transfer through the wall,

$$Q = k \times A_{c/s} \times \frac{(T_1 - T_2)}{t} = 0.8 \times 30 \times \frac{(22-2)}{0.4}$$

$$= 1200\ W = 1.2\ kW$$ **Ans.**

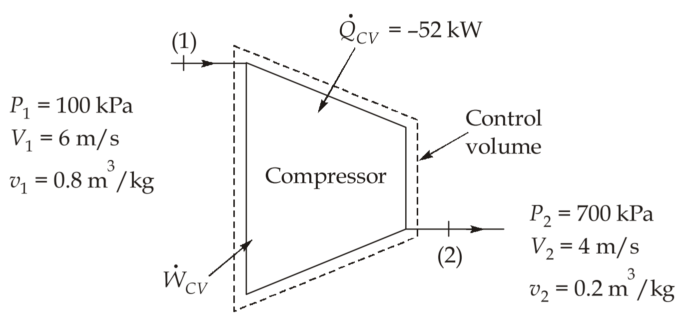
33. (c)

The rate of entropy generation in the wall,

$$\dot{S}_{gen,wall} = -\frac{Q}{T_1} + \frac{Q}{T_2} = Q\left[\frac{T_1 - T_2}{T_1 T_2}\right] = 1200 \times \left[\frac{295 - 275}{295 \times 275}\right]$$

$$= 0.2958\ W/K = 0.296\ W/K$$

34. (d)



Applying steady flow energy equation on the control volume, we get,

$$\dot{m}\left(u_1 + P_1V_1 + \frac{V_1^2}{2} + gZ_1\right) + \dot{Q}_{CV} = \dot{m}\left(u_2 + P_2V_2 + \frac{V_2^2}{2} + gZ_2\right) + \dot{W}_{CV}$$

$$\Rightarrow \quad \dot{W}_{CV} = \dot{m}\left((u_1 - u_2) + (P_1V_1 - P_2V_2) + \frac{V_1^2 - V_2^2}{2} + g\cancelto{0}{(Z_1 - Z_2)}\right) + \dot{Q}_{CV}$$

$$\Rightarrow \quad \dot{W}_{CV} = 0.7 \times \left(-85 + (100 \times 0.8 - 700 \times 0.2) + \frac{6^2 - 4^2}{2000}\right) - 52$$

$$= -153.49\ kW$$

35. (b)

Applying continuity equation at point (i) and (ii)

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

$$\Rightarrow \quad \frac{A_1 V_1}{v_1} = \frac{A_2 V_2}{v_2}$$

$$\Rightarrow \quad \frac{A_1}{A_2} = \frac{V_2 v_1}{V_1 v_2}$$

$$\Rightarrow \quad \frac{d_1}{d_2} = \sqrt{\frac{4 \times 0.8}{6 \times 0.2}} = 1.633$$ **Ans.**

36. (a)

Process 1-2: $\Delta E_{1\text{-}2} = 55$

$Q = \Delta E + W$ [First law of thermodynamics]

$\Rightarrow \quad W_{1\text{-}2} = Q - \Delta E_{1\text{-}2} = -15 - 55 = -70$ kW

Process 2-3: $Q = \Delta E + W$

$\Rightarrow \quad \Delta E_{2\text{-}3} = Q = 35$ kW

Process 3-4: $Q = \Delta E + W$

$\Rightarrow \quad +10 = \Delta E_{3\text{-}4} + (-80)$

$\Delta E_{3\text{-}4} = 90$ kW

Process 4-1: $\Sigma \Delta E = 0$ [For a cyclic process]

$\Rightarrow \quad \Delta E_{1\text{-}2} + \Delta E_{2\text{-}3} + \Delta E_{3\text{-}4} + \Delta E_{4\text{-}1} = 0$

$$\Delta E_{4\text{-}1} = -[\Delta E_{1\text{-}2} + \Delta E_{2\text{-}3} + \Delta E_{3\text{-}4}]$$
$$= -[55 + 35 + 90] = -180 \text{ kW}$$

