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⑥ THEMODYNAMICS

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THERModynamics

By :- [redacted]

⑥

Thermodynamic :-
It is the science of energy transfer and it effect in property of system.

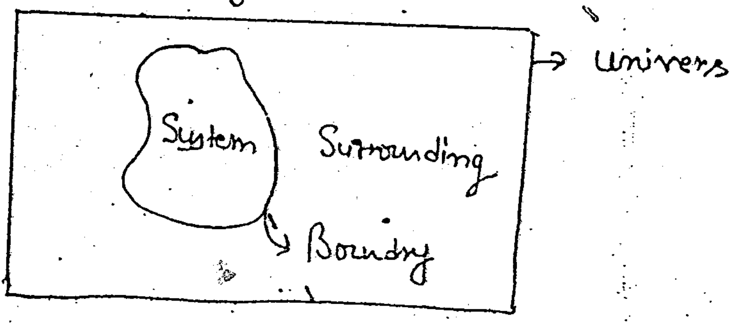
The main aim of thermodynamic study is to convert leorganise form of enery into organis. form of energy in a efficient of manner work.

thermo + dynamic
Heat - in - motion

System :- It is the region in space upon which foxed focus of constituted.

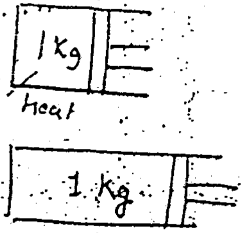
Surrounding :- Any thing external to the system is known as surrounding.

Boundry :- The speration b/w system and surroundings is known as a boundry. Boundry can be either rigid or flexible and it can be real and imajenery boundry.



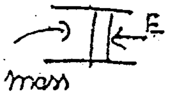
Types of system :-

Types of System.	mass of boundry	Energy transfer	Examp.
Closed	×	✓	Piston Cylinder w/o valves
open	✓	✓	turbine, pump Compressor
isolated	×	×	Univers, not Coffie-in well isolated flask

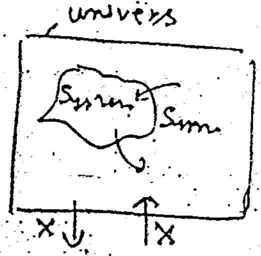


mass not transfer
(closed) (control mass)

Closed — E ✓ (transfer)
↘ m × (not tran)



E ✓
m ✓
Open sys



(isolated) sys

Microscopic and Macroscopic :-

In microscopic approach the behaviour of individual molecules is taken into considration this approch is also known as Statistical thermodynamics this approch is used at low density (higher altitudes).

In macroscopic approch the bheaviour of individual molecules is not taken into Considration.

micros → Statical (every molel)
macros — average propers
↳(classical) | molecule

when No. of molecules less than → mico easily.

$\rho = \frac{\boxed{m}}{V}$ - less

Due the average behaviour of molecules is taken into consideration this approach is also known as <u>classical thermodynamics</u>

In our study we deal with Classical thermodynamics.

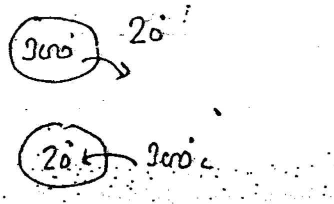
Thermodynamic Equilibrium :-

A System is said to be in thermodynamic Equilibrium if it is in <u>thermal equilibrium</u> (equality of temp), <u>mechanical Equilibrium</u>, (equality of forces / pressure)

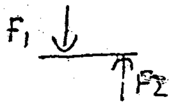
<u>Chemical equilibrium</u> (equality chemical

(a) thermal equilibrium
(b) mechanical equilibrium
(c) chemical Equilibrium

$\rightarrow$ [thermodynamic Equilibrium]

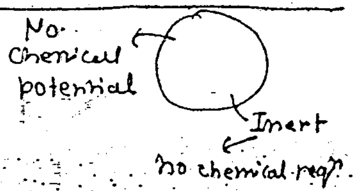


thermal Equil

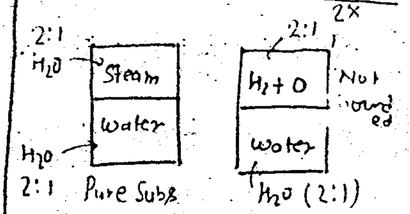


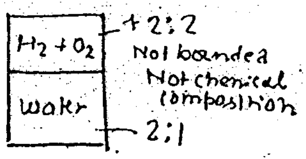
$$\left\{\begin{array}{l} F_1 = F_2 \\ P_1 = P_2 \end{array}\right.$$

Mechanical Equili.



Chemical ~~reaction~~ Equli

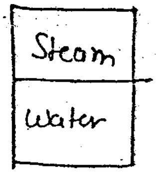




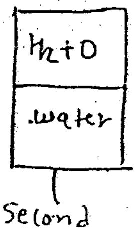
Pure Substance :-

A Substance is said to be pure substance if it is in chemical co

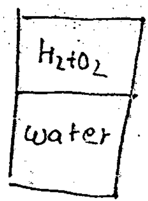
1) Homogeneous in chemical composition
2) Homogeneous in chemical aggregation



Pure Substance



Second Condition failed



both condition not satisfied

*

Property of a system :-

Propertys are Cheracistic of a System

Ex- Pressure (P), Temp. (T), Volume (v), density (ρ)

Properties are of two types

Property

- Intensive — [Independent on size and mass]
- Extensive — [dependent on Size and mass]

Intensive property :- are independent of size of mass

Ex- P, T, ρ etc

Extensive properties :- Dependent on the size or mass of the System

Ex- Volume (v), all form of energy etc.

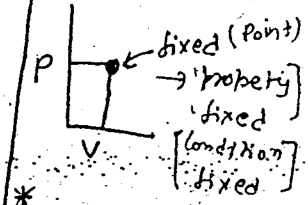
Note :- Specific properties are Extensive properties per unit mass and these property are Intensive properties

Ex- $\left(\nu = \frac{V}{m}\right)$

Specific volume (ν), Specific internal energy (u), Specific entropy (H), Speifik Enethby (S)

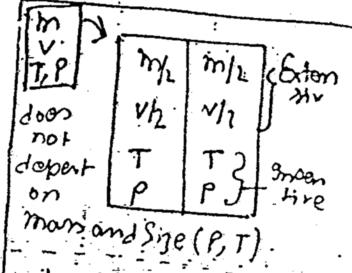
Condition → State
↓
Property (Charteristic of Sys)

$P = a$, $t = b$, $v = c$ — property



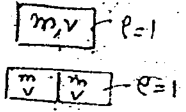
* property → point function

property change → State Change
point change



K.E, P.E > Extansive

Density — Not depend on mass

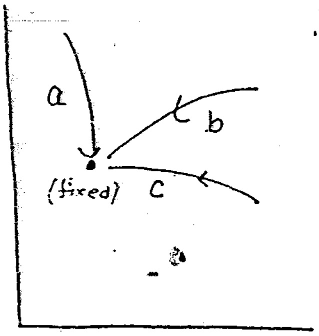


divided by mass is Called specific

Specific Volume = $\frac{V}{m}$

All Specif property is Called Intensive

If point fixed come on by any path

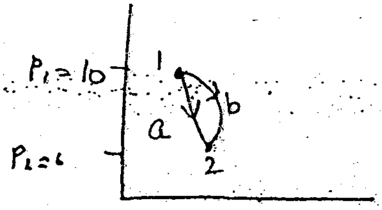


* porperty only dependedon State not on past history

property change → State change → Condition chang — Called as process

$\boxed{\text{property is Called = Exact differential}}$

does not depend on path

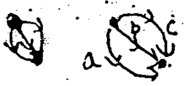


* Important points with repected to properties :-

(i) Properties are point function or state function

(ii) Properties are Independed of past history

(iii) Properties are Exact Differential (any path but ending point and Starting point same)→



Gibbs phase rule :-

*(when no of phase Incrse, decrese the no. of property for the D.O.F)

According to phase rule

$$\boxed{P + F = C + 2}$$

P = No. of phase

F = minimum no. of independent intensive variable required to fixed the state

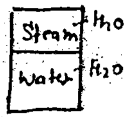
C = No. of components (chemical)

minimum no. of intensive

$P + F = C + 2$

no. of phase

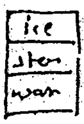
No. of composition



P=2

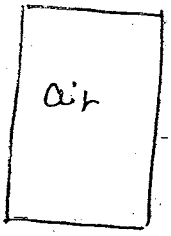
C=1 (H_2O)

$\boxed{F = 1}$



P=3

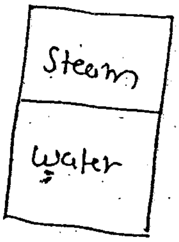
C=1



$P + F = C+2$

$1 + F = 1+2$

$\boxed{F = 2}$

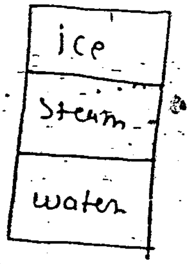


$P = 2$

$C = 1$

$2 + F = 1 + 2$

$\boxed{F = 1}$



$P = 3$

$C = 1$

$3 + F = 1 + 2$

$\boxed{F = 0}$

* Phase incrsed F decrsed

State of a System :-

The condition of a system is known as state of a System

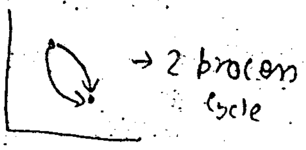
Process :-

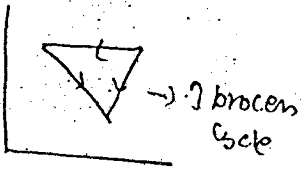
A change of state is known as a process.

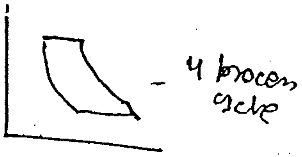
Thermodynamic Cycle :-

A System is said to have undergone a cycle if the initial and final points are same.

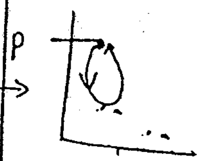
minimum no. of processes required for a cycle are 2.





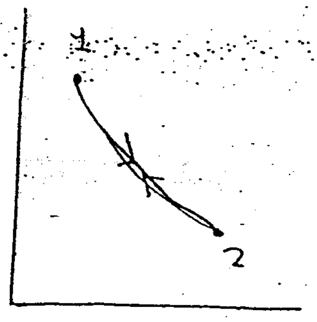


Note :- For a cycle change in property is equal to zero. Because property are point functions and for a cycle initial and final points are same.



Reversible and Irreversible process :-

A process is said to be a reversible process if ~~as~~ when reverse in direction follows the same path as that of the forward path without leaving any effect on system and surrounding

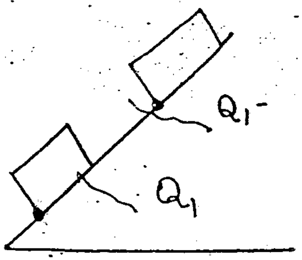


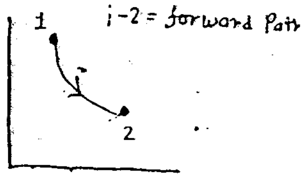
Some path

A process which is not reversible process is an irreversible process.

Friction is one of the region which make the process irreversible.

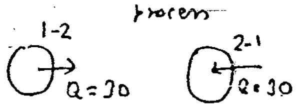
* Reversible process is the most efficient process.





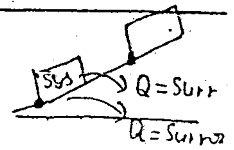
* Same path follow → Reversible process

process 1-2 = 2-1 process



	Sys	Surr
1-2	Q = -30	Q = +30
2-1	Q = +30	Q = -30
	0	0 No effect

No effect on System as will as surrounding So it called reversible



Here Friction here so Irreversible

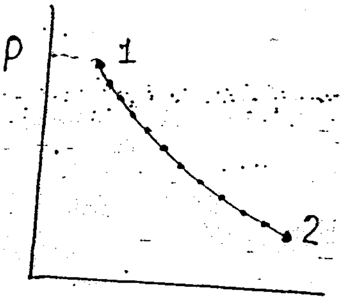
Here path same but change in surrounding only by both time so it irreversible

Here system is same but only surrounding change so called irreversible

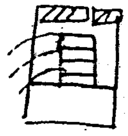
Quasi static process :-

A process which is carried out in a slow manner it is known as Quasi static process.

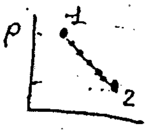
Friction less Quasi static process is a reversible process.



Quasi static process
almost rest



weight remove



when weight remove or placed friction occurs in both condition so it irreversible process.

But when friction not occuse it is reversible process.

Zeroth law of thermo dynamic :-

* (It gives a concept of temp.)

Statement -

"When a body A is in thermal Equilibrium with body B, and body B is in thermal Equilibrium of C seperatly then A and C are in thermal Equilibrium."

In zeroth law of thermodynamics one body act as a thermometer.

⇒ Thermometers are based on one principle that is "The parameter which vary with temp. and then temp. is found

The property which change with temp is known as thermometric property

Zeroth → concept of temp (1931)

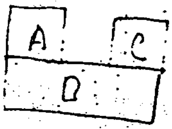
1835 – first law but known first concept of temp

when (Statement)

$A \ \underline{\ TE\ }\ B$

$B \ \underline{\ TE\ }\ C$

then $A \ \underline{\ TE\ }\ C$



Seperetly → Not in direct contact

$PV = mRT$

$V = \frac{m.R}{p} . T$

$\boxed{V = C \cdot T}$

$\boxed{T = \frac{V}{C}}$

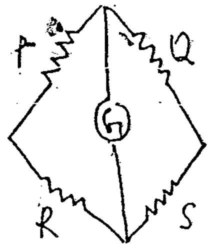
if temp change find the volume to get new temp if

⑤

Types of thermometer :-

$S = S_0(1+\alpha t+\beta t^2)$

Wheastsorn bridge



$$\frac{P}{Q} = \frac{R}{S}$$

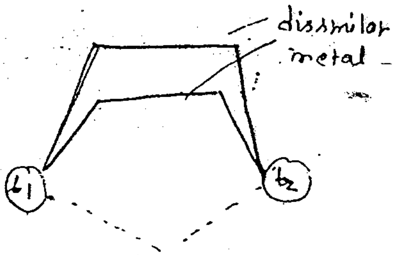
$$S = \frac{RQ}{P}$$

(1) Resistance thermometer –

Resistance thermometer is based on , wheaston bridge principle and in resistance theromometer resistance placed the role of thermometric property.

resistance thermometer → thermister

(II) Thermo Couple :-



different temp

* emf genrated V and depend on ~~both~~ temp. difference

V: thermometric property

thermo couples are based on Seeback effect according to this effect when two dissmilar metal to form to different Juction and if these two junction making at different temp emf is genrated and this emf is propostional to temp. difference b/w two Junctions.

In thermo couple e.m.f (v) placed the role of thermometric property.

(III) Constant Volume gas thermometer :-

In Constant volume gas thermter pressure is thermometric property

$PV = mRT$

$m, R, V = C$

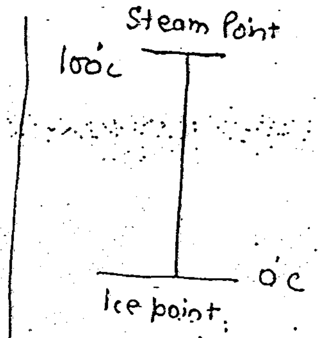
$\boxed{P \propto T}$ in this

Constant Presure gas thermometer :- (Vollume thermo property)

In C.P.G.T volume is thermometric property.

Temperature Scale :-

Temp. scale are arbitri the ice point and steam point on celcius scale or arbitrly taken as zero (0°) and 100°c respectivilly.



ice point or freezing point: water at ice point in ice

steam point or boiling point: water at this temp boilling

$$\boxed{K = {}^{0}c + 273.15}$$

Kelvin

Method used befour 1954 for measuring temp. :-

This method was based on two refrence temp. that is ice point (0°) and steam point (100°c).

By finding the unknown value of b the corresponding temp. t is found

$$\boxed{t = \frac{100}{(P_s - P_i)}(P - P_i)}$$

$$t = ap + b$$

$$t_i = aP_i + b$$

$$t_s = aP_s + b$$

$$100 = aP_s + b$$

$$\underline{-0 = -aP_i + b}$$

$$100 = a(P_s - P_i)$$

$$\boxed{a = \frac{100}{P_s - P_i}}$$

$$0 = aP_i + b$$

$$b = -aP_i$$

$$b = \frac{-100}{P_s - P_i} \cdot P_i$$

$$t = \frac{100}{P_s - P_i} P - \frac{100 P_i}{P_s - P_i}$$

$$\boxed{t = \frac{100}{(P_s - P_i)}(P - P_i)}$$

* Method used after 1954 :-

This method is based on single fixed temp. that is triple point of water.

A The triple point of water is arbitrly taken as 0.01°c (273.16 k)

Triple point water

S+L+V

$K = 0°c + 273.15$

$= 0.01 + 273.15$

$= \underline{273.16}$ (T.P.

$$PV = mRT$$

$$V = \text{Constant}$$

$$P \propto T$$

$$P = CT \quad \boxed{P = \frac{P_{tp}}{273.16}\cdot T}$$

$$\boxed{T = 273.16\left(\frac{P}{P_{t.p}}\right)}$$

$$C = \frac{P}{T}$$

$$C = \frac{P_{tp}}{T_{t.p}} \Rightarrow C = \frac{P_{t.p}}{273.16}$$

Note :- Ideal gas thermometer is independent of material of construction

(Q.1) The readings t_A an t_B

Two centigrade thermometer A and B agree at ice point (0°) and steam point (100°c) and t releted by a eqn $t_A = l + m t_B + n t_B^2$ b/w these temp where l, m, n are constant when both are immersed in oil A raised 51° and B read 50°c determin the reading on A when B reads 25°c and discuss the Question which thermometer is correct?

Ans. :- $t_A = l + m t_B + n t_B^2$

$t_A = t_B = 0$ (ice point)

$0 = l + m(0) + n(0)^2$

$\boxed{l = 0}$

$t_A = m t_B + n t_B^2$

$100 = m(100) + n(100)^2$

$\therefore 1 = m + n100$ — ①

$t_A = 51$, $t_B = 50$

$t_A = m t_B + n t_B^2$

$51 = m(50) + n(50)^2$ — (ii)

$$\boxed{\begin{array}{l} m = 1.04 \\ n = -4\times10^{-4} \end{array}}$$

$t_A = 1.04\, t_B - 4\times10^{-4}\, t_B^2$

$t_A = 1.04(25) - 4\times10^{-4}(25)^2$

$$\boxed{t_A = 25.75^\circ C}$$

Note – From the about thermometers it can be concalded that told the end point temp. are same it does not mean intermidiate temp. are also same.

(Q.2) It can not be conculded has to which temp. is correct because If one temp. correct other has to be wrong.

Assertion :- ~~Please~~ If alcohol and murury teromoter reads exactly at ice point and steam point these two thermometer will also gives same reading exactly at 50°c (x)

Reason – Temp. scale are arbitry (v)

Ans – Assertion → wronge
Reason → Right

(Q) Which ~~are~~ of the followings are intensive property.

1) K.E 2) thermal Conductive 3) Pressure 4) volume.

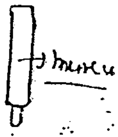
Ex In In Ex

1)

(Q.) Match the following

List I	List - II
thermometer	thermometric property
mercury in class	1) Pressure
thermometric couple	2) Resistance
thermistor	3) volume
Const. vol gas ther.	4) e.m.f

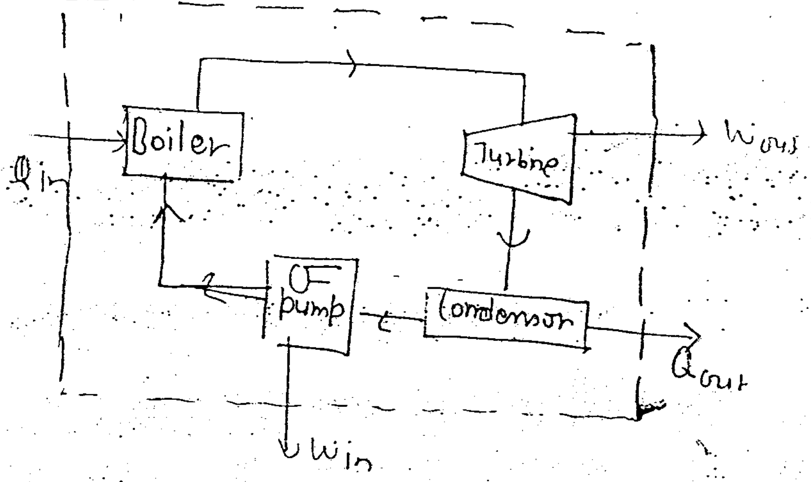
T ∝ L



Length is thermometric property so volume is also thermometric property.

*

(Q) In the figure showing A thermal power plant the closed system and open systems are correctly identify as



a) Boiler and Compressor are - open sys and turbine pum and overall plant are — Closed sys

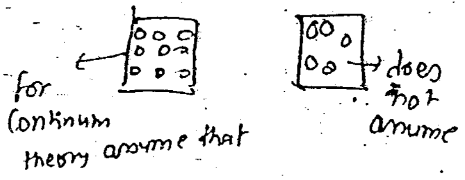
b) Tubine and pump — open sys, Boiler, Compressor, overall — Closed

✓ c) Boiler, turbine, Compressor, pump — open, overall plant — Closed

d) overall plant — open system, Boiler, turbine, Condensor, pum — Closed work book :- ①

28-7-2011

*⑤ Continum → continus



① For Continum concept the no. of atom large. and mean free path be less and give meaningful theory.

Mean three path –

*⑥ $P + F = C + 2$

$2 + F = 2 + 2$

$\boxed{F = 2}$

⑨ $PV = mRT$

P = in kelvin

$\boxed{P \propto T}$

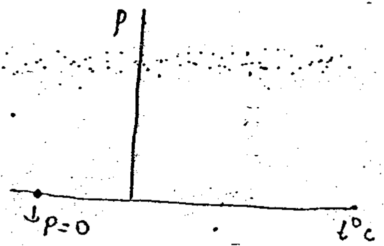
If $P = 0$

$T = 0\ K^\circ$

$K = {}^\circ C + 273.15$

$0 = {}^\circ C + 273.15$

$\boxed{C = -273.15}$



*⑬ $\delta z = M dx + N dy$

$\left(\frac{dM}{dy}\right)_x = \left(\frac{dN}{dx}\right)_y$

$\frac{dT}{T} - \frac{V dP}{T}$

$\frac{1}{T} dT + \left(-\frac{V}{T}\right) \cdot dp$

$M dx + N dy$

$M = \frac{1}{T},\ x = T,\ N = \frac{V}{T}\ y = P$

$\left(\frac{\partial M}{\partial y}\right)_x = \left[\frac{\partial}{\partial p}\left(\frac{1}{T}\right)\right]_T = 0$

$\boxed{\left(\frac{\partial M}{\partial y}\right)_x = 0}$

$\left(\frac{\partial N}{\partial x}\right)_y = \left[\frac{\partial}{\partial T}\left(-\frac{V}{T}\right)\right]_P$

$PV = mRT$

$\frac{V}{T} = \frac{mR}{P}$

$\left(\frac{\partial N}{\partial x}\right)_y = \left[\frac{\partial}{\partial T}\left(-\frac{mR}{P}\right)\right]_P$

$\boxed{\left(\frac{\partial N}{\partial x}\right)_y = 0}$

So ans is

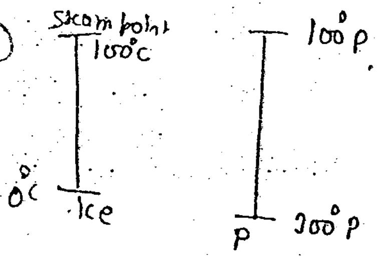
exat differential satisfied so ans is (d)

⑮ Triple point = 273.16 K

$\frac{1}{273.16}$ (triple point of water)

$= \frac{1}{273.16} \times 273.16^\circ = K$

*⑭



$\boxed{{}^\circ P = a \times {}^\circ C + b}$ ✓

$300 = 0 + b$

$b = 300^\circ$

If $P = 100,\ C = 100^\circ$

$100 = 100a + 300$

$\boxed{a = -2}$

${}^\circ P = -2 \times {}^\circ C + 300$

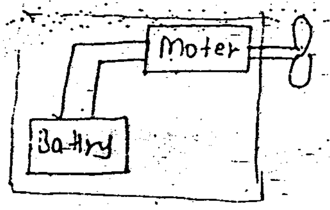
$0 = -2 \times C + 300$

$\boxed{C^\circ = 150^\circ}$

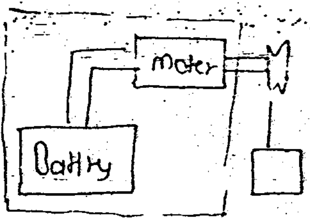
Energy interaction (Work and heat) :-

Work transfer :-

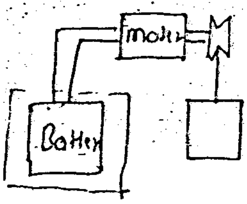
Work is said to be done by the system If the sole effect on things external to the system Can be equated to raising of weight (weight may not be actual raised but the effect is equated to raising of weight).



