CLASS TEST

Sl.: 02DLSKME_JKLMNOP_171025

MADE EASY

Leading Institute for IES, GATE & PSUs

Delhi | Bhopal | Hyderabad | Jaipur | Pune | Kolkata

Web: www.madeeasy.in | **E-mail:** info@madeeasy.in | **Ph:** 011-45124612

REFRIGERATION & AIR CONDITIONING

MECHANICAL ENGINEERING

Date of Test : 17/10/2025

ANSWER KEY

1.	(b)	7.	(b)	13.	(b)	19.	(b)	25.	(a)
2.	(b)	8.	(a)	14.	(a)	20.	(d)	26.	(a)
3.	(c)	9.	(c)	15.	(b)	21.	(d)	27.	(b)
4.	(a)	10.	(d)	16.	(a)	22.	(b)	28.	(a)
5.	(b)	11.	(d)	17.	(d)	23.	(d)	29.	(c)
6.	(a)	12.	(b)	18.	(c)	24.	(a)	30.	(a)

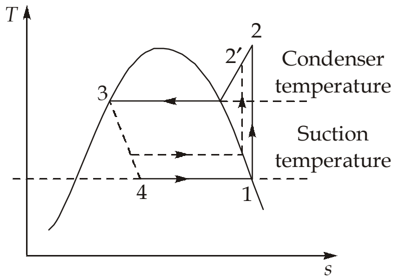
DETAILED EXPLANATIONS

1. **(b)**

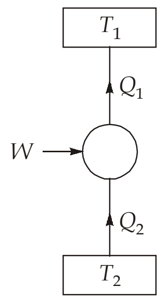
In VARS systems using water-LiBr pair are extensively used in large capacity air conditioning. It is used only in applications requiring refrigeration at temperature above 0°C. Since water is used as refrigerant.

2. **(b)**

As suction temperature increases, refrigeration effect increases and power input decreases so power per ton of refrigeration decreases.



3. **(c)**



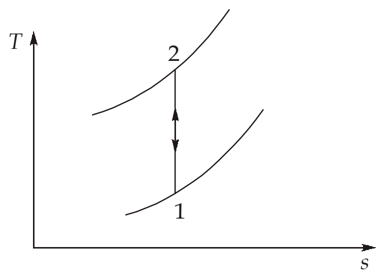
$$COP = \frac{Q_2}{Q_1 - Q_2}$$

$$COP = \frac{1000}{1000 - 750} = 4$$

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

This is for maximum (Carnot) COP.

4. **(a)**



For maximum pressure ratio,

$$W_C = W_T$$

So, net work done

$$W_{net} = W_C - W_T = 0$$

5. **(b)**

$$\frac{HP}{TR} = \frac{\dot{W}}{0.746} \times \frac{3.5}{Q_0} = 4.7\frac{\dot{W}}{Q}$$

$$\frac{HP}{TR} = \frac{4.7}{COP}$$

$$\frac{HP}{TR} = 0.94$$

6. (a)

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

$$P_v = 0.5 \times P_{vs} = 0.5 \times 6.2795 = 3.13975 \text{ kPa}$$

$$\text{Humidity ratio, } \omega = 0.622 \times \frac{P_v}{P_t - P_v} = 0.622 \times \frac{3.13975}{101.325 - 3.13975} = 0.01989 \text{ kg/kgda}$$

$$\text{Enthalpy of moist air, } h = 1.005 \times t + \omega(2500 + 1.88t)$$

$$= 1.005 \times 37 + 0.01989(2500 + 1.88 \times 37)$$

$$= 88.31 \text{ kJ/kg da}$$

7. (b)

$$\text{Mass of dry air, } \dot{m}_a = \frac{10}{0.85} = 11.765 \text{ kg/min}$$

$$\text{Mass balance, } \dot{m}_a(\omega_2 - \omega_1) = \dot{m}_s$$

$$11.765(\omega_2 - 3.5 \times 10^{-3}) = 1.2$$

$$\omega_2 = 0.106 \text{ kg/kgda}$$

8. (a)

$$(\text{COP})_{\max} = \frac{T_E(T_G - T_O)}{T_G(T_O - T_E)} = \frac{268(368 - 303)}{368(303 - 268)} = 1.35$$

