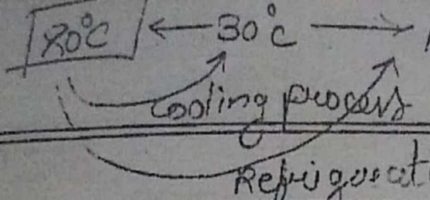
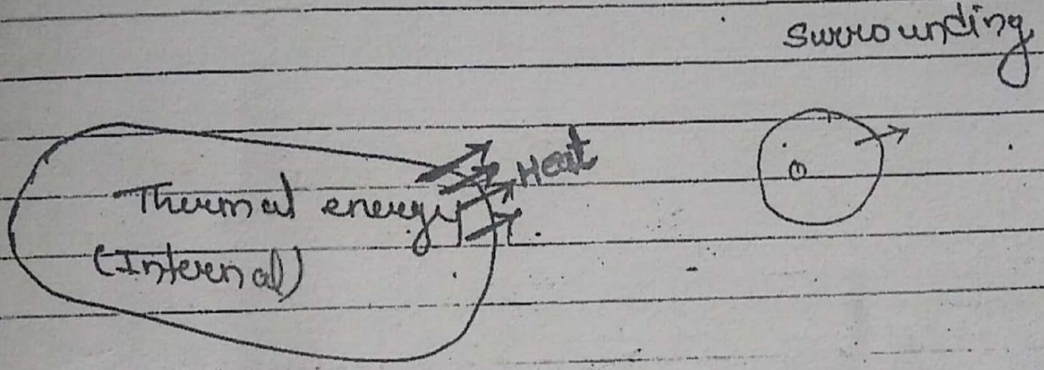


*** Heat :-** Heat is a energy which is following because of energy difference it always flow from body or region of high temp to body or region of low temp.

Heat is the energy transient (motion). It is the energy which is crossing the boundary of the system



*** Sensible heat :-** The amount of heat that changes only temp. of system but not phase is called as sensible heat.

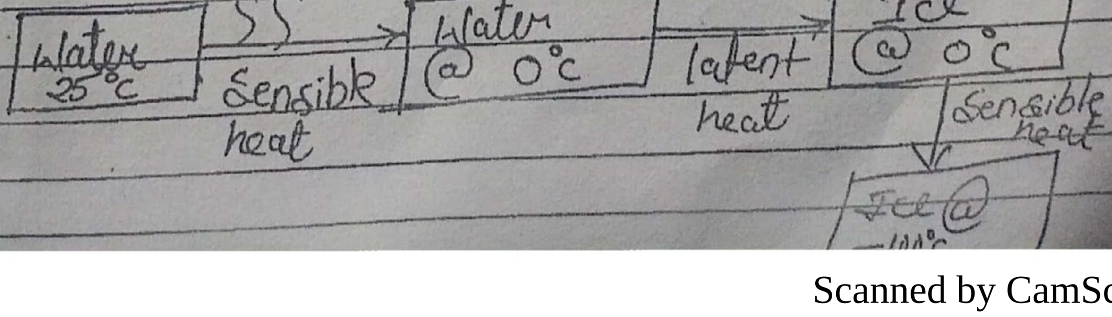
Temp changes phase remain constant

Temp = changes
phase = constant

*** Latent heat :-** The quality of heat changes the phase of substance at constant temp is called as latent heat.

Temp cont and phase changes

Temp = constant
phase = changes



critical point = 221.2 bar
374 °C
(bta nhi skip prnj h kya iki vapour

Total heat = Sensible heat + Latent heat
(enthalpy)

IMP for GATE
1 Que.

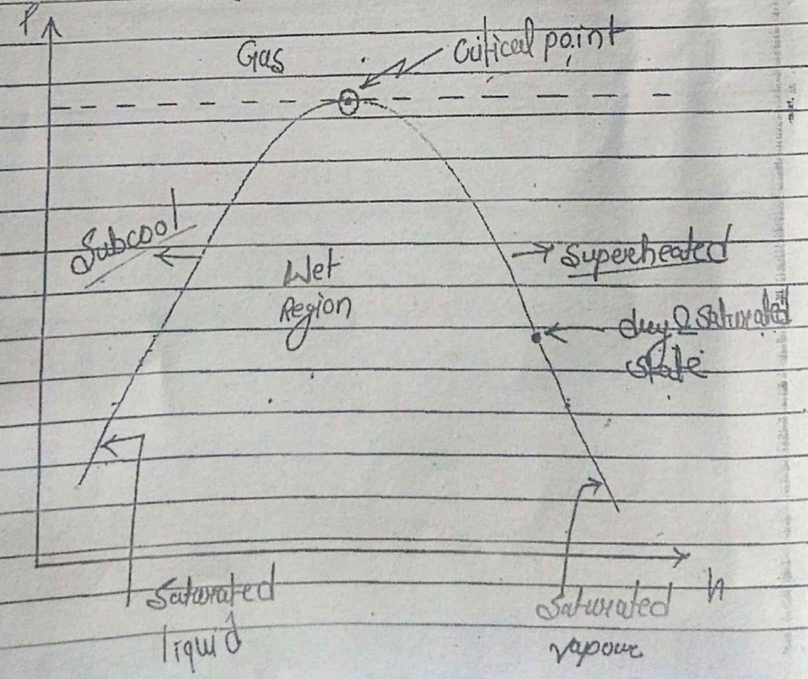
Property diagram

Boiling pt se temp jisko kam h use Sub cool khte hai.

Gas are do not change phase easily
But vapour changes phase easily

Liquid nitrogen are mainly used in fertilizer., operation of eyes :

Gas are placed in above the critical pt
vapour are placed in below the critical pt



Page No.
Date. / /

Subcooled liquid :- liquid whose temp is less than its boiling point.

Saturated liquid :- The liquid which is at its boiling point.

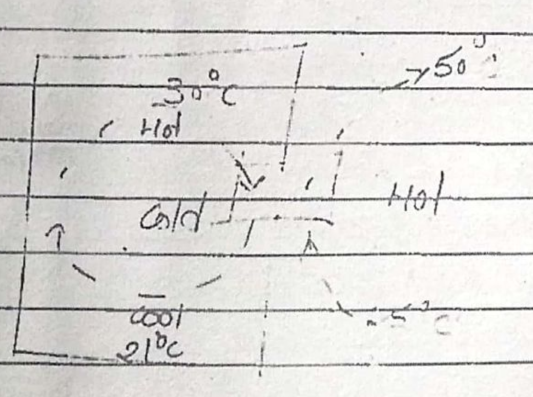
Wet vapour :- vapour containing suspended liquid particle.

