Thermodynamics

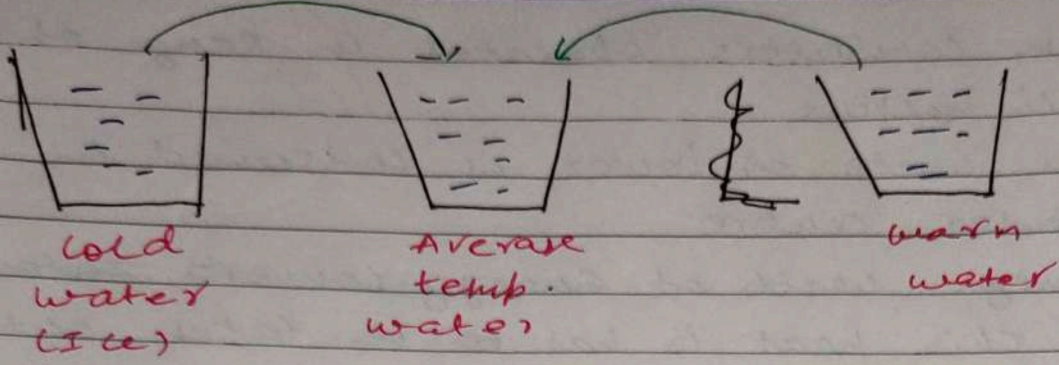
↳ Quantum computers operates in Range of milli kelvins
↳ A mega watt of power is consumed in computer centre
↳ this mega watt of Energy converts Into heat. this heat is has to be taken out otherwise temperature will keep Rising and system will be melt. there should be heat removal mechanism.
↳ Tower has model had been adapted due to its thermal profit.

Q1. Find mass of Air in closed classroom using $pV = nRT$.
Q2. At NTP, gap between two neighbouring molecules of nitrogen (for uniformly distribution).
Q3. Specific heat of monoatomic gas, (C_P, C_V, γ, R) ⇒ Relations.

↳ 4 laws of thermodynamics.
↳ Galileo (1600-1665) → had a Ambassador friend

Q.

Q. Ambassador asked to Galileo :-
water is cooler in summer & warmer in winter
↳ but in actually, water is warmer in summer and cooler in winter.



↳ newton asked first to his friend to put Right hand in Ice water and ~~left~~ hand in warm water and kept it for 5 minutes, after 5 minutes put your both ~~hand~~ hand in Avg. temperature water.

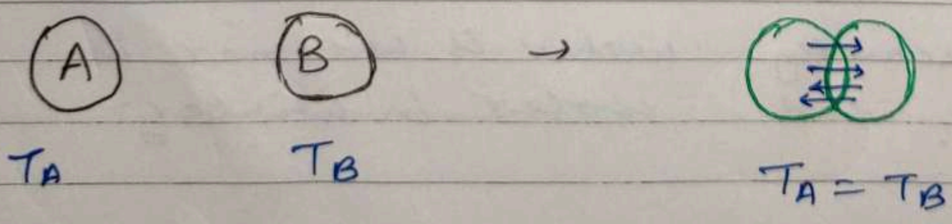
↳ Right hand feels warmer } → Psychological
↳ ~~left~~ hand feels colder } perception.

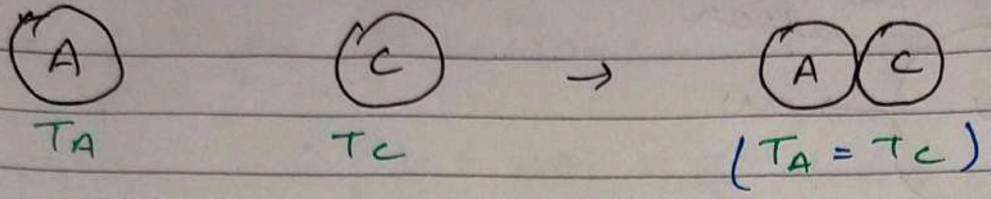
↳ but temperature should be constant for ~~right~~ left and Right hand.

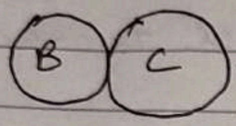
↳ from here, concept of temperature was derived.

temperature ⇒ Celsius (0-100) } → Scaling
Fehrenheit (32-212)
Roumer (0-80)

zeroth Law



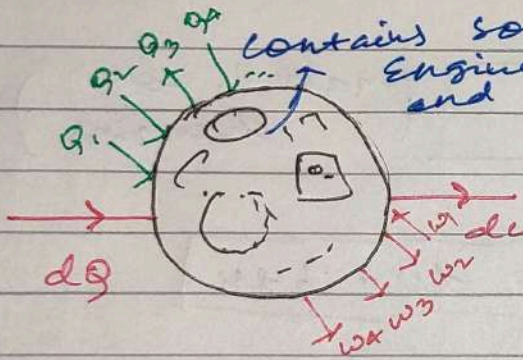




↳ there will no heat flow
$(T_B = T_C = T_A)$

↳ A & B, A & C, B & C are in thermal Equilibrium.

First law of thermodynamics

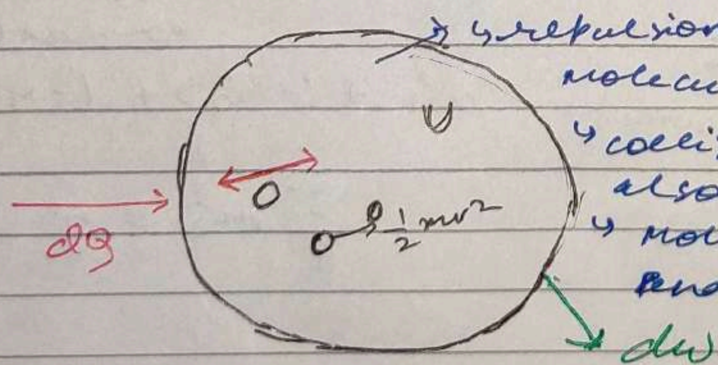


VVI

$\boxed{\begin{array}{l} Q \text{ Entering} \rightarrow \text{positive} \\ w \text{ leaving} \rightarrow \text{negative} \end{array}}$

$dQ = (Q_1 + Q_2 - Q_3 + Q_4 - \text{---})$
$dw = (-w_1 + w_2 + w_3 + w_4)$

dQ, dw → all are in Joules

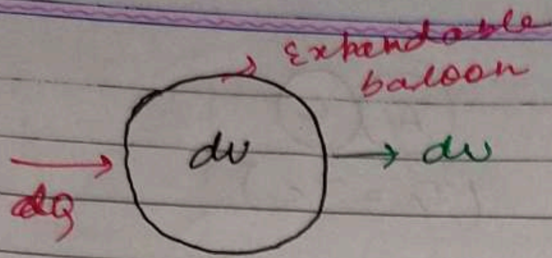


Heat — work — Internal Energy

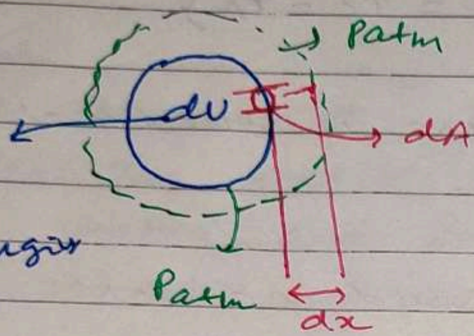
$$\boxed{dQ = dw + dU}$$

Income — Expenditure — assets

Internal energy:-
Sum of K.E + P.E + Rotational Energy + all energies — of all molecules.