9. (c)

At 35°C

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

$$0.6 = \frac{P_v}{0.05733}$$

$$P_v = 0.03439 \text{ bar}$$

$$w = 0.622 \times \frac{P_v}{(P_t - P_v)} = \frac{0.622 \times 0.03435}{(1.013 - 0.03439)}$$

$$w = 0.021858 \text{ kg/kgda}$$

$$w = 21.858 \text{ gm/kgda}$$

after removing 5 grams of water vapour,

$$w' = 21.858 - 5 = 16.858 \text{ gm/kgda}$$

$$w' = 0.622 \times \frac{P_{v'}}{(P_t - P_v)}$$

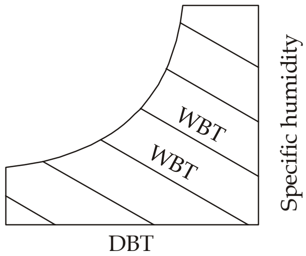
$$16.858 \times 10^{-3} = 0.622 \times \frac{P_{v'}}{(P_t - P_{v'})}$$

$$P_{v'} = 0.02673 \text{ bar}$$

So,

$$\phi = \frac{P_v}{P_{vs}} = \frac{0.02673}{0.03229} = 0.8278 = 82.78\%$$

10. (d)



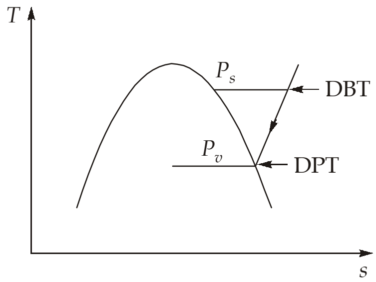
11. (d)

$$P_V = \text{Partial pressure of water vapour at 15°C DPT} = 12.79 \text{ mm of Hg}$$

$$= \frac{12.79 \times 13.6 \times 9.81 \times 1000}{1000 \times 1000}$$

$$P_V = 1.706 \text{ kPa}$$

So, relative humidity



$$\phi = \frac{P_V}{P_S}$$

$$P_S = 2.49 \text{ kPa}$$

$$\phi = \frac{1.706}{2.49} = 0.6851 = 68.51\%$$

12. (b)

$$\text{Refrigeration capacity, } RC = \dot{m}(h_1 - h_4)$$

$$RC = 0.02(1426 - 347.5)$$

$$RC = 21.57 \text{ kW}$$

$$\eta_{relative} = \frac{\text{Actual COP}}{\text{Maximum COP}} = \frac{(\text{COP})_{actual}}{5}$$

$$(\text{COP})_{actual} = 5 \times 0.6$$

$$(\text{COP})_{actual} = 3$$

$$(\text{COP})_{actual} = \frac{(RC)}{W}$$

$$W = \frac{21.57}{3}$$

$$W = 7.19 \simeq 7.2 \text{ kW}$$

13. (b)

$$x_1 = 0.9$$

$$\text{COP}_{act} = \eta_{relative} \times \text{COP}_{max}$$

$$= 0.4 \times \frac{T_E(T_G - T_o)}{T_G(T_o - T_E)} = 0.4 \times \frac{263 \times (393 - 303)}{393 \times (303 - 263)}$$

$$\text{COP}_{act} = 0.6032$$

$$W_{act} = \frac{\dot{Q}_E}{\dot{Q}_g}$$

$$\Rightarrow \qquad \dot{Q}_g = \frac{20 \times 3.5}{0.6032} = 116.047 \text{ kW}$$

$$Q_{1\text{-}2} = h_1 - h_2 = 0.9 \times h_{fg} = 0.9 \times 2201.9 = 1981.71 \text{ kJ/kg}$$

