


MADE EASY

Leading Institute for ESE, GATE & PSUs

Test Centres: Delhi, Hyderabad, Bhopal, Jaipur, Pune

ESE 2026 : 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. (c)	16. (c)	31. (d)	46. (c)	61. (c)
2. (b)	17. (d)	32. (b)	47. (c)	62. (d)
3. (d)	18. (c)	33. (c)	48. (c)	63. (c)
4. (c)	19. (d)	34. (b)	49. (c)	64. (d)
5. (d)	20. (b)	35. (d)	50. (d)	65. (d)
6. (d)	21. (c)	36. (b)	51. (c)	66. (c)
7. (d)	22. (d)	37. (a)	52. (d)	67. (b)
8. (d)	23. (d)	38. (b)	53. (d)	68. (b)
9. (c)	24. (d)	39. (c)	54. (c)	69. (c)
10. (b)	25. (d)	40. (c)	55. (d)	70. (d)
11. (a)	26. (b)	41. (a)	56. (c)	71. (a)
12. (d)	27. (c)	42. (d)	57. (d)	72. (c)
13. (b)	28. (c)	43. (c)	58. (c)	73. (a)
14. (a)	29. (b)	44. (c)	59. (c)	74. (c)
15. (d)	30. (b)	45. (c)	60. (d)	75. (b)

Section A : Thermodynamics

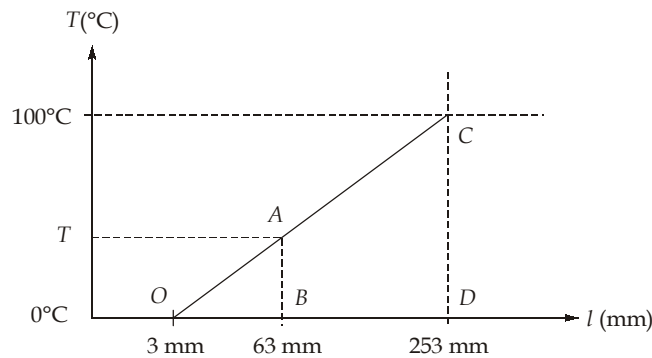
1. (c)

If p denotes the magnitude of any property for the system and by p_i the magnitude of the same property for each of the objects (or subsystems) comprising that system, we can mathematically define the two sets of properties as:

Intensive if $p = p_i$

Extensive if $p = \sum p_i$

2. (b)



From similar Δ 's OAB and OCD

$$\frac{T}{63 - 3} = \frac{100}{255 - 3}$$

$$T = \frac{100}{250} \times 60 = 24^\circ\text{C}$$

3. (d)

Given : $m = 2.5 \text{ kg}$; loss = 10% ; $h = 1 \text{ m}$; $v_1 = 1 \text{ m/s}$; $g = 10 \text{ m/s}^2$

$$\begin{aligned} \Delta U &= E_1 - \text{losses} \\ &= E_1 - 0.1 E_1 \\ &= 0.9 E_1 \\ &= 0.9 \left[mgh + \frac{1}{2} mv^2 \right] \\ &= 0.9 \times 2.5 \left[10 \times 1 + \frac{1}{2} \right] = 0.9 \times 2.5 \times 10.5 \\ &= 23.625 \text{ Joules} \end{aligned}$$

4. (c)

Given : $P_1 = 2 \text{ bar}$; $P_2 = 1 \text{ bar}$; $V_1 = 4 \text{ m}^3$; $V_2 = ?$; $T_1 = 27^\circ\text{C} = 300 \text{ K}$; $T_2 = 127^\circ\text{C} = 400 \text{ K}$

For ideal gas

$$PV = mRT$$

$$\frac{PV}{T} = \text{const} ; \{\text{for closed system}\}$$

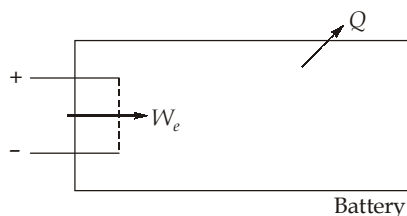
$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$V_2 = \left(\frac{P_1}{P_2} \right)^{\frac{T_2}{T_1}} V_1 = \left(\frac{\frac{2}{1}}{\frac{300}{400}} \right)^4 = \left(\frac{8}{3} \right)^4 = \frac{32}{3}$$

Now ;

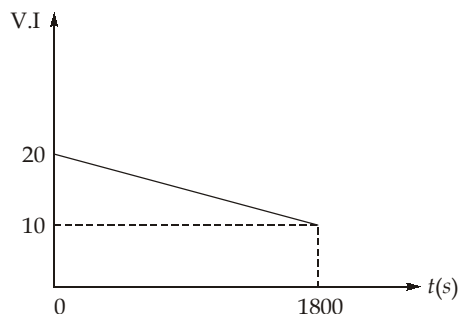
$$\begin{aligned} \Delta V &= V_2 - V_1 \\ &= \frac{32}{3} - 4 = \frac{20}{3} \text{ m}^3 \end{aligned}$$

5. (d)



Given : $V = 10 \text{ V}$; $t = 30 \text{ min} = 30 \times 60 \text{ sec} = 1800$; $\Delta u = 10 \text{ kJ}$

$$\begin{aligned} W_e &= \int_0^{1800} V.I dt \\ &= \text{Area} \\ &= \frac{1}{2} (1800) (20 + 10) \\ &= 900 \times 30 = 27000 \text{ J} = 27 \text{ kJ} \end{aligned}$$



Now;

$$\begin{aligned} W_e &= Q + \Delta u ; \{\text{according to directions taken in above diagram}\} \\ 27 &= Q + 10 \\ Q &= 17 \text{ kJ} \end{aligned}$$

6. (d)

	Work	Heat
Process-1	6.3 kJ	27.7 kJ
Process-2	0 kJ	-2.1 kJ
Process-3	W	0

For a cycle :

$$\oint dW = \oint dQ$$

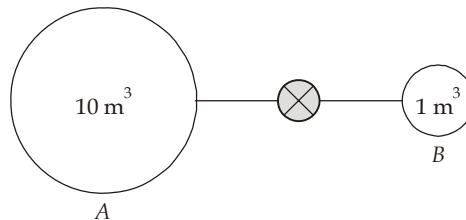
 $\Rightarrow$

$$W + 6.3 = 27.7 - 2.1$$

 $\Rightarrow$

$$W = 19.3 \text{ kJ}$$

7. (d)



$$T_{A,1} = T_{B,1} = T_{A,2} = T_{B,2} = 300 \text{ K}$$

$$m_{A,1} = 13 \text{ kg} ; m_{B,1} = 2 \text{ kg}$$

$$R_{\text{air}} = 0.3 \text{ kJ/kgK}$$

$$PV = mRT$$

Ideal Gas Equation :