↳ on providing dQ, temperature will Increase



no. of molecules is not changing

$F = p\,dA$

$dw = F \cdot dx = p\,dA\,dx$
$= p\,dV$

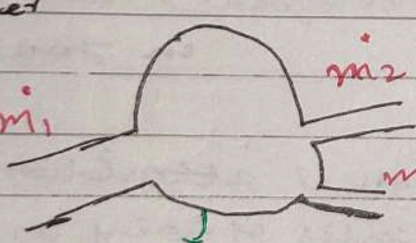
$\boxed{dw = p\,dV}$

$\boxed{dQ = dU + p \cdot dV}$ (mass is not changing)

(in closed system)

↳ FLOT ⇒ $\boxed{dQ = dU + dw = dU + p\,dV}$

conservation of matter



control volume)
Imaginary boundary

↳ After steady state,

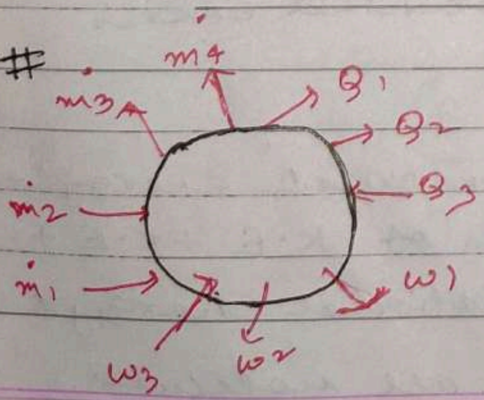
$\boxed{\dot{m}_1 = \dot{m}_2 + \dot{m}_3}$

↳ conservation of matter

$\dot{m}_1 + (-\dot{m}_2) + (-\dot{m}_3) = 0$

$\sum_j \dot{m}_j = 0$

#



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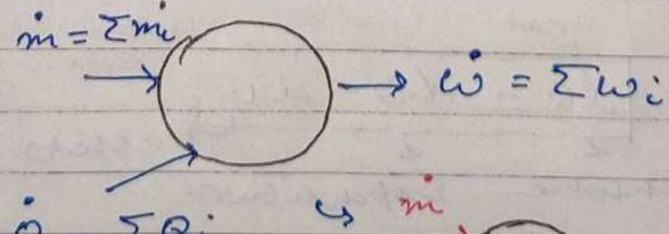
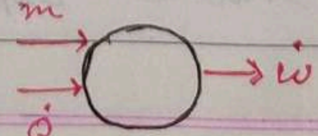
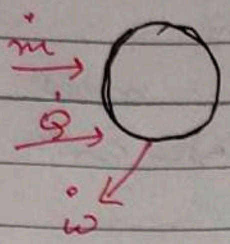


↳



Conservation of Energy :-



$$\underbrace{\dot{m}\left[u + pv + \frac{V^2}{2} + gz\right] + \dot{Q} - \dot{\omega} = 0}$$

↳ 1st Law of thermodynamics

↳ U → Internal Energy (PE + KE + —) of molecules

↳ $\frac{1}{2}\dot{m}V^2$ → K.E of $\dot{m}$
↳ velocity

↳ mgz → P.E of $\dot{m}$

(Electric / magnetic attraction or Repulsion)

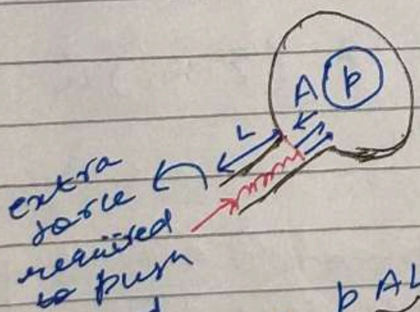
↳ pv → flow work p = pressure, pascal = $\frac{N}{m^2}$

v → specific volume $= \frac{m^3}{kg}$

flow work :- work done to push this gas/fluid inside the open boundary.

** VVI FLOT (for open system)

$$\boxed{\sum_{j=1}^{n} \dot{m}(u+pv) + \frac{V^2}{2} + gz + \dot{Q} - \dot{\omega} = 0}$$



$(pA) \times L = p\underbrace{AL}_{V}$

$\Rightarrow \frac{pV}{2}$

flow work

↳ flow work (pv) and work ($\dot{\omega}$) are Independent.

pv → unit → $\frac{pa \cdot m^3}{kg}$

$= \frac{N}{m^2} \cdot \frac{m^3}{kg}$

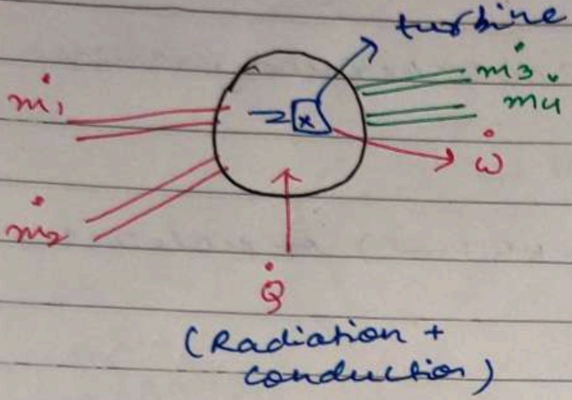
$= \frac{Nm}{kg} = \frac{J}{kg}$.

$\hookrightarrow \underset{\substack{\text{Internal}\\ \text{energy}}}{u} + \overset{\text{flow work}}{pV} = H = $ Enthalpy

open system :- mass can exchange with sorrounding

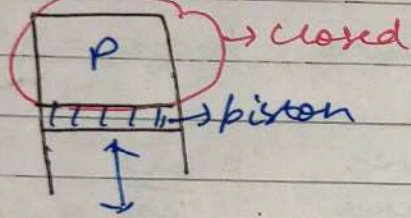
closed system :- mass can't exchange with sorrounding.

#



$$\boxed{\dot{m} \Rightarrow \text{unit} \Rightarrow \frac{kg}{s}}$$

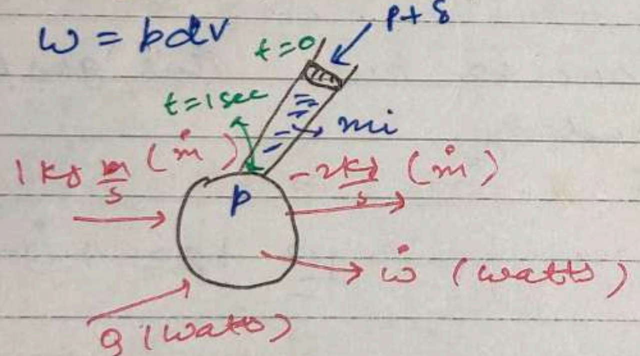
#



→ closed volume → mass doesn't enter
↓
closed system

$w = p\,dV$

#



$$\sum_{i=1}^{n} \dot{m}_i \left(u + \frac{v^2}{2} + gz\right) + \underbrace{p\dot{V}}_{\substack{\text{come to}\\ \text{this term}\\ \text{later.}}} + \dot{Q} - \dot{w} = \left(\sum \dot{m}_i\right) u$$

↳ (physical work done (work done by external to push that gas)

$$\boxed{\underbrace{\sum \dot{m}_i}_{kg/s} = \frac{\partial m}{\partial t}} \begin{matrix} \to kg \\ \to s \end{matrix}$$

$\hookrightarrow \sum m_i\left(u + \frac{v^2}{2} + gz\right) + \sum m_i \cdot pV_i + \dot{Q} - \dot{w}$

$$= \frac{\partial (MU)}{\partial t} = 0$$

M → total inside the control volume

U → Internal Energy of all molecules.