37. (c)

The net heat supplied, $Q_s = 35 + 10 = 45$ kW

$W_{net} = Q_{net} = -15 + 35 + 10 - 10 = 20$ kW

$$\therefore \quad \text{Efficiency, } \eta = \frac{W_{net}}{Q_s} = \frac{20}{45} \times 100 = 44.44\%$$

38. (c)

$T_2 = -23 + 273 = 250$ K

Now, $$\text{COP}_{ref} = \frac{Q_2}{W} = \frac{3.5}{1}$$

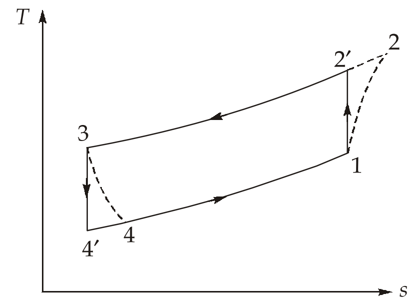
$\therefore \quad \text{COP}_{ref} = 3.5$

Also, $$\frac{T_2}{T_1 - T_2} = 3.5$$

$\therefore \quad T_2 = 3.5T_1 - 3.5T_2$

$$\therefore \quad T_1 = \frac{4.5}{3.5} \times 250 = 321.42 \text{ K}$$

39. (d)



$$T_1 = 15 + 273 = 288 \text{ K}$$
$$T_4 = -53 + 273 = 220 \text{ K}$$

$\therefore$ Net refrigerating effect, $Q = c_p(T_1 - T_4)$

$$= 1.005(288 - 220) = 68.34 \text{ kJ/kg}$$

40. (c)

Given : $n_1 = 1.35$; $n_2 = 1.3$; $T_2 = 177 + 273 = 450$ K; $T_3 = 23 + 273 = 296$ K

Net work done/kg of air, $W_{net} = \dfrac{n_1}{n_1 - 1} R(T_2 - T_1) - \dfrac{n_2}{n_2 - 1} R(T_3 - T_4)$

$$= R\left[\frac{1.35}{1.35 - 1} \times (450 - 288) - \frac{1.3}{1.3 - 1} \times (296 - 220)\right]$$

$$= R\left[\frac{1.35}{0.35} \times 162 - \frac{1.3}{0.3} \times 76\right] = 0.287(624.85 - 329.33)$$

$$= 84.81 \text{ kJ/kg}$$

$$\therefore \quad \text{COP} = \frac{R.E.}{W_{net}} = \frac{68.34}{84.81} = 0.8$$

41. (d)

Volumetric efficiency is given by, $\eta_v = 1 + c - c\left(\dfrac{v_2}{v_1}\right)$

Here, $c = 0.05$, $v_1 = 0.02 \text{ m}^3/\text{kg}$, $v_2 = 0.07 \text{ m}^3/\text{kg}$

$$\therefore \quad \eta_v = 1 + 0.05 - 0.05 \times \left(\frac{0.07}{0.02}\right) = 0.875 \text{ or } 87.5\%$$

42. (c)

Given : $h_2 = 1200$ kJ/kg; $h_1 = 320$ kJ/kg; $\dot{m}_f = \dfrac{3}{60} = 0.05$ kg/s ; $Q = \dfrac{6000}{60} = 100$ kW

Now, compressor work is given by,

$$W = \dot{m}_{ref}(h_2 - h_1) + Q = 0.05(1200 - 320) + 100$$

$$= 144 \text{ kW}$$

43. (d)

Merits of R-134a:

1. Zero ozone depleting potential.
2. Better heat transfer characteristics as compared to R-12.
3. Non-toxic

Demerits of R-134a:

1. Higher specific volume than that of R-12.
2. Highly fluorinated compound.
3. Poor compatibility with mineral oils.

44. (d)