Mass Conservation:

$$m_{A,1} + m_{B,1} = m_{A,2} + m_{B,2}$$

 $\Rightarrow$

$$13 + 2 = \frac{P_2 V_A}{RT_2} + \frac{P_2 V_B}{RT_2} = \frac{P_2}{RT_2} (V_A + V_B)$$

 $\Rightarrow$

$$P_2 = \frac{15(0.3)(300)}{11} = 122.73 \text{ kPa}$$

8. (d)

$$P = 4D ; \text{ where } P \text{ (in bar) and } D \text{ (in m)}$$

$$P = 8R$$

$$V = \frac{4}{3} \pi R^3$$

 $\Rightarrow$

$$dV = \frac{4\pi}{3} (3R^2) dR = 4\pi R^2 dR$$

$$(W)_{\text{by air}} = \int_{V_1}^{V_2} p dV = \int_1^2 (8R) 4\pi R^2 dR$$

$$\begin{aligned}
 &= 32\pi \int_1^2 R^3 dR = 32\pi \left. \frac{R^4}{4} \right|_1^2 \\
 &= 8\pi(2^4 - 1) = 120\pi \text{ bar-m}^3 \\
 &= 37.7 \text{ MJ}
 \end{aligned}$$

9. (c)

$$\text{COP}_{\text{HP}} = 1 + \text{COP}_{\text{R}} \quad \dots(\text{i})$$

$$\text{COP}_{\text{HP}} = 1.5 \times \text{COP}_{\text{R}} \quad \dots(\text{ii})$$

$$1.5 \text{ COP}_{\text{R}} = 1 + \text{COP}_{\text{R}}$$

$$\text{COP}_{\text{R}} = \frac{1}{0.5} = 2$$

$$\Rightarrow \frac{T_L}{T_H - T_L} = 2$$

$$\Rightarrow \frac{1}{\frac{T_H}{T_L} - 1} = 2$$

$$\Rightarrow \frac{T_H}{T_L} = \frac{1}{2} + 1 = 1.5$$

10. (b)

Process	Δu	Q_{in}	W_{on}
1 - 2	+40	-5	+45
2 - 3	+15	+15	0
3 - 4	-50	+10	-60
4 - 1	-5	-10	+5

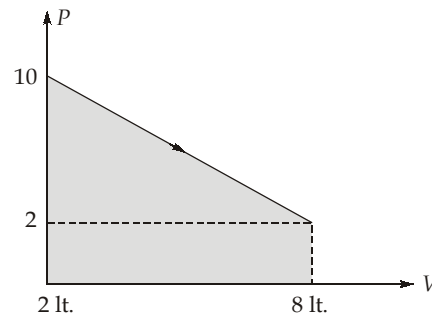
We can complete the table using

$$(i) Q_{\text{in}} = \Delta u - W_{\text{on}} \text{ and } (ii) \oint dQ = \oint dW$$

$$\eta = \frac{W_{\text{net}}}{Q_s} = \frac{10}{15 + 10}$$

$$= 0.4 \text{ or } 40\%$$

11. (a)



$$W = \frac{1}{2}(8-2)(2+10)$$

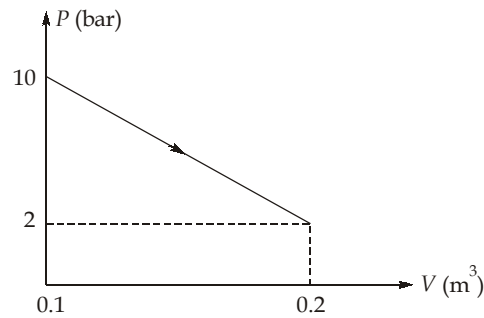
$$= 6 \times 6 = 36 \text{ lt. bar} = 3600 \text{ J}$$

$$Q = \Delta u + W$$

$$\Delta u = Q - W = 100 - 3600 = -3500 \text{ J}$$

12. (d)

Given : $P_1 = 10 \text{ bar}$; $P_2 = 2 \text{ bar}$; $V_1 = 0.1 \text{ m}^3$; $V_2 = 0.2 \text{ m}^3$



$$W = \frac{1}{2}(0.1)(10+2) = 6 \times 0.1 = 0.6 \text{ bar m}^3$$

$$W = 60 \text{ kJ}$$

$$\Delta E = P_2 V_2 - P_1 V_1 = 2(0.2) - 10(0.1)$$

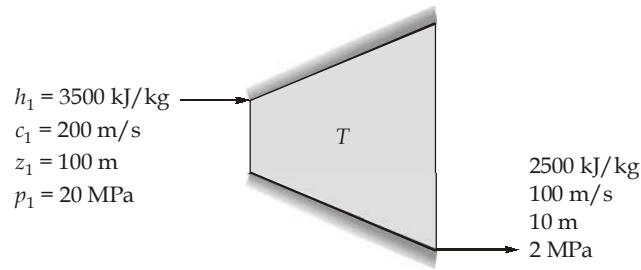
$$= -6(0.1) = -0.6 \text{ bar m}^3$$

$$\Delta E = -60 \text{ kJ}$$

$$Q = \Delta E + W$$

$$= -60 + 60 = 0$$

13. (b)



$$\begin{aligned}\dot{W}_{cv} &= \dot{m} \left[(h_1 - h_2) + \frac{1}{2000} (c_1^2 - c_2^2) + \frac{1}{1000} (z_1 - z_2) \right] \\ &= 15 \left[(3500 - 2500) + \frac{200^2 - 100^2}{2000} + \frac{1000 - 10}{1000} \right] \\ &= 15[1000 + 15 + 0.09] \\ &= 15226.35 \text{ kW} \simeq 15.23 \text{ MW}\end{aligned}$$

14. (a)

Given : $m = 25 \text{ kg}$; $u = 1 \text{ m/s}$; $h = 10 \text{ m}$ From 1st law,

$$\cancel{Q} = \Delta E + W$$

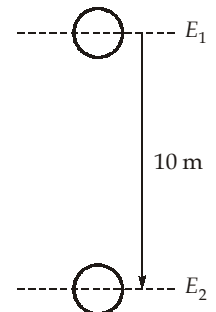
0 (adiabatic process)

$$W = -\Delta E = E_1 - E_2$$

$$E_1 = m \left(\frac{1^2}{2} + g(10) \right)$$

$$E_2 = m \left(\frac{3^2}{2} \right)$$

$$\begin{aligned}W &= 25 \left(\frac{1^2 - 3^2}{2} + 100 \right) = 25 \times 96 \\ &= 2400 \text{ J} = 2.4 \text{ kJ}\end{aligned}$$



15. (d)

