DETAILED SOLUTIONS

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## ESE 2023 : Prelims Exam
CLASSROOM TEST SERIES

## MECHANICAL ENGINEERING

## Test 2

**Section A :** Thermodynamics [All Topics]

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

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

## DETAILED EXPLANATIONS

**1. (c)**

For the given process,

$$P = V^2 + \frac{3}{V}$$

$$\therefore \quad W = \int PdV = \int_{V_1}^{V_2}\left(V^2 + \frac{3}{V}\right)dV$$

$$W = \int_3^6\left(V^2 + \frac{3}{V}\right)dV = \left[\frac{V^3}{3} + 3\ln V\right]_3^6$$

$$W = \left[\frac{6^3 - 3^3}{3} + 3\ln\frac{6}{3}\right] \times 100 \text{ kJ}$$

$$= 6507.94 \simeq 6508 \text{ kJ}$$

**2. (c)**

Work is a high grade energy while heat is a low grade energy.

**3. (b)**

After attainment of equilibrium, final temperature of water and steel piece system will be equal

$$T_f = 20 + 5°C = 25°C$$

From energy balance,

$$\text{Heat lost by mild steel} = \text{Heat gained by water}$$

$$\therefore \quad m_s C_s \left(T_{s_1} - T_f\right) = m_w C_{p_w}\left(T_f - T_{w_1}\right)$$

$$5 \times C_s \times (115 - 25) = 30 \times 4.2 \times (25 - 20)$$

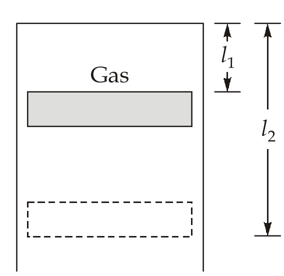
$$\therefore \quad C_s = \frac{30 \times 4.2 \times 5}{5 \times 90} = 1.4 \text{ kJ/kgK}$$

**4. (b)**

In paddle wheel work transfer, even though the volume of fluid system remains constant, the work done has a certain finite value. However, this form of work can be done in one direction only, i.e. work transfer is from the surroundings to the system and not from the system to the surrounding.

**5. (a)**

Since the heat is being supplied at constant pressure, therefore




$$\frac{V_2}{V_1} = \frac{T_2}{T_1}$$

or,

$$\frac{\text{Area of cylinder} \times l_2}{\text{Area of cylinder} \times l_1} = \frac{T_2}{T_1}$$

$$\therefore \quad l_2 = l_1 \times \frac{T_2}{T_1}$$

$$l_2 = 0.15 \times \left(\frac{327+273}{27+273}\right) = 0.3 \text{ m}$$

∴ The distance moved by the piston is

$$l_2 - l_1 = 0.15 \text{ m}$$

**6. (c)**

The concept of a perfect gas, that obeys the equation of state $pv = RT$, makes the following assumptions about the gas molecules.

- The collision of molecules with one another and with the walls of the container is perfectly elastic i.e. there is no loss in their energy due to these collisions.
- There is no molecular attraction between the particles of gas, and that they are in a state of continuous motion.
- The volume occupied by the molecules is negligible as compared to the volume of the gas.

Real gases differ from ideal ones due to presence of the intermolecular forces and also to the finite molecular volumes.

**7. (d)**

Here, mole fraction of nitrogen,

$$y_{N_2} = 0.6$$

Mole fraction of oxygen, $y_{O_2} = 0.15$

Mole fraction of methane, $y_{CH_4} = 0.25$

Using the relation,

$$P_i = y_i P \quad \text{where } P \text{ is the total pressure}$$

For methane, $0.5 = 0.25 \times P$

$\Rightarrow$ $P = 2$ bar

∴ Partial pressure of nitrogen, $P_{N_2} = y_{N_2} \times P$

$$P_{N_2} = 0.6 \times 2$$

$$P_{N_2} = 1.2 \text{ bar}$$

Also, partial pressure of oxygen, $P_{O_2} = y_{O_2} \times P$

$$P_{O_2} = 0.15 \times 2$$

$$P_{O_2} = 0.3 \text{ bar}$$

**8. (d)**

$$\text{Work done, } W = VI \times t = 20 \times 10 \times 3 \times 60 \times 60 \text{J}$$

$$W = 2160 \text{ kJ}$$

Using first law, $\delta Q = \delta W + du$

$$\delta Q = 2160 + (-1250)$$

$$\delta Q = 910 \text{ kJ}$$

**9. (d)**

**10. (d)**

**11. (b)**

The unsteady state energy equation for filling process is given by,

$$m_2u_2 - m_1u_1 = (m_2 - m_1)\left[h_p + \frac{V_p^2}{2}\right] + Q$$

$\because$ $m_1 = 0$ (initially empty), and $m_2 = 15$ kg and neglecting any change in K.E., we get