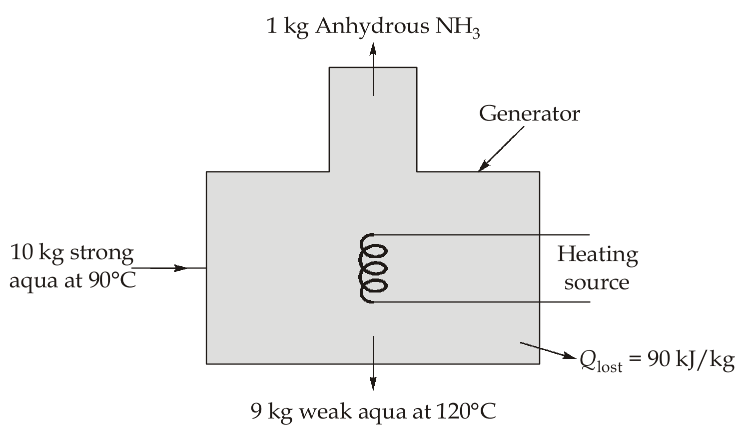
- In wet compression, specific volume of refrigerant decreases so work input to compressor decreases.
- Centrifugal or screw compressor should be used.

45. (b)

Electrolux refrigerator system uses a refrigerant, a solvent and an inert gas for the working of the system. The inert gas is confined to the low pressure side of the system i.e. evaporator and absorber only. By its presence, it is possible to maintain the uniform pressure throughout the system and at the same time permitting the refrigerant to evaporate at low temperature corresponding to its partial pressure. In the low pressure side of the system, the total pressure is the sum of partial pressure of ammonia vapour and the partial pressure of the hydrogen which is used as inert gas.

46. (c)

Refer figure,



Amount of weak solution leaving the generator per kg of anhydrous NH_3 = 10 – 1 = 9 kg

$$\text{Heat of absorption, } Q_a = 800 - 600 \times 0.2 - 6000 \times 0.2^2 = 440 \text{ kJ/kg}$$

By energy balance of the generator,

$$\text{Heat coming into generator} = \text{Heat going out of the generator}$$

$$\therefore \quad 10[420 + 4.8 \times 90] + Q_s = 2000 + 9[420 + 4.8 \times 120] + 440 + 90$$

$$\therefore \quad 8520 + Q_s = 11494$$

$$\therefore \quad Q_s = 2974 \text{ kJ/kg of } NH_3 \text{ generated}$$ **Ans.**

47. (c)

Here, h_a = 2800 kJ/kg; h_b = 1900 kJ/kg; h'_b = 2000 kJ/kg

$$\therefore \quad \eta_{\text{nozzle}} = \frac{h_a - h'_b}{h_a - h_b} = \frac{2800 - 2000}{2800 - 1900}$$

$$= 0.888 \text{ or } 88.8\%$$

48. (b)

Entrainment efficiency is given by

Here, $$\eta_e = \frac{h_a - h_d}{h_a - h'_b}$$

$$\because \quad h_d = 2250 \text{ kJ/kg}$$

$$\therefore \quad \eta_e = \frac{2800 - 2250}{2800 - 2000} = 0.6875 \text{ or } 68.75\%$$

49. (c)

Now, h_e = 2300 kJ/kg; h_f = 2500 kJ/kg; h'_f = 2600 kJ/kg

$$\therefore \quad \text{Compression efficiency, } \eta_c = \frac{h_f - h_e}{h'_f - h_e} = \frac{2500 - 2300}{2600 - 2300}$$

$$\eta_c = 0.667 \text{ or } 66.7\%$$

50. (d)

- The thermo-electric material must be excellent conductor of electricity to minimize resistance losses.
- The thermo-electric material must be a very poor conductor of heat because the heat must be absorbed at one end, and rejected at the other.
- The thermo-electric material must have high thermo-electric power. This means it must have a high rate of change in voltage with temperature that means $\frac{dE}{dt}$ must be high.

52. (a)

The centrifugal compressor is generally used for refrigerants that require large displacement and low condensing pressure such as R-11.