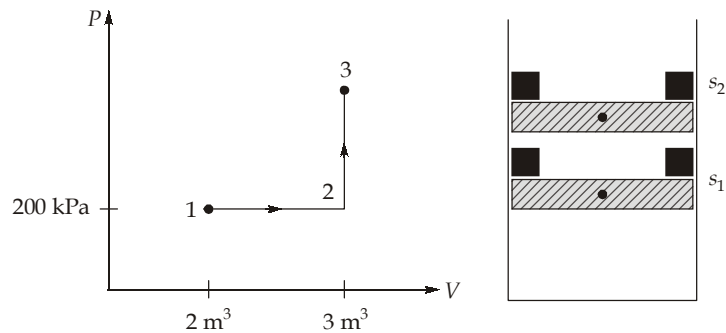
We know

$$Pv = ZRT : (\text{Real gas equation})$$

$$\frac{T}{v} = \frac{P}{ZR} = \frac{(P_r \cdot P_{cr})}{Z \left(\frac{8.314}{M} \right)}$$

$$= \frac{(2 \times 2730)}{(0.7) \left(\frac{8.314}{20} \right)} \simeq 18763.5 \text{ K kg/m}^3$$

16. (c)



Given : $P_1 = 200 \text{ kPa}$; $P_2 = ?$; $V_1 = 2 \text{ m}^3$; $V_2 = 3 \text{ m}^3$; $T_1 = T$; $T_{\text{final}} = 3T$

$1 \rightarrow 2 : P = \text{Constant}$

$$V \propto T$$

$$T_2 = \left(\frac{V_2}{V_1} \right) T_1 = \frac{3}{2} T = 1.5T$$

$$T_2 = 1.5T \neq T_{\text{final}}$$

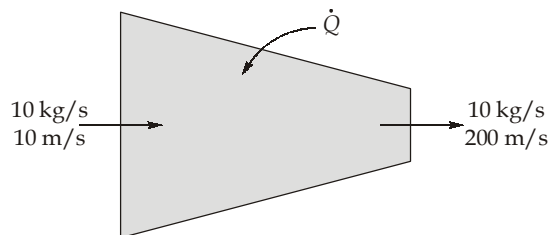
$\Rightarrow$

$$T_3 = T_{\text{final}} = 3T$$

$\therefore$

$$\text{Work done} = (3 - 2)200 \text{ kJ} = 200 \text{ kJ}$$

17. (d)



From SFEE,
$$\dot{m} \left(h_1 + \frac{c_1^2}{2000} \right) + \dot{Q} = \dot{m} \left(h_2 + \frac{c_2^2}{2000} \right)$$

$\Rightarrow$

$$\dot{Q} = \dot{m} \left(\frac{c_2^2 - c_1^2}{2000} \right) = 10 \left(\frac{40000 - 100}{2000} \right)$$

$\Rightarrow$

$$\dot{Q} = 199.5 \text{ kJ} \quad \text{to the Nozzle}$$

$$\dot{Q} = -199.5 \text{ kJ} \quad \text{from the nozzle}$$

18. (c)

For polytropic process undergone by perfect gas

$$pV^n = c$$

and

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1} \right)^{\frac{n-1}{n}} = \left(\frac{V_1}{V_2} \right)^{n-1}$$

 $\Rightarrow$

$$\frac{400}{200} = \left(\frac{0.8}{0.1} \right)^{\frac{n-1}{n}}$$

 $\Rightarrow$

$$2 = (8)^{\frac{n-1}{n}}$$

 $\Rightarrow$

$$(2)^{\frac{n}{n-1}} = 8 = 2^3$$

 $\Rightarrow$

$$\frac{n}{n-1} = 3$$

 $\Rightarrow$

$$3n - 3 = n$$

 $\Rightarrow$

$$n = \frac{3}{2} = 1.5$$

19. (d)

State	T(°C)	P(kPa)	V(litre)
1	-73	0.1 bar	1000
2	127	0.8 bar	----
3	327	----	----

$$n = 1.5$$

$$V_3 = V_1 \left(\frac{T_1}{T_3} \right)^{\frac{1}{n-1}} = 1 \left(\frac{200}{600} \right)^{\frac{1}{1.5-1}} = \frac{1}{9} \text{ m}^3$$

$$P_3 = P_1 \left(\frac{T_3}{T_1} \right)^{\frac{n}{n-1}} = 0.1 \left(\frac{600}{200} \right)^{\frac{1.5}{1.5-1}} = 0.1(3)^3 = 2.7 \text{ bar}$$

$$W = \frac{P_1 V_1 - P_3 V_3}{n-1} = \frac{0.1 \times 1 - 2.7 \times \frac{1}{9}}{1.5-1}$$

$$= 2(0.1 - 0.3) = -2 \times 0.2 = -4 \text{ bar m}^3 = -40 \text{ kJ by the gas}$$

$$= 40 \text{ kJ on the gas}$$

20. (b)

For Reversible refrigerator - 1

$$\frac{Q}{T_1} = \frac{Q+2W}{T_2}$$

and for reversible refrigerator - 2

$$\frac{Q+2W}{T_2} = \frac{Q+3W}{T_3}$$

i.e.

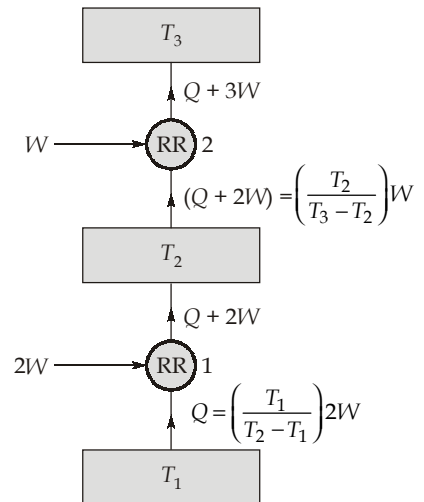
$$\frac{Q}{T_1} = \frac{Q+2W}{T_2} = \frac{Q+3W}{T_3}$$

$$\Rightarrow \frac{\left(\frac{T_1}{T_2 - T_1}\right)2W}{T_1} = \frac{\left(\frac{T_2}{T_3 - T_2}\right)W}{T_2} = \frac{\left(\frac{T_2}{T_3 - T_2} + 1\right)W}{T_3}$$