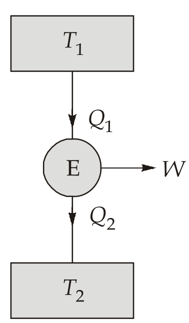
$$Q = m_2u_2 - m_2h_p$$

or $$Q = m_2[(h_2 - p_2v_2) - h_p]$$

$\therefore$ $$Q = 15\left[\left(750 - \frac{10 \times 10^5 \times 0.05}{1000}\right) - 625\right]$$

$$Q = 1125 \text{ kJ}$$

**12. (b)**




For Carnot engine, $\eta = \dfrac{T_1 - T_2}{T_1}$

In the first case:

$$\frac{T_1 - T_2}{T_1} = \frac{Q_1}{W} = \frac{1}{5}$$

$\therefore$ $5T_1 - 5T_2 = T_1$

$\Rightarrow$ $T_1 = 1.25T_2$ ...(i)

In the second case:

$$\frac{T_1 - (T_2 - 80)}{T_1} = 2 \times \frac{1}{5}$$

or $5T_1 - 5T_2 + 400 = 2T_1$

$\therefore \quad 3T_1 + 400 = 5T_2$ ...(ii)

From equation (i) and (ii), we get

$$3T_1 + 400 = 5 \times \frac{4}{5} T_1$$

or $T_1 = 400$ K

**13. (c)**

Efficiency of Carnot cycle,

$$\eta = \frac{Q_1 - Q_2}{Q_1} = \frac{\theta_1 - \theta_2}{\theta_1}$$

$$\therefore \quad \frac{Q_2}{Q_1} = \frac{\theta_2}{\theta_1}$$

From the given relations

$$kQ_1 = T_1 - \theta_1 \text{ and } kQ_2 = \theta_2 - T_2$$

$$\therefore \quad \frac{\theta_2 - T_2}{T_1 - \theta_1} = \frac{Q_2}{Q_1} = \frac{\theta_2}{\theta_1}$$

Upon simplification, $\theta_2 = \dfrac{T_2\theta_1}{2\theta_1 - T_1} = \dfrac{T_2\theta_1}{2(T_1 - kQ_1) - T_1}$

$$\therefore \quad \eta = \frac{\theta_1 - \left(\dfrac{T_2\theta_1}{T_1 - 2kQ_1}\right)}{\theta_1} = 1 - \frac{T_2}{T_1 - 2kQ_1}$$