$$\dot{Q}_g = \dot{m} \times Q_{1-2}$$

$$\Rightarrow \qquad \dot{m} = \frac{\dot{Q}_g}{Q_{1-2}} = 0.058 \text{ kg/s}$$

14. (a)

$$m_{a_1} \times \omega_1 + m_{a_2} \times \omega_2 = m_{a_3} \times \omega_3$$

$$m_{a_3} = m_{a_1} + m_{a_2}$$

$$= 36 + 14 = 50 \text{ kg/kgda}$$

$$36 \times 0.0084 + 14 \times 0.01 = 50 \times \omega_3$$

$$\omega_3 = 8.848 \times 10^{-3} \text{ kg/kgda}$$

$$m_{a_1} \times t_1 + m_{a_2} \times t_2 = m_{a_3} \times t_3$$

$$36 \times 15 + 14 \times 25 = 50 \times t_3$$

$$t_3 = 17.8°\text{C}$$

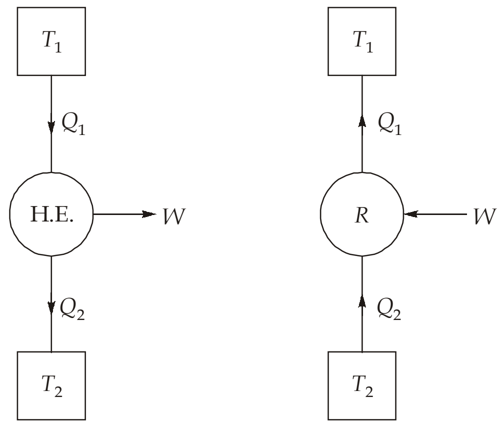
So, enthalpy

$$h_3 = 1.005 \times t_3 + w_3(2500 + 1.88 t_3)$$

$$h_3 = 40.305 \text{ kJ/kg}$$

15. (b)

$$(\text{COP})_{\text{HP}} = (\text{COP})_{\text{Ref}} + 1 = 5 + 1 = 6$$



$$(\text{COP})_{\text{HP}} = \frac{Q_1}{W} = \frac{Q_1}{Q_1 - Q_2} = \frac{T_1}{T_1 - T_2}$$

$$\eta_{\text{HE}} = \frac{W}{Q_1} = \frac{T_1 - T_2}{T_1}$$

So, $$\eta_{\text{HE}} = \frac{1}{(\text{COP})_{HP}} = \frac{1}{6} = 0.1666 = 16.67\%$$

16. (a)

$$\text{Heat added} = m_a(h_2 - h_1)$$

So, $$h_1 = 1.005 \times t_1 + w_1(2500 + 1.88 t_1) \quad \text{...(1)}$$

$$\phi_1 = \frac{P_{v1}}{P_{vs}}$$

$$0.8 = \frac{P_{v1}}{0.017}$$

$$P_{v1} = 0.0136 \text{ bar}$$

$$w_1 = 0.622 \frac{P_{v1}}{P_t - P_{v1}} = \frac{0.622 \times 0.0136}{(1.013 - 0.0136)} = 8.4642 \times 10^{-3} \text{ kg/kgda}$$

So, equation, (1)

$$h_1 = 1.005 \times 15 + 8.4642 \times 10^{-3}(2500 + 1.88 \times 15)$$

$$h_1 = 36.474 \text{ kJ/kgda}$$

For sensible heating specific humidity is same So, P_v is same.

