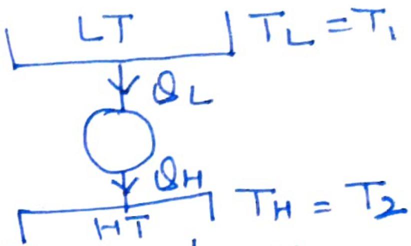
Q 24: A refrigeration system produces 40 Kg/hr of ice at 0°C from water at 25°C. Find the refrigeration effect per hour and TR. If it consumes 1KW of energy to produce the ice, find the COP. Take latent heat of solidification of water at 0°C as 335 KJ/Kg and specific heat of water is 4.19 KJ/Kg °C.

Solution:



Given

$m = 40\ Kg/hr.$

$T_1 = 0°C$

$T_2 = 25°C$

Refrigerating Effect $(Q_L) = ?$ per hour

$TR = ?$

$Work = 1KW = 1KJ/sec = 3600 KJ/hour$

$COP = ?$

$l = 335\ KJ/Kg$

$Cp = 4.19\ KJ/Kg °C$

Calculations

$Q_L = m C_p \Delta t + m l$

$= 40[4.19(25-0) + 335]$

$\boxed{= 17590\ KJ/hour}$ Ans (Desired effect)

$1\ TR = 210\ KJ/min$

$= 210 \times 60\ KJ/hour$

$= 12600\ KJ/hour.$

$1TR = 12600\ KJ/hour.$

$1KJ/hour = \frac{1}{12600}\ TR$

$17590\ KJ/hour =$

$\frac{17590}{12600}\ TR$

$= \frac{17590}{12600}$

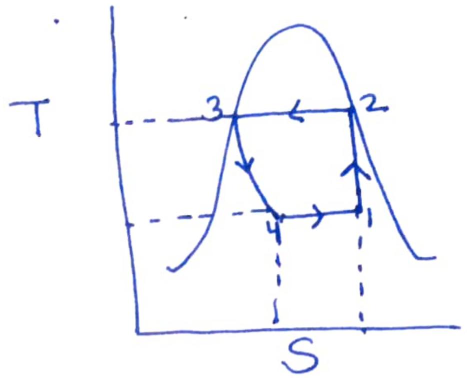
$\boxed{= 1.39\ TR}$ Ans

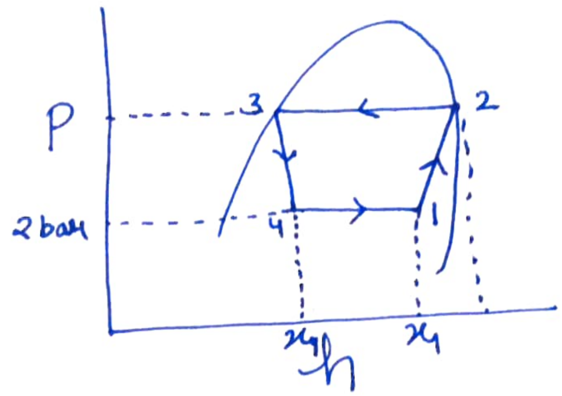
$COP = \frac{\text{Desired Effect}}{\text{work input}} = \frac{17590}{3600}$

$\boxed{COP = 4.886}$ Ans

Q 26: In an ammonia vapour compression system, the pressure in the evaporator is 2 bar. Ammonia at exit is 0.85 dry and at entry its dryness fraction is 0.19. During compression, the work done per Kg of ammonia is 150 KJ. Calculate the COP and volume of vapour entering the compressor per minutes, if the rate of ammonia circulation is 4.5 Kg/min. The latent heat and specific volume at 2 bar are 1325 KJ/Kg and 0.58 m3/Kg respectively.

Solution:





4 — 1 → Evaporator

$x_1 = 0.85$ (at exit)

$x_4 = 0.19$ (at entry)

{ x is dryness fraction

1 — 2 → Compression

$W = 150\ KJ/Kg$

$COP = ?$

Volume of vapour $(V_v) = ?$

$m_R = 4.5\ Kg/min$

$l = 1325\ KJ/kg$

$V_S = 0.58\ m^3/Kg$

$$(COP)_{VCRS} = \frac{\text{Desired Effect}}{\text{Work input}} = \frac{h_1 - h_4}{W}$$

$h_1 = x_1 \cdot l = 0.85 \times 1325 = 1126.25\ KJ/Kg$

$h_4 = x_4 l = 0.19 \times 1325 = 251.75\ KJ/Kg$

$$\boxed{(COP)_{VCRS} = \frac{1126.25 - 251.75}{150} = 5.83}$$ Ans

$$\boxed{V_v = m_R \times V_S = 4.5 \times 0.58 = 2.61\ m^3/min}$$ Ans

Q 27: In a 5kW cooling capacity refrigeration system operating on V.C. cycle, refrigerants enter evaporator with an enthalpy of 75 KJ/kg, leaves with an enthalpy of 183 KJ/kg. Enthalpy of refrigeration after compression is 210 KJ/kg. Calculate:

h_1

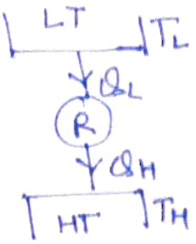
(i) COP

(ii) Power input to compressor in kW

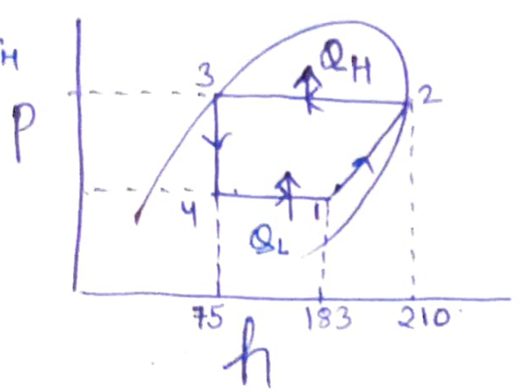
(iii) Rate of heat transfer in condenser in KW.

entering the evaporator $h_1 = 183$ KJ/Kg.
after Compression $h_2 = 210$ KJ/Kg
leaving the evapo. $h_4 = 75$ KJ/Kg.

Solution:



$Q_L = 5$ KW (Refregeration effect) or heat extracted



(i) $\text{COP} = \dfrac{\text{Desired Effect}}{\text{Work Input}}$

$= \dfrac{h_1 - h_4}{h_2 - h_1}$

{∵ workdone performed due to compres so $h_2 - h_1$ }

$= \dfrac{183 - 75}{210 - 183}$

$\boxed{\text{COP}_{VCRS} = 4}$ Ans

(ii) Power input (work input)

$(\text{COP})_{VCRS} = \dfrac{\text{Refrigeration effect}}{\text{WI}}$

$4 = \dfrac{5}{\text{WI}}$

$\boxed{\text{WI} = \dfrac{5}{4} = 1.25 \text{ KW}}$ Ans

(iii) Rate of heat transfer in Condenser

$(Q_H) = \dot{m}(h_2 - h_3)$ — ①

Refregeration Effect $\quad Q_L = \dot{m}(h_1 - h_4)$ $\quad$ {∵ $h_3 = h_4$ }

$5 = \dot{m}(h_1 - h_4)$

$5 = \dot{m}(183 - 75)$

$\dot{m} = \dfrac{5}{183 - 75} = 0.046$ Kg/sec.

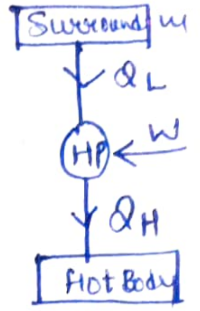
Put the value of $\dot{m}$ in equation ①

$$Q_H = 0.046\,(210-75)$$

$$\boxed{Q_H = 6.21\ KJ/sec \quad \underline{\underline{Ans}}}$$

$\underline{\underline{Ans}}$

Q 27: A heat pump has a COP of 1.7. Determine the heat transferred to and from this heat pump when 50 kJ of work is supplied.



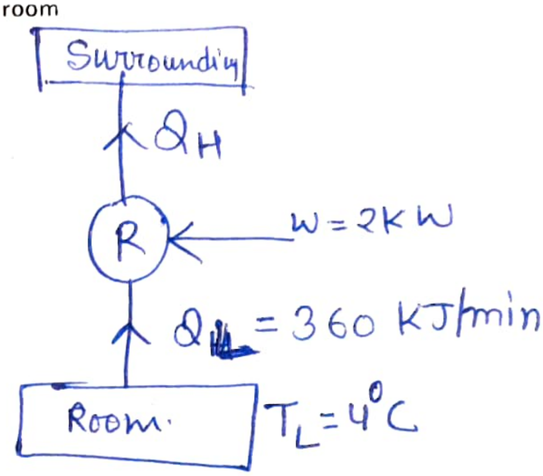
Solution:

$$(COP)_{HP} = 1.7$$
$$W = 50\,KJ$$
$$(COP)_{HP} = \frac{Q_H}{WI}$$
$$1.7 = \frac{Q_H}{50}$$
$$\boxed{Q_H = 85\,KJ}$$

$$W = Q_H - Q_L$$
$$50 = 85 - Q_L$$
$$Q_L = 85 - 50$$
$$\boxed{= 35\,KJ}$$

Q 28: The food compartment of a refrigerator is maintained at 4°C by removing heat from it at a rate of 360 kJ/min. If the required power input to the refrigerator is 2 kW, determine (a) the COP of the refrigerator and (b) the rate of heat rejection to the room

Solution:



Given data

$$T_L = 4^\circ C$$
$$Q_L = 360\,KJ/min$$
$$W = 2KW = 2\,KJ/sec$$
$$= 2 \times 60$$
$$= 120\,KJ/min$$

(a) $$COP = \frac{\text{Desired Effect}}{\text{work input}}$$

$$\boxed{COP = \frac{360}{120} = 3}$$ Ans

(b) Rate of heat rejection $(Q_H) = ?$

$$W = Q_H - Q_L$$
$$120 = Q_H - 360$$
$$Q_H = 120 + 360$$
$$\boxed{Q_H = 480\,KJ/min}$$ Ans

Q 29: The capacity of a refrigeration system is specified to be 12 tons. What is the cooling rate of the machine?