**14. (d)**

**15. (b)**

**16. (c)**

Entropy change for a thermal reservoir is defined as,

$$ds = \frac{\delta Q}{T}$$

$\therefore$ Heat lost by cold reservoir, $Q = T\Delta S = 800(-4) = -3200$ kJ

An equal amount of heat is received by cold reservoir,

$\therefore$ Entropy change of cold reservoir $= \dfrac{3200}{250} = 12.8$ kJ/K

**17. (d)**

For maximum work output between two bodies of finite capacity,

$$W_{max} = mc\left(\sqrt{T_1} - \sqrt{T_2}\right)^2$$

$$W_{max} = 20 \times 2.4\left(\sqrt{900} - \sqrt{196}\right)^2$$

$$= 12.28 \text{ MJ}$$

**18. (b)**

**19. (d)**

$$\text{Entropy change, } ds = \frac{\delta Q}{T} = \frac{1500}{500}$$

$$ds = 3 \text{ kJ/K}$$

$$\therefore \quad \text{Availability} = Q - T_0\Delta s$$

$$= 1500 - 290 \times 3$$

$$= 630 \text{ kJ}$$

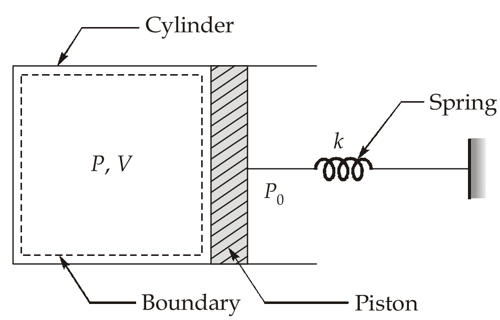
**20. (c)**

**21. (c)**

**22. (c)**

**23. (d)**

**24. (c)**




Force balance at any position of piston gives :

$$PA = P_0A + kx$$

where displacement $x = \dfrac{V}{A}$

$$\therefore \quad PA = P_0A + \frac{kV}{A}$$

or

$$P = P_0 + \frac{k}{A^2}V$$

$$\text{Work done, } W = \int PdV = \int_1^2 \left(P_0 + \frac{k}{A^2}V\right)dV$$

On integrating and simplifying, we get

$$W = (V_2 - V_1)\left(\frac{P_1 + P_2}{2}\right)$$

Given : $P_1 = 200$ kPa, $P_2 = 500$ kPa, $V_1 = 0.1$ m$^3$, $V_2 = 0.2$ m$^3$

$\therefore$ Work done by gas, $W = (0.2 - 0.1)\left(\dfrac{500 + 200}{2}\right)$

$= 35$ kJ

**25. (d)**

When the motor is not running,

$$100 = R_0(1 + 0.005 \times 30)$$

$$100 = 1.15R_0 \quad \text{...(i)}$$

When the motor is stopped after running it at full load,

$$120 = R_0(1 + 0.005t) \quad \text{...(ii)}$$

From equation (i) and (ii),

$$\frac{100}{120} = \frac{1.15R_0}{R_0(1 + 0.005t)}$$

$$\therefore \quad 1 + 0.005t = \frac{120 \times 1.15}{100} = 1.38$$

$$\therefore \quad t = \frac{1.38 - 1}{0.005}$$

$$t = 76°\text{C}$$

**26. (c)**

Given, $P \propto D$ or $P = CD$

$$\therefore \quad C = \frac{P_1}{D_1} = 200 \text{ kPa/m}$$

Now, $P_2 = CD_2$

$$\Rightarrow \quad D_2 = \frac{400}{200} = 2 \text{ m}$$

$$V = \frac{\pi}{6}D^3 \text{ or } dV = \frac{\pi}{2}D^2 \cdot dD$$

Now, Work done, $W = \int_1^2 P \cdot dV$

$$W = \int_1^2 CD \cdot \frac{\pi}{2} D^2 \cdot dD$$

or

$$W = \frac{\pi C}{8}\left(D_2^4 - D_1^4\right)$$

$$W = \frac{\pi \times 200}{8}(2^4 - 1^4)$$

$$= 1178 \text{ kJ}$$

**27. (b)**

$$\text{K.E. of vehicle} = \text{Heat gained by brakes}$$

$$\therefore \quad \frac{1}{2} \times MV^2 = mc\Delta T$$

$$\frac{1}{2} \times (2000) \times \left(90 \times \frac{5}{18}\right)^2 = 25 \times 0.5 \times 10^3 \times \Delta t$$

$$\therefore \quad 1000 \times 25 = 0.5 \times \Delta t \times 10^3$$

$$\therefore \quad \Delta t = 50°\text{C}$$

**28. (d)**

$$(P_1)_{abs} = 1 + 1.75 = 2.75 \text{ bar}$$

$$T_1 = 27 + 273 = 300 \text{ K}$$

$$T_2 = 47 + 273 = 320 \text{ K}$$

Now, using ideal gas equation for a constant volume process,

$$\frac{(P_1)_{abs}}{T_1} = \frac{(P_2)_{abs}}{T_2}$$

$$\therefore \quad (P_2)_{abs} = \frac{T_2}{T_1} \times (P_1)_{abs} = \frac{320}{300} \times 2.75$$