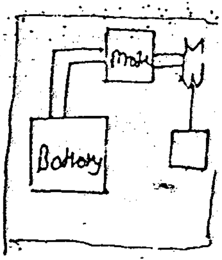
Work done



Work done



Work done

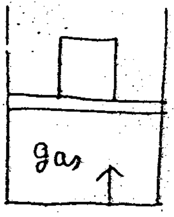


No work done

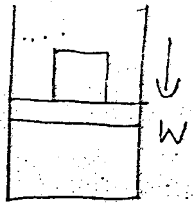
Work transfer occurs only when it crosses the boundry therefore work transfer is a boundry phenomian.

Convention of Work transfer :-

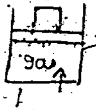
Work done by the system is taken as +ve. and work done on the system is taken as -ve.



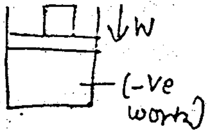
Work by the System
+ve
work



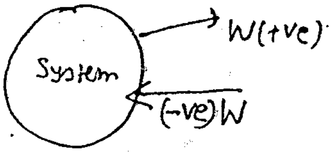
Work on the System
-ve
work
(compressive)



closed
(+work)
work by the sys
boundry expanding – expansion

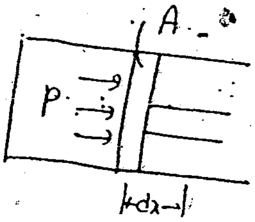


boundry shrinking



Generalised Equation for Closed System Work :- (Not flow work)

Closed system –



$P = F/A$

$\boxed{F = P \times A}$

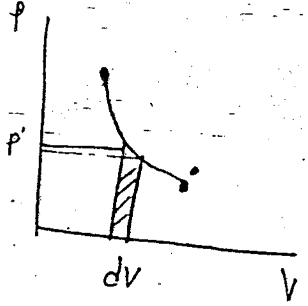
$W = F \times x$

$\delta W = P \cdot A \times dx$

$A \cdot dx = V$

$\delta W = Pdv$ (only for reversible)

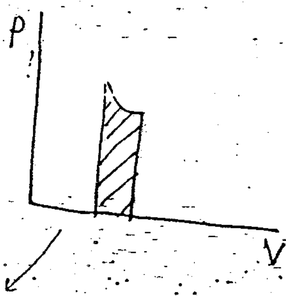
$\boxed{W = \int Pdv}$ Now flow or closed sys work



Area = Pdv

Pdv = work

$\boxed{\text{Work} = \text{Area}}$



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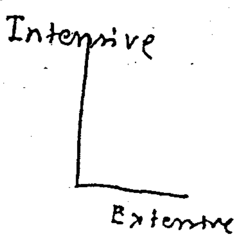


always –

* Area different

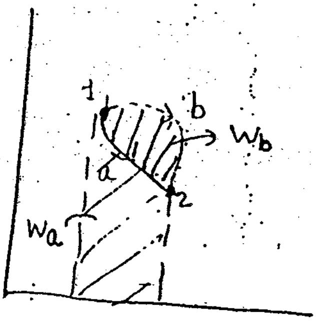
Work also different.

*

> Area under the curve when projected on volume axis gives closed system work transfer

① Through Path a and b end point are same but work transfer is not Same because areas are different for different path and hense work transfer depend on path follow by the process.

* Therefore work transfer is a path function and it is not a property and Hense it is in exact differential (đW or δW)



* work transfer – Not a property

So no exact differential

So we cant say dW

work depend on path

write as – đW or δW

(iv) Adiabatic process :- $(Q=0)$

A process is said to be adibatic process if there is no heat transfer from the system or to the system.

For an adibatic process $\boxed{PV^{\gamma}=C}$ where γ = adibatic index

$\boxed{\gamma > 1}$

$$Pv^{\gamma} = C$$

$$P = \frac{C}{V^{\gamma}}$$

$$P = C \cdot V^{-\gamma}$$

$$P_1 = C V_1^{-\gamma}$$

$$P_2 = C V_2^{-\gamma}$$

$$W = \int_{V_1}^{V_2} C \cdot V^{-\gamma} dV$$

$$W = C \int_{V_1}^{V_2} V^{-\gamma} dV$$

$$W = C \left[\frac{V^{-\gamma+1}}{-\gamma+1} \right]_{V_1}^{V_2}$$

$$W = \frac{C}{-\gamma+1} \left[V_2^{-\gamma+1} - V_1^{-\gamma+1} \right]$$

$$W = \frac{C}{-\gamma+1} \left[V_2^{-\gamma} \cdot V_2 - V_1^{-\gamma} \cdot V_1 \right]$$

$$W = \frac{1}{-\gamma+1} \left[C V_2^{-\gamma} \cdot V_2 - C V_1^{-\gamma} \cdot V_1 \right]$$

$$W = \frac{1}{-\gamma+1} \left[P_2 V_2 - P_1 V_1 \right]$$

$$W = \frac{-(P_1 V_1 - P_2 V_2)}{-(\gamma - 1)}$$

$$\boxed{W = \frac{P_1 V_1 - P_2 V_2}{\gamma - 1}}$$

(v) Polytropic Process :-

A process is said to be polytropic process if $\boxed{Pv^n = C}$ where :

n = polytropic index

Generally $n > 1$ and $n < \gamma$

$$\boxed{1 < n < \gamma}$$

Poly - many

Adiabatic	Polytropic
$Q = 0$	$Q \neq 0$ ✓
$W =$ ✓	$W =$ ✓
$P\gamma^{\gamma} = C$	$P.V^n = C$
air $= \gamma = 1.4$	$n > 1$
$\gamma > 1$	$n < \gamma$

In polytropic process there is both heat transfer and work transfer but in adiabatic process there is only work transfer. And polytropic work is —

$$\boxed{W = \frac{P_1V_1 - P_2V_2}{n-1}}$$

⟹ $\boxed{PV^k = C}$ Every process considered by this eqn

1) $\boxed{P = C}$

$PV^k = C$

$K = 0$

$P(V)^0 = C$

$P \times 1 = C$

$\boxed{P = C}$

2) $\boxed{PV = C}$

$PV^k = C$

$(P.V^k)^{\frac{1}{k}} = C^{\frac{1}{k}}$

$P^{\frac{1}{k}}.V^1 = \text{Const}$

$\boxed{K = \infty}$

$\boxed{V = C}$

3) $\boxed{T = \text{Const}}$

$PV = mRT$

$PV = C$

$PV^1 = C$

$K = 1$

4) $\boxed{\text{Adiabatic}}$

$PV^{\gamma} = C$

$\boxed{k = \gamma}$

5) $\boxed{\text{polytropic}}$

$PV^n = C$

$\boxed{n = k}$

$P = C \rightarrow k = 0$

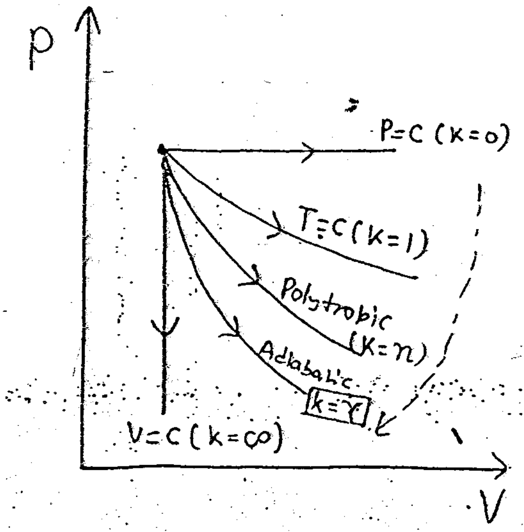
$T = C \rightarrow k = 1$

Polytropic $K = n$

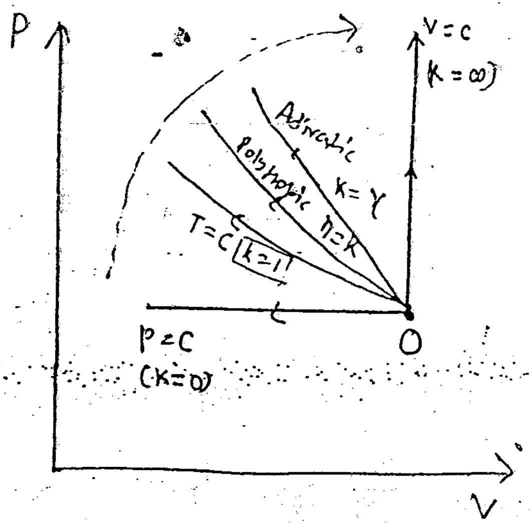
Adiabatic $K = \gamma$

$V = C \rightarrow K = \infty$

Represtion of various processes on P-V diagram :-



Expansion



Compression

⇒ Slope of isothermal curves on P-V diagram :-

$PV = mRT$

$T = \text{const.}$

$PV = C.$

$P\,dv + V\,dp = 0$

$P\,dv = -V\,dp$

$$\boxed{\frac{dP}{dV} = -\frac{P}{V}}$$

Slope of the isothermal curve on P-V $= -\dfrac{P}{V}$

⇒ Slope of adibatic Curve on P-V diagram :-

$$PV^{\gamma} = C$$

$$P[\gamma V^{\gamma-1} \cdot dV] + V^{\gamma} dP = 0$$

$$\gamma P \frac{V^{\gamma}}{V} dV = -V^{\gamma} dP$$

$$\frac{-\gamma P}{V} = \frac{dP}{dV}$$

$$\boxed{\frac{dP}{dV} = \gamma\left(-\frac{P}{V}\right)}$$

$$\boxed{\text{Slope of adiablic curve on P-V diagram} = \gamma\left(-P/V\right)}$$

slope of adiabatic curves = γ (slope of isothermal curves)

$$\frac{\text{Slop of adibatic}}{\text{Slop of isothermal}} = \gamma \qquad \boxed{\gamma > 1}$$

$$\boxed{\frac{\text{Slop of adibatic}}{\text{slope of isothermal}} > 1}$$

✡ Ideal Gas eqution for various processes :-

1) Constant volume processes :- (Charls law)

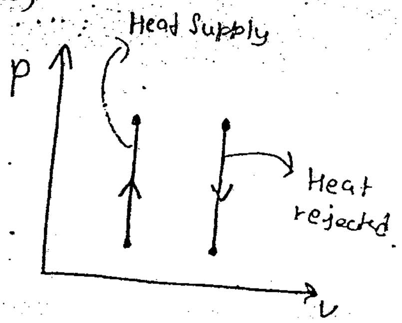
$$PV = mRT$$

$$P = \frac{mR}{V} T$$

$$P = cT$$

$$\frac{P}{T} = \text{Const.}$$

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} \Rightarrow \boxed{\frac{P_2}{P_1} = \frac{T_2}{T_1}}$$



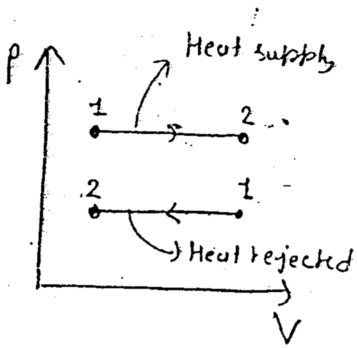
2) Constant Pressure process :-

$P = C$

$PV = mRT$

$V \propto T$

$$\boxed{\frac{V_2}{V_1} = \frac{T_2}{T_1}}$$



3) Constant temp or isothermal process :-

$T = \text{Const}$

$PV = mRT$

$$\boxed{PV = \text{Const.}}$$

$$\boxed{P_1 V_1 = P_2 V_2}$$

$$\boxed{\frac{P_1}{P_2} = \frac{V_2}{V_1}}$$

4) Adibatic process :-

$PV^{\gamma} = C$

$$\boxed{P_1 V_1^{\gamma} = P_2 V_2^{\gamma}}$$

$P = \frac{mRT}{V}$

$\frac{mRT}{V} V^{\gamma} = C$

$T \cdot V^{\gamma-1} = \frac{C}{mR}$

$TV^{\gamma-1} = \text{Const}$

$$\boxed{T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}}$$

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

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

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

$$\boxed{\begin{aligned} P_1 V_1^{\gamma} &= P_2 V_2^{\gamma} && \text{— PV} \\ T_1 V_1^{\gamma-1} &= T_2 V_2^{\gamma-1} && \text{— TV} \\ \frac{T_2}{T_1} &= \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} && \text{— TP} \end{aligned}}$$

Valid for an ideal gas undergoing adiabatic process.

5) Polytropic Process :-

$$\boxed{P_1 V_1^n = P_2 V_2^n}$$

Valid for an ideal gas undergoing polytropic process.

$$\boxed{T_1 V_1^{n-1} = T_2 V_2^{n-1}}$$

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

Question

Ⓠ.1 A system undergoes three process as shown in fig.

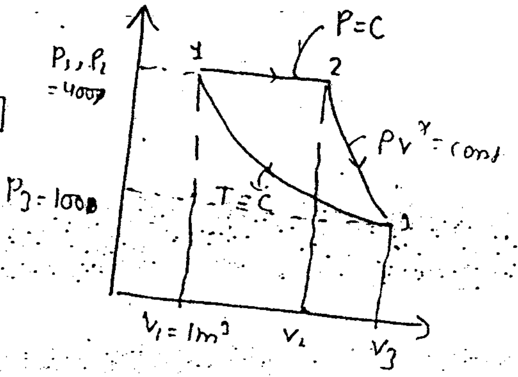
1−2 is isobaric process

2−3 is adiabatic process $\boxed{\gamma = 1.4}$

3−1 is isothermal process $\boxed{PV = C}$

ⓐ then find V_2

ⓑ net work transfer



Ans :- ⓐ 3−1 (T = C)

$P_3 V_3 = P_1 V_1$

$100 \times V_3 = 400 \times 1$

$V_3 = 4\,m^3$

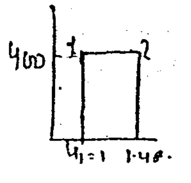
2−3 (PV^γ)

$P_2 V_2^\gamma = P_3 V_3^\gamma$

$400 \times V_2^{1.4} = 100 \times 4^{1.4}$

$$\boxed{V_2 = 1.486\,m^3}$$

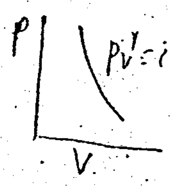
ⓑ $W_{net} = W_{12} + W_{23} + W_{31}$



$W_{12} = 400(1.486 - 1)$

$$\boxed{W_{12} = 194.4\,kJ}$$

2−3

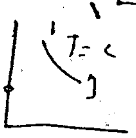


$W_{23} = \frac{P_2 V_2 - P_3 V_3}{\gamma - 1}$

$= \frac{400 \times 1.486 - 100 \times 4}{1.4 - 1}$

$$\boxed{W_{23} = 486\,kJ}$$

3−1



~~$W = P_1 V_1 \log \frac{V_3}{V_1}$~~

$W = P_i V_i \ln \frac{V_f}{V_i}$

$$\boxed{W = P_3 V_3 \ln \frac{V_1}{V_3}}$$

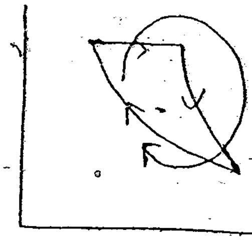
$$\boxed{W_{31} = -554.5\,kJ}$$

③

Net work = $W_{12} + W_{23} + W_{31}$

= 194.4 + 486 + (-554.5)

$\boxed{W_{net} = 125.8 \text{ KJ}}$ Ans.



If Cycle clockwise then net work is +ve. Becaus these power generation Cycle

Note :-

Net work in a Cycle is equal to Area of closed region on P-V diagram All clock wise Cycle on P-V diagram are power producing Cycles. And All anti clock wise Cycle on P-V diagram are power absorbing cycle so (-ve) work come.

Q An ideal gas is heated at constant volume untill its temp. is three times orignal temp. it is then expanded isothermally till it reaches its orignal pressure the gas is than clold at constant pressure till it is restored to the orginal state. represent the Cycle on P-V diagram and determine the network/kg of gas Express ur ans. in terms ~~of~~ R.

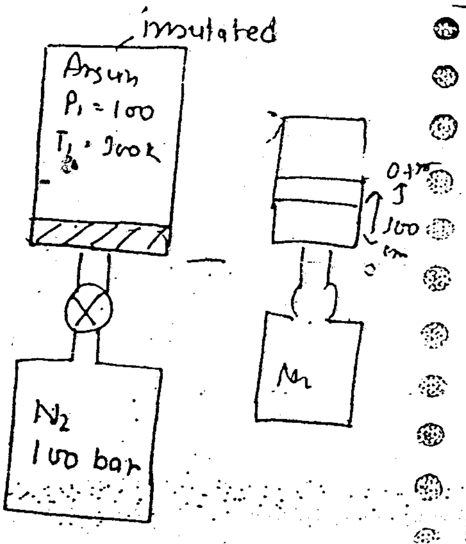
Ans: $\boxed{W = 453R}$

*Q An insulated verticle Cylinder contains ~~20~~ 0.1 kg of argon with the help of friction less non conduting piston as shown in figure. the mass of the piston is 5 kg and it initally rists on the bottom of the cylinder. Cylinder is conceted to ~~tank~~ nitrogen tank at 100 bar to a pipe line filled with a ~~to~~ valve the valve is open and nitrogen slowly enters the Cylinder during this process the piston is lifted to a hight of 10 cm by nitrogen gas the intial pressure and temp of argon are 300 K and 100 KPa respectively. the final temp of argon is 320 K take R = 0.208 KJ/KgK and $\gamma = 1.67$? find (i) work done by argon (ii) work done by nitrogen gas?

$$W = \frac{P_1V_1 - P_2V_2}{\gamma - 1} = \frac{mRT_1 - mRT_2}{\gamma - 1}$$

$$W_{argon} = \frac{mR(T_1 - T_2)}{\gamma - 1} = \frac{0.1 \times 0.208(300 - 320)}{1.67 - 1}$$

$$\boxed{W_{argon} = 0.62\ KJ}$$



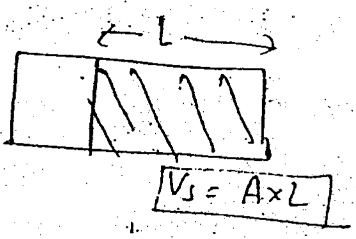
As the cylinder is insulated and piston is non conducting therefor argon gas undergoes adiabatic compression

total work done by N_2 gas = work done in raising piston + work done in compression system

Piston work = mgh

$$= \frac{5 \times 9.81 \times 0.1}{1000}\ KJ = 0.0049\ kJ$$

$$\boxed{N_2\,work = 0.0049 + 0.621 = 0.624925}$$



Q. An engin cylinder has a piston of area 0.12 m^2 and contain a gas a pressure of 1.5 MP The gas Expand according to a process which is represented by a straight line on P-V diagram the final pressure is 0.15 MP calculate the work done by the gas. If the stroke length is 0.3 m

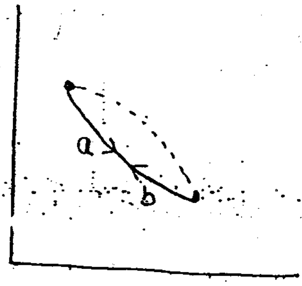
Condition for appling the eqn $W = \int P dv$

Condition are

(i) A System must be a closed system

(ii) work should to crossed the boundry

**(iii) A Process must be a reversible processes

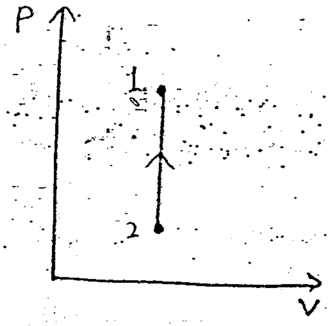


Work transfer in various non flow processes :-

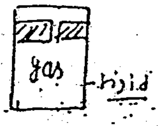
(i) Constant volume or isometric or isochroric proces :-

Whenever used rigid container means constant volume processes. Here $\boxed{V=C}$

$$W = \int P dV$$
$$V = C$$
$$dV = 0$$
$$\boxed{W = 0}$$



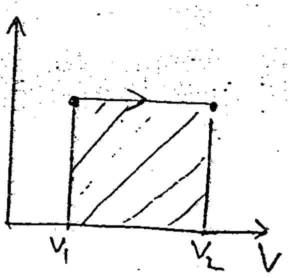
Rigid container
└ volume constant proces

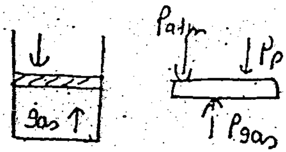


(ii) Constant Pressure or isobaric or isopiestic proces :-

$W = \text{Area} = P l$ $\boxed{P=C}$

$$W = \int_{V_1}^{V_2} P dv$$
$$W = P \int_{V_1}^{V_2} dV$$
$$\boxed{W = P[V_2 - V_1]}$$





$P_p = \frac{W}{A}$

Equilibrium

$P_{atm} + P_p = P_{gas}$

In this pressure constant then find work.

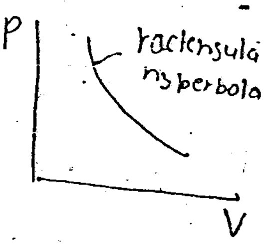
(iii) Constant temp. or Isothermal process :-

Here $\boxed{T = C}$

In ideal gas $PV = mRT$

$$\boxed{PV = C}$$

for PV=C

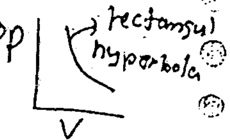


In iso thermal Ideal gas -

$P\dot{V} = mRT$

$$\boxed{PV = C}$$

PV=C →



$$PV = mRT = C$$

$$PV = C \Rightarrow P = \frac{C}{V}$$

$$P_1V_1 = P_2V_2 = C$$

$$W = \int_{V_1}^{V_2} P\,dv$$

$$W = \int_{V_1}^{V_2} \frac{C}{V}\,dv \Rightarrow C\int_{V_1}^{V_2} \frac{dV}{V}$$

$$W = C\left[\ln V_2 - \ln V_1\right]$$

$$\boxed{W = C \ln \frac{V_2}{V_1}}$$

$$\boxed{W = P_1V_1 \ln \frac{V_2}{V_1}}$$

$$\boxed{W = mRT \ln \frac{V_2}{V_1}}$$

Ans :-

W = Area

$= \frac{1}{2}(1500+150)(V_2-V_1)$

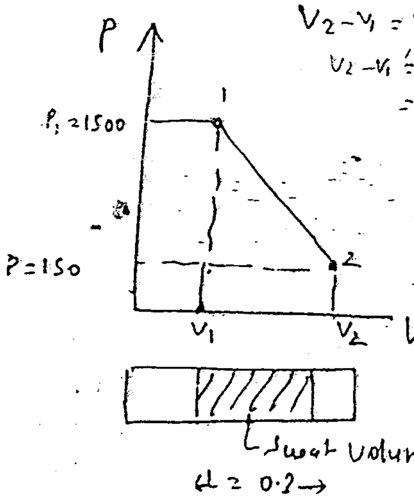
$= \frac{1}{2}(1650)(0.036)$

$\boxed{W = 29.7\ KJ}$

$V_2 - V_1 = V = AL$

$V_2 - V_1 = 0.12 \times 0.3$

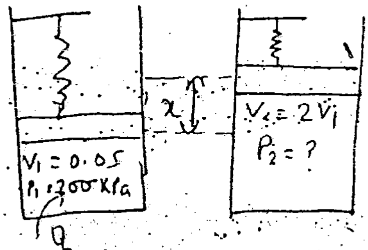
$= 0.036\ m^3$



* Q. A Piston cylinder device contains 0.05 m³ of a gas initially at 200 KPa At this state a linear spring which have spring constant of 150 KN/m Just touching the piston what exerts no forces on it now ~~it is trans~~ heat is transfer to the gas cause the piston to rise and to compressed spring untill the volume inside the cylinder doubles if the cross section area of the piston is 0.25 m² find final pressure inside the cylinder

(ii) what is the workdone by the gass

An :-



Vol = A×L

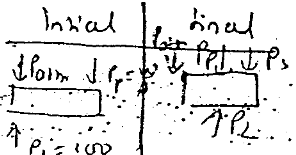
$V_2 - V_1 = A \times x$

$x = \frac{V_2 - V_1}{A}$ $x \Rightarrow \frac{2V_1 - V_1}{A}$

$x = \frac{V_1}{A}$

$x = \frac{0.05}{0.25}$

$\boxed{x = 0.2m}$



$P_{atm} + P_p = 200$

$P_{atm} + P_p + P_s = P_2$

$200 + P_s = P_2$

$F_s = Kx$

$P_s = \frac{F_s}{A} = \frac{Kx}{A}$

$P_s = \frac{Kx}{A} = \frac{150 \times 0.2}{0.25}$

$\boxed{P_s = 120\ kPa}$

$P_2 = 200 + 120$

$\boxed{P_2 = 320\ KPa}$

pressure final

ⓑ work done :-

work done by gas equal work done raise the piston + work done compressing spring

Only piston then work done

$W_1 = P(V_2 - V_1)$

$W = 200(2V_1 - V_1)$

$= 10\ KJ$

spring

$W_{spring} = \frac{1}{2}Kx^2$

$= \frac{1}{2} \times 150 \times 0.2^2$

$W_{spring} = 3KJ$

$W_{total} = 10 + 3 = \underline{13\ KJ}$

$$P_2 = 200 + P_S$$

$$P_S = 200 + \frac{Kx}{A}$$

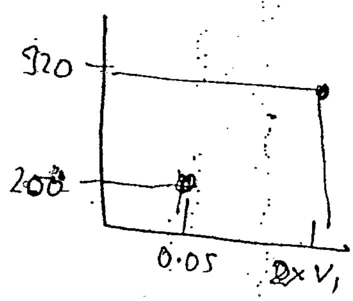
$$x = \frac{V_i - V_1}{A} = \frac{\Delta V}{A}$$

$$P_3 = 200 + \frac{K}{A} \cdot \frac{\Delta V}{A}$$

$$P_s = 200 + \frac{K}{A^2} \cdot \Delta V$$

$$W = (200 + 320)$$

$$W = 0.1 - 0.05$$



29-7-2011

Energy transfer due to temp. Difference

Energy transfer due to temp. difference is known as heat transfer.