Dry & Saturated vapour :- Vapour which is at boiling point.

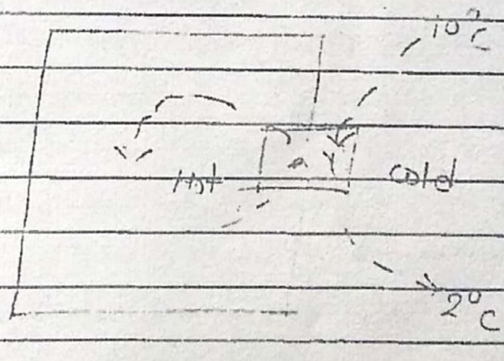
Superheated vapour :- Vapour whose temp is greater than its saturation temp (boiling point).

Saturation temp :- Temp at which phase changes.

Saturation pressure :- pressure at which phase changes.



refrigeration



Heat pump

Page No..
Date: / /

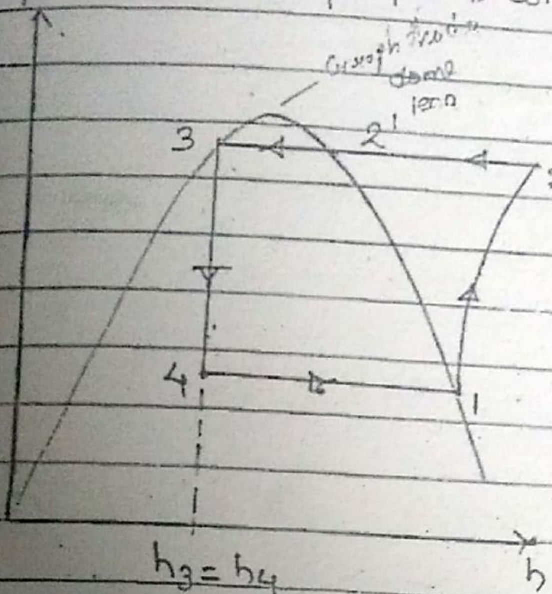
Process 3-4 :- During this process high temp, high pressure liquid is converted into low temp low pressure liquid. Throttling of liquid occurs during this process.

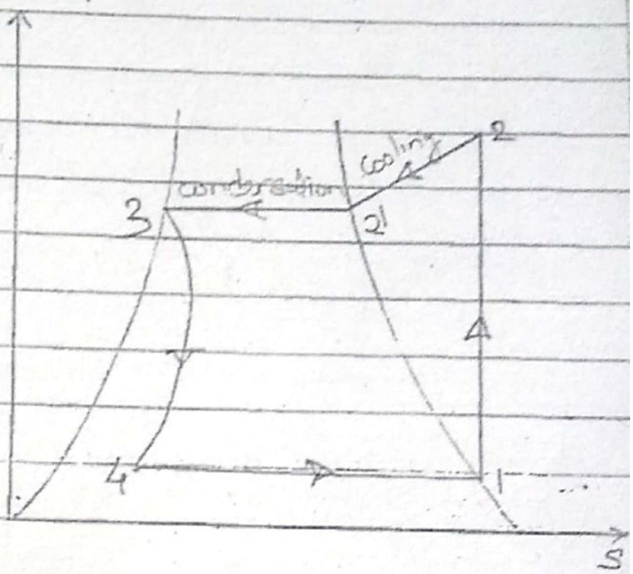
Process 4-1 :- This process is called as evaporation. During this process low temp low pressure liquid absorbs heat and the space gets cooled. That space is called as evaporator.

2 - 2' → cooling
2' - 3 → condensation or phase change process } in T v/s S graph

Case - I : Refrigerant is dry & saturated before the compression

pt (2) are lies in supersaturation region due to condensation temp will drop upto its condensation point.





At point (1)

$h_1 = h_{g_1} \ (x=1)$
$= h_{f_1} + h_{fg_1}$

$s_1 = s_{g_1}$
$= s_{f_1} + s_{fg_1}$

At point (2)

$h_2 = h_{g_{2'}} + C_{pg}(T_2 - T_{2'})$

$s_2 = s_{g_{2'}} + C_{pg} \ln\left(\frac{T_2}{T_{2'}}\right)$

At point (3)

$h_3 = h_{f_3}$

$\because h_3 = h_{f_3} + \cancel{x h_{fg_3}}$ 0

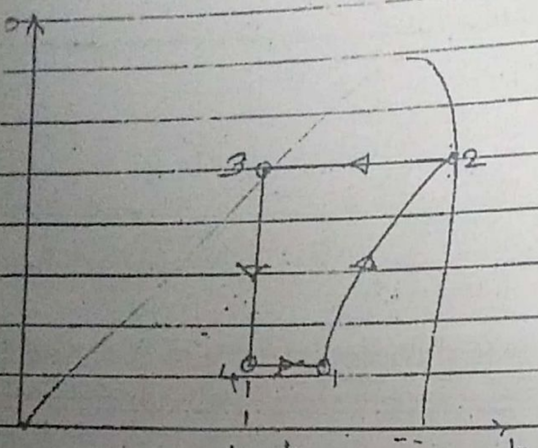
At point (4)

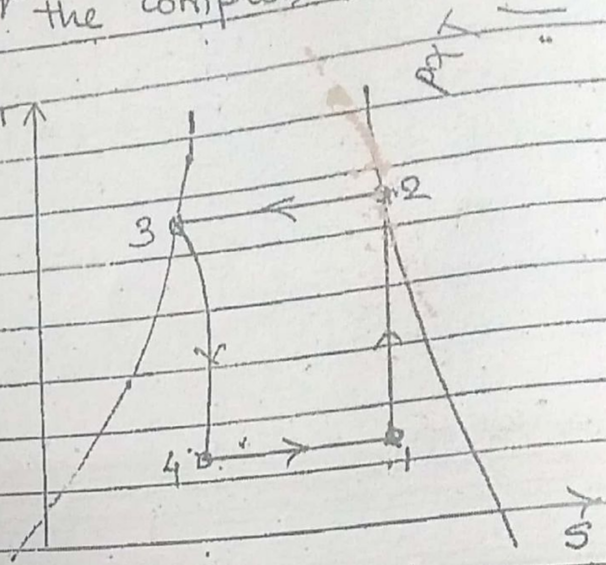
$h_4 = h_3$

$$\boxed{COP = \frac{R_E}{W} = \frac{h_1 - h_4}{h_2 - h_1}}$$

$h_f + h_{fg} \quad h_g$

Case II :- Refrigerant is wet before compression and dry & saturation after the compression