$$(P_2)_{abs} = 2.93 \text{ bar}$$

$$(P_2)_{gauge} = 2.93 - 1 = 1.93 \text{ bar}$$

**29. (b)**

Using ideal gas equation,

$$T_2 = \frac{P_2}{P_1} \times T_1 \qquad (\because V = \text{constant})$$

$$= \frac{140}{70} \times 300 = 600 \text{ K}$$

Now, change in internal energy during the process,

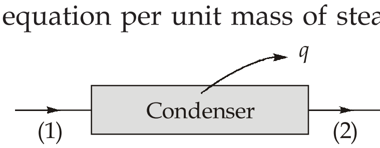
$$du = mC_V (T_2 - T_1)$$

$$du = 3 \times 0.65(600 - 300)$$

$$du = 585 \text{ kJ}$$

**30. (c)**

Applying steady flow energy equation per unit mass of steam flow,




$$q = (h_1 - h_2) + \frac{V_1^2 - V_2^2}{2000}$$

$$= (2050 - 200) + \frac{500^2 - 10^2}{2000}$$

$$= 1850 + 124.95 \text{ kJ/kg}$$
$$= 1974.95 \text{ kJ/kg}$$

**31. (c)**

Let $Q_1$ is heat rejected at higher temperature by the heat pump,

$$\therefore \quad (\text{COP})_{hp} = \frac{\dot{Q}_1}{W}$$

$$\therefore \quad \dot{Q}_1 = \dot{W} \times (\text{COP})_{hp} = 40 \times 5$$

$$\dot{Q}_1 = 200 \text{ kW}$$

Neglecting kinetic and potential energy changes and no shaft work, from SFEE we have

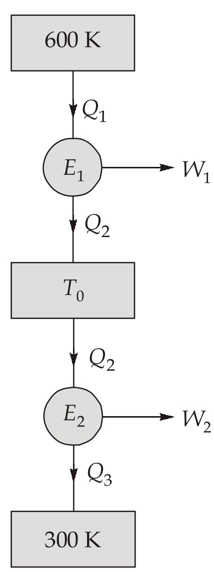
$$\dot{Q}_1 = \dot{m}(h_2 - h_1) = \dot{m}c_p(\Delta T)$$

$$\therefore \quad 200 = \dot{m} \times 4.2 \times 20$$

$$\therefore \quad \dot{m} = 2.38 \text{ kg/s}$$

**32. (d)**

**33. (c)**




For same efficiency,

$$\eta_1 = \eta_2$$

$$1 - \frac{T_0}{T_1} = 1 - \frac{T_2}{T_0}$$

or

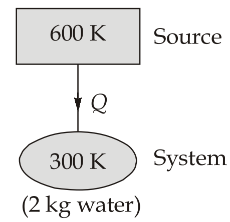
$$\frac{T_0}{T_1} = \frac{T_2}{T_0}$$

$$\therefore \quad T_0 = \sqrt{T_1 T_2}$$

$$T_0 = \sqrt{600 \times 300}$$

$$T_0 = 424.26 \text{ K}$$

**34. (d)**




Entropy change of water, $\Delta s_{water} = mc_{p_w} \ln \frac{T_2}{T_1}$

$$= 2 \times 4.2 \ln \frac{600}{300} = 5.82 \text{ kJ/K}$$

Heat withdrawn from the source, $Q = mc_{p_w}(T_2 - T_1)$

$$Q = 2 \times 4.2\,(600 - 300)$$

$$Q = 2520 \text{ kJ}$$

$\therefore$ Entropy change of the source,

$$(ds)_{source} = \frac{-Q}{T} = \frac{-2520}{600}$$

$$(ds)_{source} = -4.2 \text{ kJ/K}$$

$\therefore$ Entropy change of universe,

$$\Delta s_{univ} = 5.82 - 4.2$$

$$\Delta s_{univ} = 1.62 \text{ kJ/K}$$

**35. (d)**

For minimum work input, the pump is to operate on a reversible cycle,

$$\therefore \quad W_{min} = mc\left[\frac{T_1^2}{T_2} + T_2 - 2T_1\right]$$

$$W_{min} = 20 \times 2.5\left[\frac{900^2}{300} + 300 - 2 \times 900\right]$$

$$= 60 \text{ MJ}$$

**36. (c)**

$$(\text{COP})_{HP} = 1 + (\text{COP})_{Ref}$$

Heat pump and refrigerator work on the principle of Clausius statement.