$\boxed{Q \propto \Delta t}$

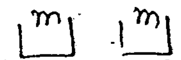
$\boxed{Q \propto m}$

$Q \propto m \Delta t$

$\boxed{Q = m c \Delta t}$ C = Specific heat

$m = 1$; $\Delta t = 1$

$\boxed{Q = C}$

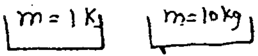


$t_i = 20$ $t_i = 20$

$t_f = 40$ $t_f = 80$

$\Delta t = 20$ $\Delta t = 60$ so

$\boxed{\Delta t \propto Q}$ —



$t_i = 20$ $t_i = 20$

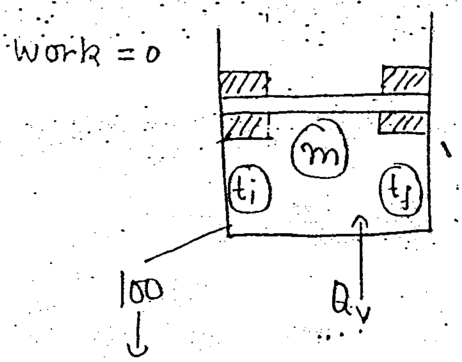
$t_f = 40$ $t_f = 40$

$\boxed{Q \propto m}$ —

Specific heat :-

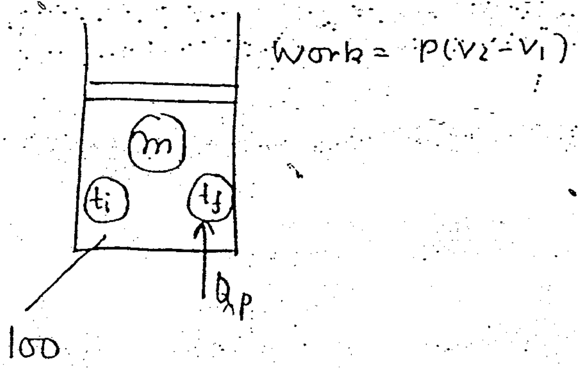
It is the amount of heat required to raise the temp. of unit mass of substance to unit degree temp diffrence.

V = C



Only incrse temp.

P = C



incrse temp + Work done

So $Q_p > Q_v$

$m C_p \Delta t > m C_v \Delta t$

$\boxed{C_p > C_v}$

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

$\boxed{\frac{C_p}{C_v} > 1}$

"Specific heat at constant ~~volume~~ Presure Cp is greater than specific heat of Constant volume Cv because Cp includes Internal energy + external work wheres Cv includes Internal energy only."

First law of thermodynamic :-

(Law of Conservation of energy)

1825 – Mayer
1835 – Joule

Statement :-

For a closed system undergoing a cycle net heat transfer is equal to net work transfer.

$$\boxed{\sum Q = \sum W}$$

Valid for a Cycle in closed system

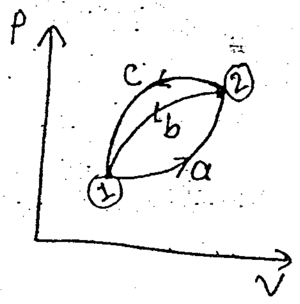
Consequences of first law of thermodynamic :-

(I) Heat transfer is path function :-

$$(\text{đ}Q)_{1a2} + (\text{đ}Q)_{2b1} = (\text{đ}W)_{1a2} + (\text{đ}W)_{2b1}$$

$$-(\text{đ}Q)_{1a2} \pm (\text{đ}Q)_{2c1} = -(\text{đ}W)_{1a2} \pm (\text{đ}W)_{2c1}$$

$$(\text{đ}Q)_{2b1} - (\text{đ}Q)_{2c1} = (\text{đ}W)_{2b1} - (\text{đ}W)_{2c1}$$



$$(\text{đ}W)_{2b1} \neq (\text{đ}W)_{2c1}$$

$$(\text{đ}W)_{2b1} - (\text{đ}W)_{2c1} \neq 0$$

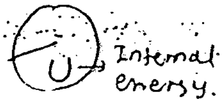
$$(\text{đ}Q)_{2b1} - (\text{đ}Q)_{2c1} \neq 0$$

$$(\text{đ}Q)_{2b1} \neq (\text{đ}Q)_{2c1}$$

through path b and c end point are same but heat transfer is not same therefore <u>Heat transfer is a Path function.</u>

⇒ **Important point w.r.t heat transfer and work transfer :-**

ⓐ Both are path functions.
ⓑ Both are in exact Differentials.
ⓒ Both are not properties
ⓓ Both are boundry phenomina.



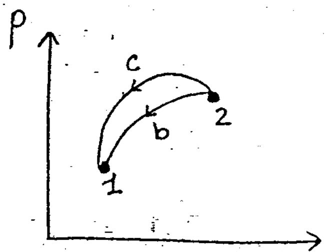
Internal Energy not heat transfer

Ⅱ Energy is a property :-

$$(\text{đ}Q)_{2b1} - (\text{đ}Q)_{2c1} = (\text{đ}W)_{2b1} - (\text{đ}W)_{2c1}$$

$$(\text{đ}Q)_{2b1} - (\text{đ}W)_{2b1} = (\text{đ}Q)_{2c1} - (\text{đ}W)_{2c1}$$

$$(\text{đ}Q - \text{đ}W)_{2b1} = (\text{đ}Q - \text{đ}W)_{2c1}$$



Cycle.

The quantity $(\text{đ}Q - \text{đ}W)$ is same for both path b and c and hense it does not depend on path it depend only end point (2-1) therfor $(\text{đ}Q - \text{đ}W)$ must be an property.

And this property is known as energy (E)

$$(\text{đ}Q - \text{đ}W)_{2b1} = (\text{đ}Q - \text{đ}W)_{2c1} = dE$$

$$(\text{đ}Q - \text{đ}W) = dE$$

$$\boxed{(\text{đ}Q = dE + \text{đ}W)}_{2b1}$$ For (Process) for [reversible or irreversible]

This is the first law of thermo for closed system undergoing Process

Note – The equation

$$\boxed{đQ = dE + Pdv}$$

is the first law of thermo for closed system undergoing reversible process.

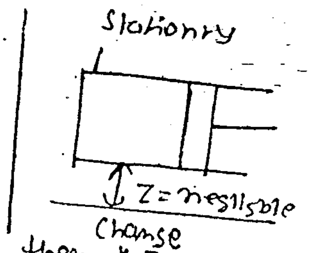
Because $\boxed{đW = Pdv}$ valid for reversible process.

⇒ $$E = \underbrace{K.E + P.E}_{\text{macroscobic}} + \underbrace{U}_{\text{microscobic}}$$

$$dE = d(KE) + d(PE) + dU$$

if K.E and PE changes are

$$dE = dU$$



then K.E = 0
P.E = 0

Genraly K.E and P.E changes are negligible for a closed stationary system and hences

$$\boxed{dE = du}$$

therfor

$$đQ = dE + đW$$

$$\boxed{đQ = du + đW}$$

Is the first law of thermo for closed stationary system undergoing a process.

Internal Energy (U) :-

It is the energy associated with molecules. It is an extensive property. and It is generly expresed in KJ. Specific Internal energy $\boxed{(u) = \frac{U}{m}}$ - It is insentive property

$$u = \frac{kJ}{kg}$$

$u = \frac{U\,(\text{extensive})}{m\,(\text{extensive})}$

(u = intensive)

(III) Energy ~~is~~ of an isolated system is always constant :-

In isolated $\begin{cases} m \times \\ E \times \end{cases}$ $\quad W = 0$, $Q = 0$

$$dQ = dE + dW$$

$$0 = dE + 0$$

$$dE = 0$$

$$E_2 - E_1 = 0$$

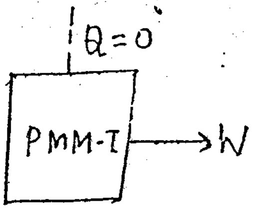
$$\boxed{E_2 = E_1}$$

ps (continous)

(IV) Perpetual Motion machine of first kind (PMM-I) is Impossibe

↳ (cycle)

There can be no machine which develop work continously without absorbing some other form of energy if such a machine is develop then it would voilet first law of thermodynamic.



$\because$ Here W done without Q

but in first law $\sum \overset{}{\underset{0}{Q}} = \sum W \rightarrow$ For cycle

But So $\boxed{\sum W = 0}$

but here work done so it is not possible for cycle.

Enthalpy :(H)(Property)

In thermo dynamics, the term U+PV appers frequently and for convineans this quantity is taken as enthalpy (H)

$$\boxed{H = PV + U}$$

U → Property
PV → Property
So - (H: property)

enthalpy is an extensive property and its unit is $\boxed{H = KJ}$

Spacific enthalpy $\underset{\text{intensive}}{(H)} = \frac{H}{m}$ - extensive

Note :-

For an ideal gas -

$du = mC_v\,dT$

$dH = mC_p\,dT$

$U = f(T)$ —— Joules law

Heat transfer in various non flow of closed syst processes :- [Closed system]

(i) Constant Volume process :-

$dQ = dU + P\,dV$ (Used for reversible process)

$V = C \Rightarrow dV = 0$

$dQ_v = dU + 0$

$$* \boxed{dQ_v = dU}$$

* If ideal gas then

$\boxed{dQ = mC_v\,dT}$

Heat transfer in constant volume closed system equal to internal energy.

(ii) Constant Pressor process :-

$$\text{đ}Q = dU + PdV$$

$$\text{đ}Q_p = dU + d(PV)$$

$$\text{đ}Q_p = d(U+PV)$$

$$* \boxed{\text{đ}Q_p = d(H)}$$

$H=(U+PV)$

if ideal gas than

$\boxed{\text{đ}Q_p = mC_p\Delta t}$

For ideal gas

Heat transfer in constant pressor closed system process is equal to enthalpy. ~~TO show that for an ideal gas.~~

✡ To show that $C_p - C_v = R$ for ideal gas :-

we know $H = U+PV$

$$dH = dU + d(PV)$$

For an ideal gas

$$mC_p dt = mC_v dt + d(mRT)$$

$$mC_p dt = mC_v dT + mR dt$$

$$C_p = C_v + R$$

$$\boxed{C_p - C_v = R}$$

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

$$C_p = \gamma C_v$$

$$C_p - C_v = R$$

$$\gamma C_v - C_v = R$$

$$C_v(\gamma - 1) = R$$

$$\boxed{C_v = \frac{R}{\gamma - 1}}$$

$$\boxed{C_p = \frac{\gamma R}{\gamma - 1}}$$

For only air

$C_p = 1.005 \frac{kJ}{Kg-k}$

$C_v = 0.718$ kJ/kg-k

$R =$ kJ/kg-k

$\gamma = 1.4$

(iii) Constant temp. process (isothermal process) :-

$$dQ = dU + dW$$

ideal gas undergoing isothermal process

$$U = f(T)$$

$$T = \text{Constant}$$

$$U = \text{Constant} \quad \boxed{dU = 0}$$

$$dQ = 0 + dW$$

$$\boxed{dQ = dW}$$

For an ideal gas undergoing isothermal process heat transfer is equal to work transfer

(iv) Adibatic process :-

In adibatic process no heat transfer $\boxed{Q = 0}$

(v) Polytropic process :-

$$dQ = dU + dW$$

$$dQ = mc_v\, dT + \frac{P_1V_1 - P_2V_2}{n-1}$$

$$dQ = mc_v(T_2 - T_1) + \frac{P_1V_1 - P_2V_2}{n-1}$$

$$dQ = \frac{mR(T_2 - T_1)}{\gamma - 1} + \frac{P_1V_1 - P_2V_2}{n-1}$$

$$dQ = \frac{P_2V_2 - P_1V_1}{\gamma - 1} + \frac{P_1V_1 - P_2V_2}{n-1}$$

$$\therefore dQ = \frac{P_1V_1 - P_2V_2}{n-1} - \frac{P_1V_1 - P_2V_2}{\gamma - 1}$$

$$dQ = (P_1V_1 - P_2V_2)\left[\frac{1}{n-1} - \frac{1}{\gamma-1}\right]$$

$$dQ = P_1V_1 - P_2V_2\left[\frac{(\gamma-1)-(n-1)}{(n-1)\ (\gamma-1)}\right]$$

$$dQ = \frac{P_1V_1 - P_2V_2}{n-1} \times \frac{\gamma-n}{\gamma-1}$$

$$\boxed{dQ = \frac{\gamma-n}{\gamma-1} \times W_{poly}}$$

Polytropic's Specific Heat :- (C_{poly})

$$dQ_{poly} = m\,C_{poly}\,dT \quad \text{——} \quad Ⓐ$$

$$dQ_{poly} = \frac{\gamma-n}{\gamma-1} \times \frac{P_1V_1 - P_2V_2}{n-1}$$

$$dQ_{poly} = \frac{\gamma-n}{\gamma-1} \times \frac{mRT_1 - mRT_2}{n-1}$$

$$dQ_{poly} = \frac{\gamma-n}{\gamma-1} \times \frac{mR\,(T_1-T_2)}{n-1}$$

$$\frac{R}{\gamma-1} = C_V$$
$$dT = T_2 - T_1$$
$$(-dT) = (T_1 - T_2)$$

$$dQ_{poly} = \frac{\gamma-n}{n-1} \times m\,C_V\,(-dT)$$

$$dQ_{poly} = \frac{n-\gamma}{n-1}\,m\,c_v\,dT$$

$$dQ_{poly} = m\left[\frac{n-\gamma}{n-1}C_V\right]\cdot dT$$

By Ⓐ * $$\boxed{C_{poly} = \frac{n-\gamma}{n-1}\cdot C_V}$$

$$C_{poly} = \left(\frac{n-\gamma}{n-1}\right) \cdot C_v$$

$n > 1$; $n < \gamma$

when heat supplied $\boxed{C_{poly} = -ve.}$

if heat supply in Const. Volu, Const Pressur Cp and Cv alway possitive.

$Q = m c_p \Delta T$
(+ve) (+ve) (+ve)

$\boxed{C_p \text{ and } C_v = (+ve) \text{ alwa.}}$

observation –

If $dQ_{poly} = \frac{\gamma - n}{\gamma - 1} \times W_{poly}$,

If when $\gamma = 1.4$, $n = 1.2$

$$dQ_{poly} = \frac{1.4 - 1.2}{1.4 - 1} \times W_{poly}$$

$$dQ_{poly} = \frac{0.2}{0.4} \times W_{poly}$$

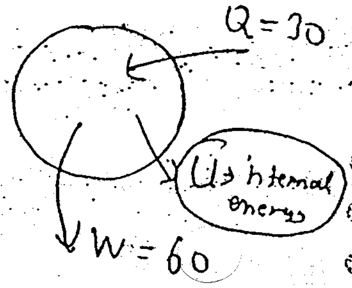
$$dQ_{poly} = \frac{W_{poly}}{2}$$

$$\boxed{W_{poly} = 2 \times dQ_{poly}}$$

But $W_{poly} = 2 \times 30$ if $Q = 30$

$W = 60$

If



For $n > 1$, $n < \gamma$

~~Sa~~ Cpoly is negative, ~~this is beca~~ that is through heat is supplied there is a reduction in temp. this is because for ~~a~~ such a polytropic process ~~heat~~ work transfer is more than heat transfer and this excess work output come from internal energy of the system and hense there is a reduction in temperature.

130

To show that $P \cdot V^{\gamma} = C$ for adibatic process :-

— reversible

$$đQ = dU + PdV$$

| Pdv used then reversible process used.

ideal gas undergoing adiabatic process

$$dU = mc_v dT \quad ; \quad đQ = 0$$

$$0 = mc_v\, dT + P dv$$

$$Pdv = -mc_v dT \quad \text{— ①}$$

$$H = U + PV$$

$$dH = \underbrace{dU + Pdv} + Vdp$$

$$dH = dQ + Vdp$$

$$mc_p dT = 0 + Vdp$$

$$mc_p dT = Vdp \quad \text{— (II)}$$

$$\frac{②}{①} \quad \frac{mc_p \Delta T}{-mc_v \Delta T} = \frac{Vdp}{Pdv} \qquad \left[\frac{c_p}{c_v} = \gamma\right]$$

$$-\gamma = \frac{Vdp}{Pdv}$$

$$-\gamma\frac{dv}{V} = \frac{dp}{p} \Rightarrow \frac{dp}{p} + \gamma\frac{dv}{V} = 0$$

$$\ln p + \gamma \ln v = \ln c$$

$$\ln p + \ln v^{\gamma} = \ln C$$

$$\ln pv^{\gamma} = \ln C$$

$$\boxed{pv^{\gamma} = c}$$

| This eqn is valid for an ideal gas undergoing reversible adibatic process

these only for ideal gas and reversible process.

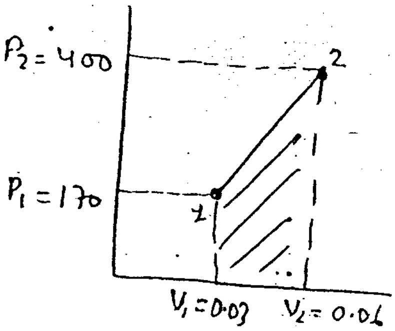
IAS - 40marks

Q. A fluid is contain in a cylinder by a spring loaded friction less piston so that the presure in the fluid is a linear function of volume that is $P = a + bV$, where a, b are constant internal energy of the fluid is given by $U = 34 + 3.15PV$ wher U is in kJ and P in kPa V in m^3 if the fluid is changes from inital state from $P_1 = 170$ kPa $V_1 = 0.3\ m^3$ to a final state of $P_2 = 400$ kPa $V_2 = 0.6\ m^3$ then find the magnitude and direction of heat and work transfer.

Ans. :-

$$W = \frac{1}{2}(170+400)(0.06-0.03)$$

$$W = 8.55\ kJ$$



$$dQ = dU + dW$$

$$dU = U_2 - U_1$$

$$U_2 = 34 + 3.15 P_2V_2$$

$$U_1 = 34 + 3.15 P_1V_1$$

$$dU = (U_2 - U_1) = 3.15(P_2V_2 - P_1V_1)$$

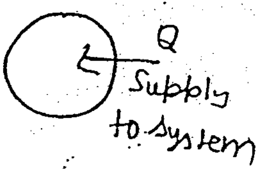
$$dU = 59.9\ kJ$$

Magnitude Q = 68.05

Direction = Q = +ve so

$$dQ = dU + dW$$

$$dQ = 59.9 + 8.55\ kJ$$



magnitude $\boxed{dQ = 68.05\ kJ}$

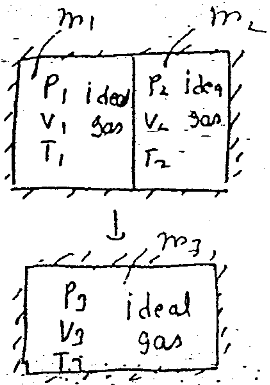
Q is +ve means ~~wor~~ heat is supplied to the system

Direction →

Q An insulated rigid pressure vessel is divided into two parts by a partician first part of the vesle is occupide by an ideal gas at a pressure P_1, volume V_1, temp T_1 the other ~~both~~ part is occupide by the same ideal gas but at pressure P_2, volume V_2 and temp T_2 suddenly the partian is removed and two portion mixed with each other show that final pressure P_3 and final temp T_3 are given by —

$$P_3 = \frac{P_1V_1 + P_2V_2}{V_1 + V_2}$$

$$T_3 = \frac{P_1V_1 + P_2V_2}{\left(\frac{P_1V_1}{T_1}\right) + \left(\frac{P_2V_2}{T_2}\right)}$$



Ans. 1 Volume are not changed when mixing because rigid body here

$$\boxed{V_3 = V_1 + V_2}$$

$$m_3 = m_1 + m_2$$

$$\frac{P_3V_3}{RT_3} = \frac{P_1V_1}{RT_1} + \frac{P_2V_2}{RT_2}$$

$$T_3 = \frac{\boxed{P_3}V_3}{\frac{P_1V_1}{T_1} + \frac{P_2V_2}{T_2}} \quad \text{—— Ⓐ}$$

$$dQ = dU + dW$$

$$0 = dU = 0$$

$$dU = 0$$

$$U_f - U_i = 0$$

$$U_f = U_i$$

$$U_3 = U_1 + U_2$$

$$m_3C_vT_3 = m_1C_vT_1 + m_2C_vT_2$$

$$\frac{m_3RT_3}{\gamma-1} = \frac{m_1RT_1}{\gamma-1} + \frac{m_2RT_2}{\gamma-1}$$

$$P_3V_3 = P_1V_1 + P_2V_2$$

$$\boxed{P_3 = \frac{P_1V_1 + P_2V_2}{V_1 + V_2}}$$

Put in Ⓐ

$$\boxed{T_3 = \frac{P_1V_1 + P_2V_2}{\frac{P_1V_1}{T_1} + \frac{P_2V_2}{T_2}}}$$

$dQ = 0$

isolated

$V = 0$

so

$dW = 0$

$V_3 = V_1 + V_2$

* Q.C A fluid system contain in a piston cylinder machine pases through a Compelt cycle of four proceses the Summeon of all heat trasfers is −340 KJ per cycle the system complites 200 Cycle/min Complete the following table and also find net work transfer in KW

Process	Q (KJ/min)	W (KJ/min)	dU
1-2	0	4340	
2-3	42000	0	
3-4	−4200		−73200
4-1			

−105806 −141340 35540

Ans. Process (1-2)

$$dQ_{1-2} = dU_{1-2} + dW_{1-2}$$

$$0 = dU_{12} + 4340$$

$$\boxed{dU = -4340}$$

process (2-3)

$$dQ_{23} = dU_{23} + dW_{23}$$

$$42000 = dU_{23} + 0$$

$$\boxed{dU_{23} = 42000}$$

Process (3-4)

$$dQ_{34} = dU_{34} + dW_{34}$$

$$-4200 = -73200 + dW_{23}$$

$$\boxed{dW_{23} = 69000}$$

Process (4-1)

$$\sum Q = -340\ \text{KJ/cycle} \times 200\ \text{cycle/min}$$

$$\sum Q = -68000\ \text{KJ/min}$$

$$\sum Q = Q_{12} + Q_{23} + Q_{34} + Q_{41}$$

$$-68000 = 0 + 42000 + 4200 + Q_{41}$$

$$\boxed{Q_{41} = -105806}$$

But for cycle

$$\sum Q = \sum W$$

$$-68000 = W_{12} + W_{23} + W_{34} + W_{14}$$

$$\boxed{W_{14} = -141340}$$

$$dQ_{41} = dU_{41} + dW_{41}$$

$$-105806 = dU_{41} + (-141340)$$

$$\boxed{dU_{41} = 35540}$$

$$\sum W = W_{net}$$

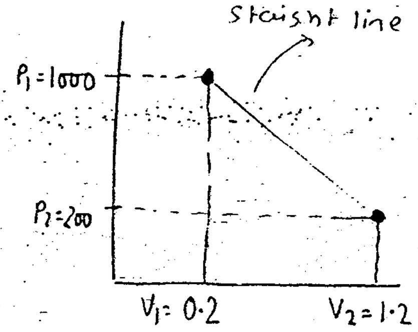
$$W_{net} = -68000\ \text{KJ/min}$$

$$= -68000\ \text{KJ}/60\ \text{sec}$$

$$\boxed{W_{net} = -1133.3\ \text{KW}}$$

2012 ****

*Q.) A gas of mas 1.5 kg undersoes a reversible expansion which follows the relation ship ~~E~~ $P = a + bV$ wher a, and b are constant the initial and final presesor are 1000 kPa and 200 kPa respectivily and corrosponding volums are $0.2\ m^3$ and $1.2\ m^3$ this specific internal energy of the gas is given by $(1.5\,Pv - 85)$ kJ/kg where P is in kPa and v is in m^3/kg calculte the heat transfer and the maximum internal energy attenc during the process ?



$P = a + bV \rightarrow$ linear eqn so Staight line come

Ans :- $W = \text{Area}$

$= \frac{1}{2}(1000+200)(1.2-0.2)$

$\boxed{W = 600\ kJ}$

$v = \frac{V}{m}$

$U = mu$

$U = (1.5\,Pv - 85)$ kJ/kg

$mu = (1.5 \cdot mv \cdot P - 85m)$ kJ

$\boxed{U = (1.5\,PV - 1.5 \times 85)\ kJ}$

$\boxed{U = 1.5\,PV - 127.5}$

$dU = U_2 - U_1$

$U_2 = 1.5\,P_2V_2 - 127.5$

$U_1 = 1.5\,P_1V_1 - 127.5$

$dU = U_2 - U_1 = 1.5(P_2V_2 - P_1V_1)$

$U_2 - U_1 = dU = 1.5(P_2V_2 - P_1V_1)$

$dU = 1.5[200 \times 1.2 - 1000 \times 0.2]$

$\boxed{dU = 60\ kJ}$

$dQ = dU + dW$

$dQ = 60 + 600 = 660\ kJ$

$\boxed{dQ = 660\ kJ}$ A.