At point ①

$h_1 = h_{f_1} + x_1 h_{fg_1}$

$= h_{f_1} + x_1 (h_{g_1} - h_{f_1})$

$= s_{f_1} + x_1 s_{fg_1}$

At point ②

$h_2 = h_{g_2}$

$= h_{f_2} + h_{fg_2}$

$s_2 = s_{g_2}$

$= s_{f_2} + s_{fg_2}$

At point ③

$h_3 = h_{f_3}$

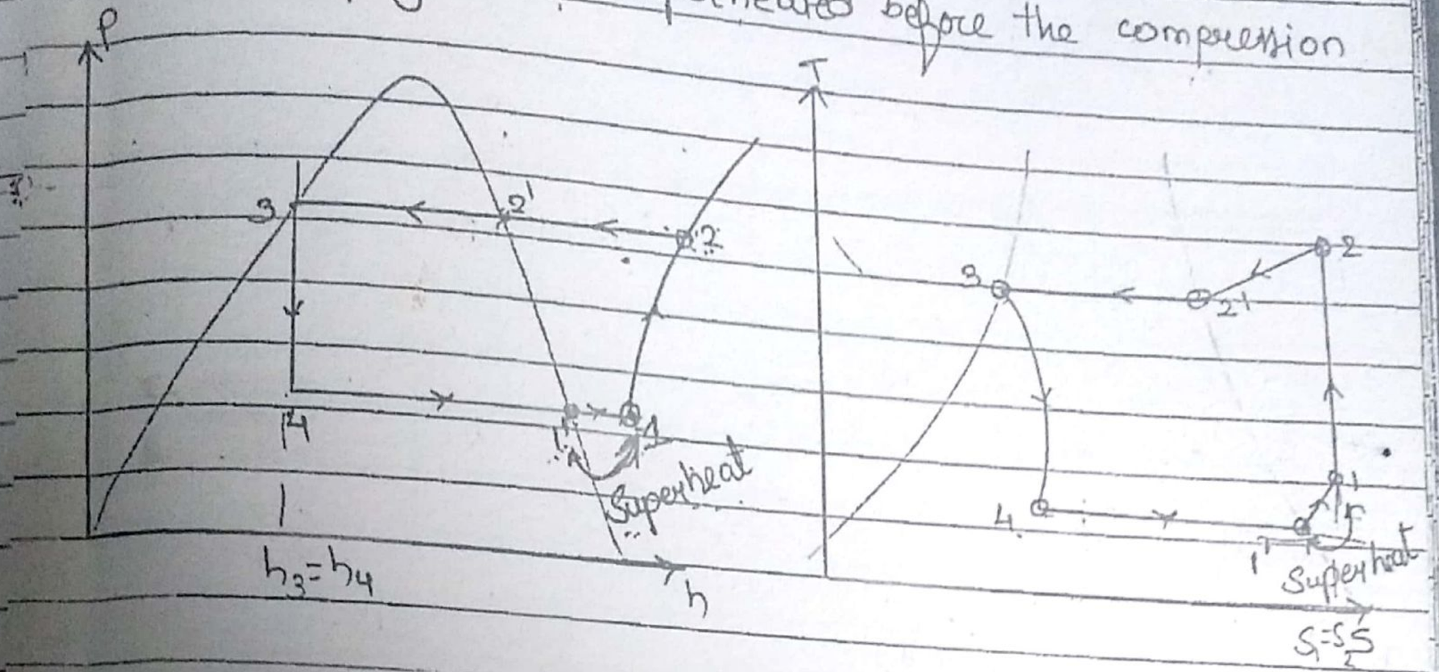
At point ④

$h_3 = h_4$

$$\boxed{COP = \frac{R_E}{W} = \frac{h_1 - h_4}{h_2 - h_1}}$$

Page No:
Date: 05/7/14

Case III :- Refrigerant is superheated before the compression



At point (1)

$h_1 = h_{g_1'} + C_{pg}(T_1 - T_1')$

$S_1 = S_{g_1'} + C_{pg}\ln\left(\frac{T_1}{T_1'}\right)$

At point (2)

$h_2 = h_{g_2'} + C_{pg}(T_2 - T_2')$

$S_2 = h_{g_2'} + C_{pg}\ln\left(\frac{T_2}{T_2'}\right)$

At point (3)