**37. (d)**

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

**38. (a)**

**39. (b)**

$$\text{COP}_R = \frac{T_L}{T_H - T_L}$$

$$(COP_R)_I = \frac{T_L + 20}{T_H - (T_L + 20)} = \frac{T_L + 20}{T_H - T_L - 20}$$

$$(COP_R)_{II} = \frac{T_L}{(T_H - 20) - T_L} = \frac{T_L}{T_H - T_L - 20}$$

$$\frac{(COP_R)_I}{(COP_R)_{II}} = \frac{T_L + 20}{T_L} = \frac{270}{250}$$

$$= 1.08$$

**40. (a)**

- Vortex tube refrigeration system has extremely simple design with no moving parts.
- Its COP is very low.
- It is not suitable for large capacity refrigeration units and generally used for localised cooling of small components.
- Temperature of the cold stream can be easily regulated by moving the nozzle.

**41. (b)**

- In SSS VCRS, both heat rejection and addition are isobaric with exit conditions of evaporator and condenser as saturated.
- Compression is entirely in superheated region.
- Expansion process is isenthalpic.

**42. (b)**

- For maximum COP for given evaporator and condenser temperature, suction state may be saturated, may lie in wet region or superheated depending on the refrigerant.
- Practically all common refrigerants have approximately the same COP and power requirement between two given temperatures.

**43. (c)**

- On increasing the pressure ratio the mass flow rate through the compressor decreases and through the capillary tube increases.
- On increasing the load both the evaporator and the condenser temperature increases.

**44. (b)**

**45. (c)**

In hermetic compressors, motor and compressor are sealed in a casing and for cooling, suction gas is made to flow over the motor and the compressor. This reduces the efficiency of the compressor.

**46. (c)**

Addition of fluorine atoms increases GWP of CFCs. R-23 has a GWP of 14800. GWP of $CO_2$ is 1.

**47. (d)**

Vapour and liquid phase of Azeotropic mixtures maintain identical composition for a wide range of temperatures. They have a sharp boiling point unlike zeotropic mixtures.

**48.** **(a)**

R-11 has 3 Chlorine atoms per molecule.

**49.** **(d)**

Vapour compression refrigeration systems are critically charged to avoid slugging of compressors in case of reduction in load. Critically charged systems have refrigerant in the system to just fill the evaporator in case of load decrease and avoid slugging of the compressor.

**50.** **(b)**

Ideal materials for thermoelectric systems should have high electrical conductivity and low thermal conductivity.

**51.** **(b)**

For heat transfer temperature of refrigerant in the evaporator is kept 10°C lower than room temperature and 10°C higher than ambient in the condenser.

$$\frac{\dot{Q}_1}{\dot{W}_1} = COP_1 = \frac{T_L}{T_H - T_L} = \frac{T_{room} - 10}{(T_{amb} + 10) - (T_{room} - 10)}$$

$$= \frac{T_{room} - 10}{T_{amb} - T_{room} + 20}$$

$$\frac{\dot{Q}_2}{\dot{W}_2} = (COP)_{mod.} = \frac{T_{room} - 5}{(T_{amb} + 5) - (T_{room} - 5)}$$

$$= \frac{T_{room} - 5}{T_{amb} - T_{room} + 10}$$

$$\dot{Q}_1 = \dot{Q}_2$$

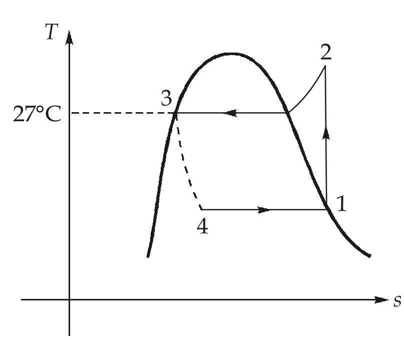
$$\dot{W}_1 \times \frac{283}{40} = \dot{W}_2 \times \frac{288}{30}$$