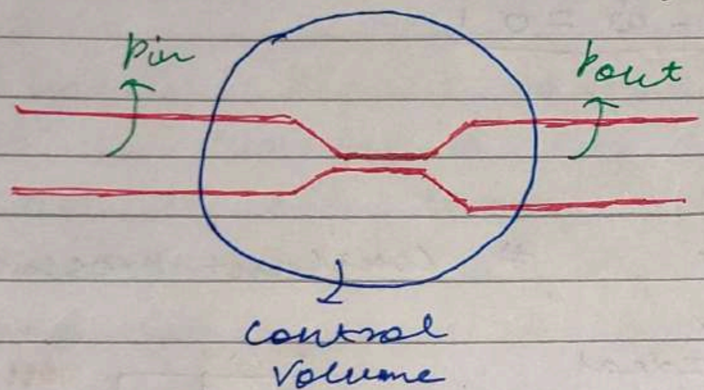
↳ In steady state, $\Sigma \dot{m}_i = 0$

↳ $H = u + pv$ = Enthalpy

$$\boxed{\Sigma \dot{m}_i \left(h_i + \frac{v^2}{2} + gz\right) + \dot{Q} - \dot{\omega} = 0}$$

↳ most valuable equation of first law.

Ex:



$$\dot{m}_{in}\left(h + \frac{v^2}{2} + gz\right)_{in} - \dot{m}_{out}\left(h + \frac{v^2}{2} + gz\right)_{out} + \dot{Q} - \dot{\omega} = 0$$

↳ $\dot{m}_{in} = \dot{m}_{out}$ (conservation of mass)

↳ $v_{in} \neq v_{out}$ (velocity)

↳ but $h \gg \frac{v^2}{2}$

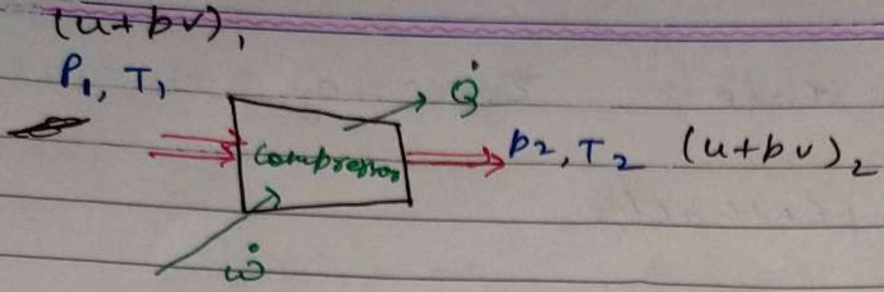
↳ both are at same level $z_{in} = z_{out}$

$$\dot{m}(h_{in} - h_{out}) + \dot{Q} - \dot{\omega} = 0$$

$$\Downarrow$$

$$\boxed{\dot{m}\,\Delta h + \dot{Q} - \dot{\omega} = 0}$$

$\underline{\underline{Ex}}$:



$$\dot{m}h_1 + \dot{W} = \dot{Q} + \dot{m}h_2$$

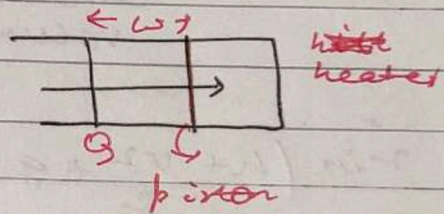
$$\boxed{\dot{m}(h_2 - h_1) + \dot{Q} - \dot{W} = 0}$$

Enthalpy (h)

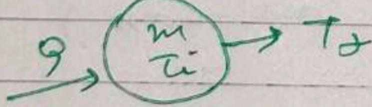
\# $h = \underbrace{u + pv}_{\text{Valid for all type of gases}} = \underbrace{u + RT}_{\text{for only Ideal gas}}$

(fluids, Ideal gas, non-Ideal gas, liquids, mixture)

\# constant pressure



(Cv) → Assuming volume is constant



$$Q = m \cdot C_v (T_f - T_i)$$

$$\boxed{C_v = \frac{Q}{m \cdot \Delta T}}$$

(Cp) → Assuming the pressure is constant

$$Q = m C_p (T_f - T_i)$$

$$\boxed{C_p = \frac{Q}{m \cdot \Delta T}}$$

\# $Q = m(U_f - U_i) + p(V_f - V_i)$

$= m[(U + pV)_f - (U + pV)_i]$

$= m[h_f - h_i]$

$= m\Delta h = m C_p \Delta T$ $\boxed{\Delta h = C_p \Delta T}$

$h = u + RT$ (for Ideal gas)

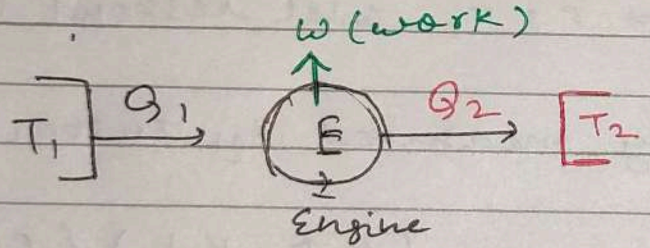
$\frac{dh}{dT} = \frac{du}{dT} + R$ $\qquad$ $C_p = \frac{dh}{dT}$, $C_v = \frac{du}{dT}$

↳ $\boxed{C_p = C_v + R}$ VVI.

Second law of thermodynamics (SLOT)

(i) Keelvin - Planck statement

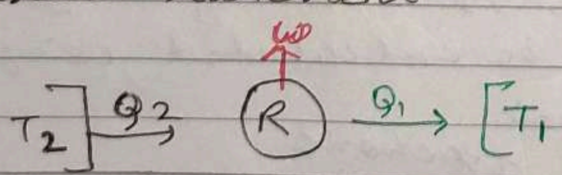
↳ If u running a Engine in closed cycle, and u are taking heat from higher temperature T_1 and amount of Q_1 and you expect to get work out from Engine, atmospheric T_2 and amount of Q_2 should be positive $(Q_2 > 0)$.



$(Q_2 > 0)$

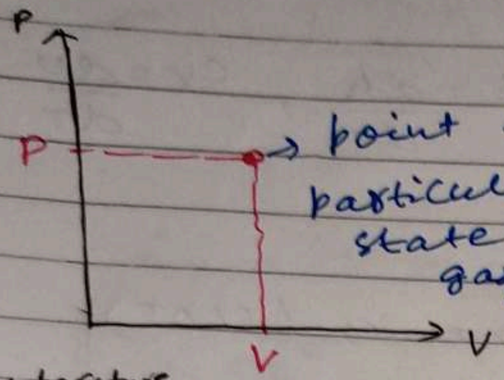
↳ 100% of heat is not converted into work. Some amount of heat is lossed in atmosphere.

(ii) clasius statement

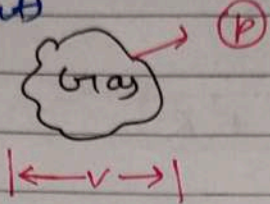


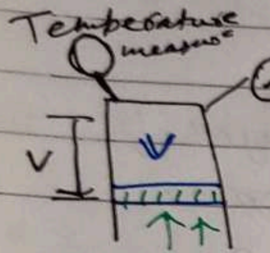
↳ 100% of heat is not converted into heat. (from T_2 to T_1). Some amount of work done should be there.

carnot, Sadi



→ point represents particular state of gas.





P → pressure measuring Instrument

on changing volume, we get different value of pressure.