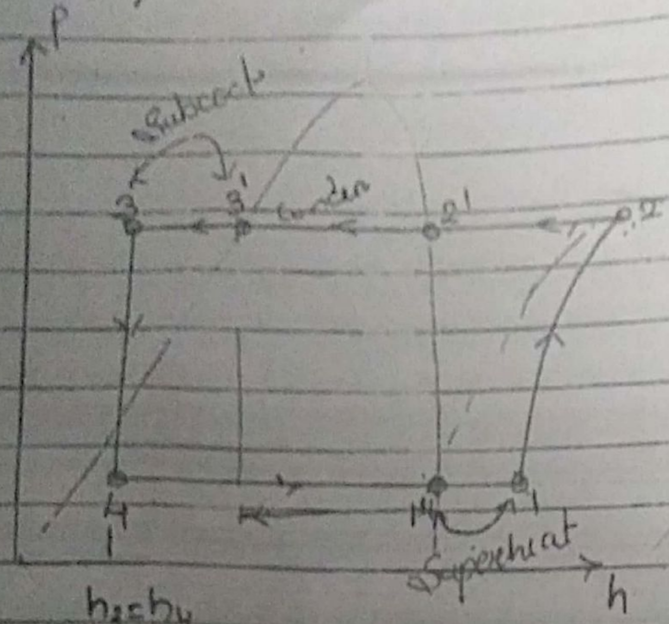
$h_3 = h_{f_3}$

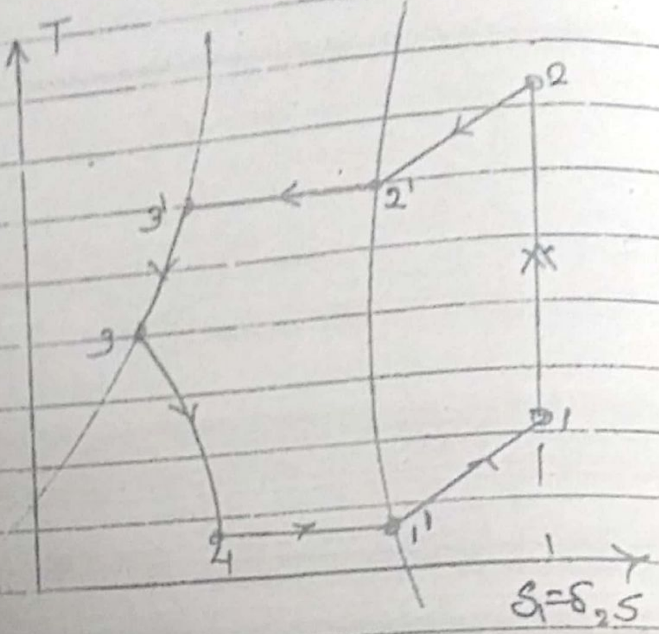
At point (4)

$h_3 = h_4$

$$\boxed{COP = \frac{RE}{W} = \frac{h_1 - h_4}{h_2 - h_1}}$$

Case IV: Refrigerant is superheated before compression & subcooled before expansion





$h_3 = h_4$

At point (1)

$h_1 = h_{g_1'} + C_{pg}(T_1 - T_{1'})$

$s_1 = s_{g_1'} + C_{pg} \ln\left(\frac{T_1}{T_1'}\right)$

At point (2)

$h_2 = h_{g_2'} + C_{pg}(T_2 - T_{2'})$

$S_2 = S_{g_2'} + C_{pg} \ln\left(\frac{T_2}{T_2'}\right)$

At point (3)

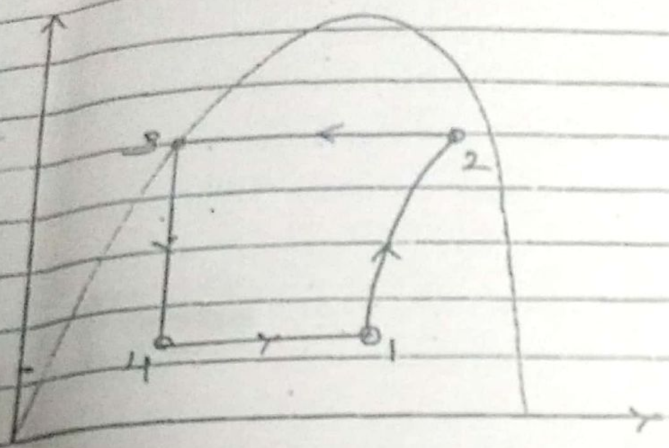
$h_3 = h_{f_3'} - C_{PL}(T_3' - T_3)$

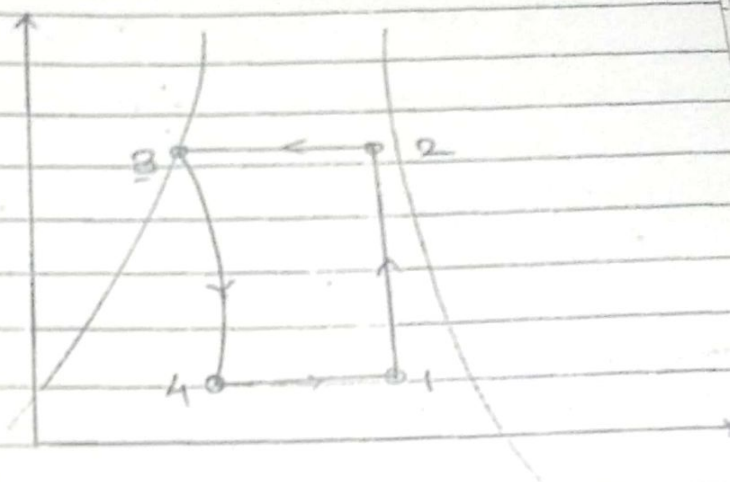
At point (4)

$h_3 = h_4$

$$\boxed{COP = \frac{R_E}{W} = \frac{h_1 - h_4}{h_2 - h_1}}$$

Case V : Refrigerant is wet before and after compression





At point 1

$h_1 = h_{f_1} + x_1 h_{fg_1}$

$s_1 = s_{f_1} + x s_{fg_1}$

At point 2

$h_2 = h_{f_2} + x_2 h_{fg_2}$

$s_2 = s_{f_2} + x_2 s_{fg_2}$

At point 3

$h_3 = h_{f_3}$.

At point 4

$h_3 = h_4$

$$\boxed{COP = \frac{R_E}{W} = \frac{h_1 - h_4}{h_2 - h_1}}$$

* Unit of Refrigeration :-

Def^n :-

It is capacity to freezed one tonne of water (1000 kg) from 0°C within one day (24 hr)

Latent heat of ice is $334 \frac{KJ}{kg}$

∴ Amount of heat removed $= \frac{1000 \times 334}{24 \times 60 \times 60}, \frac{KJ}{sec}$

∴ 1TR (One tonne Refrigerant) $= 3.5 \frac{KJ}{sec}$ (Kwatt)

These is the rating of refrigerator

Que 1)
Page no 11

Data :-

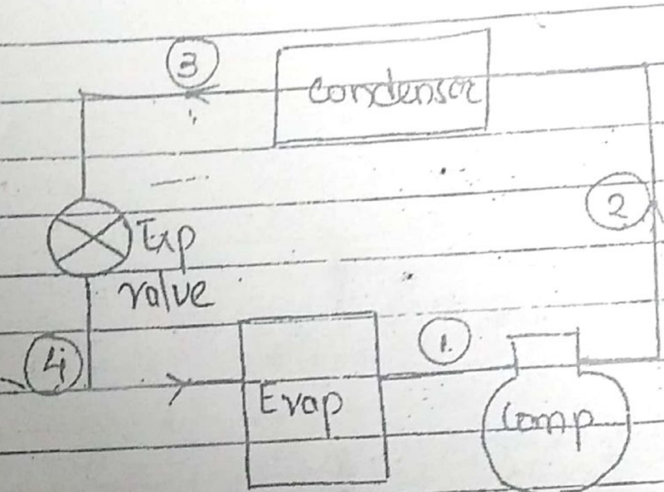
process
1-2 → comp
2-3 → Condensor
3-4 → Exp valve
4-1 → Evaporator