For maximum internal enersy :-

$U = (1.5\,PV - 127.5)$

$P = a + bV$

$U = 1.5(a + bV)V - 127.5$

$U = 1.5(aV + bV^2) - 127.5$ —— Ⓐ

For max $\frac{dU}{dV} = 0$

$\frac{dU}{dV} = 1.5[a(1) + b(2V)] - 0 = 0$

$1.5[a + 2bV] = 0$

$V = -\frac{a}{2b}$

$V = \frac{-1160}{2 \times (-800)}$

$\boxed{V = 0.725\ m^3}$ put in Ⓐ

$P_1 = a + bV_1$

$P_2 = a + bV_2$

$b = \frac{1000 - 200}{0.2 - 1.2}$

$b = -800$

$a = 1160$

$U = 1.5(aV + bV^2) - 127.5$

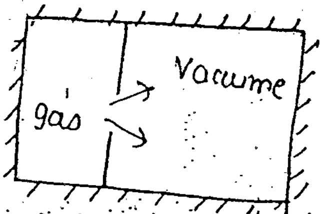
$U = 1.5(1160 \times 0.725 + (-800)\,0.725^2) - 127.5$

$\boxed{U_{max} = 503.25\ kJ}$ A

Free expansion :- ($W=0$) [For real gas and ideal also] [and irreversible]

The expansion of a gas againt vaccume is known as free expansion

As the gas is expanding ascint vaccume (no resistance) Free expansion
Work = 0



*** Analysis — $dU = 0$

$U_f - U_i = 0$

$U_f = U_i$

$dQ = dU + dW$

$0 = dU + 0$

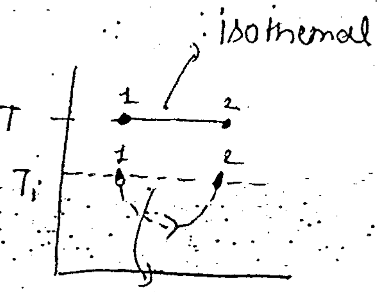
$\boxed{dU = 0}$

if an ideal gas undergoes free Expansion then

$U = f(T)$

$U_f = U_i \Rightarrow T_f = T_i$

Here $T_f = T_i$ but it not isothermal procees because Temp not consint



But it does not tem=c so does not isothermal

*** Let us assume that an ideal gas is undergoing free expansion we know that we the internal energy of an ideal gas is an function of temp. therefor for free expansion as $U_i = U_f \Rightarrow \boxed{T_i = T_f}$ it does not mean free expansion of an ideal gas is an isothermal process because during the process the temp. is not constant through out. So initial temp. is = final temp.

*(II)

$H = U + PV$

$H = f(t) + \cancel{n}RT$

$\boxed{H = f(t)}$

enthalpy is also function of temp.

$T_f = T_i$

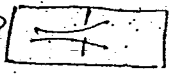
so

$\boxed{H_f = H_i}$

*(I)

When free expan the total enery Constant

*→



gas expand

PE = incresed

m×g×h

h = incresed

but K.E decresed

$V^2 \propto T$

Temp-decresed

But in expansion last temp incresed

we know that H = U + PV and for an ideal gas

$$H = U + PV$$

$$f(T) + mRT$$

$$\boxed{H = \phi(T)}$$

For an ideal gas enthalpy is a function of temp and hense during free expansion as $T_i = T_f$ therfor

$$\boxed{H_i = H_f}$$

*** **Note** :- when an ideal gas undergoes free expansion

$$\begin{array}{ll} \text{(i)} & U_i = U_f \\ \text{(ii)} & T_i = T_f \\ \text{(iii)} & H_i = H_f \end{array}$$

Note :- Here in ~~wor~~ free expansion $\boxed{W=0}$ but in prob. here volume of gas change when gas comes from to vaccum

because in this friction are avilable so it become as irreversible process.

So in this does not used Pdv because it used in the reversible process where $\boxed{W=0}$ So it used only where process is irreversible.

Q an ideal gas at 20 bar and 40° is contain in a small Cylinder having a volume of 15 cm³ this Cylinder is placed in a large container having a volume of 1500 cm³. the large Container is perfectly ~~evaporated~~ evacuated and insulate by an apporiate means the gas is allowed to discharged and feel the large container find ① final pressure when the entire assembly reaches equilibrium?

Ans:- $PV = mRT$

$m = \frac{PV}{RT}$

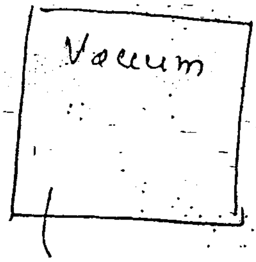
$m_1 = m_2$

$\frac{P_1V_1}{RT_1} = \frac{P_2V_2}{RT_2}$

~~$H_1 = H_2$~~ $P_1V_1 = P_2V_2$

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

$P_1 = 20\left(\frac{15}{1500}\right) = P_2 = 0.2$ bar



$V_2 = 1500$ m.

$P_1 = 200$ bar

$T_1 = 40°C$

✓

$H_1 = H_2$

$U_1 + P_1V_1 = U_2 + P_2V_2$

$P_1V_1 = P_2V_2$

Ideal gas

ideal gas ($PV = mRT$)

Perfect gas
↓
(C_p and C_v are constant)

Semi perfect gas
↓
(C_p and C_v vary with temp)

$PV = mRT$

$$\text{no. of moles } (n) = \frac{\text{mass } (m)}{\text{molecular wt. } (M)}$$

$$n = \frac{m}{M}$$

$$\boxed{m = nM}$$

$$PV = nMRT$$

$$\boxed{PV = n\bar{R}T}$$

$\bar{R}$ = universal gas constant
= 8.314 KJ/kg mol-K

$$\bar{R} = MR$$

$$\boxed{R = \frac{\bar{R}}{M}}$$

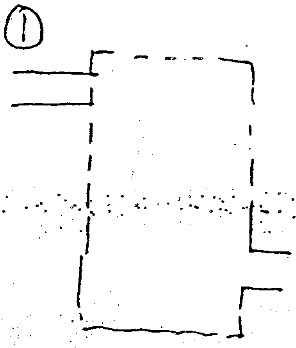
in isothermal

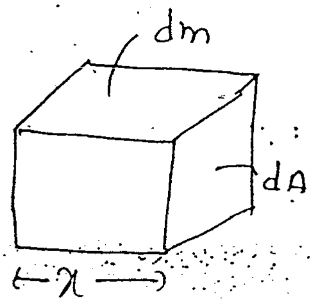
$$W = mRT \ln\frac{V_2}{V_1}$$

$$\boxed{W = n\bar{R}T \ln\frac{V_2}{V_1}}$$

30-7-2011

Flow work :- The work transfer involved in casting the fluid element either to enter or leave the control volume is known as flow work.





$dV = dA\,x$

$$\boxed{v = \frac{dv}{dm}}$$

$P = F/A$

$F = PA$

Work = Force

$\text{work} = P\,dA \times x$

$\text{work} = P\,dv$

$\frac{\text{Work}}{\text{mass}} = \frac{P\,dv}{dm}$

$\frac{\text{Work}}{\text{mass}} = P\,v$

if mass m in extensive $v = \frac{V}{m}$

if mass is entering then flow work = $P v m$

$$\boxed{\text{flow work} = PV}$$

* If the entry occurs at ① then entry ~~work~~ flow work is $-P_1V_1$ (on the system)

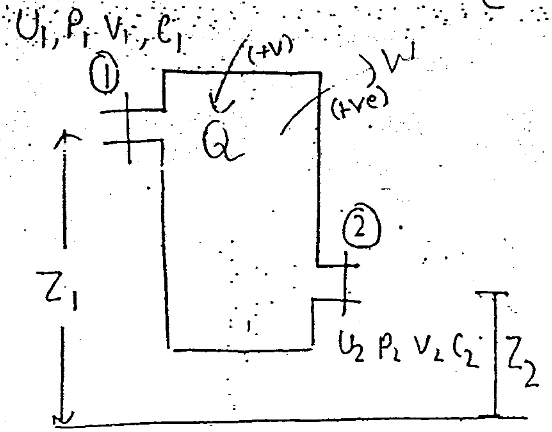
* If the exit occurs at ② then the exit flow work = $+P_2V_2$ (By the system)

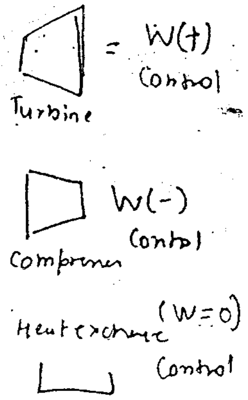
Steady flow energy equation (S.f.e.e) :- (open system)

In a steady flow properties do not vary w.r.t to time at any given section.

For steady flow there is no accumalition of mass and energy in the control volume and hense mass entring is equel mass leaving.

$$\left[\begin{array}{l} \text{Energy}_{(enter)} = \text{Energy}_{(out)} \\ \text{mass}_{(in)} = \text{mass}_{(out)} \end{array}\right]$$





In steady flow $E_{enter} = E_{(exit)}$

$$\frac{1}{2}mc_1^2 + mgz_1 + U_1 + Q = \frac{1}{2}mc_2^2 + mgz_2 + U_2 + W$$

$$\frac{1}{2}mc_1^2 + mgz_1 + U_1 + Q = \frac{1}{2}mc_2^2 + mgz_2 + U_2 + (-P_1V_1 + W_{CV} + P_2V_2)$$

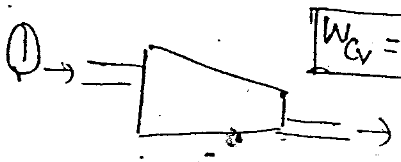
$$\frac{1}{2}mc_1^2 + mgz_1 + \underbrace{U_1 + P_1V_1} + Q = \frac{1}{2}mc_2^2 + mgz_2 + \underbrace{U_2 + P_2V_2} + W_{CV}$$

$$H_1 + \frac{1}{2}mc_1^2 + mgz_1 + Q = H_2 + \frac{1}{2}mc_2^2 + mgz_2 + W_{CV}$$

divided by mass for specific

$$\boxed{h_1 + \frac{1}{2}\cancel{m}c_1^2 + gz_1 + q = h_2 + \frac{c_2^2}{2} + gz_2 + w_{CV}}$$

- For turbine



$\boxed{W_{CV} = \text{take}(+ve)}$

total work in turbine

$$W_{net} = W_{entry} + W_{control\ volume} + W_{exit\ work}$$

$$\boxed{W_{turbine} = -P_1V_1 + W_{CV} + P_2V_2}$$

For turbine $\boxed{W_{CV} = +ve}$

(II) Compressor = $\boxed{W_{CV} \text{ take } (-v)}$

(III) For heat exchanger = $\boxed{W_{CV} = 0}$

This is the first law of thermodynamic eqn for open system under steady flow ~~eqn~~ conditions.

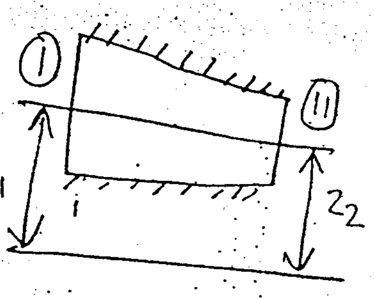
Spacial Cases :-

(1) nozzel :- $\boxed{W=0}$ Nozzel is the device which is used for incrising the velocity at the expense of pressure energy. (No role of work transfer)

* If nozzel insulatated and steady flow here work

$\boxed{W=0}$ $\boxed{Q=C}$

$$h_1 + \frac{C_1^2}{2} + \cancelto{0}{Z_1 g} + \cancelto{0}{Q} = h_2 + \frac{C_2^2}{2} + \cancelto{0}{Z_2 g} + \cancelto{0}{W_{CV}}$$

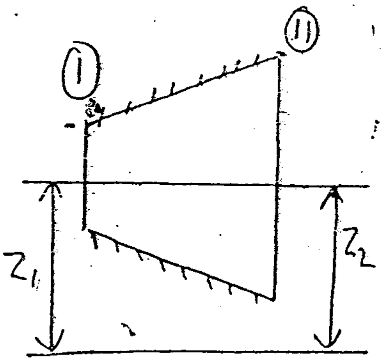


$$h_1 + \frac{C_1^2}{2} = h_2 + \frac{C_2^2}{2}$$

$$C_1 <<< C_2$$

$$\boxed{h_1 = h_2 + \frac{C_2^2}{2}}$$

② Turbine :-



assumption occurs :-

- (I) Steady flow
- (II) Perfect insulated
- (III) Neglecting PE changed
- (IV) Neglecting K·E changed

$$\text{eq}^n = \quad h_1 + \cancelto{0}{\frac{C_1^2}{2}} + \cancelto{0}{Z_1 g} + \cancelto{0}{q} = h_2 + \cancelto{0}{\frac{C_2^2}{2}} + \cancelto{0}{Z_2 g} + W_{cv}$$

$$h_1 = h_2 + W_{cv}$$

$$\boxed{W_{cv} = h_1 - h_2}$$ → Under the assumption.

*work is equal to changed in enthalpy

[Here C_1 more less than h_1 so neglected]

(III) Compressor :-

assumption occurs – Same assumption

$$W = h_1 + h_2$$
$$W = -(h_2 - h_1)$$
$$-W = h_2 - h_1$$
$$\boxed{W_{comp} = h_2 - h_1}$$

here = $h_1 - h_2$ (decrese
So work (+ve) and
by the system
* in compressor ($\dot{W}_{cv}$ = −ve)
because enthalpy
incresed

④ Throttling valve :- *(open system)

$\boxed{T_1 = T_2}$

Examples of throtling :-

1. Flow through a partialy open valve
2. Flow through orfice (very small opening)
3. Flow through a porous plug.

* Charaterstic of throttling :-

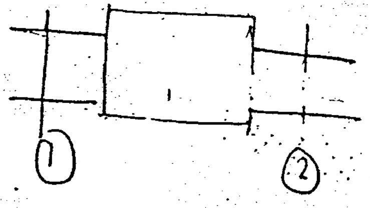
(I) No heat transfer (II) no work transfer

$\boxed{đQ = 0}$ $\boxed{đW = 0}$

(III) enthalpy constant so (isoenthalpy process)

(IV) highly irreversible process.

$$h_1 + \frac{C_1^2}{2} + z_1 g + Q = h_2 + \frac{C_2^2}{2} + z_2 g + W_{CV}$$



$$h_1 + \frac{C_1^2}{2} = h_2 + \frac{C_2^2}{2}$$

$\boxed{h_1 \approx h_2}$

$\boxed{h = \text{Constant}}$

[Compretto to
h1 and h2 C1 and
C2 small]

Work-book Question - Chabter ②

① $n = 70$ moles $\boxed{T=C}$

$T_1 = 354\,K$

$V_1 = 1\,m^3$

work = -206 kJ

$\boxed{T=C}$

$W = P_1 V_1 \ln \frac{V_2}{V_1}$

$PV = n\bar{R}T$

$W = n\bar{R}T \ln \frac{V_f}{V_i}$

$-206 = 70 \times 8.314 \times 354 \times \ln \frac{V_2}{V_1}$

$\frac{-206}{70 \times 8.314 \times 354} = \ln \frac{V_2}{V_1}$

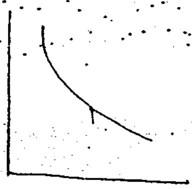
$\frac{V_2}{V_1} = e^{\frac{-206}{70 \times 8.314 \times 354}}$

$\frac{V_2}{V_1} = 1.001 \approx 1$

$\boxed{V_2 = V_1}$

(II) P_0, T_0 $\boxed{T=C}$ P_1 R, Q=?

$\boxed{T=C}$



$W = mRT \ln \frac{V_f}{V_i}$

$PV = mRT$

$\boxed{PV = C}$

$P_1 V_1 = P_f V_f$

$\frac{V_f}{V_i} = \frac{P_1}{P_f}$

$W = mRT \ln \frac{P_i}{P_f}$

$1 \times R \times T_0 \times \ln \frac{P_0}{P_1}$

For isother

$dQ = dU + dW$

$\boxed{dQ = dW}$

$T = C$

$W = Q = RT_0 \ln \frac{P_0}{P_1}$

$\boxed{W = Q = -RT_0 \ln \frac{P_1}{P_0}}$ ans ©

If ideal and isothermal then $\boxed{dQ = dW}$ so in question tell work or heat for closed system ✓

(III) $V = 86.4\,m^3$

$T_1 = 22^\circ C$

$P_1 = 100\,kPa$

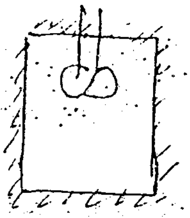
Time = 4 hrs

$C_v = 0.718$ kJ/kg-K

$R = 0.287$ kJ/kg-K

$dQ = dU + dW$

Closed system



$\boxed{dQ = 0}$

$0 = dU + dW$

$W = -60$ watt

$= -60 \frac{J}{sec}$

$= -60 \frac{J}{sec} \times 4 \times 3600$ sec

$\boxed{W = -864\,kJ}$

When

$R =$ kJ/kg-K

then

P → in kPa

$0 = du + (-864)$

$du = 864\ KJ$

$mc_v dT = 864$

$dT = \frac{864}{mc_v} = \frac{864}{98.7 \times 0.718}$

* $du = mc_v dT$ because air as ideal gas

$\boxed{dT = 12.1\ K \text{ or } 12.1^\circ C}$

$PV = mRT$

$m = \frac{PV}{RT}$

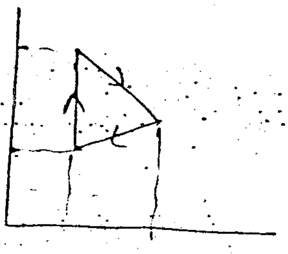
$m = \frac{100 \times 86.4}{0.287 \times 305}$

$m = 98.7\ kg$

ⓐ

if $T_1 = 20$ $T_2 = 40^\circ$ $\Delta t = 40-20 = 20^\circ C$	if $T_1 = 20+273$ $T_2 = 40+273$ $\Delta t = 20+273 - (273+40)$ $\Delta t = 20^\circ$

④



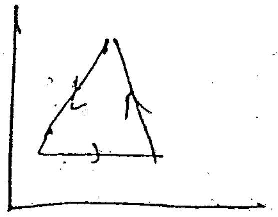
Clock wise $W = +ve$

Net work

$W_{net} = \frac{1}{2}(10-2)(5-2)$

$\frac{1}{2}(8)(3)$

$= +12$



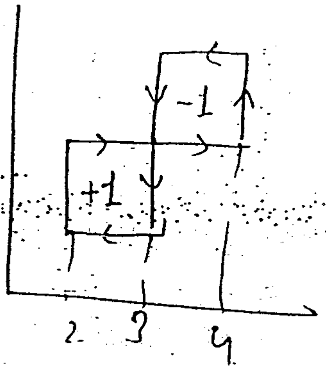
anti clock $W = -ve$

$W = \frac{1}{2}(8-2)(10-6)$

$\frac{1}{2} \times (6 \times 4) = \underline{\underline{-12}}$?

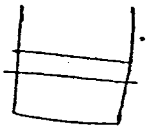
⑤

Ⓒ

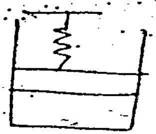


≤ 0

* ⑥ ~~P+E+C+2~~



Work mode only one



here two work mode but only two information so we must want one variable spring constant k so variable P, ΔV, k for 2 mode

* if three mode → 4 variable

if n mode → n+1 variable

so ans ⓓ

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⑦ $m = 1\,Kg$

$t_1 = 15$

$t_2 = 45$

$c_p = 1.042\ KJ/kg\text{-}k$

$R = 0.2968\ KJ/kg\text{-}k$

$C_p - C_v = R$

$1.042 - C_v = 0.2968$

$\boxed{C_v = 0.7432}$

$Q_v = m c_v dT$ ⓐ

$Q_p = m c_p dT$

$Q_v = 1 \times 0.7452 (45-15) = 22.35$

$Q_p = 1 \times 1.042 (45-15)$

$= 31.26\ KJ$

---

⑧ $C_p = 5.19$

$M = 4$

$R = \frac{\overline{R}}{M} = \frac{8.314}{4}$

$R = 2.07$

$C_p - C_v = R$ ⓒ

$5.19 - C_v = 2.07$

$\boxed{C_v = 3.11}$

⑨ ⓐ

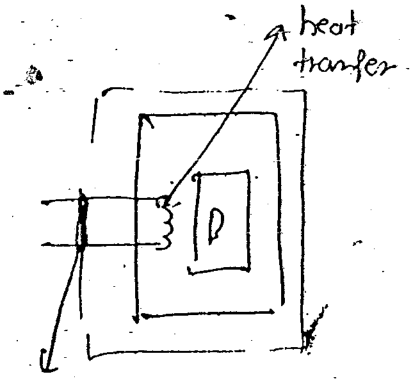
⑩

⑪ open system

if closed then PdV

⑫

ⓑ



For A work tranfer

electron flowing

⑬ $P_1 = 0.5$ ⓒ

$V_1 = 0.837$

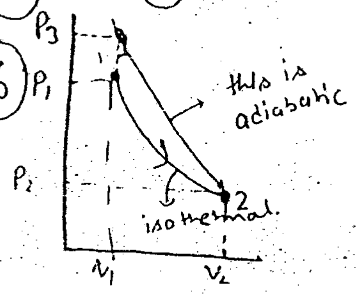
$P_2 = 0.1$

$V_2 = 1.435$

⑭ C

⑮ — as ③ 25.57 ⓑ

Imp ⑯



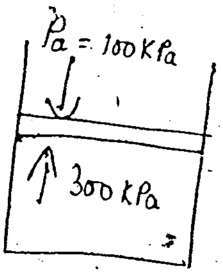
ⓒ

$\boxed{\text{we know slope adiabatic > isothermal slop}}$

in isothermal more work → (Area more) pressure - more - $P_3 > P_2$ so C ans.

⑰ (C)

1 kg

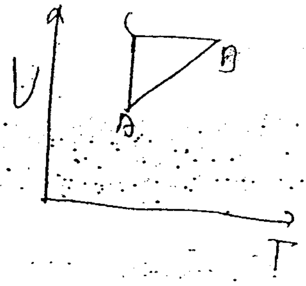


$W = 300(0.01)$
$= 3$ KJ

the total work done by the gas is $300(0.01) = 3$ KJ out of this total work $(100 \times 0.01) = 1$ KJ is used in removing atmospheric air and hence the work done could be utilize is $3 - 1 = \underline{2 \text{ KJ}}$ work.

⑱ (d)

⑲



BC = $\boxed{V = C}$

AC = $\boxed{T = C}$

$y = Mx$

$PV = mRT$

$V = \left(\frac{mR}{P}\right) T$

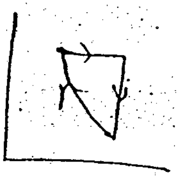
$y = Mx$

Slope. $= \frac{mR}{P}$

Const $= \frac{mR}{P}$

AB = $\boxed{P = C}$

(d)



⑳ $T = \text{Const}$

(d)

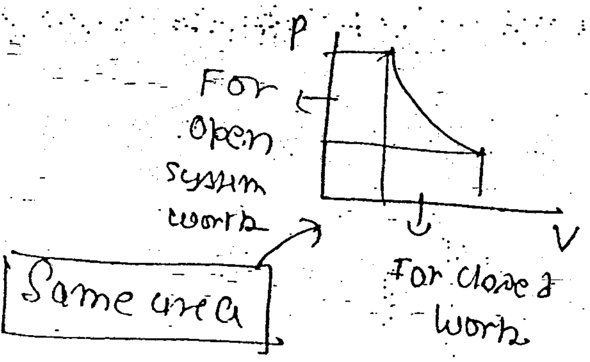
$PV = mRT$

$\boxed{PV = C}$

$Pdv + Vdp = 0$

$\boxed{Pdv = -Vdp}$

For closed System — For open System



*
For an isothermal of an ideal gas open system work equal to closed system work because a rectangular hyperbola when projected on ~~pressures and~~ ~~Temp axis~~ pressure axis and volume axis gives same area.

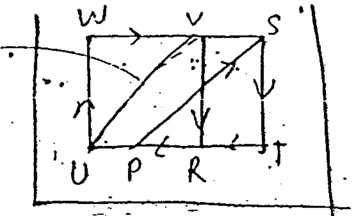
$\boxed{Pdv = -Vdp}$

If same area projected P and T becum re.

㉑ (C)

Internal energy = property and for a cycle change in property is zero because it point function $\boxed{dU = 0}$ Ans.