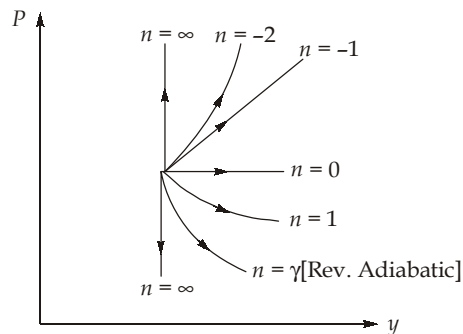
$$\Rightarrow \frac{2}{T_2 - T_1} = \frac{1}{T_3 - T_2} = \frac{1}{T_3 - T_2}$$

$$\Rightarrow 2T_3 - 2T_2 = T_2 - T_1$$

$$\Rightarrow T_2 = \frac{2T_3 + T_1}{3}$$



21. (c)



$$\Delta s = c_p \ln\left(\frac{V_2}{V_1}\right) + c_v \ln\left(\frac{P_2}{P_1}\right)$$

and

$$pv^n = c ; \text{ \{for reversible polytropic process\} }$$

$$\frac{P_2}{P_1} = \left(\frac{V_2}{V_1}\right)^{-n}$$

$$\Delta s = c_p \ln\left(\frac{V_2}{V_1}\right) - nc_v \ln\left(\frac{V_2}{V_1}\right)$$

For $\Delta s > 0$,

$$\ln\left(\frac{V_2}{V_1}\right)[c_p - nc_v] > 0$$

i.e. if $V_2 > V_1$ i.e. expansion $c_p - nc_v > 0$

$$\gamma > n$$

or if $V_2 < V_1$ i.e. compression $c_p - nc_v < 0$

$$\gamma < n$$

For $\Delta s < 0$,

$$\ln\left(\frac{V_2}{V_1}\right)[c_p - nc_v] < 0$$

i.e. if $V_2 > V_1$ i.e. expansion $c_p - nc_v < 0$

$$\gamma < n$$

or if $V_2 < V_1$ i.e. compression $c_p - nc_v > 0$

$$\gamma > n$$

i.e. for polytropic process 's' may increase or decrease

(1) Correct

(2) Incorrect

$$\begin{aligned}\Delta s &= \left(\frac{dQ}{T}\right)_{rev} \text{ (may be +, -, 0 for polytropic rev. process)} \\ &= \left(\frac{dQ}{T}\right)_{irr} + (s_g) \text{ (always } \geq 0\text{)}\end{aligned}$$

$\Rightarrow \Delta s$ for irreversible polytropic process may also be +, -, 0.

(3) Incorrect

22. (d)

23. (d)

24. (d)

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

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

$\therefore$

$$\begin{aligned}\text{Availability} &= Q - T_0 \Delta s \\ &= 1500 - 290 \times 3 \\ &= 630 \text{ kJ}\end{aligned}$$

25. (d)

$$Tds = du + \cancel{p}d\cancel{v}^0 = dh - \cancel{v}d\cancel{p}^0$$

$$\left(\frac{\partial u}{\partial s}\right)_v = \left(\frac{\partial h}{\partial s}\right)_p = T \quad [\text{Always positive}]$$

26. (b)

$$\text{COP}_{\text{HP}} = 1 + \text{COP}_R = \frac{1}{\eta_{\text{HE}}}$$

$$\text{COP}_R = 2; \quad (\text{Given})$$

$$\text{COP}_{\text{HP}} = 1 + 2 = 3$$

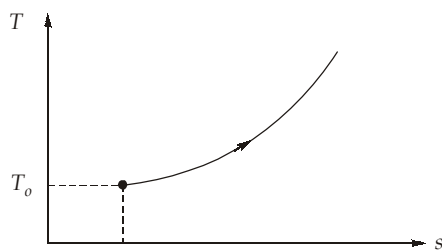
$$\eta_{\text{HE}} = \frac{1}{3}$$

$$\eta_{\text{HE}} : \text{COP}_R : \text{COP}_{\text{HP}}$$

$$\frac{1}{3} : 2 : 3$$

$$1 : 6 : 9$$

27. (c)

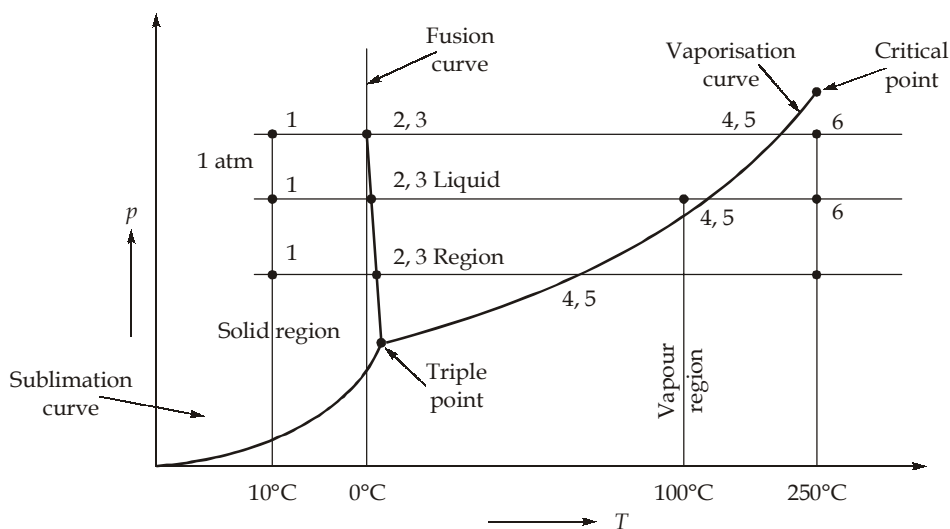


$$s - s_0 = c \ln\left(\frac{T}{T_0}\right)$$

$$T = T_0 e^{\left(\frac{s-s_0}{c}\right)} \quad \text{exponential variation}$$

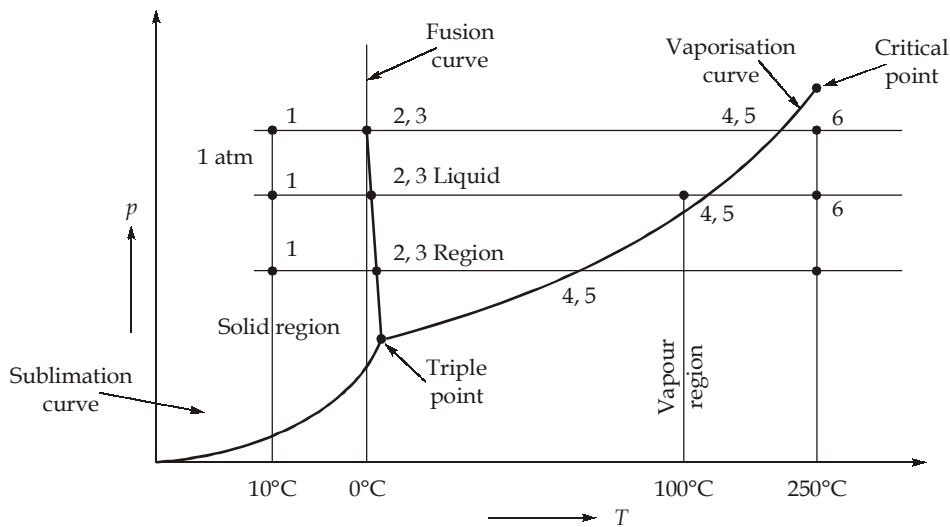
28. (c)