~~2 out of 3~~

(i) change volume ⇒ P & T will respond
(ii) change Temperature ⇒ P & V will respond

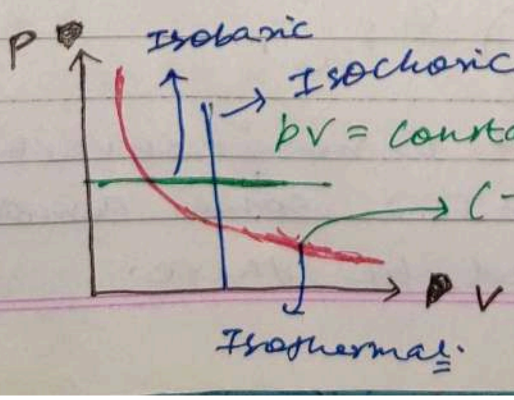
↳ P, V, T → can be easily measured by Instruments

Isothermal ⇒ T = constant (P ↑, V ↓) (P ↓, V ↑)
Isochoric ⇒ V = constant (P ↑, T ↑) (P ↓, T ↓)
Isobaric ⇒ P = constant (V ↑, T ↑) (V ↓, T ↓)

Ex: If p, V are given, then T = ? (Ideal gas)

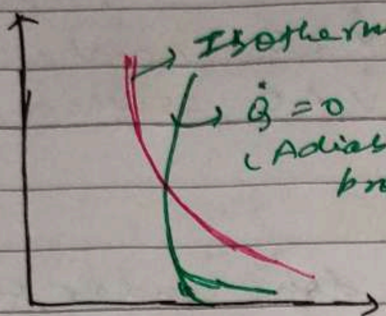
$T = \frac{pV}{nR}$ ⇒ H, W, Q ⇒ many things can be calculated using

T = constant
↓
- PV curve is hyperbola



Adiabatic process ⇒ Q = constant

(pv^{γ} = constant)



$$\boxed{\gamma = \frac{C_p}{C_v}}$$

($\gamma > 1$)

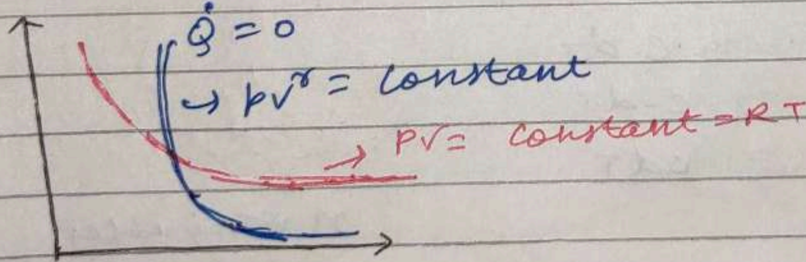
$\Delta T|_{V=\text{constant}} \Rightarrow \frac{Q}{C_v \cdot m}$

	T	p	V
old			
new ($Q=0$)	↳ T	↳ 2p	?

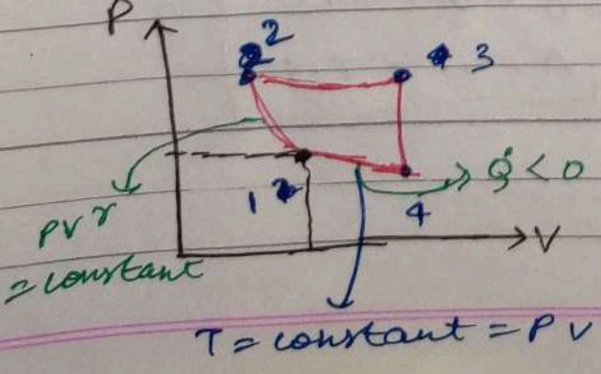
↳ $C_p - C_v = R$

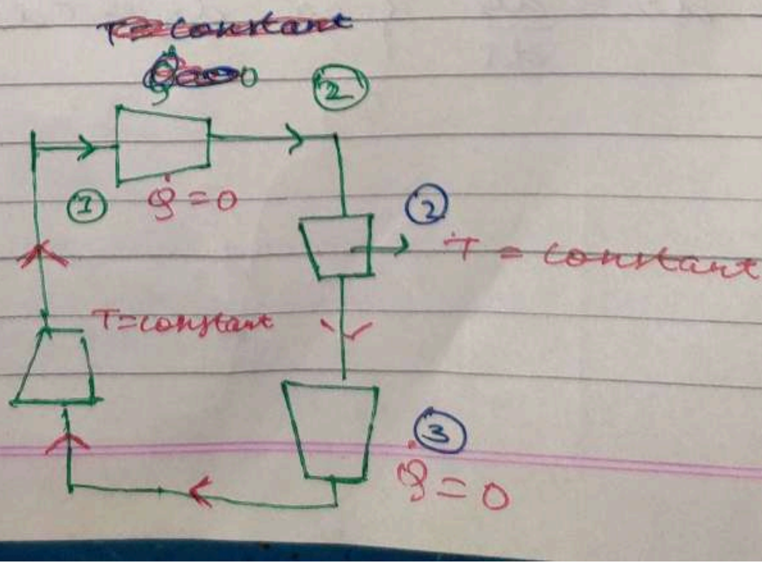
$\Rightarrow \gamma - 1 = \frac{R}{C_v} \Rightarrow \gamma = 1 + \frac{R}{C_v}$ → positive ⇒ $\gamma > 1$

↳ $C_v = \frac{R}{\gamma - 1}$ ↳ $C_p = \frac{R\gamma}{\gamma - 1}$

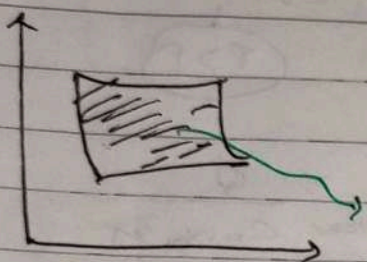


carnot cycle





1- 2 , $\dot{Q}=0$, $\dot{W}<0$, $\dot{V}<0$ Adiabatic
2→3 , $\dot{Q}>0$, $\dot{W}>0$, $\dot{V}>0$ Isothermal
3→4 , $\dot{Q}=0$, $\dot{W}>0$, $\dot{V}>0$ Adiabatic
4→1 , $\dot{Q}<0$, $\dot{W}<0$, $\dot{V}<0$ Isothermal



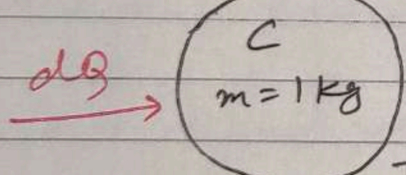
$\dot{W}_{total}$ = work done under the p-v curve

Area = net work output

$$\boxed{\eta_{carnot} = 1 - \frac{T_L}{T_H}}$$

Entropy (S) :-

$dQ = cdT$



$T \rightarrow T+dt$

$dQ = m \cdot c\, dT$
$= 1 \cdot c \cdot dT$
$= cdT$

p, v, T,
ρ, u, h,
s, g, A

n variables

n-2 eqns

$ds = \dfrac{dQ}{dT}$ } or $dQ = Tds$

$$\boxed{\begin{aligned} g &= h \cdot T \cdot s \\ A &= u \cdot T \cdot s \end{aligned}}$$