(22) when Sliding

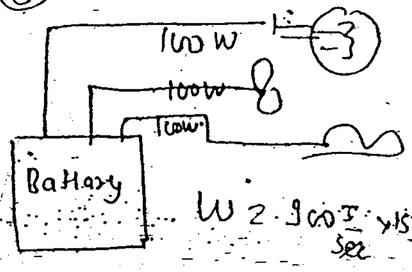


$\boxed{UP = PR = RT}$

$\boxed{VR = ST}$

(22) – (C)

(23)



$W = 900 \frac{J}{sec} \times 15 \times 60 sec$

$W = 270 \times 10^3 J$

$\boxed{W = 270 KJ}$

(C) W

(24) a

(25) → home

(26) $\boxed{T = C}$ process so

$\left(P + \frac{a}{V^2}\right)V = RT \rightarrow$ constant

$P_1 = 10, V_1 = 1$

$T_1 = 300$

$\left(P_1 + \frac{a}{V_1^2}\right)V_1 = \left(P_2 + \frac{a}{V_2}\right)V_2$

$\left(10 + \frac{a}{1^2}\right)\times 1 = \left(P_2 + \frac{a}{2^2}\right)2$

$10 + a = \left(P_2 + \frac{a}{4}\right)\times 2$

$\frac{10 + a}{2} = P_2 + \frac{a}{4}$

$5 + \frac{a}{2} = P_2 + \frac{a}{4}$

485

$W = J/sec$

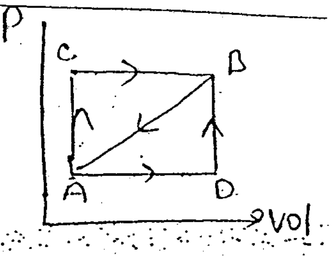
$5 + \frac{a}{2} - \frac{a}{4} = P_2$

$\boxed{5 + \frac{a}{4} = P_2}$ (b)

(27) (b)

(28) $Q_{ACB} = 180 KJ$

$W_{ACB} = 130$



$dQ = dU + dW$

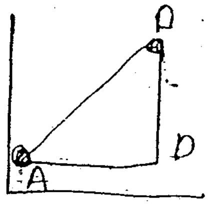
$180 = dU_{ACB} + 130$

$180 = (U_B - U_A) + 130$

$\boxed{(U_B - U_A) = 50}$

$\boxed{dU = \text{property}}$

But dU → internal energy → property so ADB



$dQ = dU + dW$

$dQ_{ADB} = (U_B - U_A) + 40$

$Q_{ADB} = ?$

$W_{ADB} = 40$

$dQ_{ADB} = 50 + 40$

$= 90 KJ$ (C)

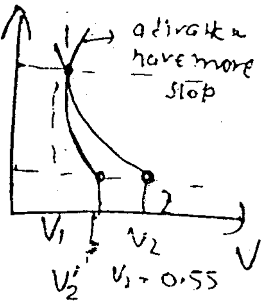
(29) P_1 to $\left(P_2 = \frac{P_1}{10}\right)$

$\boxed{V = C}$ $\boxed{V_2 = 0.55 m^3}$

is addibatically

$\boxed{V_2 = ?}$

(a)



Adibatically slop → more than isothermal

So Volume less then Isothermal

So ans is (a)

$\boxed{V_2' = 0.45m}$

30 (b)

31 (a)

32 Assertion (A) = ✓

Reason (R) = ✓

(a)

33 (a)

34 - d - Class 35

36
$P_0 = 100$ kPa
$V_0 = 20$ m³
$P = P_0 + 2(V - V_0)^2$

$T_1 = 20°c$
$P_1 = 100$ kPa ———— 150 kP
$V_1 = 15$ m3 ———— $V_2 = 25$ m3

T_1
P_1
V_1

$T_2 = ?$
P_2
V_2

mass same so
$m_1 = m_2$

$PV = mRT$

$$\frac{P_1V_1}{\cancel{R}T_1} = \frac{P_2V_2}{\cancel{R}T_2}$$

$$\frac{100 \times 15}{291} = \frac{150 \times 25}{T_1}$$

(d)

$\boxed{T_1 = 732 \text{ k}}$

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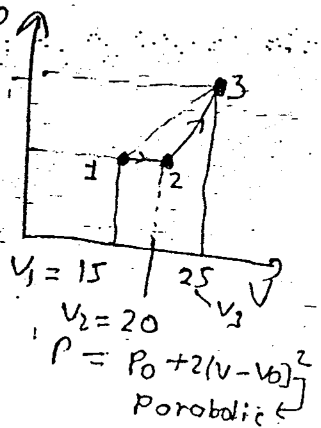
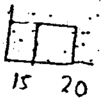


$P = P_0 + 2(V - V_0)^2$ Parabolic

total work

$W = W_{12} + W_{23}$

$W_{12} = 100(20 - 15)$



$\boxed{W_{12} = 500 \text{ kJ}}$

$W_{23} = \int P dV$

$$= \int_{V_2}^{V_3} [P_0 + 2(V - V_0)^2] dV$$

$$= \int_{V_2}^{V_3} P_0 dV + 2(V - V_0)^2 dV$$

$$= \int_{20}^{25} P_0 V + \left[\frac{2(V - V_0)^3}{3}\right]_{20}^{25}$$

$$= \left[P_0 V + 2\frac{(V - V_0)^3}{3}\right]_{20}^{25}$$

$$= 100(25 - 20) + \frac{2}{3}[(25 - 20)^2 - (20 - 20)^2]$$

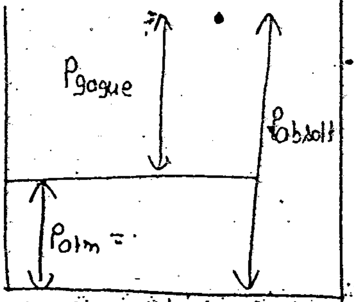
$W_{23} = 583$

$W = W_{12} + W_{23}$ Ⓒ

$= 500 + 589$

$\boxed{W = 1089\ kJ}$

(38)



* In $\boxed{PV = mRT}$

P always in absolute

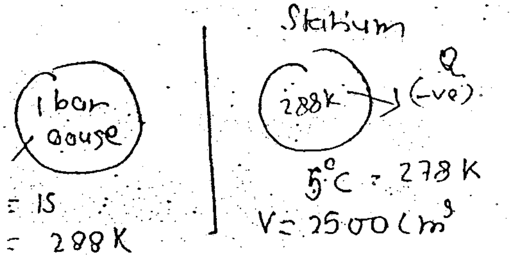
In equation $(PV = mRT)$ P is pressure in absolute scale

$\boxed{\text{Absolute pressure} = P_{gague} + P_{atm}}$

* if in exam Ques give P_{gauge} Change into P_{abs} must then used in $\boxed{PV = mRT}$

Q- $P_{gauge} = 1$ bar

$P_{atm} = 15°C$



$T_1 = 15$

$= 288\ K$

$5°C = 278\ K$

$V = 2500\ cm^3$

Constnt volume heat transfer

$dQ = dU = mC_v dT$

$dQ = du = mC_v(T_2 - T_1)$

When $R = k$

$PV = mRT$

$$m = \frac{PV}{RT}$$

$$= \frac{201.3 \times 2500 \times (10^{-2})^3}{0.287 \times 288}$$

$\boxed{m = 6.08 \times 10^{-3}\ kg}$

$dQ = du = mC_v(T_2 - T_1)$

$= 6.08 \times 10^{-3} \times 0.718 \ (278 - 288)$

$\boxed{\frac{Kg \times kJ - k}{K \times Kg}}$

$dQ_v = -43.7 \times 10^{-3} \times 10^{3}\ J$

$\boxed{dQ_v = -43.7\ J}$ 9;

$P_{abs} = 1 + 1.013$

$P_1 = 2.013$ bar

$T_1 = 288\ K$

"For ball

$PV = mRT$ $P \rightarrow$ in absolute

$P \alpha T$

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

$$\frac{P_2}{2.013} = \frac{278}{288}$$

$\boxed{P_2 = 1.94\ bar}$

$P_2 =$ absoult

but Pressure in gauge

$P_{gauge} = 1.94 - P_{atm} = 0.93$ bar gauge

$P_2 = 1 + 0.93$

$= 1.93$ ⟶ ⓑ

(39) $P_1 = ?$, $T = 288$ P_2, $T_2 = 288$ $P_2 = 1 + 1.013$

$= 2.013$

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

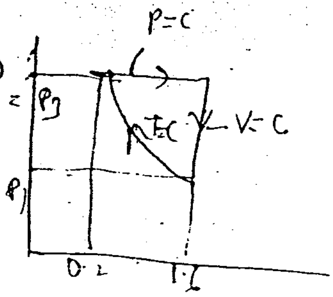
$$\frac{P_1}{2.013} = \frac{288}{T_2} \Rightarrow P_1 = \frac{2.88 \times 2.013}{}$$

$\boxed{2.083 - 1.013}$

$P_1 = 1.07$ bar (C)

$\boxed{P_{gauge} = 1.07 \text{ bar}}$

(40) - ideal gas



$U_3 - U_1 = 3549$ KJ.

$P_1 V_1 = P_2 V_2$

$1 \times 1.6 = P_2 \times 0.2$

$\boxed{P_2 = 8 \text{ bar}}$

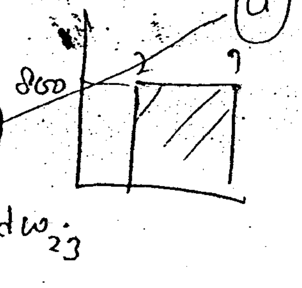
If W → KJ then
P → KPa

$P_2 = 800$ KPa

(a)

$W = 800(1.6 - 0.2)$

$\boxed{W = 1120}$ — (40)



$dQ_{23} = dU_{23} + dW_{23}$

(41) $dU_{23} = \boxed{U_3 - U_2 = U_3 - U_1} = 3549$

$dQ_{23} = 3549 + 1120$

$\boxed{dQ_{23} = 4669}$ (d)

(*) $h_1 + \frac{C_1^2}{2} = h_2 + \frac{C_2^2}{2}$

$h = C_p T$

$h = \frac{KJ}{Kg\,\cancel{K}} \times \cancel{K}$

$C_1 = m/s$

$C_1^2 = \frac{m^2}{s^2}$

$\frac{J}{Kg} = \frac{Nm}{Kg}$

$N = \frac{Kg\,m}{s^2} \times \frac{m}{\cancel{Kg}} = \frac{m^2}{s^2}$

$\boxed{\frac{J}{Kg} = \frac{m^2}{s^2}}$

$dH = mC_p dT$

$H = mC_p T$

$\frac{H}{m} = C_p T$

$\boxed{h = C_p T}$

$\boxed{U = C_v T}$

$\boxed{h = C_p T}$

$h_1 + \frac{C_1^2}{2} = h_2 + \frac{C_2^2}{2}$

$\frac{KJ}{Kg}$ $\frac{J \times 10^3}{Kg \times 10^3}$ $\frac{KJ}{Kg}$ $\frac{J \times 10^3}{Kg \times 10^3}$

$C_p T_1 + \frac{C_1^2}{2000} = C_p T_2 + \frac{C_2^2}{2000}$

Chapter – ③

① d

② $C_p = 1.005$ kJ/kg-K

$P_1 = 100$ kPa

$T_1 = 500$ K

$C_1 = 150$ m/s

$T_2 = 510$ K

Nozzle or diffuser $\boxed{W=0}$

Adiabatic $\boxed{Q=0}$

$$h_1 + \frac{C_1^2}{2000} = h_2 + \frac{C_2^2}{2000}$$

ideal

$$C_pT_1 + \frac{C_1^2}{2000} = C_pT_2 + \frac{C_2^2}{2000}$$

$$1.005\times500 + \frac{150^2}{2000} = 1.005\times510 + \frac{C_2^2}{2000}$$

$\boxed{C_2 = 49}$ diffuser

③ $T_1 = 800$ K, $P = 200$ kPa, $C_1 = 50$ m/s | $T_2 = 650$, $P_2 = 100$ kPa, $Q = -25$ kW, $C_2 = ?$

$C_p = 1.005$

$q = -25$ kJ/kg

$$q = \frac{Q}{m} = \frac{-25 \text{ kJ/sec}}{1 \text{ kg/sec}}$$

ⓐ

$$h_1 + \frac{C_1^2}{2000} + \cancel{gz}^0 + q = h_2 + \frac{C_2^2}{2000} + \cancel{gz}^0 + \cancel{w}^0$$

$$C_pT_1 + \frac{C_1^2}{2000} + q = C_pT_2 + \frac{C_2^2}{2000}$$

$$1.005\times800 + \frac{50^2}{2000} + (-25) = 1.005\times650 + \frac{C_2^2}{2000}$$

$\boxed{C_2 = 504 \text{ m/s}}$

④ d

⑤

⑥ $\boxed{Q=0}$

$P_1 = 400$ kPa, $T_1 = 900$ K, $C_1 = 0$ | $P_2 = 100$ kPa, $T_2 = ?$, $C_2 = ?$

ideal flow → Reversible flow

Ideal adiabatic → reversible adiabatic process

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

$$\frac{T_2}{900} = \left(\frac{100}{400}\right)^{\frac{1.4-1}{1.4}}$$

$\boxed{T_2 = 605.7}$

$$\boxed{h_1 = h_2 + \frac{C_2^2}{2000}}$$

$C_p T_1 = C_p T_2 + \frac{c_2^2}{2000}$

$1.005 \times 300 = 1.005 \times 265.7 + \frac{c_2^2}{2000}$

$\boxed{c_2 = 268.2 \text{ m/s}}$

ⓐ

⑦ ⓐ

$dQ = dE + dW$
└ process → reversible, irreversible
both ke liye

⑧ $P_1 = 0.1$ MPa | $P_2 = 1$ MPa
$T_1 = 300$ K

Comp. work $W = h_2 - h_1$

$h \to \frac{kJ}{kg} \to \frac{kJ}{kg} \times \frac{kg}{s} = \frac{kJ}{s} \to kW$

h → kW me change to $h \times \frac{kg}{s}$

$\text{Power} = \dot{m} \times W$

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

$\text{Power} = \dot{m}[C_p T_2 - C_p T_1]$

$\text{power} = \dot{m} C_p [T_2 - T_1]$

$\dot{m} = 1$ kg/s ⓒ

$P_1 = 0.1$ MPa

$T_1 = 300$ K

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

$\frac{T_2}{300} = \left(\frac{1}{0.1}\right)^{\frac{1.4-1}{1.4}}$

$\boxed{T_2 = 579.2}$

$\text{Power} = 1 \times 1.005[579.2 - 300]$

$\boxed{\text{Power} = 280 \text{ kW}}$

⑨ ⓑ

⑩ $dQ = du + dW$ ⓒ

$0 = mC_v(T_2 - T_1) + dW$

$dW = -mC_v(T_2 - T_1)$

$dW = -1 \times C_v(T_2 - T_1)$

$\boxed{W = C_v(T_1 - T_2)}$

⑪

⑪

	$T=C$	
1-2	2-3	3-1
$V=c$	$W=500$	$P=C$
$Q=50$	$du=0$	$W=-200$
$\boxed{W=0}$	$Q=500$	$Q=?$
		$du=?$

$$\Sigma Q = \Sigma W$$

$$Q_{12}+Q_{23}+Q_{31}=W_{12}+W_{2-3}+W_{31}$$

$$50+500+Q_{31}=0+500+(-100)$$

$$\boxed{Q_{31}=-250}$$

ⓓ

$$dQ_{31}=du+dW_{31}$$

$$-250=du_{31}+(-200)$$

$$\boxed{dU_{31}=-50}$$

⑫

pG-8

⑮

$$dQ=0$$

$$dQ=du+dw$$

$$du=-dw$$

$$du=180\ KJ$$

$$du=mC_v dT$$

$$dT=\frac{180}{30\times 0.7}=8.34$$

$$T_f=21+8.34=\underline{\underline{29.57^0}}$$

$$W=-100\frac{J}{Sec}$$

$$=-100\times\frac{J}{Sec}\times 1800$$

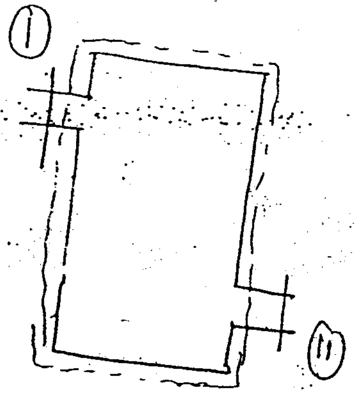
$$W=-180\ KJ$$

Unsteady state flow :- (change in m, E

Let m_i and m_e be mass entering and leaving the control volume and let m_1 and m_2 be the masses into control volume intialy and finaly.

① Conservation of mass

$$\boxed{\left(\frac{dm}{dt}\right)_{CV} = \overset{\circ}{m}_i - \overset{\circ}{m}_e} \text{ — ①}$$



⑪ Conservation of energy.

$$\boxed{\left(\frac{dE}{dt}\right)_{CV} = \frac{dE_i}{dt} - \frac{dE_e}{dt}}$$

$$\left(\frac{dE}{dt}\right)_{CV} = \frac{d}{dt}\left[m_i h_1 + \tfrac{1}{2} m_i C_1^2 + m_i Z_i g + Q\right] - \frac{d}{dt}\left[m_e h_e + \tfrac{1}{2} m_e C_e^2 + m_e Z_e g + W\right]$$

$$\left(\frac{dU}{dt}\right)_{CV} = \frac{d}{dt}(m_i h_i + Q) - \frac{d}{dt}(m_e h_e + W)$$

$$\left(\frac{dU}{dt}\right)_{CV} = \frac{d}{dt}(m_i h_i) + \overset{\circ}{Q} - \frac{d}{dt}(m_e h_e) - \overset{\circ}{W}$$

m – kg

$\overset{\circ}{m} = \frac{m}{t} = \frac{kg}{Sec}$

$h_i + \frac{C_i^2}{2} + Z_i g + Q$

$E_i = m_i h_i + \frac{1}{2} m_1 C_1^2 + m_i Z_i g + Q$ ⌞ ①

$E_e = m_e h_e + \frac{1}{2} m_e C_e^2 + m_e Z_e g + W$

$E = K.E + P.E + U$

$dE = d(K.E) + d(P.E) + dU$

neglected $d(KE)$ $d(PE)$

So $\boxed{dE = dU}$

If h_i and h_e remain Constant w.r.t to time then

$$\left(\frac{dU}{dt}\right)_{CV} = h_i \frac{m_i}{dt} + \overset{\circ}{Q} - h_e \frac{dm_e}{dt} - \overset{\circ}{W}$$

$$② \text{ — } \boxed{\left(\frac{dU}{dt}\right)_{CV} = \overset{\circ}{m}_i h_i + \overset{\circ}{Q} - \overset{\circ}{m}_e h_e - \overset{\circ}{W}}$$

Two assumption
① K.E. P.E neglec
⑪ h_i and h_e remain constant

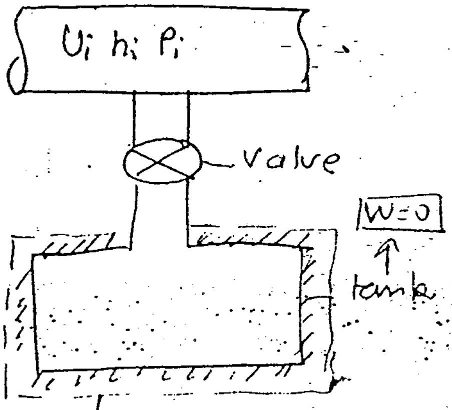
$\dot{m}_i h_i \to \frac{kJ}{s}$ or $\frac{kg}{s} \times \frac{kJ}{kg}$

$\frac{dU}{dt} - \frac{kJ}{sec}$

$u = \frac{U}{m} - \frac{kJ}{kg}$

$U = mu$

Q An insulated storage tank is initially vacuum evaporated and is conected to a supply pipe line carrying a fluid at specific internal energy u_i and specific enthalpy h_i the valve is opened and fluid flow into the tank from the supply line and reaches the pressure same as that of supply line show that the final specific internal energy of the flowing fluid in the tank is equal to h_i ?



$m_1 = 0$ becau vacuum here

$\dot{m}_e = 0$ - no mass leav

Ans - $$\left(\frac{dm}{dt}\right)_{cv} = \dot{m}_i - \overset{0}{\dot{m}_e}$$

$$\left(\frac{dm}{dt}\right)_{cv} = \dot{m}_i \quad \text{— ①}$$

$$\left(\frac{dU}{dt}\right)_{cv} = \dot{m}_i h_i + \overset{0}{\cancel{\dot{Q}}} - \overset{0}{\cancel{\dot{m}_e h_e}} - \overset{0}{\cancel{\dot{W}}}$$

$$\left(\frac{dU}{dt}\right)_{cv} = \dot{m}_i h_i \quad \text{— ①}$$

$$\left(\frac{dU}{dt}\right)_{cv} = \left(\frac{dm}{dt}\right)_{cv} h_i$$

$$(dU)_{cv} = (dm)_{cv} h_i$$

$$(U_2 - U_1) = (m_2 - m_1) h_i$$

$u = \frac{U}{m}$

$U = um$

$$(m u_2 - m_1 u_1) = (m_2 - m_1) h_i$$

$m_1 = 0$ (evacuated)

$u = \frac{U}{m}$

$U = mu$

$$m_2 u_2 = m_2 h_i$$

$$\boxed{u_2 = h_i}$$ Ans.

If the fluid in an ideal gas

5.30

$C_V T_2 = C_P T_i$

$T_2 = \frac{C_p}{C_v} T_i$

* $\boxed{T_2 = \gamma T_i}$

* fluid is throwing ideal then $T_2 = \gamma T_i$

T_2 grater than T_i.

$\boxed{T_2 > T_i}$

Note :- as $\gamma > 1$ the final temp T_2 in the tank is grater than the supply Temp T_i.

31-7-07

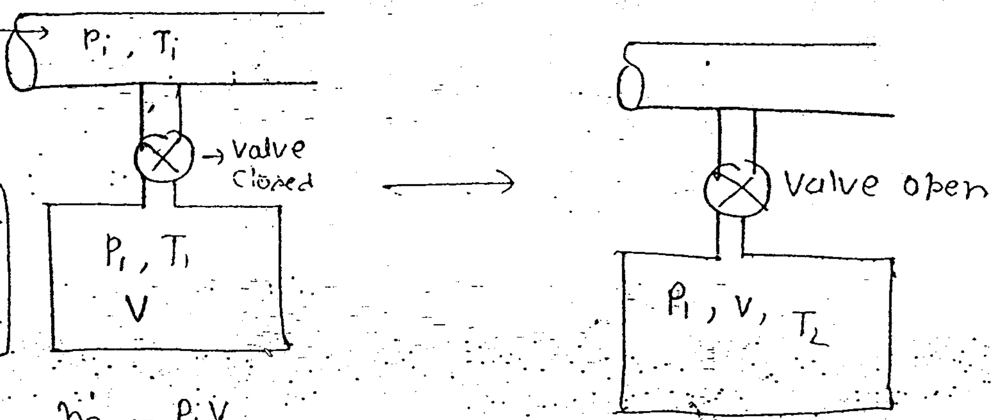
Q. A pressure cylinder have volume V contains air at pressure P_1 temp T_1. It is to be filled from a supply air line maintain at a constant pressure P_i and temp T_i. Show that the temp. of of air in the cylinder after it have been charged to supply line pressure is given by T_2 =

$$\boxed{T_2 = \frac{\gamma T_i}{1 + \frac{P_1}{P_i}\left(\frac{\gamma T_i}{T_1} - 1\right)}}$$

Assume the cylinder to be perfectly insulated ?

A:-

$PV = mRT$
$m = \frac{PV}{RT}$



$$\dot{m}_1 = \frac{P_1 V}{R T_1}$$

final

$$m_2 = \frac{P_i V}{R T_2}$$

$$m_2 T_2 = \frac{P_i V}{R} \quad \text{— (A)}$$

$$\left(\frac{dm}{dt}\right)_{CV} = \dot{m}_i - \dot{m}_e$$

$$[\dot{m}_e = 0]$$

$$\left(\frac{dm}{dt}\right)_{CV} = \dot{m}_i \quad \text{— (1)}$$

$$\left(\frac{dU}{dt}\right)_{cv} = \overset{0}{\dot{m}_i h_i} + \overset{0}{\dot{Q}} - \dot{m}_e h_e - \overset{0}{\dot{W}}$$

but here, $\boxed{Q=0}$, $\boxed{W=0}$ and $\boxed{m_e=0}$

$$\left(\frac{dU}{dt}\right)_{cv} = \dot{m}_i h_i \quad \text{———} ②$$

$$\left(\frac{dU}{dt}\right)_{cv} = h_i \left(\frac{dm}{dt}\right)_{cv}$$

$$(dU)_{cv} = h_i\,(dm)_{cv}$$

$$(U_2 - U_1) = h_i\,(m_2 - m_1)$$

$$m_2 u_2 - m_1 u_1 = h_i\,(m_2 - m_1)$$

$$m_2 c_v T_2 - m_1 c_v T_1 = c_p T_i\,(m_2 - m_1)$$

$$c_v\,(m_2 T_2 - m_1 T_1) = c_p T_i\,(m_2 - m_1)$$

$$\frac{P_i V}{R} - \frac{P_1 V}{R} = \gamma T_i \left[\frac{P_i V}{R T_2} - \cancel{B}\,\frac{P_1 V}{R T_1}\right]$$

$$P_i - P_1 = \gamma T_i \left[\frac{P_i}{T_2} - \frac{P_1}{T_1}\right]$$

$$P_i - P_1 = \frac{\gamma T_i P_i}{T_2} - \frac{\gamma T_i P_1}{T_1}$$

$$P_i - P_1 + \frac{\gamma T_i P_1}{T_1} = \frac{\gamma T_i P_i}{T_2}$$

$$T_2 = \frac{\gamma T_i P_i}{P_i - P_1 + \frac{\gamma T_i P_1}{T_1}} \Rightarrow T_2 = \frac{\gamma T_i P_i}{P_i\left(1 - \frac{P_1}{P_i} + \gamma \frac{T_i}{T_1}\frac{P_1}{P_i}\right)}$$

$$\boxed{T_2 = \frac{\gamma T_i}{1 + \frac{P_1}{P_i}\left(\frac{\gamma T_i}{T_1} - 1\right)}}$$

Second Law of Thermodynamic :- (Directional law) (Entropy)

Need of second law of thermodynamic :—

first law of thermo simbly says that energy is conserved it does not gives any direction for a perticular process. It is the second law of thermodynamic which gives direction for a perticular process to the concept of entropy. and hense Second law of thermo is also known as direction law.

Work transfer is known as high grade energy and it is organise form of energy.

heat transfer is LGE and it is deorganise form of energy. Complete Combustion of LGE (Q) into (H.G.E (W) in a cycle is impossible.