$R_E = 20TR$
$T_E = -28^\circ c$
$T_c = 26^\circ c$

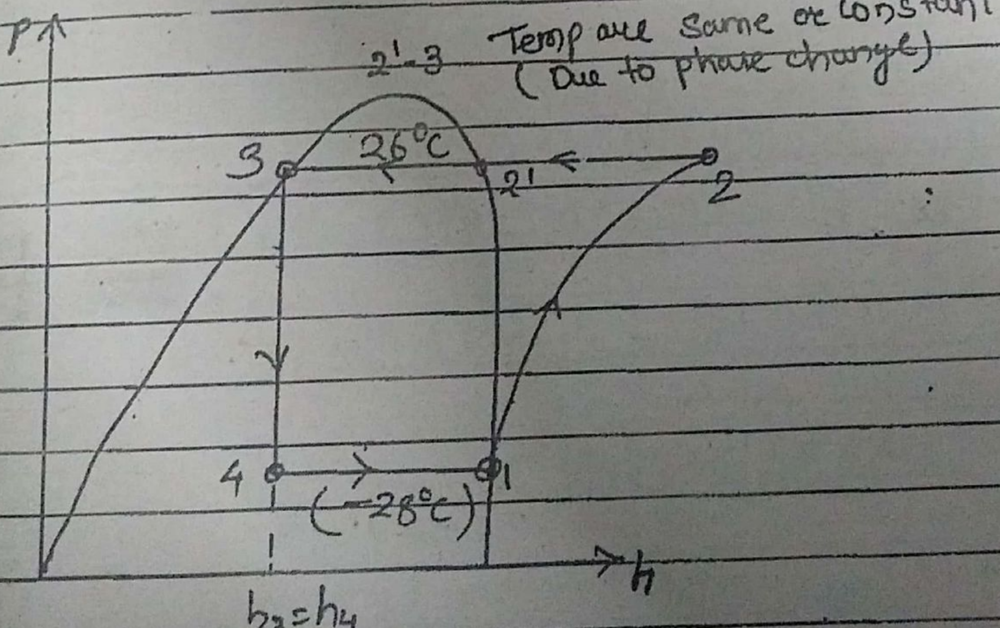
$K = 6$
$i = 1$
$L = 1.25 D$
$V_c = 3\% \ V_s$

$\therefore \frac{V_c}{V_s} = 3\%$

$\therefore \boxed{c = \frac{V_c}{V_s} = 0.03}$



The Refrigerant is dry & saturated before compression



$C_{P_g} = 0.7035 \ KJ/KgK$

Temp °C	Sp. vol^m (m^3/Kg)	Enthalpy (KJ/Kg)		Entropy (KJ/Kg-K)	
		Liquid h_f	vapour h_g	liquid s_f	vapour s_g
-28 1.4 245K	0.15	10.64	175.11	0.04	0.72
2,3 26 299K	0.09	60.67	198.11	0.23	0.69

At point 1 (vapour is dry)

$$\boxed{h_1 = h_{g_1} = 175.11 \text{ KJ/Kg}}$$

$$\boxed{S_1 = S_{g_1} = 0.72 \text{ KJ/Kg-K}}$$

At point 2 (Super heated)

As $S_2 = S_1$ as compression is isentropic

$$S_2 = S_{g_{2'}} + C_{pg} \ln\left(\frac{T_2}{T_{2'}}\right)$$

$$0.72 = 0.69 + 0.7035 \times \ln\left(\frac{T_2}{299}\right)$$

Ans i) $\boxed{T_2 = 312.02 K} = 39.02\,^\circ C$

Temp at the end of compression is $T_2 = 312.02 K$

$$h_2 = h_{g_{2'}} + C_{pg}(T_2 - T_{2'})$$

$$= 198.11 + 0.7035(312.02 - 299)$$

$$\boxed{h_2 = 207.26 \text{ KJ/Kg}}$$

At point 3 (Liquid condition)

$$\boxed{h_3 = h_{f_3} = 60.67 \text{ KJ/Kg}}$$

At point 4

$$\boxed{h_4 = h_3 = 60.67 \text{ KJ/Kg}}$$

Page No.:
Date: / /

$$COP = \frac{O/P}{I/P} = \frac{h_1 - h_4}{h_2 - h_1} = 3.55 \quad \text{Ans(ii)}$$

iii) Refrigerant circulate rate i.e $\dot{m}_R$

$$\dot{m}_R = \frac{3.5 \times TR}{(h_1 - h_4)} = \frac{3.5 \times 20}{(175.11 - 60.67)}$$

$$\boxed{\dot{m}_R = 0.61167 \text{ kg/sec}}$$

mass of refrigerant circulated

iv) Heat rejected by refrigerant in condenser

$$q_c = \dot{m}_R (h_2 - h_3) = \dot{m}_R (h_2 - h_3)$$
$$= 0.6116 (207.26 - 60.67)$$

$$\boxed{q_c = 89.66 \text{ KWatt}} \quad \text{— (Ans iv)}$$

v) power input required to derive the refrigerator

$$W_{IN} = \dot{m}_R (h_2 - h_1) = 0.6116 \times (207.26 - 175.11)$$

$$\boxed{W_{IN} = 19.66 \text{ KW}}$$

vi) Vapour condition entering in the evaporator i.e (x_4)

$$h_4 = hf_4 + x_4 \, hfg_4 = hf_4 + x_4 (hg_4 - hf_4)$$

$$60.67 = 10.64 + x_4 (175.11 - 10.64)$$

$$\boxed{x_4 = 0.3041}$$

30% vapour evaporate m ja rha aur 70% liquid hi aaghe apna kam karega

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

vii) volumetric eff

$$\eta_v = 1 + 0.03 - 0.03\left(\frac{P_d}{P_s}\right)^{\frac{1}{n}}$$

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

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

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

$$\therefore \eta_v = 1 + c + c\left(\frac{V_1}{V_2}\right)$$

V_2 is not given Then we use chale's law

i.e $$\frac{V_2}{T_2} = \frac{V_{21}}{T_{21}}$$

$$\frac{V_2}{312.02} = \frac{0.03}{299}$$

$$\boxed{V_2 = 0.0313\ m^3/kg}$$

$$\eta_v = 1 + 0.03 - 0.03\left(\frac{0.15}{0.0313}\right) = 0.886$$

$$\therefore \boxed{\eta_v = 88.62\ \%}$$

Date: 12/09/14

viii) To find dimensions of compressor

$L = 1.25D$

$N = 1000$ rpm

$\rho = \frac{m}{v}$ ∴ $v = \frac{m}{\rho}$

∵ ρ = kg/m³

$\frac{1}{\rho}$ = m³/kg — Specific vol^m

$v = \frac{m \times v_s}{\eta_v \times K}$

∵ K - No. of cylinder

Swept vol^m is given by

$$V_s = \frac{m_R \times V_1}{\eta_v \times K} = \frac{0.61167 \times 0.15}{0.8862 \times 6}$$