29. (b)



Phase equilibrium diagram on p-T coordinates

30. (b)



Phase equilibrium diagram on p-T coordinates

31. (d)

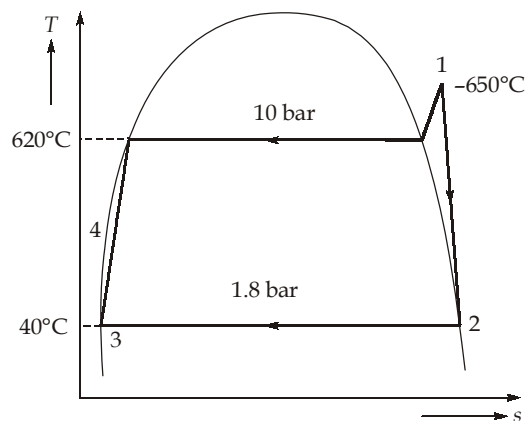
From carnot's principle

Efficiency of any reversible heat engine cycle working between same temperature limit is same.

32. (b)

1. The fluid should have a high critical temperature so that the saturation pressure at the maximum permissible temperature (metallurgical limit) is relatively low. It should have a large enthalpy of evaporation at that pressure.
2. The saturation pressure at the temperature of heat rejection should be above atmospheric pressure so as to avoid the necessity of maintaining vacuum in the condenser.

3. The specific heat of liquid should be small so that little heat transfer is required to raise the liquid to the boiling point.
4. The saturated vapour line of the T-s diagram should be steep, very close to the turbine expansion process so that excessive moisture does not appear during expansion.
5. The freezing point of the fluid should be below room temperature, so that it does not get solidified while flowing through the pipelines.
6. The fluid should be chemically stable and should not contaminate the materials of construction at any temperature.
7. The fluid should be nontoxic, noncorrosive, not excessively viscous, and low in cost.



T-s diagram of an ideal working fluid for a vapour power cycle

The characteristics of such an ideal fluid are approximated in the T-s diagram as shown in figure. Some superheat is desired to reduce piping losses and improve turbine efficiency. The thermal efficiency of the cycle is very close to the Carnot efficiency.

33. (c)

Efficiency of otto-cycle in terms of compression ratio (r_c), $\eta = 1 - \frac{1}{r_c^{\gamma-1}}$ and compression process in

Otto cycle is isentropic.

Hence Relation between T and P is

$$\begin{aligned} \frac{T_2}{T_1} &= \left(\frac{P_2}{P_1} \right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{V_1}{V_2} \right)^{\gamma-1} \\ &= r^{\frac{\gamma-1}{\gamma}} = r^{\gamma-1} \end{aligned}$$

Hence, efficiency of otto-cycle in terms of pressure ratio (r) = $1 - \frac{1}{r^{\frac{\gamma-1}{\gamma}}}$

34. (b)

Relation between
Compression Ratio (r_c)
Expansion Ratio (r_e) and Cutoff Ratio (ρ)
for Diesel Cycle is

$$r_e = \frac{r_c}{\rho} = \frac{14}{1.5} = \frac{28}{3} = 9.33$$

35. (d)

$$\left(P + \frac{a}{v^2}\right)(v - b) = RT$$

The coefficient a was introduced to account for the existence of mutual attraction between the molecules. The term $\frac{a}{v^2}$ is called the force of cohesion. The coefficient b was introduced to account for the volumes of the molecules, and is known as co-volume.

36. (b)

Adiabatic process,

$$Q = 0$$

$\Rightarrow$

$$\dot{Q} \Delta t = 0$$

$\Rightarrow$

$$\text{Either, } \dot{Q} = 0 \text{ (Insulated)}$$

or

$$\Delta t = 0 \text{ (Quick process)}$$

37. (a)

$$P + F = C + 2$$

$$2 + F = 1 + 2$$

$$F = 1$$

Hence, saturated liquid or the saturated vapour has only one independent variable.

For saturated liquid or the saturated vapour states only one property is required to be known to fix up the state.

Section B : Refrigeration and Air-Conditioning

38. (b)

Hermetically Sealed Compressor : To avoid the complete leakage of refrigerant, the compressor and motor are enclosed in one housing. The motor in the housing is exposed to the low vapour refrigerant which helps for cooling also. The dehydration of the unit before charging is essential as the moisture in the system may damage the motor. This compressor is less noisy than the ordinary systems, being more compact requires small space.

39. (c)

Some clearance is always necessary and desirable to provide cushioning and to prevent slap on the cylinder head. For two similar compressors each having same piston displacement, the capacity will be smaller for the machine having greater clearance.

- The superheating of the gas to the higher temperature as it enters the cylinder, and friction loss to gas through ports & valves, thereby reducing the pressure, also contribute for lowering volumetric efficiency.
- The volumetric efficiency also decreases with an increase in elements as well as index of compression for same pressure ratio.

40. (c)

Given, $c = 0.04$; $V_{\text{suction}} = 0.45 \text{ m}^3/\text{kg} = v_1$

$$V_{\text{suction}} = 0.45 \text{ m}^3/\text{kg} = v_1$$

$$V_{\text{discharge}} = 0.135 \text{ m}^3/\text{kg} = v_2$$

$$\eta_v = 1 + c - c \left[\frac{v_1}{v_2} \right] = 1 + 0.04 - 0.04 \left[\frac{0.45}{0.135} \right]$$

$$\Rightarrow \eta_r = \frac{68}{75} = 0.9067 \text{ or } 90.67\%$$

41. (a)

Evaporative Condensers:

- These condensers were developed for big refrigeration systems. These condensers are more preferable where acute water shortage exists. These are also desirable where water costs are also high and use of cooling tower for small installations is uneconomical, and unpracticable.
- Most of the heat given by the refrigerant vapour is carried by the air in the form of sensible & latent heat, therefore, the effectiveness of this type of condenser depends upon the WBT of the incoming air.
- The capacity of the condenser also depends upon the quantity of air circulated through the condenser but this is limited by maximum air velocity permitted through the eliminators without the carryover of water particles.