Ex:

dQ → ice 1 kg

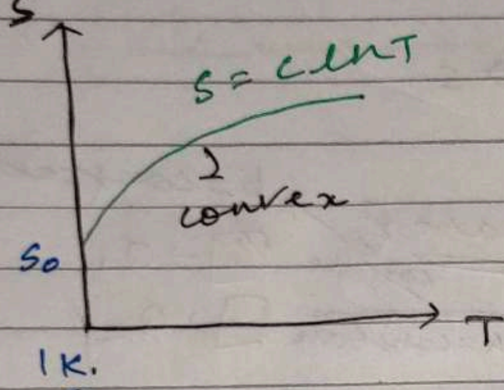
−20°C

$$dQ = \cancel{m}\,c\,dT$$

$$dQ = T\,ds$$

$$c\,dT = T\,ds$$

$$ds = \int \frac{c\,dT}{T}$$



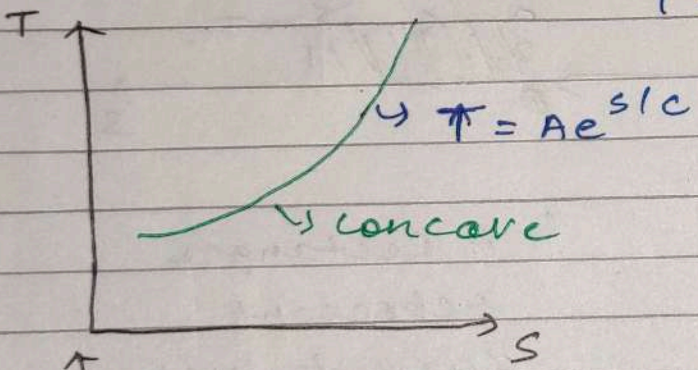
$$S = c.\ \ln T + S_0$$

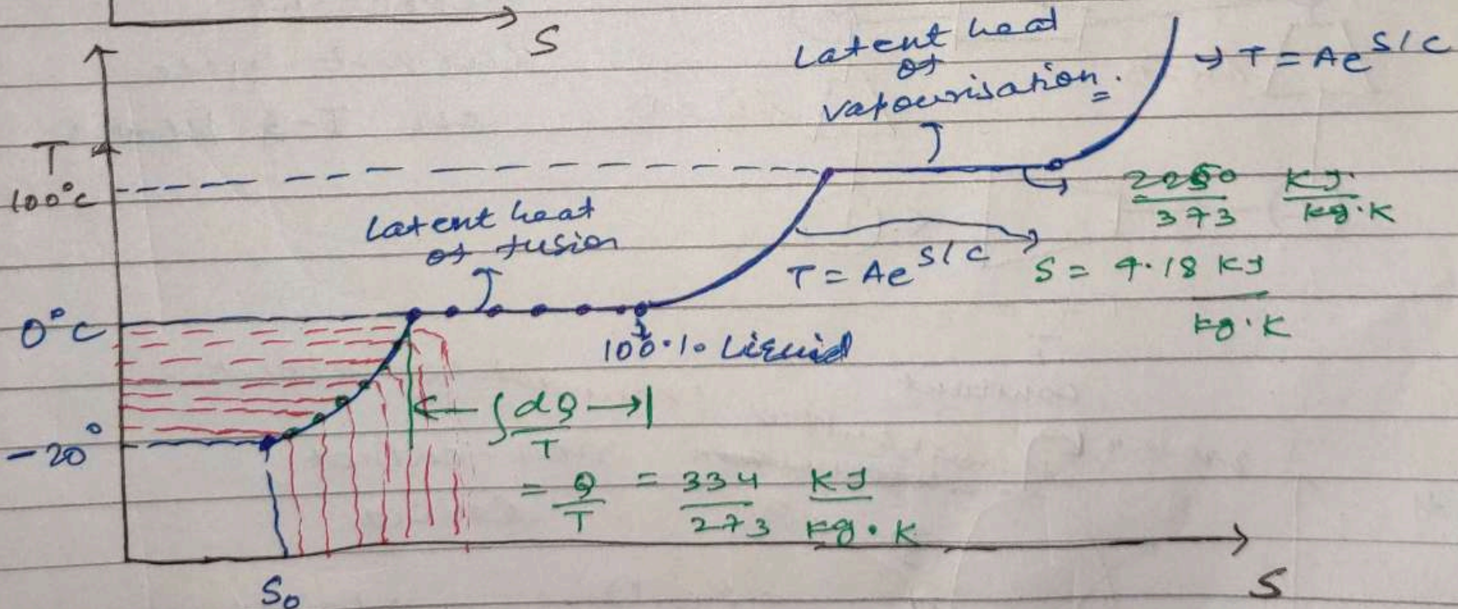
$$S - S_0 = c \cdot \ln T$$

$$\Delta S = c \cdot \ln T$$

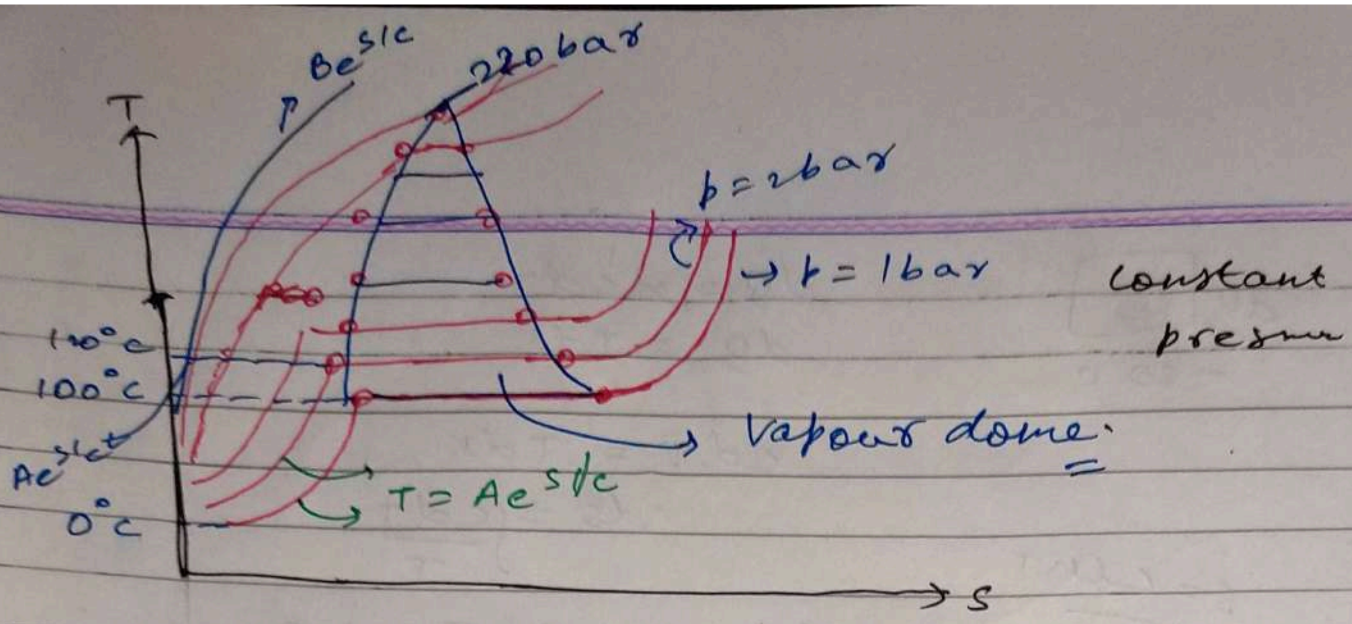
$$\frac{S - S_0}{c} = \ln T$$

$$T = Ae^{\frac{S - S_0}{c}}$$





entropy ↑, as Heat ↑.