53. (a)

Flooded type evaporators offer high heat transfer rates due to the continuous liquid refrigerant flooding the heat transfer surfaces, ensuring a more efficient transfer of heat. This constant contact between the liquid refrigerant and the surface area allows for better heat absorption and transfer, enhancing the overall efficiency of the evaporation process.

54. (c)

Refrigeration capacity is given by,

$$\text{R.C} = \dot{m}_{ref}(h_2 - h_1)$$

$$\therefore \quad 7.5 \times 211 = \dot{m}_{ref}(210 - 90)$$

$$\therefore \quad \dot{m}_{ref} = \frac{7.5 \times 211}{120} = 13.2 \text{ kg/min}$$

55. (d)

Given : $\phi = 0.55$; $P = 1.05$ bar; $P_{vs} = 0.06$ bar

Now, $$\phi = \frac{P_v}{P_{vs}}$$

$$\Rightarrow \quad 0.55 = \frac{P_v}{0.06}$$

$$\therefore \quad P_v = 0.033 \text{ kg/kg.d.a.}$$

$$\therefore \quad \omega = 0.622\frac{P_v}{P - P_v} = \frac{0.622 \times 0.033}{1.05 - 0.033} = 0.02 \text{ kg/kg.d.a.}$$

56. (b)

$$\omega' = 0.02 - 0.005 = 0.015$$

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

$$0.015 = 0.622\left(\frac{P_v'}{1.05 - P_v'}\right)$$

$$0.015 \times 1.05 - 0.015P_v' = 0.622P_v'$$

$$\therefore \quad P_v' = \frac{0.015 \times 1.05}{0.622 + 0.015} = 0.0247$$

$$\therefore \quad \phi' = \frac{P_v}{P_{vs}} = \frac{0.0247}{0.06}$$

$$\phi' = 0.412 \text{ or } 41.2\%$$

58. (d)

In actual practice, the conditions may vary from person to person, from nation to nation and from place to place due to their different food-habits, climate conditions, types of clothes duration of stay, altitude of the place, sex of the person, age of the person and so on.

59. (d)

Total cooling load is given by

$$Q = \dot{m}_a(h_1 - h_2)$$

We have, $h_1 = 62$ kJ/kg, $h_2 = 21$ kJ/kg, $v_1 = 0.8$ m^3/kg

$$\dot{m}_a = \frac{\dot{V}}{v_1} = \frac{2400}{60 \times 0.8} = 50 \text{ kg/sec}$$

$$\therefore \quad Q = 50\,(62 - 21) = 2050 \text{ kW}$$

or $$Q = \frac{2050}{3.5} = 585.7 \text{ tons}$$

60. (b)

By energy balance,
$$Q_{water} = Q_{coil}$$
$$\therefore \quad \dot{m}_w c_{pw}(T_2 - T_1) = 2050$$
$$\therefore \quad \dot{m}_w = \frac{2050}{4.18 \times (14-8)} = 81.73 \text{ kg/sec}$$

61. (c)

$$\text{Sensible heat load from persons} = 320 \times 350 = 112000 \text{ kJ/hr}$$
$$\text{Latent heat load from person} = 100 \times 320 = 32000 \text{ kJ/hr}$$
$$\text{Total sensible heat load} = 112000 + 160000 = 272000 \text{ kJ/hr}$$
$$\text{Total latent heat load} = 32000 + 70000 = 102000 \text{ kJ/hr}$$
$$\therefore \quad \text{Sensible heat factor, SHF} = \frac{272000}{272000 + 102000} = 0.73$$

62. (d)

It is generally used for small capacity refrigerating systems as household refrigerator or small capacity coolers.

63. (d)

Evaporative condensers use the combined principles of water-cooled condensers and cooling towers. These condensers are more preferable where acute water shortage exists and drain facilities are not available. This type of condenser gives better performance in dry weather (low WBT) compared with wet weather (higher WBT).