42. (d)

Different Types of water cooled Condensers:

1. **Double Tube Condenser:** It is preferred only for the units below 10kW capacity as it requires more space compared with shell & tube Condenser. The advantages are easy in construction & easy for cleaning.
2. **Shell & Coil Condenser:** It can be used for units upto 50 tons. The condenser is preferable where clean water is available as coil cannot be cleaned easily.
3. **Shell & tube Condenser:** It is most satisfactory among all Condensers. The tubes can be perfectly cleaned by removing the headers. These condensers are available from 2 to 1000 tons capacity units.
4. **Evaporative Condenser:** Evaporative condensers use the combined principles of water-cooled condensers and cooling towers.

43. (c)

- **Flooded evaporator:** In flood evaporator, the evaporator (cooled or header coil) is always kept filled with liquid refrigerant. This type of evaporator gives high heat transfer rates so that smaller evaporators can be used.
- **Dry expansion system:** The amount of liquid present in the dry expansion evaporator will vary with the load of the evaporator.
- **Forced convection Evaporators:** These are more efficient than natural convection evaporators because it requires less cooling surface and higher evaporative pressures can be used which save considerable power input to the compressor.

44. (c)

Secondary Evaporators:

- When the chilled water or brine is used to carry out the heat from the refrigerated space and this heat is given to the refrigerant in the evaporator.
- This is more economical when the place to be cooled is far away from refrigeration system. In such cases, direct expansion system is not practical because it requires large refrigerant charge.
- Indirect cooling system is desirable where leakage of refrigerant or oil from pipings may cause the contamination to the stored product.

45. (c)

Solenoid control valve is the device used as expansion device in refrigeration systems. These are placed in the liquid line between the condenser and evaporator. This valve either allows to flow constant quantity of refrigerant to the evaporator or stops the flow.

46. (c)

Expansion Devices:

1. **Capillary Tube:** The rate of flow to a selected capillary tube is the function of the pressure differential between the condenser and evaporator.
2. **Automatic (constant pressure) expansion valve:** This valve maintains a constant pressure throughout the varying load operation on the evaporators controlling the quantity of refrigerating flow.
3. **Thermostatic expansion valve (constant degree of superheat):** This is widely used because of high efficiency and its ability to provide effective use of all evaporator surface under all load conditions.
4. **High-side float valve:** The high-side flow valve may be installed either above or below the evaporator as it is independent of the liquid level in the evaporator.

47. (c)

Thermo-electric Refrigeration System:

- Thermo-electric materials must be excellent conductors of electricity to minimise resistance losses and very poor conductor of heat because the heat must be absorbed at one end and rejected at other end.
- Thermo-electric units are much more flexible than conventional units. These units are being static are more reliable than rotating or reciprocating units.

- The first serious disadvantage of this unit is low COP and it decreases with the increase in temperature difference.

48. (c)

Vortex-Tube: The air enters the tube tangentially and forms a free vortex. The vortex travels along the wall due to centrifugal action. The pressure near the valve is more than outside the diaphragm at the other end, a reversal axial flow starts.

- The turbulent mixing in centrifugal field results in pumping of energy from the low pressure region at the axis to the high pressure region at periphery. For the insulated tube the energy carried away by the peripheral hot stream is equal to the energy rejected by the axial layer of cold stream.

49. (c)

The comfort chart shows the percentage of people feeling comfort at different effective temperature. The effective temperature is a measure of feeling warmth or cold to the human body in response to the air temperature, moisture content and air motion. The chart represents the percentage of people feeling comfort for various combinations of DBT and RH, based on effective temperature lines obtained from ASHVE experiments.

50. (d)

For Unsaturated Halocarbon

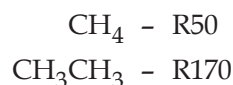
Chemical formula	Designation
$C_2H_4Cl_3$	R120
C_3H_6	R1270

For saturated Halocarbon :

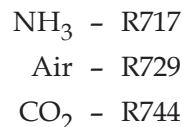
$$C_m H_n Cl_p F_q - R(m-1)(n+1)q$$

$$n + p + q = 2m + 2$$

Hydrocarbons :



Inorganic Compound :



51. (c)

52. (d)

Given, $T_e = -3^\circ C = 270 K$, $T_g = 117^\circ C = 390 K$; $T_c = 27^\circ C = 300 K$, $h_{fg} = 2200 kJ/kg$

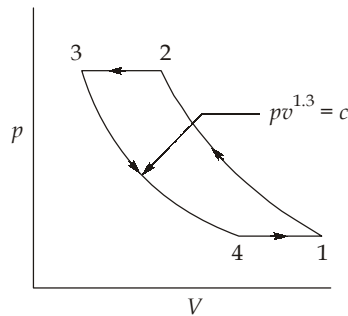
$$1. \quad (COP)_{\max} = \frac{T_e}{T_g} \left(\frac{T_g - T_c}{T_c - T_e} \right) = \frac{270}{390} \left(\frac{390 - 300}{300 - 270} \right)$$

$$= \frac{27}{13} = 2.077$$

$$\begin{aligned}
 2. \quad (\text{COP})_{\text{actual}} &= 0.65 \times 2.077 = 1.35 \\
 \text{Actual heat supplied} &= \frac{RC}{\text{COP}} = \frac{33}{1.35} = 24.44 \text{ kN} \\
 \therefore \dot{m}(xh_{fg}) &= 24.44 \\
 \Rightarrow \dot{m} \times 0.81 \times 2200 &= 24.44 \\
 \Rightarrow \dot{m} &= 0.0137 \text{ kg/s} = 49.38 \text{ kg/h}
 \end{aligned}$$

53. (d)

Given: $T_1 = -8^\circ\text{C} = 265 \text{ K}$; $T_2 = 152^\circ\text{C} = 425 \text{ K}$; $T_3 = 17^\circ\text{C} = 290 \text{ K}$; $T_4 = -73^\circ\text{C} = 200 \text{ K}$

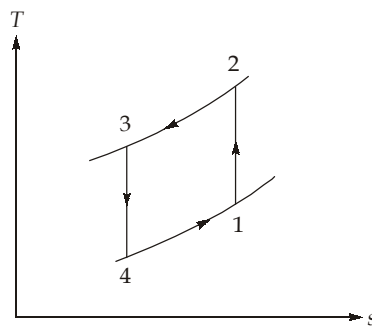


$$W_{\text{in}} = W_c - W_e$$

$$W_{\text{in}} = \frac{\gamma}{\gamma-1}(p_2 v_2 - p_1 v_1) - \frac{n}{n-1}(p_3 v_3 - p_4 v_4)$$

$$\begin{aligned}
 W_{\text{in}} &= R \left[\frac{\gamma(T_2 - T_1)}{\gamma-1} - \frac{n(T_3 - T_4)}{n-1} \right] \\
 &= 0.287 \left[\frac{1.4(425 - 265)}{0.4} - \frac{1.3(290 - 200)}{0.3} \right] \\
 &= 0.287[560 - 390] = 48.79 \text{ kJ/kg}
 \end{aligned}$$