Statements of second law of thermo :-

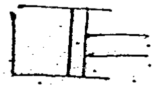
① Kelvin - plank statement :- (valid for cycle)

It is impossible to develop a device operating on a cycle producing work while exchanging heat with a single reservoir. This device is known as PMM-2 and efficiency of PMM-2 is 100%.

$$\eta = \frac{O}{I} = \frac{W}{Q} = \frac{Q}{Q} = 1$$

$$\boxed{\eta = 100\%}$$

*



U = f(T)

T = Constant

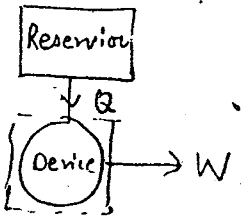
U = Const

$du = 0$

$dQ = du + dW$

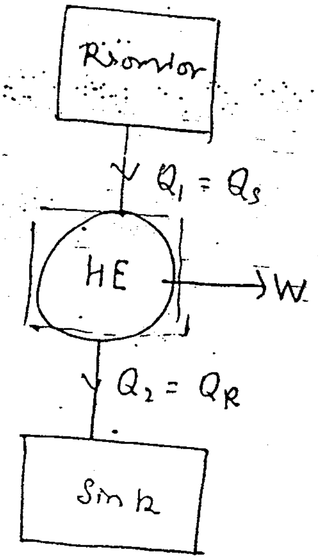
$\boxed{dQ = dW}$

it happen when process occurs



Concept of heat engine :-

Heat ensine is a device which Converts part of heat into work and remaining to sink or Surrounding



$$\eta = \frac{O}{I} = \frac{W}{Q_1}$$

$$Q_1 = W + Q_2$$

$$W = Q_1 - Q_2$$

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

$$\boxed{\eta = 1 - \frac{Q_2}{Q_1}}$$

$$\boxed{\eta = 1 - \frac{Q_R}{Q_S}}$$

This eqn is valid for reversible as will as irreversible ~~proce~~ Cycle.

(II) Clausius statement :- [cycle]

It is impossible to transfer heat from lower temp. to higher temp. without any external Input.

Spontaneous proces (natural)

higher → lower lev (natural)

Concept of refrigertor :- [cycle]

A refriserator is a dence which maintain lower temp. Cor Compared to surrounding. As lower temp are maintain continusly therefore refrigrator operte on a cycle.

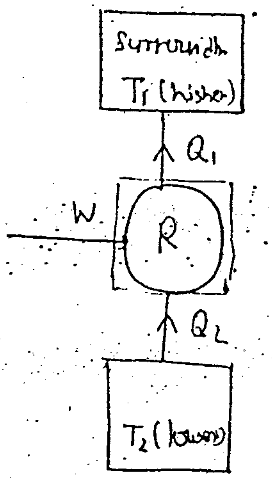
$$W + Q_2 = Q_1$$

$$W = Q_1 - Q_2.$$

$$COP = \frac{\text{Desired effect}}{\text{Energy input}}$$

$$(COP)_R = \frac{Q_2}{W}$$

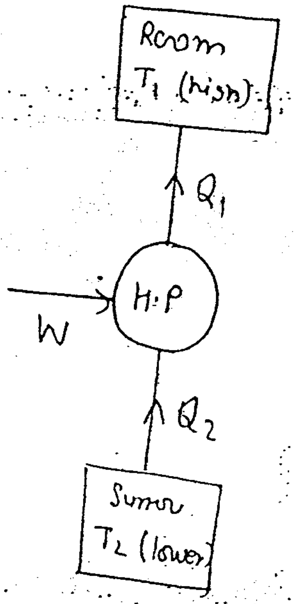
$$\boxed{(COP)_R = \frac{Q_2}{Q_1 - Q_2}}$$



Heat pump :- (Subbly heat)

Heat bump is a device which maintains higher temp Compaired to surroundings.

$$(Cop)_{h.p} = \frac{Q_1}{W}$$



$$\boxed{(Cop)_{h.p} = \frac{Q_1}{Q_1 - Q_2}}$$

This eqn is applicable for reversible as will irreversible heat bump.

$$(Cop)_{H.P} - (Cop)_R = \frac{Q_1}{(Q_1 - Q_2)} - \frac{Q_2}{(Q_1 - Q_2)}$$

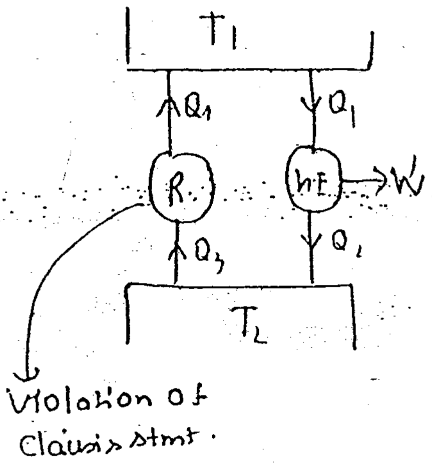
$$(Cop)_{h.p} - (Cop)_R = 1$$

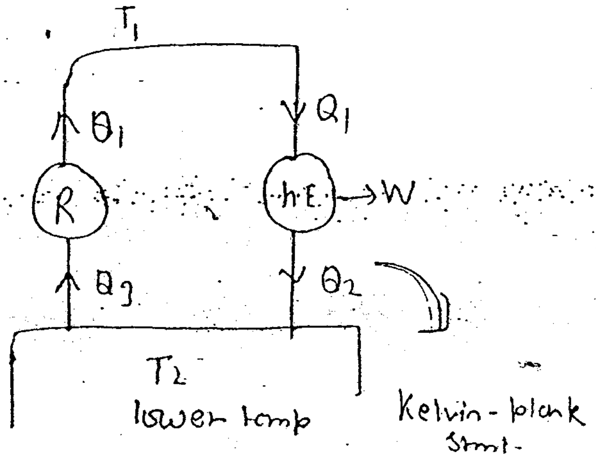
*
* $\boxed{(Cop)_{h.p} = 1 + (Cop)_R}$

heat pump and refrigerator → reversed heat engine.

To show that Clevin blank and Clausis statement are parrelel statement of second law of thermo :-

Cas-I - Violation of clausis statment :-



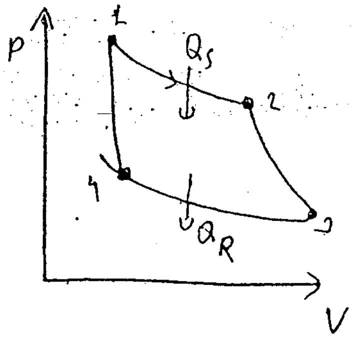


Similarly we can show that violation of Clevin-plank stamt to violation of Clausis statement. and hence these two are parrele stament of second law of thermo.

Carnot Cycle :-

It is a reversible cycle. A cycle is said to be a reversible cycle when each procen in cycle is a reversible procen.

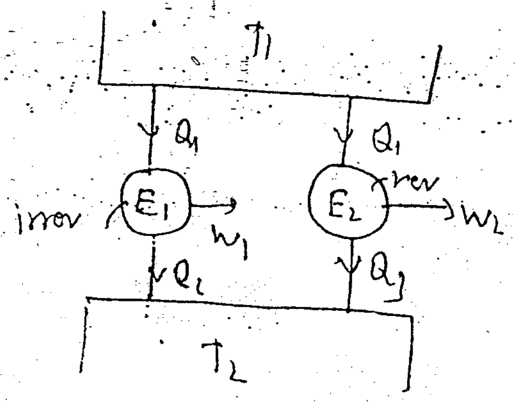
1-2 – isothermal heat addition (Expansion)
2-3 – Adiabatic expansion
3-4 – isothermal heat rejection (compression)
4-1 → Adiabatic compresion



Carnot Cycle is Consists of two reversible adibatics and two reversible isothermal processes to relised isothermal Conditions a the process must be carried out in a very slow manner and to relised adibatic condition the process must be carried out in a very fast manner and hence these two combination in a cycle are not possible therefore Carnot Cycle is a theoratical Cycle. and this cycle is used for comparing other acutal cycles.

Carnots theorem :-

For different cycle operating b/w same temp. limit non has the efficiency grater than reversibe cycle efficiecy.



Let us assume $\eta_{irrev} > \eta_{rev}$

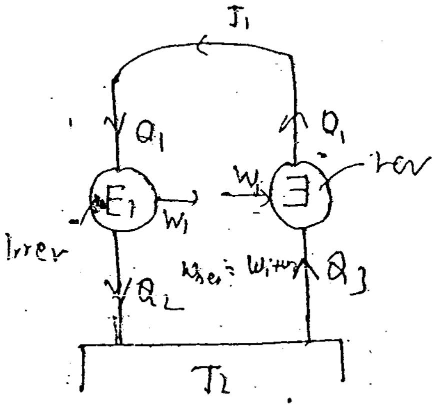
$$\eta_{ire} = \frac{W_1}{Q_1}, \quad \eta_{rev} = \frac{W_2}{Q_1}$$

$$\frac{W_1}{Q_1} > \frac{W_2}{Q_1}$$

$$W_1 > W_2$$

Let us asume two engines e_1 and E_2 working b/w E_1 and E_2 let E_1 be irreversible engine and E_2 be ~~irreversible~~ reversible engine.

As E_2 is a reversible Eensine



This is a violation of Kelvin plank statement and hense our assumption is wronge

similarly if both efficiency is are assume to be same then it would ~~leave to~~ lead to Violation Of Clausis statement and hence this also not possible therefore efficiency of a reversible Cycle is always greater than the efficiency of Irreversible cycle working b/w same temp limit.

Thermodynamic temp scale :-

$$\eta = 1 - \frac{Q_R}{Q_S}$$

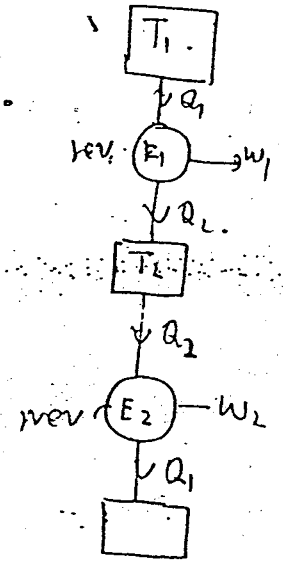
$$\eta_1 = 1 - \frac{Q_2}{Q_1}$$

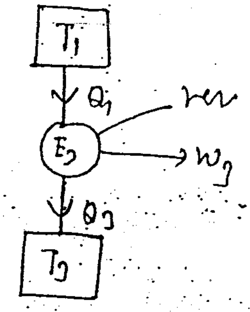
$$\eta_1 = f_1(T_1, T_2)$$

$$1 - \frac{Q_2}{Q_1} = f_1(T_1, T_2)$$

$$1 - f_1(T_1, T_2) = \frac{Q_2}{Q_1}$$

$$\frac{Q_1}{Q_2} = \frac{1}{1 - f_1(T_1, T_2)}$$





$$\frac{Q_1}{Q_2} = \phi_1(T_1, T_2)$$

$$\frac{Q_2}{Q_3} = \phi_2(T_2, T_3)$$

$$\frac{Q_1}{Q_2} = \phi_3(T_1, T_3)$$

$$\frac{Q_1}{Q_2} = \frac{Q_1/Q_3}{Q_2/Q_3}$$

$$\frac{Q_1}{Q_2} = \frac{\phi_2(T_1, T_3)}{\phi_2(T_2, T_3)}$$

$\phi_1(T_1, T_2)$

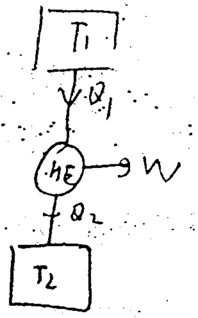
$$\frac{Q_1}{Q_2} = \frac{\psi_1(T_1)}{\psi_2(T_2)}$$

$$\boxed{\frac{Q_1}{Q_2} = \frac{T_1}{T_2}} \longrightarrow \text{For reversible}$$

Heat engine

$$\eta = 1 - \frac{Q_2}{Q_1}$$

For all Cycle



Let the engine be reversible

$$\boxed{\eta_{rev} = 1 - \frac{T_2}{T_1}}$$

$$\frac{Q_1}{Q_2} = \frac{T_1}{T_2}$$

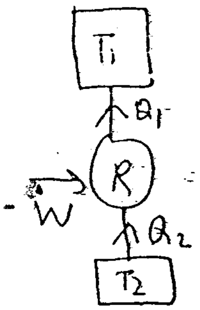
$$\boxed{\eta_{rev} = 1 - \frac{T_l}{T_h}}$$

$$\boxed{\eta_{max} = 1 - \frac{T_l}{T_h}}$$

reversible Cycle

श्री

Refrigerator :-



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

$$\left.\begin{aligned} Cop &= \frac{Q_2}{Q_2\left[\frac{Q_1}{Q_2} - 1\right]} \\ Cop &= \frac{1}{\left[\frac{Q_1}{Q_2} - 1\right]} \end{aligned}\right\} \text{— For all cycle}$$

$$(Cop)_{rev} = \frac{1}{\frac{T_1}{T_2} - 1}$$

$$\boxed{(Cop)_{rev} = \frac{T_2}{T_1 - T_2}} = \boxed{(Cop)_{max} = \frac{T_2}{T_1 - T_2}}$$

$$\boxed{(Cop)_{max} = \frac{T_l}{T_h - T_l}}$$

reversible only

Clausis Inequality :- Valid for Cycle

1-8-08

The cyclic integral of $\boxed{\frac{dQ}{T} \leq 0}$

$$\boxed{\oint \frac{dQ}{T} \leq 0}$$

$\oint \frac{dQ}{T} = 0$ — Cycle is reversible

$\oint \frac{dQ}{T} < 0$ — Cycle is irreversible

$\oint \frac{dQ}{T} > 0$

impossibe Cycle

Case-I Reversible Cycle —

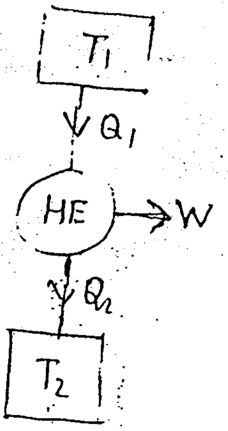
$$\oint_{rev} \frac{dQ}{T} = \frac{Q_1}{T_1} + \left(-\frac{Q_2}{T_2}\right)$$

$$\oint_{rev} \frac{dQ}{T} = \frac{Q_1}{\cancel{Q_2} T_1} - \frac{Q_1}{T_1} = 0 \text{ — by Ⓐ}$$

* $\left[\frac{Q_1}{Q_2} = \frac{T_1}{T_2}\right] \rightarrow$ Ⓐ

for reversible cycle

$$\boxed{\oint_{rev} \frac{dQ}{T} = 0}$$



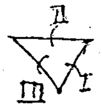
* This is the ~~Cyc~~ Integral of cyclic is always Zero means $\frac{dQ}{T}$ = property

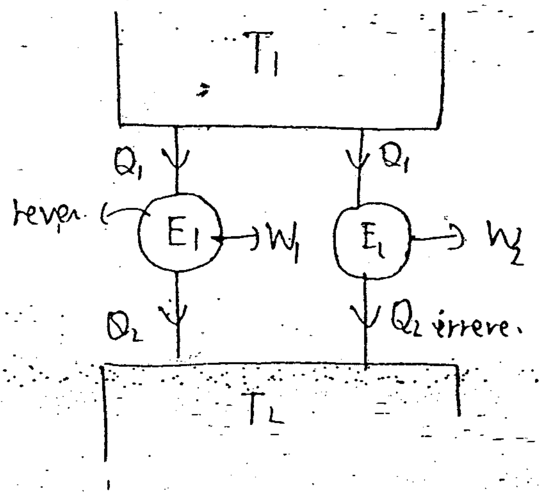
Case-II :-

Irreversible-cycle :-

⊛ cyclic integral of property = 0

$\boxed{\oint du = 0}$





For irreversible

$$\oint_{irrev} \frac{dQ}{T} = \frac{Q_1}{T_1} + \left(-\frac{Q_{2irev}}{T_2}\right)$$

$$\oint_{irrv} \frac{dQ}{T} = \frac{Q_1}{T_1} - \frac{Q_{2irr}}{T_L}$$

But $Q_2 < Q_{2\,irrew}$

$$\int_{irre} \frac{dQ}{T} = \frac{Q_2}{T_L} - \frac{Q_{2\,irre}}{T_2}$$

$$\oint_{irre} \frac{dQ}{T} = \frac{Q_2 - Q_{2\,irre}}{T_2}$$

$$\boxed{\oint_{irren} \frac{dQ}{T} < 0}$$

Here
$\frac{Q_1}{T_1} = \frac{Q_2}{T_2}$
↳ For reversible

But $\frac{Q_1}{T_1}$ (reversible) $= \frac{Q_1}{T_1}$ irreversible in fig

So we put

We know

$\eta_1 > \eta_2$

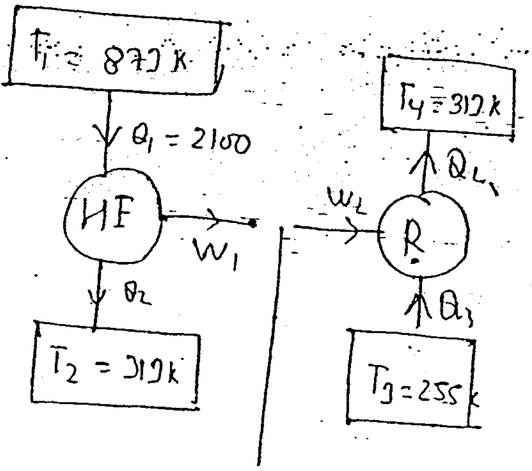
efficy of reversible more than irreversible

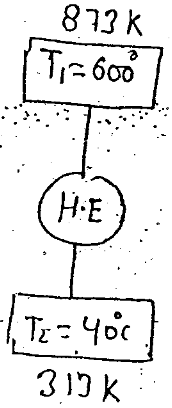
$W_1 > W_2$

$\frac{W_1}{Q_1} > \frac{W_2}{Q_2}$

Q. A Rev Heat Engine operates on 600°c and 40°c this engine drives a reversible refrigerator operating b/w 40°c and $-18°c$ still there is a net work output of 370 kJ by the heat received by the engine is 2100 kJ determine the cooling effect?

An:-





$W_{net} = 370$

$W_{net} = W_1 - W_2$

Cooling effect — Q_3

$$Cop = \frac{Q_3}{W_2} = \frac{T_l}{T_h - T_l}$$

$$\frac{Q_3}{W_2} = \frac{255}{313-255}$$

$W_1 - W_2 = 370$

$W_1 = Q_1 - Q_2$
↳ find

We know reversible cycle
So

$$\frac{Q_1}{T_1} = \frac{Q_2}{T_2}$$

$$\frac{2100}{873} = \frac{Q_2}{313}$$

$$\boxed{Q_2 = 752.9}$$

$W_1 = 2100 - 752.9$
$= 1347.1$

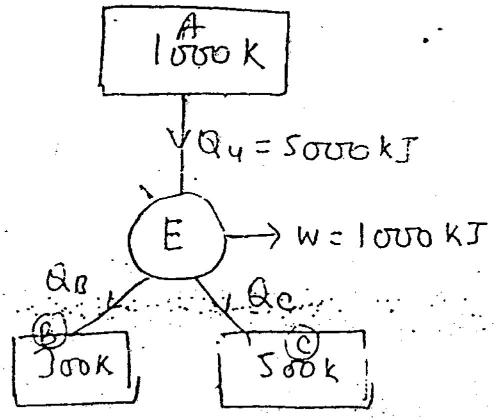
$W_1 - W_2 = 370$

$$\boxed{W_2 = 977.1}$$

$$\frac{Q_3}{W_2} = \frac{255}{313-255}$$

$$\boxed{Q_3 = 4295.8}$$

11 ***** Q fig show a reversible cycle during which it exchanges heat with three thermal resorvtors and develops 1000 KJ of work find the magnitude and direction of Q_B and Q_C



Ans-①

is rerrsible

$$\frac{Q_A}{T_1} = \frac{Q_B}{T_2}$$

$$\frac{5000}{1000} = \frac{Q_B}{300K}$$

$$\boxed{Q_B = 1500 K}$$

$$\frac{Q_A}{T_1} = \frac{Q_C}{T_2}$$

$$\frac{5000}{1000} = \frac{Q_C}{500}$$

$$\boxed{Q_C = 2500}$$

$$5000 = 1000 + Q_A + Q_C$$

$$Q_B + Q_C = 4000 — ①$$

$$\oint \frac{dQ}{T} = 0$$

$$\frac{5000}{1000} + \left(-\frac{Q_C}{500}\right) + \left(\frac{-Q_B}{300}\right) = 0 - ②$$

$$5 = \frac{Q_C}{500} + \frac{Q_B}{300}$$

$$Q_B = -2250, \quad Q_C = 6250$$

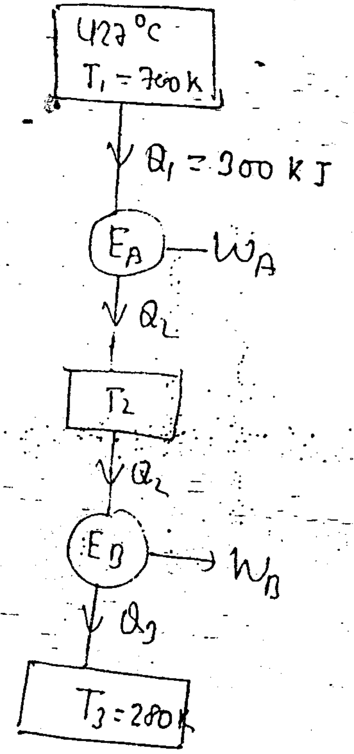
Q. Two reversible heat engines A and B are arranged in a series A rejects heat directly to B engine A recives 3000 KJ of heat at temp of 427°C from a high temp. source By engine reject heat to a sink at 7°C if the work output of A is 2 time that of B find

(i) Intermiddiate temp of A and B

(ii) efficiency of each engine

(iii) Heat rejected by engine A that is Heat reciced by B

(iv) Heat rejected to sink, both engine are reversible?