So, $$\omega_1 = \omega_2$$

at 22°C $$h_2 = 1.005 \times 22 + 8.4642 \times 10^{-3}(2500 + 1.88 \times 22)$$

$$h_2 = 43.6205 \text{ kJ/kgda}$$

$$P_1 V_1 = maRT_1$$

$$m_a = \frac{(1.013 - 0.0136) \times 100 \times 100}{0.287 \times 288}$$

$$m_a = 120.91 \text{ kg/min}$$

So, $$\text{Heat added} = 120.91 \times (43.6205 - 36.474)$$

$$= 864.083 \text{ kJ/min}$$

17. (d)

$$(\Delta h)_{net} = 20.01 \text{ kJ/kg}$$

For degree of superheating

$$(\Delta h)_{net} = (c_p)_v (\Delta T)_{superheat}$$

$$(\Delta T)_{superheat} = \frac{20.01}{1.9}$$

$$(\Delta T)_{superheat} = 10.5 \text{ K}$$

18. (c)

$$\text{Maximum COP} = COP_{max} = \frac{T_e}{T_g}\frac{(T_g - T_c)}{(T_c - T_e)}$$

T_e = Evaporator temperature = –4 + 273 = 269 K
T_g = Generator temperature = 120 + 273 = 393 K
T_c = Condensation temperature = 30 + 273 = 303 K

$$COP_{max} = \frac{269\,(393 - 303)}{393\,(303 - 269)} = 1.812$$

$$COP_{actual} = 0.8 \times COP_{max}$$

$$= 0.8 \times 1.812 = 1.45$$

$$\text{COP}_{\text{actual}} = \frac{Q_e}{Q_g} = \frac{\text{Heat absorbed in evaporator}}{\text{Heat absorbed in generator}}$$

$$1.45 = \frac{20 \times 3.5}{Q_g}$$

$$Q_g = 48.27 \text{ kW}$$

From energy balance,

Where, Q_C = Heat rejected in condenser

Q_A = Heat rejected in absorber

$$Q_g + Q_e = Q_C + Q_A$$

$$48.27 + 20 \times 3.5 = 35 + Q_A$$

$$Q_A = 83.27 \text{ kW}$$

19. (b)

$$T = 297\text{K}$$

$$P_{vs} = 20 \text{ kPa}$$

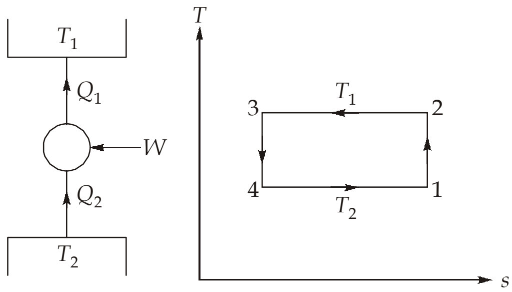
$$\phi = \frac{P_v}{P_{vs}}$$

$$P_v = \phi P_{vs} = 8 \text{ kPa}$$

$$P_a = P - P_v = 100 - 8 = 92 \text{ kPa}$$

$$v = \frac{R_a T}{P_a} = \frac{0.287 \times 297}{92} = 0.93 \text{ m}^3/\text{kg of dry air}$$

20. (d)



$$\text{COP} = \frac{Q_2}{W} = \frac{3.5}{1.3} = 2.69$$

for Carnot cycle, $\text{COP} = \dfrac{T_2}{T_1 - T_2}$ [Given: $T_2 = -40 + 273 = 233$ K]

$$2.69 = \frac{233}{T_1 - 233}$$

$$T_1 = 319.617 \text{ K}$$

and heat rejected, $Q_1 = Q_2 + W$

$= 3.5 + 1.3 = 4.8 \text{ kW} = 288 \text{ kJ/min}$

21. (d)

We know that,

$$\dot{Q}_s = \dot{m}_a c_p \Delta T$$

$$15 = \dot{m}_a \times 1.0216 \times (27 - 7)$$

$$\dot{m}_a = 0.7341 \text{ kg dry air per second}$$

$$\dot{m}_a = 0.7341 \times 3600 = 2642.913 \text{ kgda/h}$$

Ratio of moist air to dry air in supply air = $(1 + \omega_s)$

$$\omega_s = \text{Specific humidity at supply}$$

$$\omega_s = 0.622 \frac{P_V}{P_t - P_V} \qquad [\because P_V = 1 \text{ kPa and } P_t = 1.0132 \text{ bar}]$$

$$= 0.622 \times \frac{1}{(101.32 - 1)}$$

$$= 6.2 \times 10^{-3} \text{ kg/kgda}$$

Ratio of moist air to dry air in supply air = $(1 + \omega_s) = (1 + 6.2 \times 10^{-3}) = 1.0062$