54. (c)



Given : $W_c = 165 \text{ kJ/kg}$; $W_e = 100 \text{ kJ/kg}$; $T = 290 \text{ K}$, $T = 190 \text{ K}$

$$R_E = C_p(T_1 - T_4) = 1.005 (290 - 190) = 100.5 \text{ kJ/kg}$$

$$W_{in} = W_c - W_e = 65 \text{ kJ/kg}$$

$$\text{COP} = \frac{R_E}{W_{in}} = \frac{100.5}{65} = 1.546$$

55. (d)

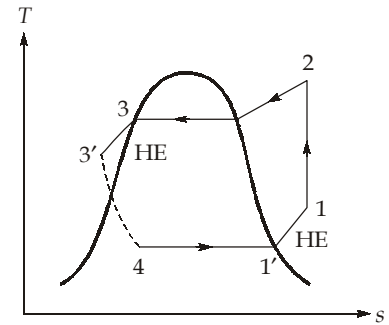
Given, $h'_1 = 170$, $h_3 = 95$; $h_1 = 175$, $h_2 = 215$

$$\therefore h_1 - h'_1 = h_3 - h'_3$$

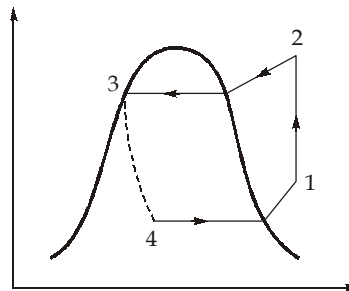
$$\Rightarrow h'_3 = 95 - 5 = 90$$

and $h_4 = h'_3 = 90$

$$\begin{aligned} \therefore \text{COP} &= \frac{R_E}{W_{in}} = \frac{h'_1 - h_4}{h_2 - h_1} \\ &= \frac{170 - 90}{215 - 175} = 2 \end{aligned}$$



56. (c)



Given, $h_1 = 195 \text{ kJ/kg}$; $h_2 = 239 \text{ kJ/kg}$; $h_3 = h_4 = 85 \text{ kJ/kg}$

$$P_{in} = 2.2 \text{ kW}$$

$$\therefore P_{in} = \dot{m}(h_2 - h_1)$$

$$\Rightarrow 2.2 = \dot{m}(44)$$

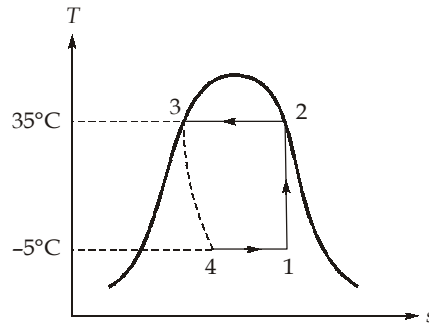
$$\Rightarrow \dot{m} = 0.05 \text{ kg/s}$$

$$\therefore RC = \dot{m}(h_1 - h_4) = 0.05 (195 - 85)$$

$$\therefore RC = 5.5 \text{ kW} = 1.57 \text{ tons}$$

57. (d)

Given, $h_2 = 1354 \text{ kJ/kg}$; $s_2 = 4.5 \text{ kJ/kgK}$; $s_{f1} = 0.1$, $s_{g1} = 5.1$; $h_{f1} = 10$, $h_{g1} = 1310$


 $\therefore$

$$s_1 = s_2$$

 $\Rightarrow$

$$s_{f1} + x_1 s_{fg} = 4.5$$

 $\Rightarrow$

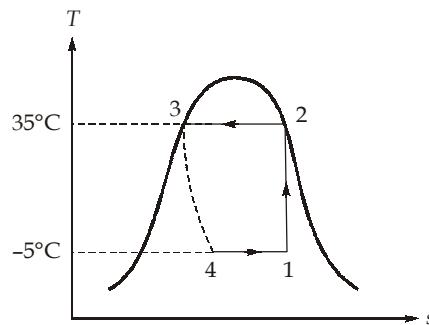
$$0.1 + x_1(5) = 4.5$$

 $\Rightarrow$

$$x_1 = \frac{4.4}{5} = 0.88$$

58. (c)

Given, $h_2 = 1354 \text{ kJ/kg}$; $s_2 = 4.5 \text{ kJ/kgK}$; $s_{f1} = 0.1$, $s_{g1} = 5.1$; $h_{f1} = 10$, $h_{g1} = 1310$



$$h_1 = h_{f1} + x_1 h_{fg1} = 10 + 0.88(1300) = 1154 \text{ kJ/kg}$$

$$h_4 = h_3 = 400 \text{ kJ/kg}$$

$$(\text{COP})_{\text{ideal}} = \frac{h_1 - h_4}{h_2 - h_1} = \frac{754}{1354 - 1154} = 3.77$$

$$(\text{COP})_{\text{actual}} = 0.5 \times 3.77 = 1.885$$

59. (c)

Given, $T_L = 280 \text{ K}$; $T_H = 300 \text{ K}$

$\therefore$ Cycle is working as heat pump

 $\therefore$

$$\text{COP}_{\text{HP}} = \frac{T_H}{T_H - T_L} = \frac{300}{20} = 15$$

$$\therefore \text{Power input} = \frac{DE}{COP} = \frac{1800}{15} = 120 \text{ kW}$$

60. (d)

Given, $T_L = -23^\circ\text{C} = 250 \text{ K}$; $RC = 3 \text{ ton} = 3 \times 3.5 = 10.5 \text{ kW}$; $P = 5 \text{ kW}$

$$COP = \frac{10.5}{5} = 2.1$$

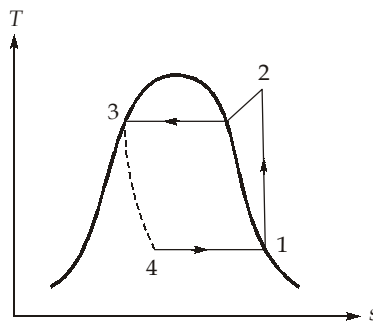
$$COP = \frac{T_1}{T_2 - T_1}$$

$$\Rightarrow 2.1 = \frac{250}{T_2 - 250}$$

$$\Rightarrow T_2 = 369.047 \text{ K} = 96.047^\circ\text{C}$$

61. (c)

Given, $h_1 = 190 \text{ kJ/kg}$; $h_2 = 205 \text{ kJ/kg}$; $h_3 = h_4 = 81 \text{ kJ/kg}$



$$\text{Theoretical compression work} = h_2 - h_1 = 205 - 190 = 15 \text{ kJ/kg}$$