$$\boxed{V_s = 0.0172 \ \frac{m^3}{sec}}$$

$$V_s = \frac{\pi}{4} D^2 L \frac{N}{60} i$$

$$0.0172 = \frac{\pi}{4} D^2 (1.25D) \times \frac{1000}{60} \times 1$$

$\boxed{D = 0.1016 \text{ m}}$ & $\boxed{L = 0.127 \text{ m}}$

ix) Quantity of water required in the condenssor

∴ Heat rejected by the refrigerant in the condensor

=

Heat absorb by the water in condenssor

$$\therefore \boxed{Q_c = Q_w = 89.66\ KW}$$

$$Q_w = m_w \times C_{pw} \times (T_{wo} - T_{wi})$$

∴ C_p of water $= 4.18\ KJ/Kg\,K$

∴ C_p of air $= 1.00\ KJ/Kg\,K$

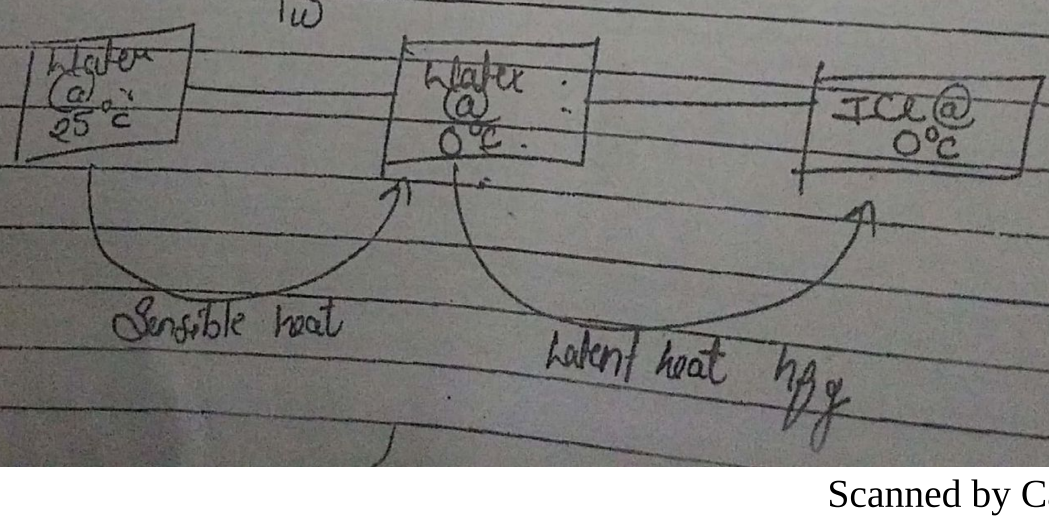
$$89.66 = m_w \times 4.18 \times (27 - 20)$$

$$\boxed{m_w = 3.064\ Kg/sec}$$

x) power input per TR

$$\text{power I/p per TR} = \frac{W}{TR} = \frac{19.66}{20} = 0.983\ KW/TR$$

xi)



Heat removed from water $= \overset{1\,Kg}{\cancel{m_w}}\, C_{pw}(T_w - T_f) + h_{fg}$

$= \underline{438}$

Heat removed from 1 Kg of water to form 1 Kg of Ice $= C_{pw}(T_w - T_f) + h_{fg}$

$= 4.18\,(25 - 0) + 333.5$

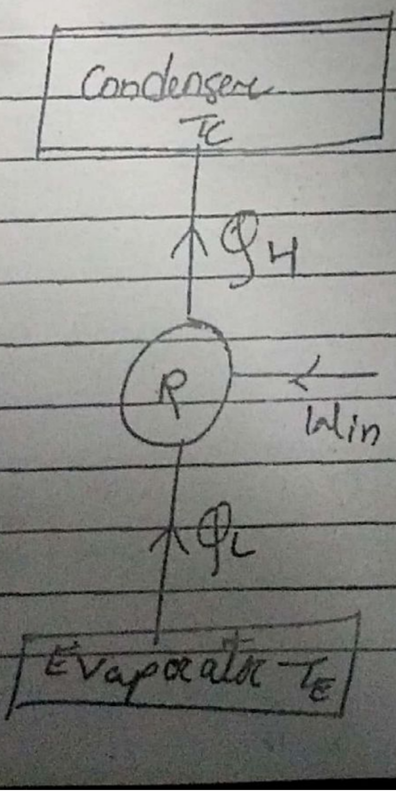
$= \cancel{438\ \frac{KJ}{Kg}}$

$= \underline{438\ KW}$

Amount of ice formed per KW-hr $= \dfrac{3600 \times COP}{\text{Heat removed from 1 kg of water to form 1 kg of Ice}}$