Solution:

Refrigeration capacity = 12 tons

Cooling rate = 12×3.5 KJ/sec

$\boxed{= 42 \text{ KJ/sec}}$ Ans

Q 30: 250 litres of drinking water is required per hour at 10°C. Would the use of 1.5 ton refrigerating system be justified if the available water is at 30°C?

Solution:

$m = 250$ lt , $C_p = 4.18$ KJ/kgK

$T_L = 10^\circ C + 273 = 283K$, $T_H = 30^\circ C + 273 = 333K$

$Q = m C_p \Delta T$

$= 250 \times 4.18 (333 - 283)$

$\boxed{Q = 20900 \text{ KJ/hr}}$ Ans

1 ton of Refrigeration = 3.5 KJ/sec

= 12600 KJ/hr

$\therefore$ Tonnage required = $\frac{209\cancel{00}}{126\cancel{00}}$

= 1.6

So that, the use of 1.5 ton machine will not serve the purpose.

Q 31: A refrigerating machine takes 1.25kW and produces 25kg/hr of ice at 0°C from water available at 30°C. Determine refrigerating effect, tonnage and coefficient of performance of machine. Take

Specific heat of water = 4.18 KJ/Kg K

Enthalpy of solidification of water from and at 0°C = 335 KJ/kg

Solution:

$W = 1.25\ KW = 1.25\ KJ/sec = 1.25 \times 3600$
$= 4500\ KJ/hr$

$\dot{m} = 25\ kg/hr$

$T_L = 0°C + 273 = 273\ K$

$T_H = 30°C + 273 = 303\ K$

→ Refrigerating Effect $(Q_L) = \dot{m} c_p \Delta t + m l$

$= 25 \times 4.18\ (303 - 273)$
$+ 25 \times 335$

$\boxed{= 11510\ KJ/hr}$ Ans

→ tonnage requires -:

1 ton of refrigeration $= 3.5\ KJ/sec$
$= 3.5 \times 3600\ KJ/hr$
$= 12600\ KJ/hr$

tonnage requires $= \dfrac{11510}{12600}$

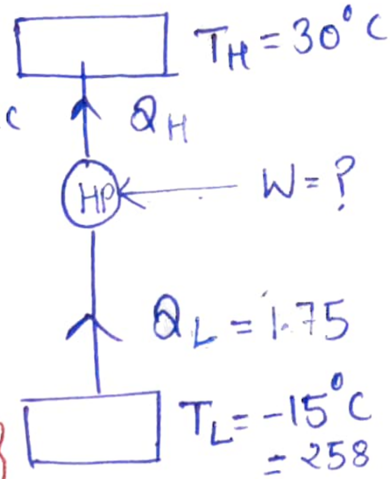
$\boxed{= 0.913}$ Ans

→ $COP = \dfrac{\text{Refrigerating Effect}}{\text{Work Input}} = \dfrac{11510}{4500}$

$\boxed{= 2.558}$ Ans

Q 32: A domestic food freezer maintains a temperature of -15 °C. The ambient air temperature is 30º C. If heat leaks into the freezer at the continuous rate of 1.75 kJ/s what is the least power necessary to pump this heat out continuously.

Solution:



heat leaks $(Q_L) = 1.75$ KJ/sec

minimum Power re

$$\frac{Q_H}{T_H} = \frac{Q_L}{T_L}$$ {as per the carnot cycle}

$$Q_H = \frac{1.75}{258} \times 303$$

$$Q_H = 2.05 \text{ KJ/sec}$$

$$W = Q_H - Q_L$$

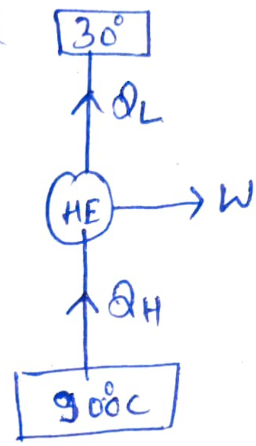
$$= 2.05 - 1.75$$

$$\boxed{= 0.305 \text{ KJ}}$$ Ans

Q 33: A cyclic heat engine operates between a source temperature of 900º C and sink temperature of 30º C. What is the least rate of heat rejection per KW not output of the engine?

$T_H = 900^\circ C + 273 = 1173K$

$T_L = 30^\circ C + 273 = 303K$



$$\eta = \frac{W}{Q_H} = \frac{T_H - T_L}{T_H}$$

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

$\because W = 1 \, KW$

$$\frac{1}{Q_H} = 1 - \frac{303}{1173}$$

$Q_H = 1.34 \, KW$

$W = Q_H - Q_L$

$1 = 1.34 - Q_L$

$Q_L = 1.34 - 1$

$\boxed{= 0.34 \, KW}$ Ans