$$\dot{W}_2 = 2 \times \frac{283}{40} \times \frac{30}{288}$$

$$= 1.474 \simeq 1.5 \text{ kW}$$

**52.** **(c)**

**53.** **(c)**




$$h_1 = 180 \text{ kJ/kg}$$

$$h_3 = h_g - T(s_g - s_f) \qquad \text{[At 27°C]}$$

$$h_3 = 200 - 300(0.68 - 0.28)$$

$$= 200 - 300 \times 0.4$$

$$= 80 \text{ kJ/kg}$$

$$h_4 = h_3 = 80 \text{ kJ/kg}; \quad W = \frac{50}{\dot{m}} = \frac{50}{2} = 25 \text{ kJ/kg}$$

$$\text{COP} = \frac{h_1 - h_4}{W} = \frac{180 - 80}{25} = 4$$

**54. (a)**

Volumetric efficiency of compressor is given by,

$$\eta = 1 + C - C\left(\frac{P_2}{P_1}\right)^{1/n} \qquad \text{where } C = \frac{V_C}{V_S} = 0.06$$

Also,

$$\left(\frac{P_2}{P_1}\right)^{1/n} = \frac{v_1}{v_2}$$

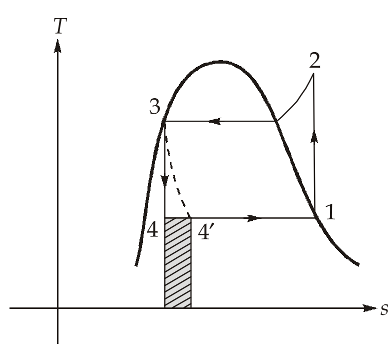
$$0.86 = 1 + 0.06 - 0.06 \times \frac{0.08}{v_2}$$

$$v_2 = 0.024 \text{ m}^3\text{/kg}$$

$$T_2 = \frac{p_2 v_2}{R} = \frac{550}{0.044} \times 0.024$$

$$= 300 \text{ K} = 27°\text{C}$$

**55. (b)**




$$\text{Decrease in COP} = \text{COP}_I - \text{COP}_{II}$$

$$= \left(\frac{R.E.}{W_{net}}\right)_I - \left(\frac{R.E.}{W_{net}}\right)_{II}$$

$$= \frac{h_1 - h_4}{(h_2 - h_1) - (h_3 - h_4)} - \frac{h_1 - h_{4'}}{h_2 - h_1}$$

$$= \frac{120}{50-20} - \frac{100}{50} = 2$$

**56. (b)**

$$COP_{max} = \eta_{carnot} \times COP_{rev\text{-}carnot}$$

$$= \frac{T_G - T_A}{T_G} \times \frac{T_E}{T_C - T_E}$$

$$= \frac{50}{380} \times \frac{260}{60} = 0.57$$

**57. (d)**

Reversible heat operated refrigerating machine refers to VARS and for VARS,

$$COP = \frac{T_1 - T_2}{T_1} \times \frac{T_3}{T_2 - T_3}$$

Thus, for higher COP

- $T_1$ should be as high as possible.
- $T_2$ should be as low as possible.
- $T_3$ should be as high as possible.

**58. (b)**

$$P_{NH_3,\ condenser} = P_{total} = P_{sat,\ 50°C} = 20.34 \text{ bar}$$

$$P_{NH_3,\ evaporator} = P_{total} - P_{H_2} = 20.34 - 17.97 = 2.37 \text{ bar}$$

$$\therefore \quad T_{evaporator} = T_{sat,\ 2.37\ bar} = -15°C$$

**59. (a)**

$$\eta_c = 1 + C - C\left(\frac{P_d}{P_s}\right)^{\frac{1}{n}}$$

$$0 = 1 + C - C\left(\frac{P_d}{P_s}\right)^{\frac{1}{n}}$$

$$P_d = P_s\left(\frac{1+C}{C}\right)^n$$

**60. (b)**

As the pressure ratio increases, compressor work increases, volumetric efficiency decreases.

Since,

$$\frac{P_c}{P_e} = \exp\left[\frac{h_{fg}}{R}\left(\frac{1}{T_e} - \frac{1}{T_c}\right)\right]$$

So for higher pressure ratios, $h_{fg}$ is also higher.

So for given mass flow rate refrigeration capacity is also higher.