$= \dfrac{3600 \times 3.55}{438}$

$= \underline{29.178}\ Kg/KW\text{-}hr$



$COP = \dfrac{O/P}{I/P} = \dfrac{Q_L}{W_{in}}$

$$\boxed{(COP)_R = \dfrac{T_E}{T_C - T_E}}$$

Carnot cop of refrigerator
or
Ideal cop

$$(COP)_R = \frac{T_E\ (K)}{T_C - T_E} = \frac{245}{299 - 245}$$

$$= 4.537$$

Carnot cop is greater than actual cop

Q.3
page no. 12

Refrigerant = R-12

$R_E = 14\ KW$ $\left[\begin{array}{l} 1\ TR = 3.5\ KW \\ ? = 14\ KW \end{array}\right]$

$$\boxed{R_E = 4\ TR}$$

$T_E = -5°c = 268\ K$

$T_c = 40°c = 313\ K$

Subcooling $= 5°c$

Superheating $= 6°c$

$N = 1000$ rpm

$K = 2$ — no. of cylinder

$L = 1.5\ D$

$V_c = 2\%\ V_s$

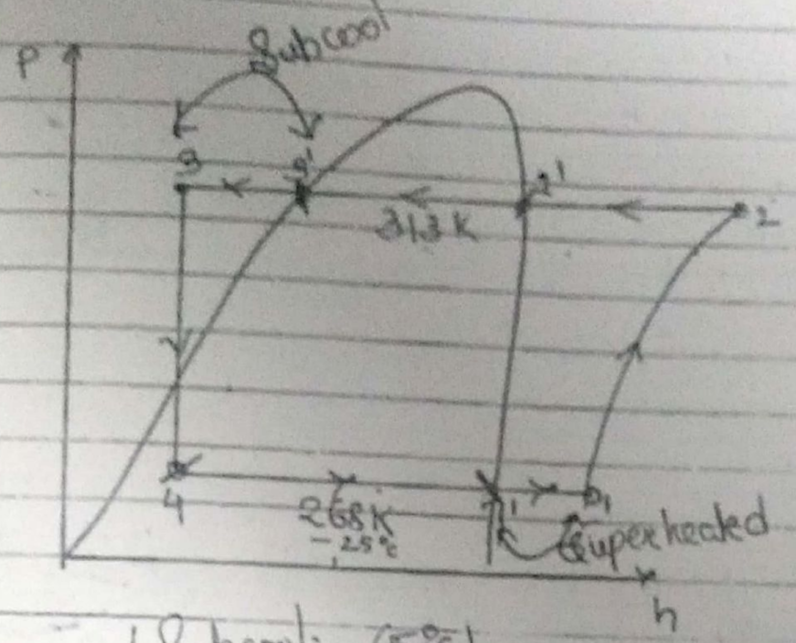
$$\therefore C = \frac{V_c}{V_s} = 2\% = 0.02$$

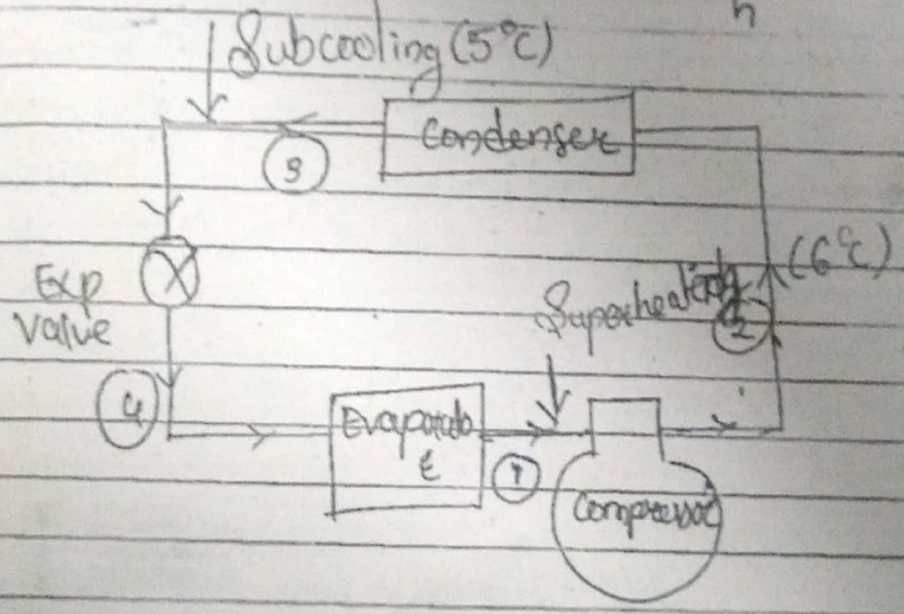
$$\boxed{C = 0.02}$$

Scanned by CamScanner

Subcool karne se jaada output ...

Ans(i) Refrigetaing effect is 4TR





Temp	Pressure	Enthalpy		Entropy		Sp. vol^{m}
		hf	hg	sf	sg	vg
40°c	9.6065 bar	238.535	367.146	1.12954	1.54051	0.018170
2', 3'						
-5°c	2.6096	185.395	349.321	0.98311	1.55710	0.06496
1', 4						

At point 1 (Superheated condition)

$T_1 = T_1' + 6°C = 1°C = 274\ K$

$h_1 = h_{g_1'} + C_{p_g}(T_1 - T_1')$

$h_1 = 349.321 + 0.7035 \times (274 - 268)$

$$\boxed{h_1 = 353.542\ KJ/Kg}$$

$S_1 = S_{g_1'} + C_{p_g} \ln\left(\frac{T_1}{T_1'}\right)$

$S_1 = 1.55710 + 0.7035 \times \ln\left(\frac{274}{268}\right)$

$$\boxed{S_1 = 1.573\ KJ/Kg\text{-}K}$$

At point (2) (Superheated condition)

Assuming the process of compression is isentropic hence $\boxed{S_1 = S_2}$

$h_2 = h_{g_{2'}} + C_{p_g}(T_2 - T_{2'})$

$S_2 = S_1 = S_{g_{2'}} + C_{p_g} \ln\left(\frac{T_2}{T_{2'}}\right)$

$1.573 = 1.54051 + 0.7035 \times \ln\left(\frac{T_2}{313}\right)$

$\boxed{T_2 = 327.79\ K}$ $\therefore T_2 = 54.794\ °C$

$h_2 = 367.146 + 0.7035 \times (327.79 - 313)$

$$\boxed{h_2 = 377.551\ KJ/Kg}$$

Scanned by CamScanner

Page No.:
Date: / /

At point ③ (Subcooling)

$$h_3 = h_{f3'} - Cp_L(T_{3'} - T_3)$$

$T_{3'} = 313\ K$

$T_3 = 308\ K$

~~= 367 KJ~~

$$= 238.535 - 0.963(313 - 308)$$

$$\boxed{h_3 = 233.720\ KJ/Kg}$$

At point ④

$$\boxed{h_3 = h_4 = 233.720\ KJ/Kg}$$

iii) $COP = \dfrac{R_E}{W} = \dfrac{h_1 - h_4}{h_2 - h_1} = \dfrac{353.542 - 233.720}{377.551 - 353.542}$

$$\boxed{COP = 4.991}$$

ii) $\dot{m}_R = \dfrac{3.5 \times TR}{h_1 - h_4} = \dfrac{3.5 \times 4}{353.542 - 233.720}$