64. (d)

The electric resistance of the refrigerant becomes an important factor when it is used in hermetically sealed unit where the motor is exposed to the refrigerant. High dielectric strength is desirable for ideal refrigerants.

65. (c)

The high pressure float valve also maintains the flow to the evaporator by actuating the level in the float chamber in the same manner as the low pressure float valve except that the high pressure float valve is located on the high pressure side and controls the amount of liquid by maintaining level in the float chamber.

67. (b)

$$T_E = -13 + 273 = 260 \text{ K}$$
$$T_G = 167 + 273 = 440 \text{ K}$$
$$T_o = 47 + 273 = 320 \text{ K}$$

Now,
$$(\text{COP})_{max} = \frac{T_E(T_G - T_o)}{T_G(T_o - T_E)} = \frac{260(440-320)}{440(320-260)} = 1.18$$
$$\therefore \quad (\text{COP})_{act} = 0.4 \times 1.18 = 0.47$$

69. (d)

- Relative humidity lines are curved.
- Specific volume lines are straight and inclined.

70. (c)

$$\text{B.P.F.} = \frac{t_c - t_2}{t_c - t_1}$$

$$0.4 = \frac{42 - t_2}{42 - 16} \Rightarrow t_2 = 42 - 10.4$$

$$t_2 = 31.6°\text{C}$$

71. (d)

Given: h_1 = 55 kJ/kg d.a., ω_1 = 0.005 kg/kg d.a.

$$\dot{m}_a = \frac{\dot{V}}{v_1} = \frac{120}{0.8} = 150 \text{ kg/min}$$

$$\dot{m}_\omega = 60 \text{ kg/hr} = 1 \text{ kg/min}$$

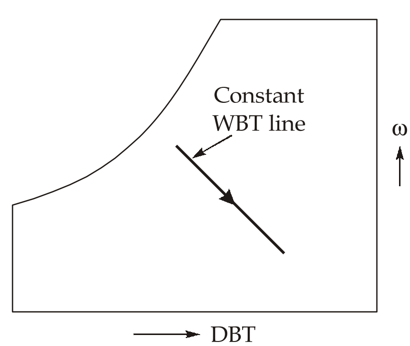
Now, specific humidity of leaving air after water injection,

$$\omega_2 = \omega_1 + \frac{\dot{m}_\omega}{\dot{m}_a} = 0.005 + \frac{1}{150} = 0.0116 \text{ kg/kg.d.a.}$$

∴ Enthalpy at leaving condition is,

$$h_2 = h_1 + (\omega_2 - \omega_1) \times C_{pw} \times t_w$$
$$= 55 + (0.0116 - 0.005) \times 4.18 \times 20$$
$$= 55.5 \text{ kJ/kg d.a.}$$

72. (c)



73. (d)

Humidifying efficiency is given by,

$$\eta_{\text{humidifying}} = \frac{t_{c1} - t_{c2}}{t_{c1} - t_{wbt}} = \frac{35 - 25}{35 - 20} = 0.67$$

74. (c)

Sensible heat is given by, $Q_s = 0.0204\ (\text{cmm}) \times (t_1 - t_{\text{supply}})$

∴ $50 = 0.0204 \times \text{cmm} \times (30 - 15)$

$$\therefore \qquad \text{cmm} = \frac{50}{0.0204 \times 15} = 163.4\ \text{m}^3/\text{min}$$

$$\therefore \qquad (\text{cmm})_{\text{fresh air}} = \frac{163.4}{4} = 40.85\ \text{m}^3/\text{min}$$

75. (c)

The refrigerants NH_3, CO_2 and SO_2 are immiscible refrigerants. All freons, CH_3Cl, CH_2Cl_2 and most refrigerants from hydrocarbon group are miscible. When the lubricating oil is carried by the refrigerant of immiscible type, some means must be provided to remove the lubricating oil which forms a coating over the heat transfer surfaces and in turn decreases the load capacity of the system.

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