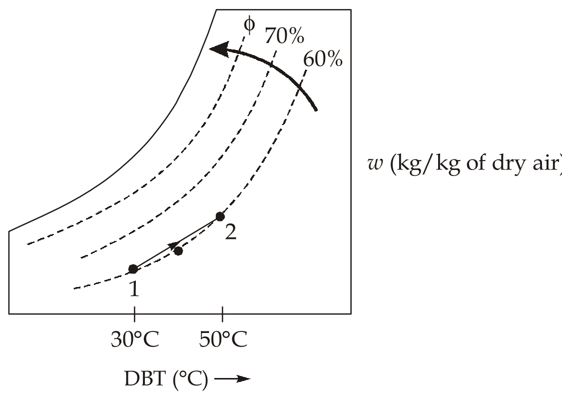
**61. (c)**

$$SHF = \frac{RSHL}{RTL} = \frac{RTL - RLHL}{RTL}$$

$$0.7 = \frac{RTL - 30}{RTL}$$

$$RTL = 100 \text{ MJ/h}$$

**62. (d)**




**63. (b)**

Freon (Chlorofluoro carbon based) refrigerants can be detected using hallide torch method. In this methyl alcohol or hydrocarbon flame is used which is blue in colour and turns bluish green in the presence of halocarbon vapours.

**64. (a)**

$$\text{Contact factor} = 1 - X = \frac{t_1 - t_2}{t_1 - t_s} = 0.4$$

$$\frac{40 - t_2}{40 - 12} = 0.4$$

$$t_2 = 28.8°C$$

**65. (c)**

$$SHL = \dot{m} c_p \Delta T$$

$$0.5 = \frac{4 \times 15}{3600} \times 1.2 \times 1.005 \times \Delta T$$

$$\Delta T = 24.87°C$$

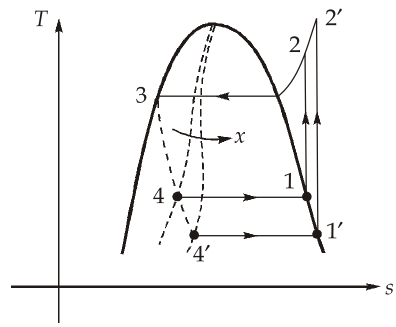
**66. (b)**

$$COP = \frac{1}{r_p^{\frac{\gamma-1}{\gamma}} - 1} = \frac{T_4}{T_3 - T_4}$$

- As $r_p$ increases, COP decreases.
- For fixed $T_4$ and $T_3$ COP remains constant.
- For a given pressure ratio, COP is dependent on $\gamma$ which is a property of refrigerant.

**67. (a)**

Amount of vapour at the evaporator inlet increases on decreasing the evaporator pressure as depicted in $T$-$s$ diagram below.




**68. (d)**

**69. (a)**

$$m_{a_1}\omega_1 + m_{a_2}\omega_2 = (m_{a_1} + m_{a_2})\omega_3$$

$$\omega_3 = \frac{0.5 \times 32 + 4 \times 20}{4.5}$$

$$= 21.3 \text{ g/kg of dry air}$$

**70. (b)**

**71. (b)**

**72. (c)**

COP of heat pump operating in winters,

$$\text{COP}_{\text{HP}} = \frac{T}{T - T_w}$$

COP of refrigerator in summer,

$$\text{COP}_{\text{R}} = \frac{T}{T_s - T}$$

$$\text{COP}_{\text{HP}} = \text{COP}_{\text{R}}$$

$$\Rightarrow \quad \frac{T}{T - T_w} = \frac{T}{T_s - T} \qquad (T \neq 0)$$

$$T = \frac{T_s + T_w}{2}$$

**73. (a)**

Motor windings are cooled by suction vapour in hermetically sealed compressors. So dielectric strength is a crucial property.

**74. (c)**

At higher altitudes both the temperature and density of air is very low. This air needs to be compressed before supplying to the cabin. Due to ram effect temperature of the air increases.

Also due to skin friction there is enormous heat generated. So, cooling systems are required to keep the cabin temperatures at a comfortable level in an aircraft.

**75. (d)**

For VARS, refrigerant should have excellent solubility in the absorbent but the boiling point difference of refrigerant-absorbent should be very large. So, Azeotropic mixtures are not suitable as refrigerant absorbent pair.

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