Mass of moist air supplied to space

$$\dot{m} = (1 + \omega_s)m_a = 1.0062 \times 2642.913$$

$$= 2659.299 \text{ kg/h}$$

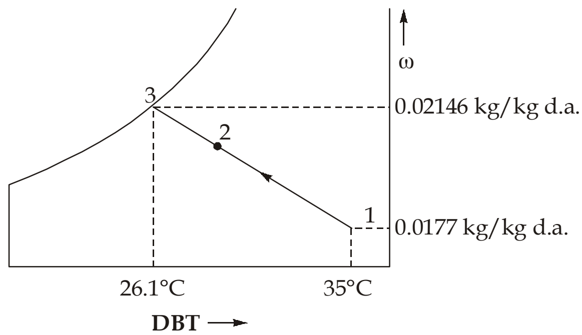
22. (b)

So, humidifying efficiency,

$$\eta = \frac{t_{d1} - t_{d2}}{t_{d1} - t_{d3}} = \frac{\omega_2 - \omega_1}{\omega_3 - \omega_1}$$

So,
$$0.85 = \frac{\omega_2 - 0.0177}{0.02146 - 0.0177}$$

$$\omega_2 = 0.02089 \text{ kg/kg d.a.}$$



We know that,
$$\omega_2 = 0.622 \frac{p_v}{p_t - p_v}$$

$$0.02089 = 0.622 \frac{p_v}{p_t - p_v}$$

$$\frac{p_t - p_v}{p_v} = \frac{0.622}{0.02089}$$

$$\frac{p_t}{p_v} = 1 + \frac{0.622}{0.02089}$$

$$p_v = \frac{1.0132}{30.775} = 0.0329 \text{ bar}$$

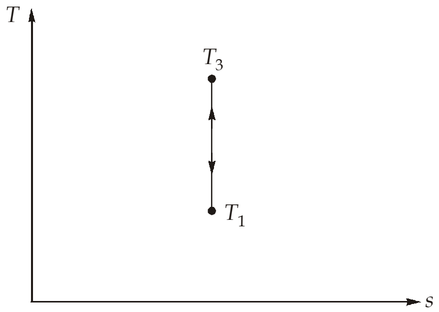
So, Relative humidity
$$= \frac{p_v}{p_{vs}} = \frac{0.0329}{0.03658} = 0.9$$

$$= 90\%$$

23. (d)

As refrigerant is compressed upto ambient temperature T_3, and it is the minimum temperature to which the gas can be cooled. That means, without any change in temperature or without any condenser process, it expanded to the temperature T_1, so refrigeration effect and net work done both are zero.

$$\text{COP} = \frac{\text{Refrigeration effect}}{\text{Net work done}} = \frac{0}{0} = \text{Indeterminate form}$$



24. (a)

$V_1 = 30 \text{ m}^3$, $\quad v_1 = 0.827 \text{ m}^3/\text{kg}$

$$m_{a1} = \frac{30}{0.827} = 36.275 \text{ kg of dry air}$$

$V_2 = 12 \text{ m}^3$, $\quad v_2 = 0.96 \text{ m}^3/\text{kg}$

$$m_{a2} = \frac{12}{0.96} = 12.5 \text{ kg of dry air}$$

Mass of the mixture $m_{a3} = m_{a1} + m_{a2} = 48.775$ kg of dry air

So, DBT of mixture is

$$\text{DBT}_3 = \frac{m_{a1} \times DBT_1 + m_{a2}DBT_2}{m_{a1} + m_{a2}} = \frac{36.275 \times 15 + 12.5 \times 25}{48.775}$$

$$= 17.562°\text{C}$$

25. (a)