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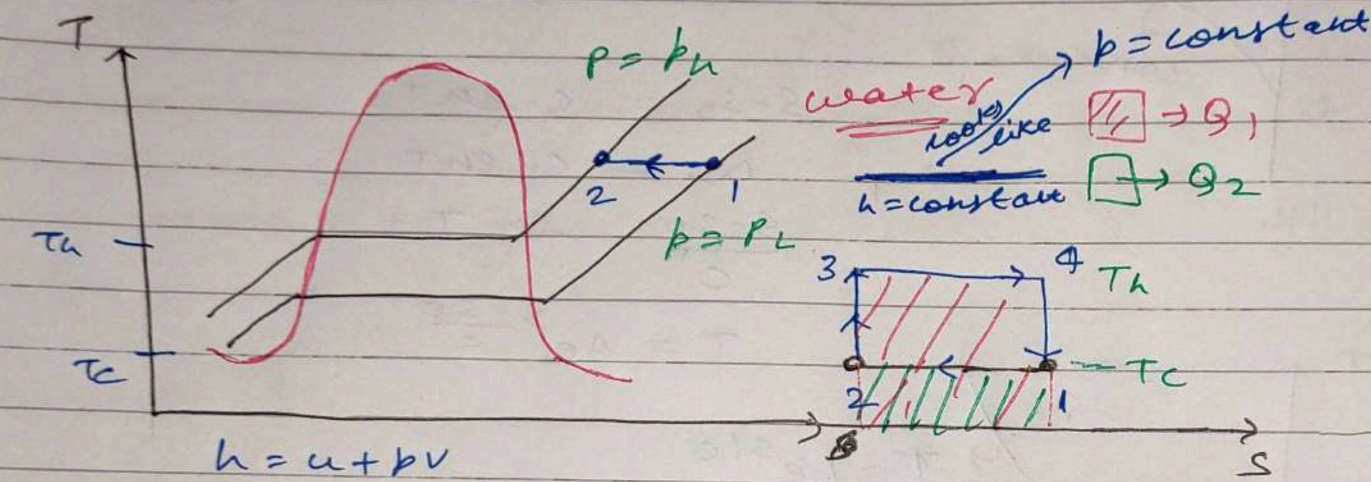
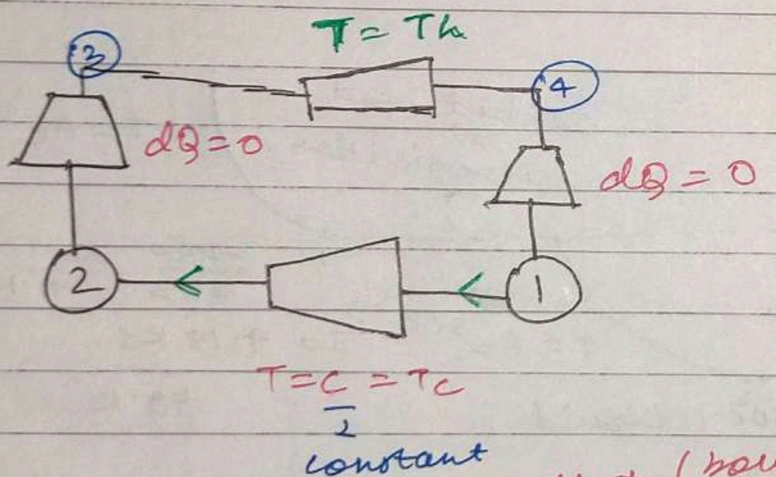


$h = u + pv$
$= f(T) + RT = f(T)$

#



↳ A Rectangle represent carnot cycle on T-S plane

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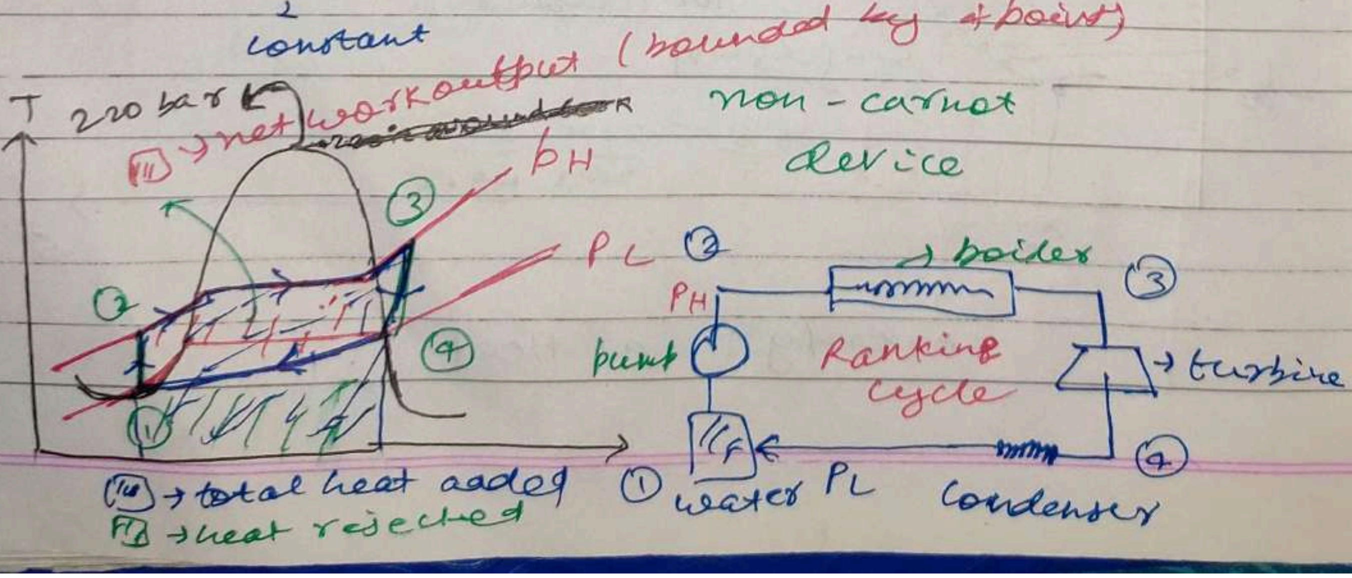
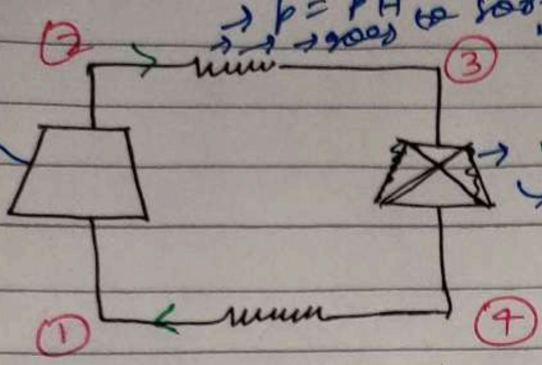


Adiabatic compressor (s = constant)