$\frac{Q_1}{T_1} = \frac{Q_2}{T_2}$ [because both reversible]

$\frac{Q_2}{T_2} = \frac{Q_3}{T_3}$

~~$\frac{Q_1}{Q_2} = \frac{Q_2}{Q}$~~

$\frac{Q_1}{T_1} = \frac{Q_2}{T_2} = \frac{Q_3}{T_3}$

$\frac{Q_1}{T_1} = \frac{Q_3}{T_3}$

$\frac{300}{700} = \frac{Q_3}{280} \Rightarrow \boxed{Q_3 = 120}$

$W_A = 2W_B$

$(Q_1 - Q_2) = 2[Q_2 - Q_3)$

$Q_1 - Q_2 = 2[Q_2) - 2Q_3$

$300 - Q_2 = 2Q_2 - 2(120)$

$\boxed{Q_2 = 180 \text{ kJ}}$

$\frac{Q_1}{T_1} = \frac{Q_2}{T_2}$

$\frac{300}{700} = \frac{180}{T_2}$

$\boxed{T_2 = 420 \text{ K}}$

$\eta = 1 - \frac{T_l}{T_h}$ [for 1st engine]

$\eta_1 = 1 - \frac{420}{700}$

$\boxed{\eta_1 = 0.4 = 40\%}$

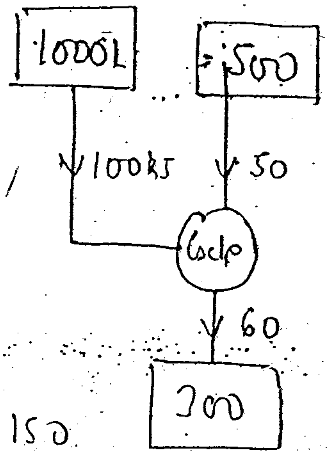
$\eta_2 = 1 - \frac{280}{420} = 0.333$

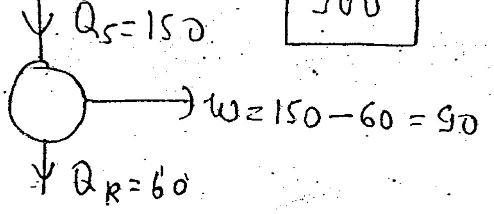
$\boxed{\eta_2 = 33.33\%}$

Chapter-④

~~$\frac{100}{1000}$ $\frac{50}{500}$ $\frac{60}{300}$~~

①





$$\oint \frac{dQ}{T} = \frac{100}{1000} + \frac{50}{500} - \frac{60}{300}$$

$$\boxed{\oint \frac{dQ}{T} = 0 \quad \text{Rev}}$$ ⓐ

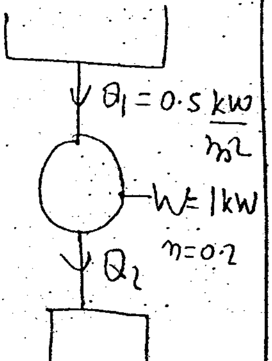
⑪

$\eta = \frac{O}{I}$

$0.2 = \frac{1}{0.5A}$

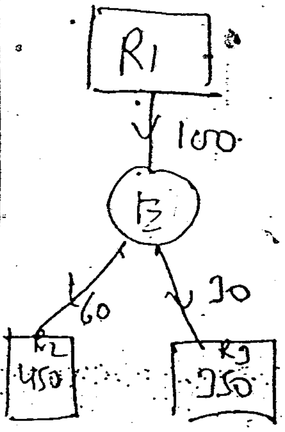
$A = \frac{1}{0.5 \times 0.2} = 10m^2$

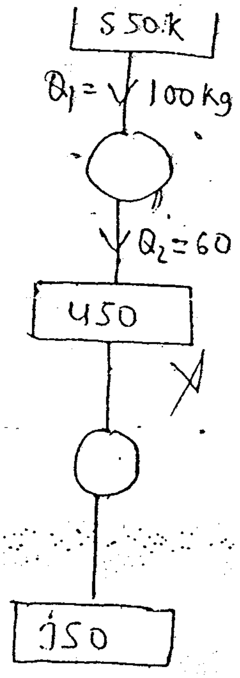
$A = 10m^2$

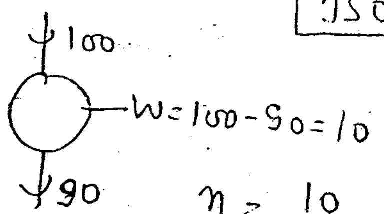


$O = 0.5 \times A$ KW

④



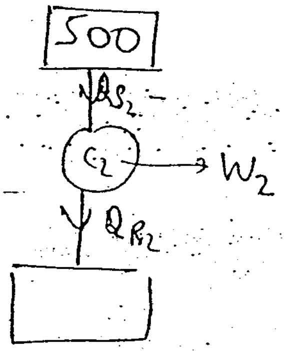


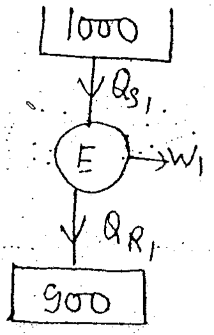


ⓐ

$\eta = \frac{10}{100} = 0.1$

⑥





* Carnot cycle so η in term of Temp

$\eta_1 = 1 - \frac{T_l}{T_h}$

$\eta = 1 - \frac{900}{1000}$

$\eta = 0.1$

$\eta_2 = 1 - \frac{450}{500}$

$= 0.1$

$\boxed{\eta_1 = \eta_2}$

$\eta_1 = \eta_2$

$$\frac{W_1}{Q_{s1}} = \frac{W_2}{Q_{s2}} \quad ⓓ$$

$$\frac{Q_{s1} - Q_{R1}}{Q_{s1}} = \frac{Q_{s2} - Q_{R2}}{Q_{s2}}$$

$$\boxed{Q_{s1} = Q_{s2}}$$

$$\therefore -Q_{R1} = Q_{R2}$$

$$\boxed{Q_{R1} = Q_{R2}}$$

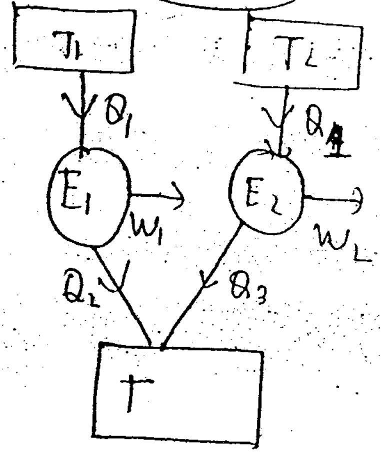
⑦ A - 2 ⓓ
B - 1
C - 3

⑧ A - 2 C → ① ⓑ
B - 3

⑨ ⓑ

⑩

$T_2 < T_1$



$$\eta_1 = \frac{W}{Q} = 1 - \frac{T}{T_1}$$

$$W_1 = Q\left(1 - \frac{T}{T_1}\right)$$

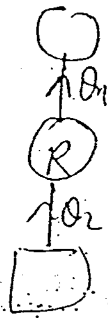
$$W_2 = Q\left(1 - \frac{T}{T_2}\right)$$

$$\boxed{W_1 > W_2} \quad ⓑ$$

because $(T_2 < T_1)$

⑪ $(Cop)_{hp} = 1 + (Cop)_{Ref}$

$$(Cop)_{Rf} = (Cop)_{hp} - 1$$



W = 0

never done in Refrigerator

Air Condition (Cop > ?)

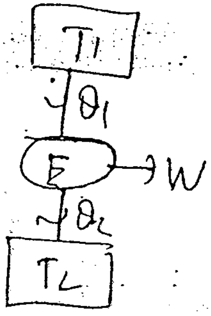
Domcl Refriz (Cop = 1)

$$Cop_R = \frac{Q_2}{W}$$

$$Cop = \frac{Q_2}{0}$$

$$Cop = \infty$$ never possible

⑫



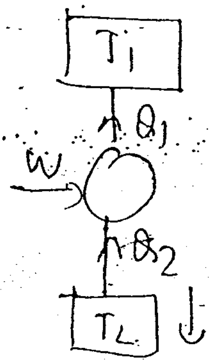
$$\eta = \frac{W}{Q_1}$$

heat engine Ki

Diff heat pump

$$\eta = \frac{W}{Q_1}$$

pump —



$$(Cop)_{hp} = \frac{Q_1}{W}$$

$$(Cop)_{hp} = \frac{1}{\frac{W}{Q_1}}$$

$$\boxed{(Cop)_{hp} = \frac{1}{\eta}}$$

$$Cop_{pump} = \frac{Q_1}{W}$$

$$Cop_{Ref} = \frac{Q_2}{W}$$

$$(Cop)_{hp} = 1 + (Cop)_{(Ref.)}$$

$$(Cop)_R = (Cop)_{hp} - 1$$

$$\boxed{(Cop)_R = \frac{1}{\eta} - 1}$$ ⓐ

(13) W = 50 kW

$$\boxed{\eta_{rev} > \eta_{irrev.}}$$

$T_h = 627 + 273 = 900$ k

$T_l = 27 + 273 = 300$ k

$m_f = 3$ kg/hr

$C_V = 75000$ kJ/kg

$$= 75000 \times 3 \frac{kJ}{kg} \times 3 \frac{kg}{hr}$$

$$= \frac{75000 \times 3 \text{ kJ}}{3600 \text{ sec}}$$

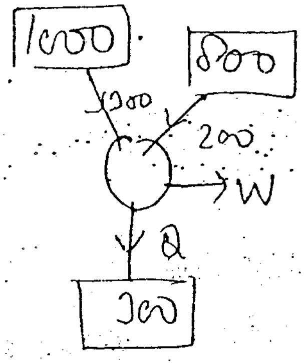
$\dot{Q}_S = 62.5$ kW

$$\eta = \frac{O}{I} = \frac{50}{62.5} = 0.8$$

η = more than 50

not possible

(h)



$$\oint \frac{dQ}{T} = 0$$

$$\frac{300}{1000} + \frac{200}{800} - \frac{Q}{300} = 0$$

Q = 165

$W = Q_1 - Q_2$

$= 500 - 165 = 335$ kJ

⑯ $\eta_1 = \eta_2$

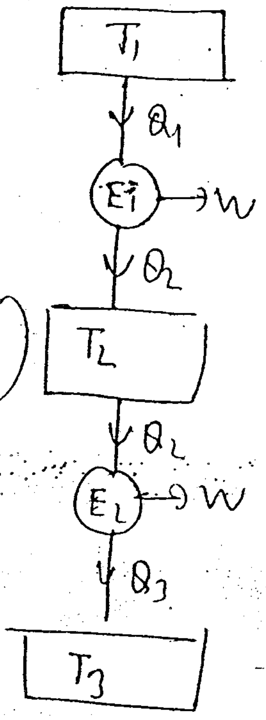
$$\frac{W_1}{Q_1} = \frac{W_2}{Q_2}$$

$$\left(\cancel{1} - \frac{T_2}{T_1}\right) = \left(\cancel{1} - \frac{T_3}{T_2}\right)$$

$$\frac{T_2}{T_1} = \frac{T_3}{T_2}$$

$$T_2^2 = T_3 T_1$$

$$\boxed{T_2 = \sqrt{T_3 T_1}}$$



(17) $W_1 = W_2$

$$(Q_1 - Q_2) = (Q_2 - Q_3)$$

$$Q_1 - Q_2 = Q_2 - Q_3$$

$$Q_1 = 2Q_2 - Q_3$$

$$Q_1 + Q_3 = 2Q_2$$

Reversible then

$$\cancel{\frac{Q_1}{Q_2} = \frac{T_1}{T_2}}$$

$$\frac{Q_1}{T_1} = \frac{Q_2}{T_2} = \frac{Q_3}{T_3} = K$$

$Q_1 = KT_1$

$Q_2 = KT_2$

$Q_3 = KT_3$

$$KT_1 + KT_3 = 2KT_2$$

$$T_1 + T_3 = 2T_2$$ (b)

$$\boxed{T_2 = \frac{T_1 + T_3}{T_2}}$$

⑲ $Q_3 = ?$

$$COP_{hp} = \frac{Q_3}{W}$$

$$(COP)_{hp} = \frac{T_h}{T_h - T_l}$$

$$= \frac{300}{300 - 250} = 6$$

$$\frac{Q_1}{T_1} = \frac{Q_2}{T_2}$$

$$\frac{1000}{500} = \frac{Q_2}{250}$$

$$\boxed{Q_2 = 500}$$

$$W = Q_1 - Q_2$$

$$= 1000 - 500 = 500$$

$$\frac{Q_3}{W} = 6$$

$$\frac{Q_3}{500} = 6$$

$$\boxed{Q_3 = 3000}$$

Chapter - ③

⑫ ⓒ

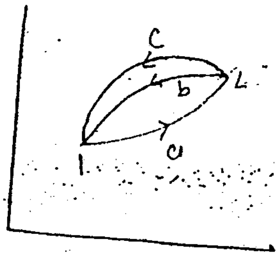
⑬ $dU = U_2 - U_1 = 20 \text{ KJ}$
ⓓ

⑭

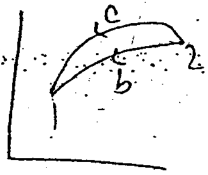
ENTROPY :-

Cas-I Reversible cycle

$$\oint_{rev} \frac{dQ}{T} = 0$$



1 - a - 2 - b - 1 rev cyc.
1 - a - 2 - c - 1 rev cyc.



$$\left(\frac{dQ}{T}\right)_{1a2} + \left(\frac{dQ}{T}\right)_{2b1} = 0$$

$$\left(\frac{dQ}{T}\right)_{1a2} + \left(\frac{dQ}{T}\right)_{2c1} = 0$$

$$\left(\frac{dQ}{T}\right)_{2b1} - \left(\frac{dQ}{T}\right)_{2c1} = 0$$

$$\left(\frac{dQ}{T}\right)_{2b1} = \left(\frac{dQ}{T}\right)_{2c1}$$

$$\left(\frac{dQ}{T}\right)_{rev\,b} = \left(\frac{dQ}{T}\right)_{rev,C}$$

For paths b, and c end point are same (2,1) and $\left(\frac{dQ}{T}\right)_{rev}$ is found to depend only on end points and hense $\left(\frac{dQ}{T}\right)_{rev}$ must be a Property... and this property is known as entropy. therefor ...

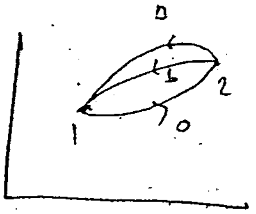
$$\boxed{dS = \left(\frac{dQ}{T}\right)_{rev}{}^{*}}$$

㊺ 500

$ds = \left(\frac{dQ}{T}\right)_{rev}$ is the second law of thermodynamic eqn for a process.

Case-II Irreversible cycle :-

$$\oint_{irr} \frac{dQ}{T} < 0$$



1-a-2-b-1 - rev cycle

1-a-2-c-1 - irrev

$$\left(\frac{dQ}{T}\right)_{1a2} + \left(\frac{dQ}{T}\right)_{2b1} = 0$$

$$\left(\frac{dQ}{T}\right)_{1a1} + \left(\frac{dQ}{T}\right)_{2c1} < 0$$

$$\left(-\frac{dQ}{T}\right)_{2b1} + \left(\frac{dQ}{T}\right)_{2c1} < 0$$

$$\underset{irrev}{\left(\frac{dQ}{T}\right)_{2c1}} < \underset{rev}{\left(\frac{dQ}{T}\right)_{2b1}}$$

$$\left(\frac{dQ}{T}\right)_{irrev} < ds$$

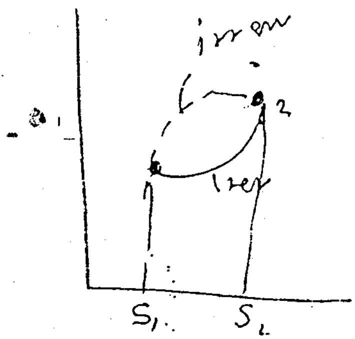
$$\left(ds > \frac{dQ}{T}\right)_{\cancel{Irrev}}$$

irreversible

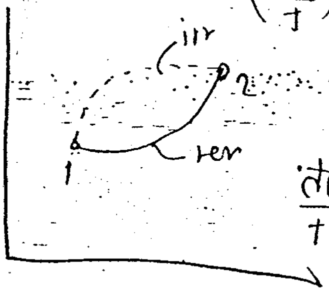
$(\Delta S)_{rev} = S_2 - S_1$

$(\Delta s)_{irrev} = S_2 - S_1$

$$\boxed{(\Delta S)_{rev} = (\Delta s)_{irrev}}$$



Ex- $\left(\frac{dQ}{T}\right)_{irrev} = 8$



$\frac{dQ}{T} = 10 = ds$

$\left[ds > \frac{dQ}{T}\right]_{irre}$

$10 > 8$

Entropy is a property it depend only on end points as long as end point are same the entropy change remain same for reversible as will will as irreversible path to find out entropy change for irreversible path it must be replace by a reversible path b/w same end point.

Entropy change for reversible process :-

* Case-I - When heat is added to the system
(Only for system)

$ds = \frac{dQ}{T}$ (+ve)

In K negative not possible

when heat is added to system dQ — (+ve) and

$ds = \left(\frac{dQ}{T}\right)^{+v}_{rev}$ (+ve)

$ds = +ve$

$ds > 0$

$S_2 - S_1 > 0$

$\boxed{S_2 > S_1}$ ∴ entroby incresed

that is in reversible proces when heat is added entroby of the system incrses

$\boxed{\text{Case-II}}$ Reversible heat rejection :-

$$ds = \left(\frac{\overset{(-ve)}{dQ}}{\underset{(+ve)}{T}}\right)_{(rev)}$$

$ds = -ve$

$\boxed{ds < 0}$

entroby of the system decrseses when heat is rejected in a reversible monner

$\boxed{\text{Case-III}}$ Reversible adibatic procen :-

$$ds = \left(\frac{dQ}{T}\right)_{rev}$$

in adibatic $\boxed{dQ = 0}$

$\boxed{dS = 0}$

$\boxed{S_2 = S_1}$ → entroby Constant

iso + entroby → isentrobic

* A reversible adibatic procen is an isentrobic procen. Here entroby constant

Note :- In a reversible process the system entropy can increased, can decreased or it can be remain constant depending on heat transfer.

Entropy change for irreversible process :-

$$ds > \left(\frac{dQ}{T}\right)_{irrev}$$

$$ds = \left(\frac{dQ}{T}\right)_{irrev} + \underbrace{\overbrace{(\delta S)_{gen}}^{(+ve)\ value}}_{irrev}$$

Ex :- $ds = -3 + 3$ ① Irrev process

$ds = 0 \to$ isentropic ② Heat rejection (Non-adiabatic)

** A Rev adiabatic process is always Isentropic (✓)

An Isentropic is always reversible (X)

though reversible adiabatic is always isentropic and Isentropic process need not be reversible adiabatic

Adibatic procen $(dQ = 0)$

(rev.)

$$ds = \frac{dQ}{T}$$

$$ds = \frac{0}{T}$$

$$ds = 0$$

$$\boxed{S = \text{constant}}$$

↳ Isentropic

(irreven)

$$ds > \left(\frac{dQ}{T}\right)_{irrev}$$

$$ds = \left(\frac{dQ}{T}\right)_{irre} + (\delta S)_{gen}$$

$$ds = (\delta S)_{gen}$$

$$\boxed{ds > 0} \rightarrow \text{non-isentropic}$$

An adibatic procen need not be isentropic always if the adibatic procen is reversible then it must be isentropic

An if the adibatic procen is irreversible then it must be non isentropic.

$$\text{irrever} \leftarrow ds = \left(\frac{dQ}{T}\right)_{irrev} + \underset{\text{(+ve)} \rightarrow \text{more positive}}{(\delta S)_{gen}}$$

↑

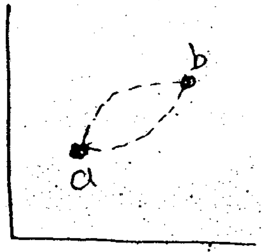
$$\text{reve} \text{ — } ds = \left(\frac{dQ}{T}\right)_{rev} + 0$$

then if a is more irreve than b

$$(ds)_a = \left(\frac{dQ}{T}\right)_{irr} + (\delta S)_{gen\,a}$$

$$(ds)_b = \left(\frac{dQ}{T}\right)_{irr\,b} + (\delta S)_{gen,\,b}$$

$$(\delta S)_{gen\,a} > (\delta S)_{gen\,b}$$



$$\underbrace{(ds)_a = (ds)_b}_{\text{property}}$$

through entropy is the property entropy generation is ~~bo~~ not a property. It depends on irreversibilities.

* Greater the irreversibility greater is the entropy generation

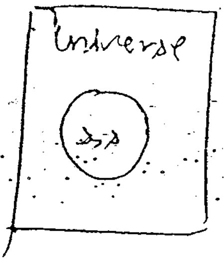
And hence entropy generation is a path function.

Physical meaning of entropy :-

Entropy is the measure of molecular disorderness greater the disorderness greater is the entropy change lesser is the efficiency.

Entropy of universe :-

$$ds \geq \frac{dQ}{T}$$



Universe → isolated sys

$m\times$ $E\times$

$Q\times$ $W\times$

for an isolated system $dQ = 0$

$$(ds)_{Universe} \geq \frac{0}{T}$$

$$\boxed{(ds)_{unirse} \geq 0}$$

$$\boxed{(ds)_{sys} + (ds)_{surr} \geq 0}$$

Entropy of the system increased, decreased, /

Surroundings < increased / decreased → but overall entropy change of universe can never decreased. this is known as

Principle of incresed of entropy:

~~T-S~~ diagram

* Directional law :-

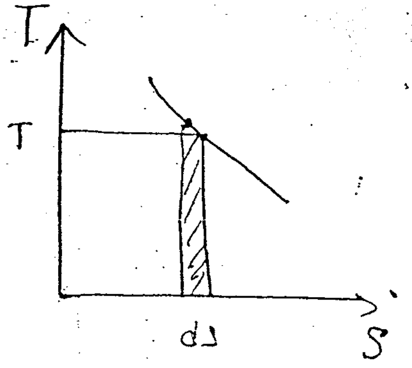
According to second law of thermodynamic all those process are possible for which the change in entropy for universe is grater than or equal to zero

T-S diagram :- (S depeded on mass so extensive property)

$$\frac{dQ}{T} = dS \rightarrow \text{this for reversible}$$

$$dQ = T.dS$$

$$\boxed{dQ = Area} \rightarrow \text{so it for reven}$$

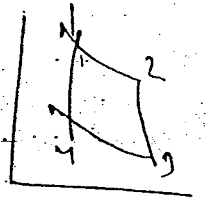


Area under the curve when projected on entropy axis gives reversible heat transfer

$\boxed{Area = T.dS}$

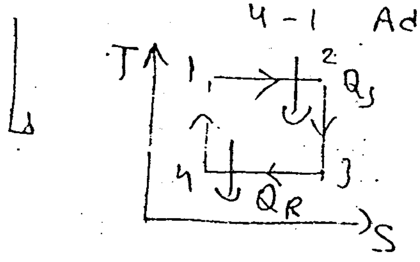
Representation of Carnot cycle on (T-S) diagram :-

three important
$Q_S \rightarrow S\uparrow$
$Q_R \rightarrow S\downarrow$
$Q = 0$, S = const



1-2 → Isothermal heat addition
2-3 Adiabatic expansion
3-4 Isothermal heat rejection
4-1 Adiabatic compression

reversible process



Princible ot incresed of entropy:

~~T-S~~ diagram

* Directional law :-

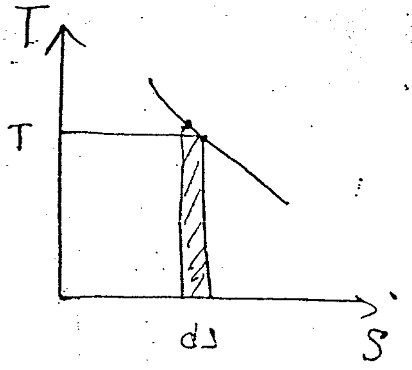
According to second law of thermodynamic all through process are possible for which the change in entropy for universe is grater than or equal to zero

T-S diagram :- (S depended on mass so extensive property)

$$\frac{dQ}{T} = dS$$ → this for reversible

$$dQ = T_1 ds$$

$$\boxed{dQ = \text{Area}}$$ → so it for reven.



Area under the curve when projected on entropy axis gives reversible heat transfer

$$\boxed{\text{Area} = T\,ds}$$

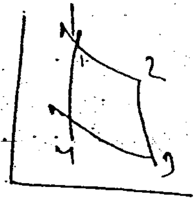
Representation of Carnot Cycle on (T-S) Diagram :-

three important

$Q_S \rightarrow S\uparrow$

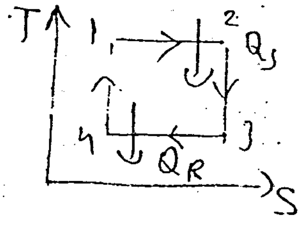
$Q_R \rightarrow S\downarrow$

$Q = 0$, $S = const$



1-2 → Isothermal heat addition
2-3 Adiobatic expansion
3-4 Isothermal head rejection
4-1 Adiobatic compression

} reversible process



Combined Ist and IInd law of thermod:-

$$đQ = du + Pdv \longrightarrow rev \ (I^{st} \ law)$$

$$ds = \left(\frac{đQ}{T}\right)_{rev} \ \ldots$$

$$đQ = Tds \longrightarrow rev \ (II^{nd} \ law)$$

$$\boxed{Tds = du + PdV}$$ → For all (rev + Irrev) → all property

this eqn is valid for any process (reversible or irreversible process) because it correlates various properties and property depends only on end point.