As per given information,

Heat engine, $\Rightarrow \quad Q_1 = W + Q,$

Heat pump, $\Rightarrow \quad Q_2 = W + 2Q$

$$(\eta_E) = (\eta_E)_{max} \times 40\%$$

$$(\text{COP})_{HP} = 0.5 \times [(\text{COP})_{HP}]_{max}$$

$$(\eta_{E\ max}) = \left(1 - \frac{T_2}{T_1}\right)$$

$$\eta_E = \left(1 - \frac{300}{1000}\right) \times 0.4 = 0.28 \qquad \text{... (i)}$$

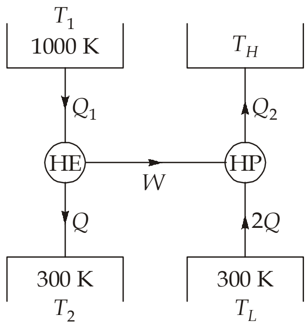
$$(\eta_E) = \frac{W}{Q_1}$$

$$\Rightarrow \qquad 0.28 = \frac{W}{Q_1} \qquad \text{... (ii)}$$

From (ii)

$$\Rightarrow \qquad W = 0.28Q_1 = 0.28\,(W + Q)$$

$$W = \frac{0.28Q}{1-0.28} = 0.388Q$$



$$[(\text{COP})_{\text{HP}}]_{\max} = \frac{T_H}{T_H - T_L}$$

$$(\text{COP})_{\text{HP}} = 0.5 \times \left(\frac{T_H}{T_H - 300}\right)$$

$$\frac{Q_2}{W} = 0.5 \times \frac{T_H}{T_H - 300}$$

$$\frac{W + 2Q}{W} = \frac{0.5T_H}{T_H - 300}$$

$$\Rightarrow \qquad \frac{0.388Q + 2Q}{0.388Q} = \frac{0.5T_H}{T_H - 300}$$

$$\Rightarrow \qquad T_H = 326.5 \text{ K}$$

26. (a)

$$\text{COP} = \frac{\text{Refrigeration effect (RE)}}{\text{Work input }(W_C)}$$

$$\text{Work input} = \frac{70}{60} = 1.166 \text{ kW}$$

$$\text{RE} = \text{One ton of refrigeration} = 3.5 \text{ kW}$$

$$\text{COP} = \frac{3.5}{1.166} = 3$$

Note: Here it is not a Carnot refrigeration. So, COP in terms of absolute temperature cannot be taken.

27. (b)

Relative humidity, $\phi = \dfrac{P_v}{P_{vs}}$

P_{vs} at 21°C $= 2.489$ kPa

So, $P_v = \phi \times P_{v_s} = 0.75 \times 2.489 = 1.866$ kPa

Total pressure, $P_t = \dfrac{736}{1000} \times 9.81 \times 13.6 \times 10^3 \times 10^{-3}$

$P_t = 98.194$ kPa

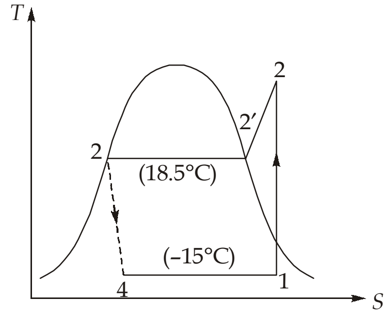
Specific humidity, $\omega = 0.622\dfrac{P_v}{P_t - P_v} = 0.622 \times \dfrac{1.866}{98.194 - 1.866}$

$\omega = 0.0120$ kg/kgd.a.