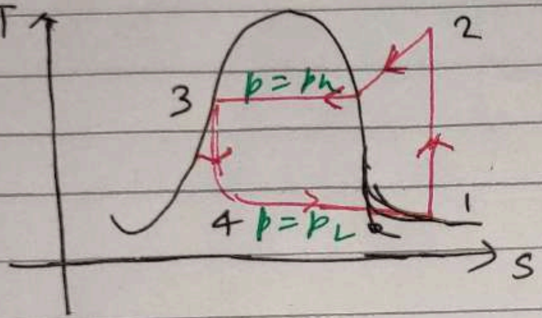
R134a ⇒ $C_2H_2F_4$

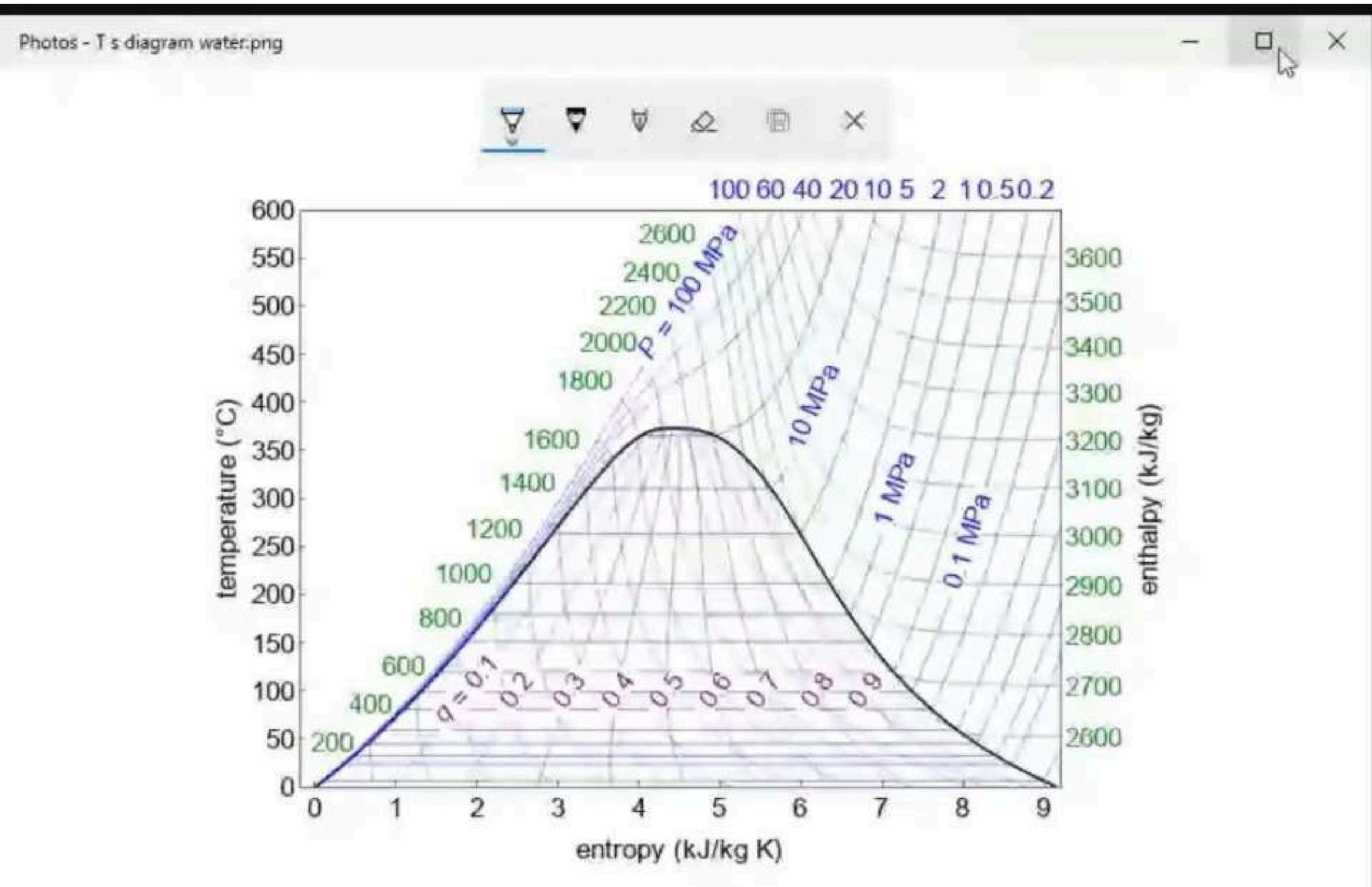
R22 ⇒ ~~CH_3F_2Cl~~ CHF_2Cl

→ expansion wall

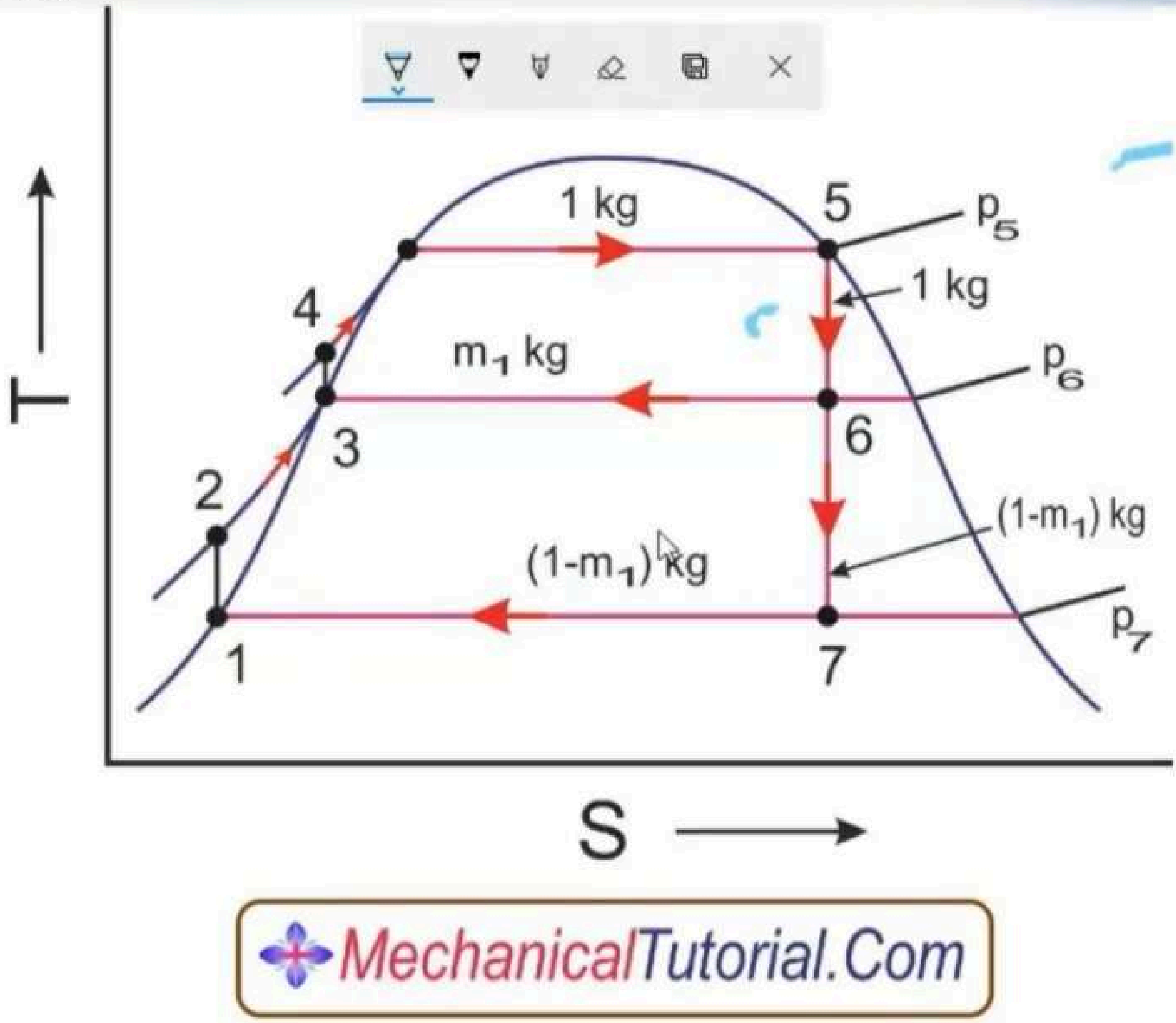
→ $\dot{m}(h_3 - h_4) = 0$

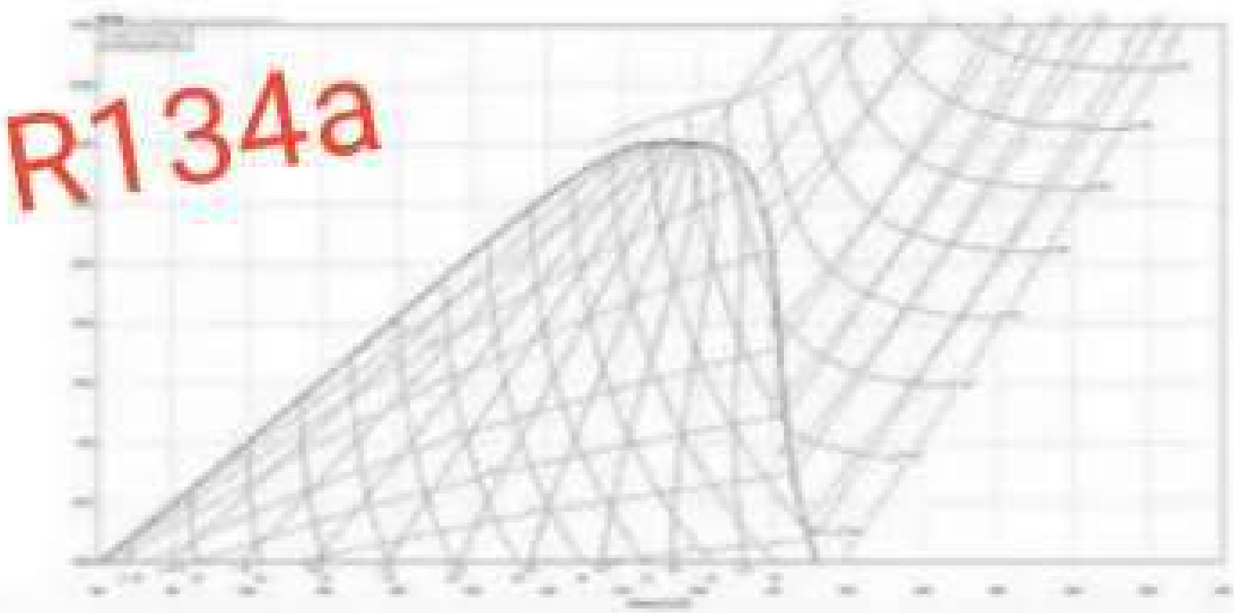
→ $h_4 = h_3$.

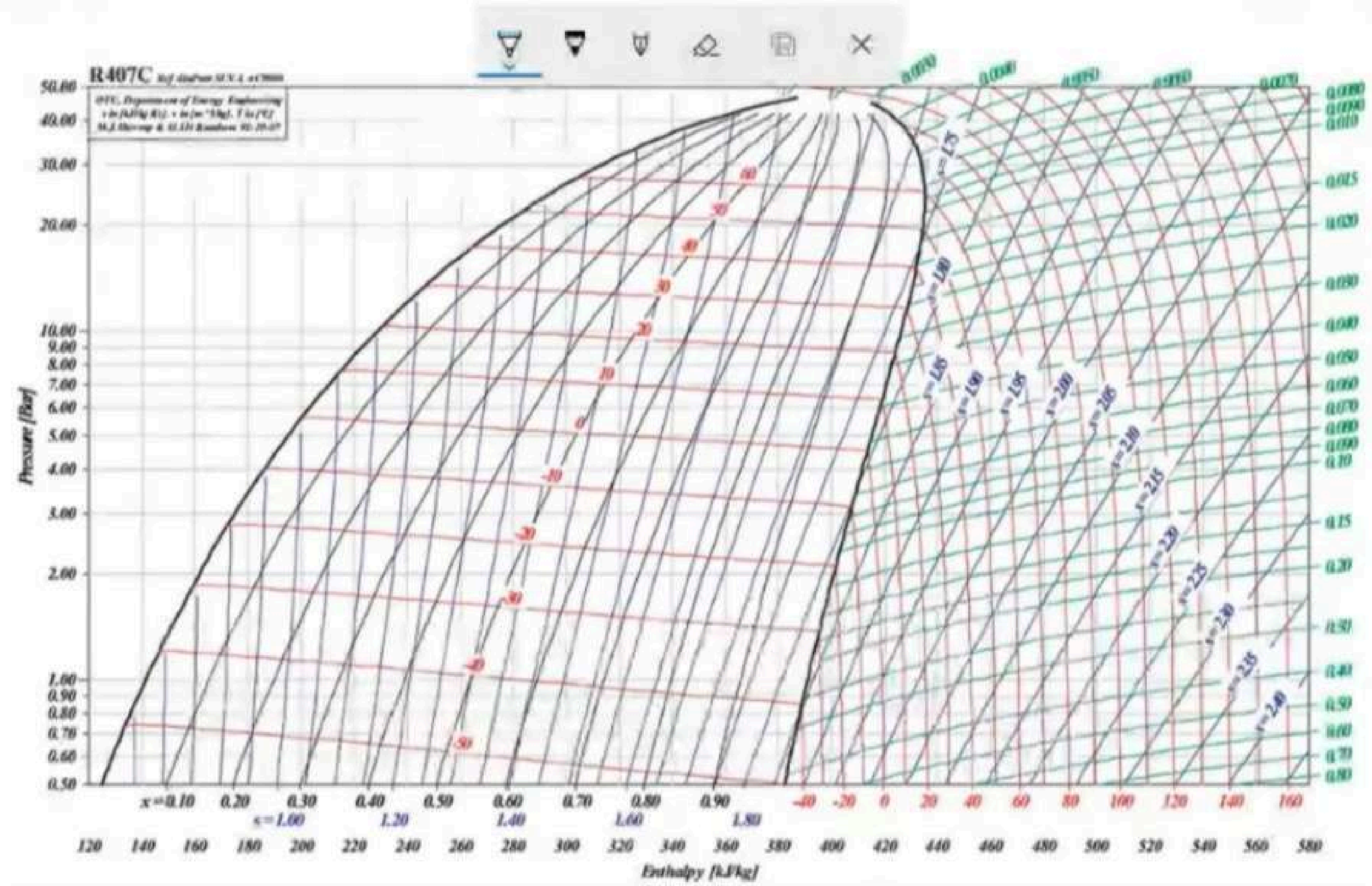



Photos - T s diagram water.png
100 60 40 20 10 5 2 1 0.5 0.2
P = 100 MPa
10 MPa
1 MPa
0.1 MPa
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
q = 0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
temperature (°C)
600
550
500
450
400
350
300
250
200
150
100
50
0
0 1 2 3 4 5 6 7 8 9
entropy (kJ/kg K)
enthalpy (kJ/kg)
3600
3500
3400
3300
3200
3100
3000
2900
2800
2700
2600

Photos - Rankine cycle.png




R134a


R407C
Pressure [Bar]
Enthalpy [kJ/kg]
50.00
40.00
30.00
20.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.90
0.80
0.70
0.60
0.50
x=0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90
s=1.00 1.20 1.40 1.60 1.80
-40 -20 0 20 40 60 80 100 120 140 160
120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 480 500 520 540 560 580
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
s=1.75
s=1.80
s=1.85
s=1.90
s=1.95
s=2.00
s=2.05
s=2.10
s=2.15
s=2.20
s=2.25
s=2.30
s=2.35
s=2.40
0.015
0.020
0.030
0.040
0.050
0.060
0.070
0.080
0.090
0.10
0.15
0.20
0.30
0.40
0.50
0.60
0.70
0.80