$$\boxed{\dot{m}_R = 0.117\ Kg/sec}$$

$\dot{m}_R = 0.117 \times 60$

$$\boxed{\dot{m}_R = 7.010\ Kg/min}$$

Scanned by CamScanner

iv) Compressor volumetric efficiency

$$\eta_v = 1 + c - c\left(\frac{v_1}{v_2}\right)$$

$\because v_1' = 0.0649629 \ m^3/kg$

$v_2' = 0.0181706 \ m^3/kg$

$$\frac{v_1'}{T_1'} = \frac{v_1}{T_1}$$ — Charle's law for process 1 - 1'

$$\frac{0.0649629}{268} = \frac{v_1}{274} \Rightarrow \boxed{v_1 = 0.06641 \ m^3/kg}$$

$$\frac{v_2'}{T_2'} = \frac{v_2}{T_2}$$ — Charle's law process 2 - 2'

$$\frac{0.0181706}{313} = \frac{v_2}{327.79} \Rightarrow \boxed{v_2 = 0.0190 \ m^3/kg}$$

$$\eta_v = 1 + 0.02 - 0.02 \times \left(\frac{0.06641}{0.0190}\right)$$

$$\boxed{\eta_v = 0.950\%} = 95\%$$

Page No.
Date. / /

v) Bore & stroke length

$$V_S = \frac{\dot{m}_R \times V_1}{\eta_V \times K} = \frac{0.117 \times 0.06641}{0.95 \times 2}$$

$$\boxed{V_S = 0.00405\ m^3/sec}$$

$$V_S = \frac{\pi}{4} D^2 L \frac{N}{60} i$$

~~Assuming Single acting i.e. $i = 1$~~

$$0.00405 = \frac{\pi D^2 (1.5D) \times 1000}{4 \times 60}$$

$\boxed{D = 0.0590\ m}$ $\boxed{L = 0.089\ m}$

Q.6

page no. 12

Refrigerant R-12

$R_E = 20\ TR$

Sub cool $= 4^\circ C$

Super heated $= 5^\circ C$

$\frac{kJ}{sec} \times \frac{m^3}{sec}$

$T_E = -28^\circ C$

$T_C = 26^\circ C$

$K = 6$

$i = 1$

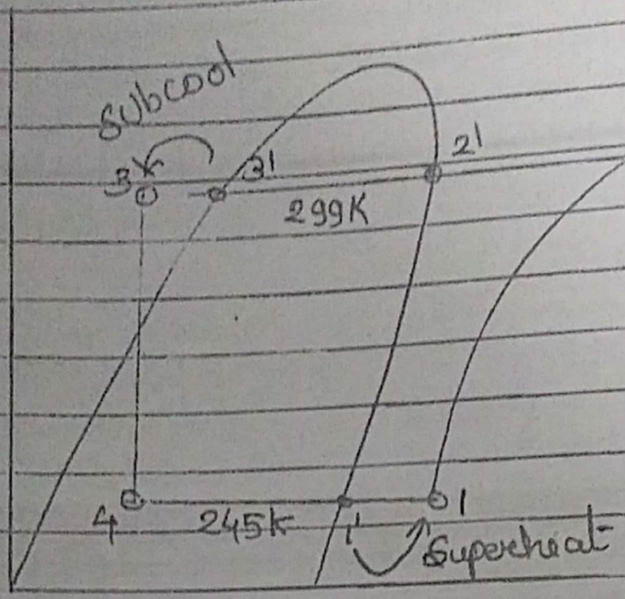
$L = 1.25D$

$V_C = 0.03\ V_S$

$C = \frac{V_C}{V_S} = 0.03$

$N = 1000$ rpm

Scanned by CamScanner



Temp	Enthalpy		Entropy		Sp vol$^{(g)}$
	h_f	h_g	S_f	S_g	v_g
26°C (299K) 2', 3'	224.623	362.059	1.08514	1.54453	0.0261422
-28°C (245K) 1', 4	174.593	339.057	0.90244	1.57326	0.147275

At point (1) (Superheated condition)

$$T_1 = T_1' + 5 = -28+5 = -23 = 250K$$

$$h_1 = hg_{1'} + C_{pg}(T_1 - T_1') = 339.057 + 0.65(250-245)$$

$$\boxed{h_1 = 342.307 \text{ KJ/Kg}}$$

At point (2)

Assume $S_2 = S_1$ as compression is isentropic

$s_1 = s_2 = s_{g_1'} + c_{pg} \ln\left(\frac{T_1}{T_{1'}}\right) = 1.57326 + 0.65 \ln\left(\frac{250}{245}\right)$

$$\boxed{s_1 = s_2 = 1.5863 \ \frac{KJ}{Kg\text{-}K}}$$

$s_2 = s_{g_{2'}} + c_{pg} \ln\left(\frac{T_2}{T_{2'}}\right) = 1.54453 + 0.65 \ln\left(\frac{T_2}{299}\right)$

$= 1.5863$

$$\boxed{T_2 = 318.845 \ K}$$

$h_2 = h_{g_{2'}} + c_{pg} (T_2 - T_{2'}) = 362.059 + 0.65 (318.845 - 299)$

$$\boxed{h_2 = 374.95 \ \frac{KJ}{Kg}}$$

At point (3) (Subcooling)

$h_3 = h_{f_{3'}} - C_{PL} (T_{3'} - T_3)$ $\because T_3 = 26 - 4 = 22^\circ c$ 295 K

$= 224.623 - 1 (299 - 295)$

$$\boxed{h_3 = 220.623 \ KJ/Kg}$$

At point (4)

$$\boxed{h_3 = h_4 = 220.623 \ KJ/Kg}$$

1) Mass flow rate of refrigerant $\dot{m}_R$

$\dot{m}_R = \frac{3.5 \times TR}{h_1 - h_4}$ (Kg/sec)

$= \frac{3.5 \times 20}{342.307 - 220.623}$

$$\boxed{\dot{m}_R = 0.5752 \ Kg/sec}$$

ii) Refrigeration capacity

iv) $COP = \frac{h_1 - h_4}{h_2 - h_1} = \frac{342.307 - 220.623}{374.35 - 342.307}$

$\boxed{COP = 3.727}$

iii) Compressor power

$\cancel{P_{com} = \frac{O/P}{I/P}} =$