Humid specific heat, $c_p = c_{pa} + \omega c_{pv}$

$= 1.005 + 1.88 \times 0.120 = 1.0276$ kJ/kgd.a.K

28. **(a)**



$$s_1 = s_2$$

$$(s_f)_{-15°C} + x_1(s_{fg})_{-15°C} = (s_g)_{18.5°C} + c_{pg}\ln\frac{T_2}{T_2'}$$

$$-0.1505 + x_1\,[0.9154 - (-0.1505)] = 0.7231 + 2.35\ln\frac{(32+273)}{(18.5+273)}$$

$$x_1 = 0.92$$

So,

$$h_1 = (h_f)_{-15°C} + x_1(h_{fg})_{-15°C}$$

$$= -37.60 + 0.92[234.50 - (-37.60)]$$

$$h_1 = 212.732 \text{ kJ/kg}$$

$$\text{Work done/kg} = W = h_2 - h_1$$

$$= 245.78 - 212.732$$

$$W = 33.048 \text{ kJ/kg}$$

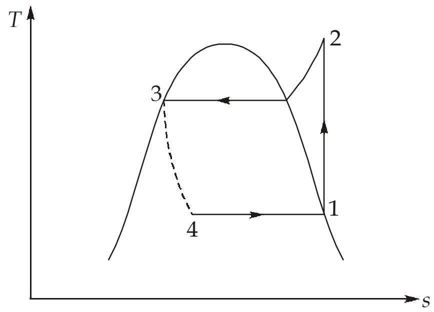
29. **(c)**

Mass flow rate for 1 tons of refrigeration,

$$\text{Refrigeration effect, (RE)} = \dot{m}(h_1 - h_4)$$

$$3.5 = \dot{m}(354.885 - 239.03) \qquad (\because h_4 = h_3)$$

$$\dot{m} = 0.0302 \text{ kg/sec per TR}$$



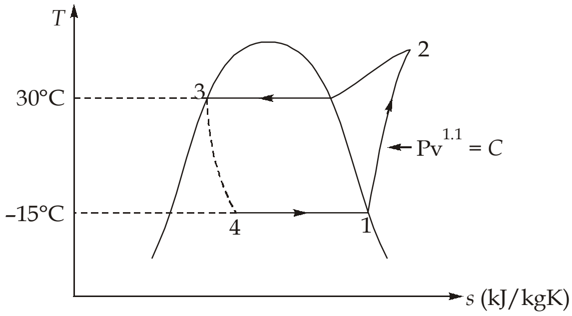
So, theoretical piston displacement,

$$V_s = \dot{m} \times v_1$$

$$= 0.0302 \times 0.04799 = 1.449 \times 10^{-3} \text{ m}^3/\text{s}$$

$$= 0.0869 \text{ m}^3/\text{min} = 5.217 \text{ m}^3/\text{hr}$$

30. (a)



Refrigeration capacity, RC = $\dot{m}(h_1 - h_4)$

$$10 \times 3.5 = \dot{m}(1444.19 - 342.08)$$

$$\dot{m} = 0.03175 \text{ kg/s}$$

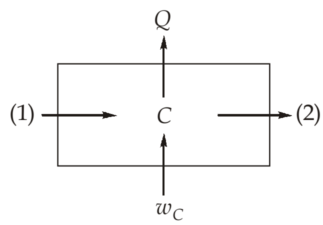
Work done per kg for compressor,

$$w_c = \frac{n}{(n-1)} \times p_1 \times v_1 \times \left[\left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}} - 1\right]$$

$$= \frac{1.1}{(1.1-1)} \times 2.3637 \times 10^2 \times 0.50905 \times \left[\left(\frac{11.671}{2.3637}\right)^{\frac{1.1-1}{1.1}} - 1\right]$$

$$= 206.7899 \text{ kJ/kg}$$

Apply SFEE to compressor,



So, $\dot{m}_1 h_1 - Q = \dot{m}_2 h_2 - w_c$

$$-Q = (\dot{m}h_2 - \dot{m}h_1) - 206.7899 \times \dot{m}$$

$$Q = 2.888 \text{ kW}$$

■■■■