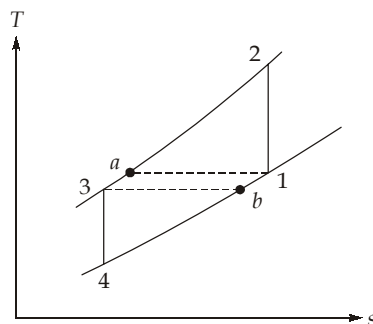
$$DE = \dot{m}(h_2 - h_3)$$

$$\Rightarrow \frac{90 \times 10^3}{3600} = \dot{m}(205 - 81)$$

$$\Rightarrow \dot{m} = 0.2016 \text{ kg/s}$$

$$\text{Actual compression work} = 1.24 \times 0.2016 \times 15 = 3.75 \text{ kW}$$

62. (d)



Regenerative Bell-Coleman cycle

- The heat can be extracted from the air coming out of the conventional cooler till the temperature of air coming out of refrigerator becomes equal to atmospheric temperature. The further cooling below atmospheric temperature using the cool air coming out of the refrigerator is known as Regenerative cooling. This type of the cycle improves the COP of the system and lowers the lowest temperature of the cycle and ultimately refrigerator temperature also.

63. (c)Given, $P_0 = 99.4 \text{ kPa}$; DPT = 11°C

$$\therefore P_v = 1.4 \text{ kPa}$$

$$\omega = \frac{0.622 P_v}{P_0 - P_v} = \frac{0.622 \times 1.4}{98} = \frac{0.622}{70}$$

$$\begin{aligned}\omega &= 8.886 \times 10^{-3} \text{ kg/kg of dry air} \\ &= 8.886 \text{ g/kg of dry air}\end{aligned}$$

64. (d)Given, $t = 25^\circ\text{C}$; $P_{vs} = 0.063 \text{ bar}$

$$P_{vs} = 0.063 \text{ bar}$$

$$\therefore \phi = 0.7$$

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

$$\Rightarrow P_v = 0.063 \times 0.7 = 0.0441 \text{ bar}$$

$$\text{or } P_v = 4.41 \text{ kPa}$$

65. (d)Given, DBT = 30°C ; $P_{vs} = 0.072 \text{ bar}$; DPT = 21°C ; $P_v = 0.048 \text{ bar}$

$$\phi = \frac{P_v}{P_{vs}} \times 100 = \frac{0.048}{0.072} \times 100 = 66.67\%$$

66. (c)

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

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

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

67. (b)Given, $w = 0.012 \text{ kg/kg}$; $P_0 = 1.015 \text{ bar}$; $P_{vs} = 0.035 \text{ bar}$

$$w_s = \frac{0.622 P_{vs}}{P - P_{vs}} = \frac{0.622 \times 0.035}{0.98}$$

$$\Rightarrow w_s = \frac{0.622}{28} = 0.02221 \text{ kg/kg}$$

$$\therefore \mu = \frac{w}{w_s} = \frac{0.012}{0.0222} = 0.54$$

68. (b)

69. (c)

Given, $m_{a1} = 36 \text{ kg}$, $m_{a2} = 12 \text{ kg}$; $w_1 = 8 \text{ g/kg}$, $w_2 = 9 \text{ g/kg}$

$$\therefore m_3 = m_{a1} + m_{a2} = 48 \text{ kg}$$

$$w_3 = \frac{m_{a1}w_1 + m_{a2}w_2}{m_3}$$

$$= \frac{36 \times 8 + 12 \times 9}{47} = 8.255 \text{ g/kg of air} \simeq 8.26 \text{ g/kg}$$

70. (d)

The degree of saturation is a measure of the capacity of air to absorb moisture.

$$\mu = \frac{\text{Specific humidity}}{\text{Specific humidity of saturated air at DBT}}$$

Specific humidity : mass of water vapour present per kg of dry air

Relative humidity : Ratio of actual water vapour in a given volume to the mass of water vapour if the air is saturated at the same temperature.

Absolute humidity : The weight of the water vapour in unit volume of air.

71. (a)

Given, $B = 0.7$

Let number of coils = n

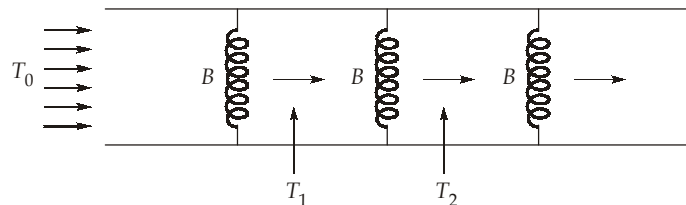
$$\therefore (0.7)^n = 0.2401$$

$$n \ln(0.7) = \ln(0.2401) = \ln(0.7)^4$$

$$\Rightarrow n = 4$$

72. (c)

Given, $B = 0.8$; $T_0 = 25^\circ\text{C}$; $T_s = 15^\circ\text{C}$



$$\therefore B = \frac{T_1 - T_s}{T_0 - T_s} \text{ or } B = \frac{T_2 - T_s}{T_1 - T_s}$$

$$\Rightarrow B^2 = \frac{T_2 - T_s}{T_0 - T_s} \Rightarrow T_2 = T_0 B^2 + T_s (1 - B^2)$$

$$\Rightarrow T_2 = (25 - 15)(0.8)^2 + 15 = 6.4 + 15 = 21.4^\circ\text{C}$$

73. (a)

High condensation temperatures are not at all desirable for heat pumps used for heating the building because the COP is reduced to even 2.7 which is regarded as minimum for electric motor drive. (With COP = 2.7 and power plant efficiency = 33%, the primary energy utilization is about 90%; which is equal to the boiler efficiency burning fossil fuel). Therefore, heat pumps should be installed only for low temperature heating system with 45 to 50°C.

74. (c)

Electrolux Refrigerator : This is known as three fluid absorption system. It uses a refrigerant, a solvent and a inert gas for working of system.

The inert gas is confined to the low pressure side of the system only (to the evaporator and absorber). By its presence, it is possible to maintain the uniform pressure (total pressure) throughout the system and at the same time permitting the refrigerant to evaporate at low temperature corresponding to its partial pressure. In the high pressure side (generator and condenser), there exits only the refrigerant.

The evaporator side is charged with H_2 (inert gas). The cycle operates on the principle of Dalton's law where $P_{\text{NH}_3} + P_{\text{H}_2} = \text{constant}$, so that the total pressure is same throughout the system.

75. (b)

Keeping the condenser temperature same, and reducing the evaporator (suction) temperature increases the brake power per ton. While decrease in evaporator temperature, the work of compression increases and mass flow rate of the refrigerant decreases. Decrease in mass flow outweighs the increase in compression work per kg. Therefore, the net effect is to decrease the total B.P. of the compressor.

○○○○