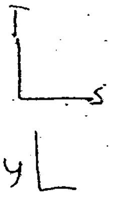
$$h = u + pv$$
$$dh = \underbrace{du + pdv} + vdp$$
$$dh = đQ + vdp$$
$$dh = Tds + vdp$$
$$\boxed{Tsd = dh - vdp}$$

for all process (rev + irrev)

$$dQ = du + Pdv$$
$$\frac{dQ}{T} = ds$$
$$\boxed{dQ = Tds}$$

The Representation of Const - Constant pressure and Constant volume lines on T-S diagram

Represention of Constnt presure and Constant volume lines on T-S diagram for an ideal gas :-



$\frac{dT}{ds}$

$Tds = du + pdv$	$Tds = dh - vdp$
$V = C$, $\boxed{dv = 0}$	$p = \text{Const}$. $dp = 0$
$du = C_v dT$	$dh = C_p dT$
$Tds = C_v dT + 0$	$Tds = C_p dT - 0$
$Tds = C_v dT$	$Tds = C_p dT$
$\frac{dT}{dS} = \frac{T}{C_v}$	$\frac{dT}{ds} = \frac{T}{C_p}$
Slop of Const volume On T-S digram $= \frac{T}{C_v}$	Slop of const presure on (T-S) diagram $= \frac{T}{C_p}$

$$P \Rightarrow C \longrightarrow \frac{T}{C_p}$$

$$V = C \longrightarrow \frac{T}{C_v}$$

But

$$\boxed{C_p > C_v}$$

Here - As $C_p > C_v$ Slop of Const volume lines is > Slop of Const. presure lines On T-S diagram

Entropy change For ideal gas :-

$Tds = dU + pdv$	$Tds = dh - Vdp$
$PV = mRT$	$ds = \frac{dh}{T} - \frac{V}{T} dp$
$Pv = RT \Rightarrow \frac{P}{T} = \frac{R}{V}$	$dh = C_p dT$, $PV = RT$

$$du = C_v\,dT$$

$$ds = \frac{du}{T} + \frac{P}{T}\,dV$$

$$\int_{S_1}^{S_2} ds = \int_{T_1}^{T_2} \frac{C_v\,dT}{T} + \int_{T_1}^{T_2} \frac{R}{V}\,dV$$

$$\boxed{S_2 - S_1 = C_v \ln\frac{T_2}{T_1} + R\ln\frac{V_2}{V_1}}$$

$$\frac{V}{T} = \frac{R}{P}$$

$$\int_{S_1}^{S_2} ds = \int_{T_1}^{T_2} C_p\frac{dT}{T} - \int_{P_1}^{P_2} \frac{R}{P}\,dP$$

$$\boxed{(S_2 - S_1) = C_p \ln\frac{T_2}{T_1} - R\ln\frac{P_2}{P_1}}$$

Valid for ideal gas

Q. Show that for an ideal gas -

$$S_2 - S_1 = C_p \ln\frac{V_2}{V_1} + C_v \ln\frac{P_2}{P_1}$$

Ans

$$S_2 - S_1 = C_v \ln\frac{T_2}{T_1} + R\ln\frac{V_2}{V_1}$$

$$S_2 - S_1 = C_p \ln\frac{T_2}{T_1} - R\ln\frac{P_2}{P_1}$$

$$= \ln\frac{T_2}{T_1}(C_p - C_v) - R\left[\ln\frac{P_2}{P_1} + \ln\frac{V_2}{V_1}\right]$$

$$= R\ln\frac{T_2}{T_1} - R\left[\ln\frac{P_2}{P_1} + \ln\frac{V_2}{V_1}\right] = 0$$

$$= \ln\left(\frac{T_2}{T_1}\right) - \left[\ln\frac{P_2}{P_1} + \ln\frac{V_2}{V_1}\right]$$

$$S_2 - S_1 = C_v \ln \frac{T_2}{T_1} + R \ln \frac{V_2}{V_1}$$

$$S_2 - S_1 = C_v \ln \frac{T_2}{T_1} + (C_p - C_v) \ln \frac{V_2}{V_1}$$

$$S_2 - S_1 = C_v \ln \frac{T_2}{T_1} + C_p \ln \frac{V_2}{V_1} - C_v \ln \frac{V_2}{V_1}$$

$$S_2 - S_1 = C_v \left[\ln \frac{T_2}{T_1} - \ln \frac{V_2}{V_1} \right] + C_p \ln \frac{V_2}{V_1}$$

$$S_2 - S_1 = C_v \left[\ln \left(\frac{\frac{T_2}{T_1}}{\frac{V_2}{V_1}} \right) \right. + C_p \ln \frac{V_2}{V_1}$$

$$(S_2 - S_1) = C_v \ln \left(\frac{T_2}{T_1} \cdot \frac{V_1}{V_2} \right) + C_p \ln \frac{V_2}{V_1}$$

$$\boxed{S_2 - S_1 = C_v \ln \frac{P_2}{P_1} + C_p \ln \frac{V_2}{V_1}}$$

$Pv = mRT$

$\frac{Pv}{T} = mR = \text{con}$

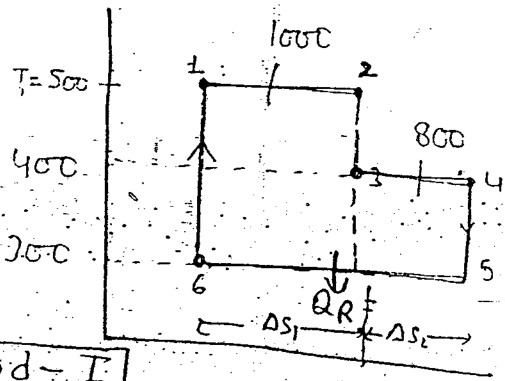
$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$

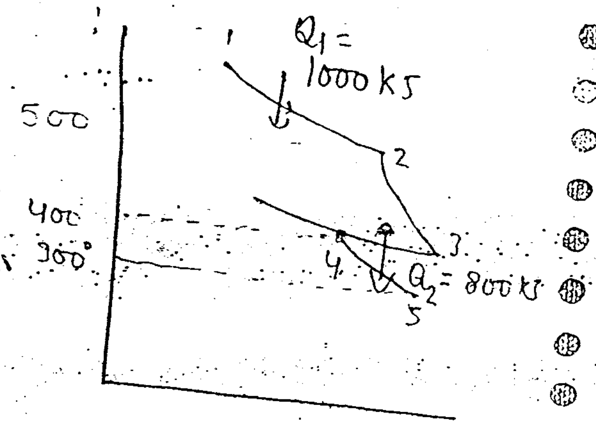
ES

2-8-11

Q. A closed system aejcuted a reversible cycle 1-2-3-4-5-6-1 consisting of 6 processes during process 1-2 the dis system recived 1000 KJ of heat at a const. temp of 500°K 2-3 is adibatic expansion in which the temp. decreses from 500°K to 400°K during 3-4 800 KJ of heat is added at a constant temp of 400°K, 4-5 is adibatic expansion it ~~means~~ which the ~~temp.~~ system temp decreses from 400 to 300°K the system rejected heat during process 5-6 at a constant temp. of 300°K Process 6-1 is adibatic compression determin the net work done by the system and efficiency of the cycle? Also representation of cycle on T-S diagram?

Ans :-





Method - I

① work done = ?

② efficiency = ?

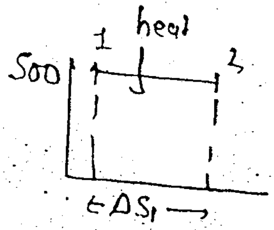
Work done

$W = Q_S - Q_R$

$= (1000+800) - 1200$

$= 1800 - 1200$

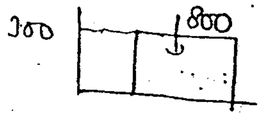
$\boxed{W = 600\ KJ}$



heat = Area

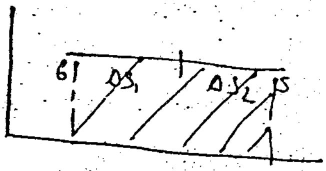
$1000 = 500\,\Delta S_1$

$\Delta S_1 = \frac{1000}{500} = 2$



$800 = 300 \times \Delta S_2$

$\boxed{\Delta S_2 = 2}$



$(\Delta S_1 + \Delta S_2)$

Heat = Area

$Q_R = 300(\Delta S_1 + \Delta S_2)$

$Q_R = 300(2+2)$

$Q_R = 1200$

$\boxed{Q_R = 1200}$

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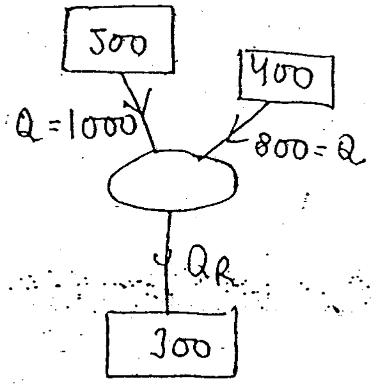
$$\eta = \frac{W}{Q_S} = \frac{600}{1800} = 0.333 = 33.3\,\%$$

$$\boxed{\eta = 33.3\,\%}$$ A.

Method – II



For reversible

$$\boxed{\oint \frac{dQ}{T} = 0}$$

$$\left[\frac{1000}{500} + \frac{800}{400}\right] - \frac{Q_R}{300} = 0$$

$$\boxed{Q_R = 1200}$$ A.

$$W_{re} = Q_S - Q_R$$
$$= 1800 - 1200 = 600$$ A.

✡ $$ds = \left(\frac{dQ}{T}\right)_{irrev} + \underbrace{(\delta s)_{generation}}$$ ↱ Irreversiblty

$\left(\frac{dQ}{T}\right)_{irrev}$ ↓ due to [External intration of heat]

$(\delta s)_{generation}$ ↓ due to [Internal Irreversiblity]

$$ds = \left(\frac{dQ}{T}\right)_{reve}$$
↳ only introction extrnal

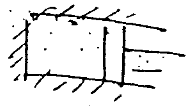
Entropy change occuse due to External introction and internal irreversiblities. In reversible process entropy change occuse only due to external intraction.

For problem

⇒ In an adibatic process as their is no external interaction with surroundings in the form of heat transfer therefore entropy change for surrounding is equal to zero

$$dS = \left[\frac{dQ}{T}\right]_{rev}$$

in adibatic



hear $\Delta Q = 0$

So heat Intraction with the system is zero

$$dS = \left(\frac{dQ}{T}\right) + \delta S$$

$\downarrow$ (zero) be $(\Delta Q = 0)$

Q Air is flowing stadying in an insulated pipe the pressures and temp. at two stations A and B or given in the table stablished the direction of flow of air in pipe take $C_p = 1.005$ KJ/kg-K and $R = 0.287$ KJ/kg-K

	Station Ⓐ	Station Ⓑ
Pressure	130 kPa	100 kPa
Temp.	50°c	13°c

* Just Pressure does not decide the flow direction

total energy decide the direction of flow

Ans :- We know from the IInd law of thermo all process possible when

$$(\Delta S)_{univers} \geq 0$$

As the system is insulated their is no entropy change for surroundings therefor

$$(\Delta S)_{sys} + \underset{=0 \text{ (insulated)}}{\underbrace{(\Delta S)_{surr}}} \geq 0$$

$$\boxed{(\Delta S)_{sys} \geq 0}$$

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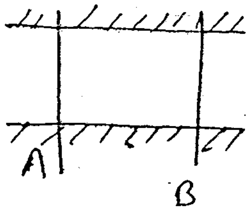
Let us assume the flow from A to B



$$\boxed{S_2 - S_1 = C_p \ln \frac{T_2}{T_1} - R \ln \frac{P_2}{P_1}}$$

$$\boxed{(S_B - S_A) = C_p \ln \frac{T_B}{T_A} - R \ln \frac{P_B}{P_1}}$$

$$= 1.005 \ln\left[\frac{286}{322}\right] - 0.287 \times \ln\left(\frac{100}{130}\right)$$

$$(\Delta S)_{sys} = -0.0469 \text{ kJ/kg-K}$$

(It is not bossible because $(\Delta S)_{sys} \geq 0$

So flow from B to A Ans.

As $(\Delta S)_{univ} < 0$ therefor the flow is not bossible from A to B and hense the flow ocure from B to A.

* E

For adibatic

$(\Delta S)_{univ} \geq 0$

$(\Delta S)_{sys} + (\Delta S)_{surr} \geq 0$

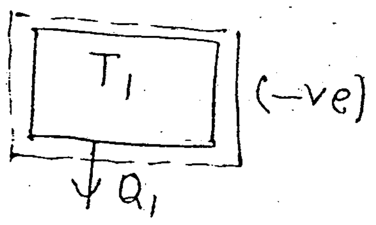
For adibatic $(\Delta S)_{sur} = 0$

$(\Delta S)_{sys} \geq 0$

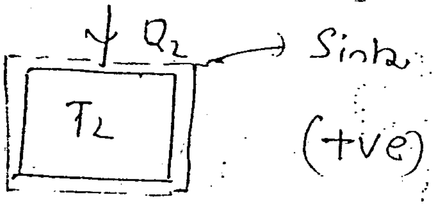
So $\boxed{(\Delta S)_{sys} = (\Delta S)_{univers}}$

For adibatic procen

Entropy change for reservoirss :-



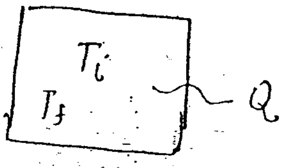
Source



$$\boxed{(\Delta s)_{source} = -\frac{Q_1}{T_1}}$$

$$\boxed{(\Delta s)_{sink} = \frac{Q_2}{T_2}}$$

*** Entropy change for a finit body :-



$$dQ = mc\,dT$$

$$dS = \frac{dQ}{T}$$

$$\int_{S_i}^{S_f} dS = \int_{T_i}^{T_f} \frac{mc\,dT}{T}$$

$$\boxed{S_f - S_i = mc \ln \frac{T_f}{T_i}}$$

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Chapter - ⑤

① $ds = \left(\frac{dQ}{T}\right)_{irrev} + (\delta s)_{gen}$

adiabatic $dQ = 0$ ⓓ

$ds = (\delta s)_{gen}$ — (+ve)

③ $m = 10$ kg

$C_v = 5R/2$; $R = 287$ J/kg-K

$P_1 = 100$ kPa $T_1 = 300$K

$P_2 = 200$ kPa $T_2 = 500$K

$\Delta S = ?$

$(S_2 - S_1) = C_p \ln \frac{T_2}{T_1} - R \ln \frac{P_2}{P_1}$

~~$(S_2 - S_1) =$~~ $R = 287$ J/kg-k

$R = \frac{287}{10^3}$ kJ/kg-k

$R = 0.287$ kJ/kg-k

$C_v = \frac{5R}{2} \Rightarrow C_p - C_v = R$

ⓑ $C_p = \frac{7R}{2}$

$C_p = \frac{7 \times 0.287}{2} = 1.0045$

$(S_2 - S_1) = 1.0045 \ln\left[\frac{500}{300}\right] - 0.287 \left[\frac{200}{100}\right]$

$(S_2 - S_1) = 0.314$ kJ/kg-k

this for one kg

$(S_2 - S_1) = 0.314 \times 10 = 3.14$ kJ/k

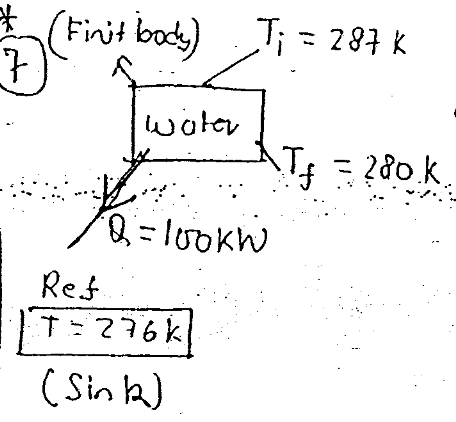
$\boxed{\Delta S = 3.14 \text{ kJ/K}}$ A.

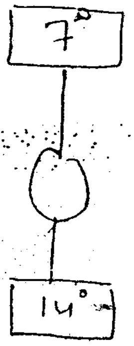
⑤ ⓓ

⑥ $- \Delta S = C_p \ln \frac{T_2}{T_1} - R \ln \frac{P_2}{P_1}$

ⓒ temp + Press depend

* ⑦





$(\Delta S) = (\Delta S)_{water} + (\Delta S)_{ref}$

$(\Delta S)_{ref} = \frac{100}{276} \frac{kW}{K}$

$(\Delta S)_{H_2O} = mc \ln \frac{T_f}{T_i}$

$(\Delta S)_{H_2O} = \frac{100}{7} \times \ln\left(\frac{280}{287}\right)$

$= \frac{100}{276} + \frac{100}{7} \ln\left(\frac{280}{287}\right)$ | $100 = mc(7)$ $mc = \frac{100}{7}$

$= 9.5 \times 10^{-3} \frac{kW}{K}$

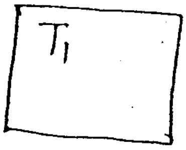
$= 9.5 \times 10^{-3} \times 10^3 \frac{W}{K}$

$= 9.5$ W/K

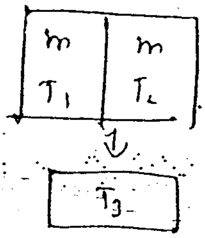
ⓐ

veImp

⑧ * [Mixing process ↓ irreversible process]



A liquid of mass m at temp T_1.



$$\Delta S = \Delta S_1 + \Delta S_2$$

$$\Delta S = mc\ln\left(\frac{T_3}{T_1}\right) + mc\ln\left(\frac{T_3}{T_2}\right)$$

$$\Delta S = mc\left[\ln\left(\frac{T_3}{T_1}\right) + \ln\frac{T_3}{T_2}\right]$$

$$\Delta S = mc\ln\frac{T_3^2}{T_1T_2}$$

$$\Delta S = mc\ln\frac{T_3^2}{(\sqrt{T_1T_2})^2}$$

$$\boxed{\Delta S = 2mc\ln\left[\frac{T_3}{\sqrt{T_1T_2}}\right]}$$

$$T_1 > T_2$$

$$m(T_1 - T_3) = m(T_3 - T_2)$$

$$T_1 - T_3 = T_3 - T_2$$

$$\boxed{T_1 + T_2 = 2T_3}$$

$$\boxed{\Delta S = 2mc\ln\left[\frac{2\,T_1 + T_2}{2(\sqrt{T_1T_2}}\right]}$$

So here

$$\boxed{\Delta S > 0}$$

$$\frac{T_1+T_2}{2} > \sqrt{T_1T_2}$$

but > → irreversible process

then

* $\boxed{\Delta S > 0}$

Mixing is irreversible process

⑬ $m = 1$ kg/s

$T_1 = 70°C$ $T_2 = 40°C$

$C_p = 4.2$ kJ/kg-K

$$\Delta S = 2mc\ln\left[\frac{T_1+T_2}{2\sqrt{T_1T_2}}\right]$$

$$= 2\times1\times4.2\ln[$$

$$\Delta S = 8.8$$

* Arithmetic mean:

$$\boxed{\frac{T_1+T_2}{2} > \sqrt{T_1T_2}}$$

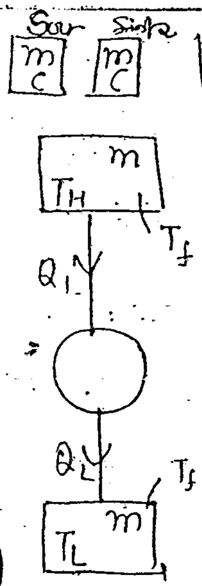
therefor

$$\boxed{\Delta S > 0}$$

and hence mixing is an irreversible process.

SH

mTf ⑨



$Q_1 = mc(T_H - T_f)$

$Q_2 = mc(T_f - T_L)$

$W = Q_1 - Q_2$

$= mc(T_H - T_f)$

$- (mc(T_f - T_L)$

$W = mc[T_H - T_f - T_f + T_L]$

$\boxed{W = mc[T_H + T_L - 2T_f]}$

But $\boxed{(\Delta S)_{univ} = 0}$ - (because reversible)

$(\Delta S)_{sys} + (\Delta S)_{surro} = 0$

$\boxed{(\Delta S)_{sys} = 0}$

as ~~system is~~

As the engine is undergoing n times for cycle therefor system undergoes cyclic processes and as entropy is the property change in entropy is zero for a cycle. therefor

$\boxed{(\Delta S)_{sys} = 0}$

$(\Delta S)_{sys} + (\Delta S)_{surro} = 0$

$\overset{\|}{0}$

$\boxed{(\Delta S)_{surr} = 0}$

$$mc \ln \frac{T_f}{T_H} + mc \ln \frac{T_f}{T_L} = 0$$

$$mc \ln\left[\frac{T_f^2}{T_h T_L}\right] = 0$$

$$\ln \frac{T_f^2}{T_h + T_L} = 0 = \ln 1$$

$$\frac{T_f^2}{T_f + T_L} = 1$$

$\boxed{T_f = \sqrt{T_H \times T_L}}$

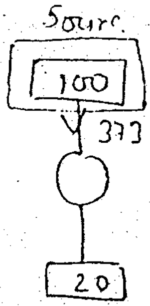
Ⓒ

$\boxed{W = mc(T_H + T_L - 2\sqrt{T_h T_L})}$

⑩ d (all process irreversible)

⑪ C

⑫ $dS = \frac{dQ}{T}$



$\boxed{\Delta S_1 = ?}$

$$dS = -\frac{Q}{T}$$

$$= \frac{-373}{373} = -1 \ A_2.$$

(14) $C = a + bT^2$ (13) a

$\Delta S = mc \ln \frac{T_f}{T_i}$

$\int_{S_1}^{S_2} ds = m \int_{T_1}^{T_2} (a+bT^2)\left(\frac{T_2}{T_1}\right)$

$ds = \frac{dQ}{T}$ (a)

$dQ = mc\,dT$

$\int_{S_1}^{S_2} ds = \int_{T_1}^{T_2} \frac{mc\,dT}{T}$

$(S_2 - S_1) = \int_{T_1}^{T_2} m(a+bT^2) \frac{dT}{T}$

$(S_2 - S_1) = m\int_{T_1}^{T_2} a \ln[T]_{T_1}^{T_2} + b \times \left[\frac{T^2}{2}\right]_{T_1}^{T_2}$

$= m\left[a \ln[T_2 - T_1] + \frac{b}{2}[T_2^2 - T_1^2]\right]$

$= m = 1$

$= a \ln(T_2 - T_1) + \frac{b}{2}(T_2^2 - T_1^2]$

(15) $(U + PV)$ — enthalpy ($P=C$)

$\frac{dH}{ds}$ | $Tds = dh - Vdp$

↳ const Press proce

$Tds = dh$

$\boxed{dh \propto T}$

(a)

(16) (d) Reversible

Q_S Q_R $Q=0$

$S\uparrow$ $S\downarrow$ $S = \text{Const.}$

(17) (A) Slope of Const. P $\frac{T}{C_p} = \frac{T}{\frac{\gamma R}{\gamma - 1}}$

$\frac{(\gamma-1)T_0}{\gamma R}$

(18)

$\Delta S = mC \ln \frac{T_f}{T_i}$

$= 1 \times 1 \times \ln \frac{303}{873} = -1.058$ (b)

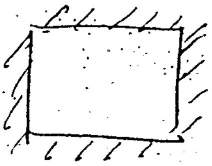
(19) Free expansion

$\boxed{W=0} + \boxed{Q=0}$

(20) – $\Delta S = mC \ln \frac{T_f}{T_i}$

adibatic

$\boxed{(\Delta s)_{surr} = 0}$



initial = V_i

final = $2V_i$ for ideal gas

$S_2 - S_1 = C_v \ln \frac{T_2}{T_1} + R \ln \frac{V_2}{V_1}$

$T_1 = T_2$

$\ln \frac{T_2}{T_1} = \ln 1 = 0$

$S_2 - S_1 = +R \ln \frac{V_2}{V_1}$

$\Delta S = R \ln \frac{2V}{V}$ (b)

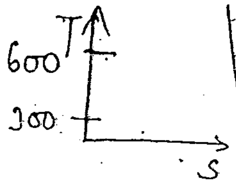
* When free expansion

$T_1 = T_2$

$V_1 = V_2$

$h_1 = H_2$

(21)



$\eta = \frac{O}{I}$

↓

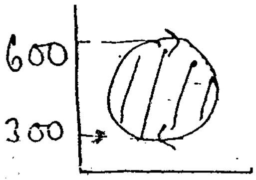
means → output

↓

means → work producing

↓

means clock wise

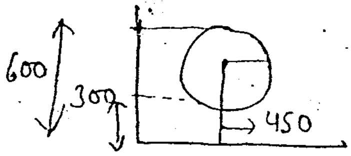


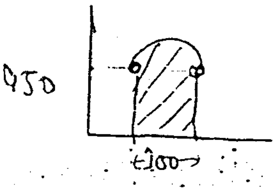
T-S closed are $= \Sigma Q = \Sigma W$

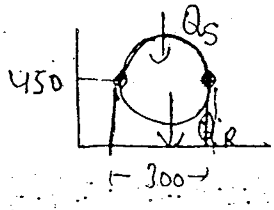
$\eta = \frac{W_{net}}{Q_s}$

$\Sigma W =$ Area $= \frac{\pi}{4}(300)^2$

(b)







$Q_s = \frac{\pi}{4} \cdot \frac{(300)^2}{2} + 450 \times 300$

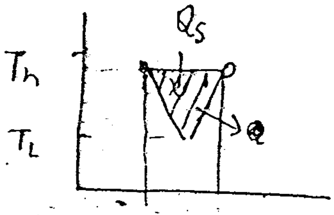
$$\boxed{\eta = \frac{\Sigma W}{\Sigma Q_s} = \frac{\frac{\pi}{4}(300)^2}{\frac{\pi}{4}\frac{(300)^2}{2} + 450 \times 300}}$$

(22) (d)

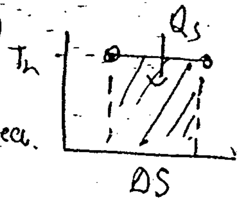
(23) d

(24)

(24) $\eta = \frac{W_{net}}{Q_s}$



$W_{net} = \frac{1}{2} \Delta S (T_h - T_c)$



heat supplied = Area.

$Q_s = T_h \times \Delta S$

$= \frac{\frac{1}{2} \Delta S (T_h - T_c)}{\Delta S \, T_h}$ (b)

$$\boxed{\eta = 0.5 \frac{(T_h - T_c)}{T_h}}$$

(25) C

(26) $C_v \ln \frac{T_2}{T_1} + R \ln \frac{V_2}{V_1}$

Isid $\boxed{V = C}$

$V_1 = V_2$

$\ln \frac{V_1}{V_2} = 0$

$S_2 - S_1 = C_v \ln \frac{T_2}{T_1}$

$S_2 - S_1 = -ve$

= decreased entropy

$T_2 < T_1$

$\frac{T_2}{T_1} < 1$

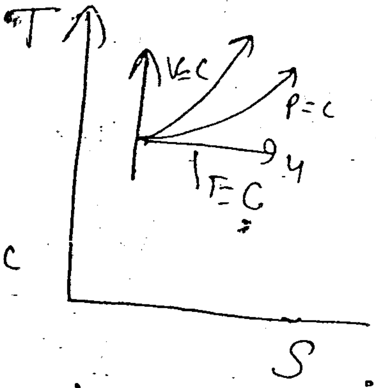
$\ln < 1$

↳ negati

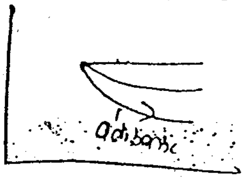
(a)

(27)

On T-S more slope V=C
less slope = P=C



(b)



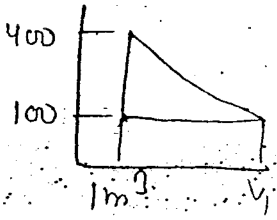
expansion so temp - less

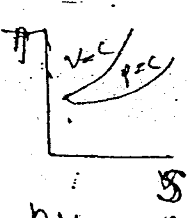
(28) a

same

(29) d (30) d

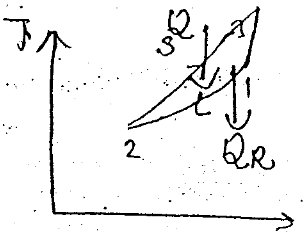
(31) 1-2 → P=C
2-3 → V=C
3-1 → adibatic





$PV = mRT$

$\boxed{V \propto T}$



(C)

$PV = mRT$
$P \propto T$

(32) $\boxed{\eta = 1 - \frac{Q_R}{Q_S}}$

ideal
$dU = mC_v dT$

$Q_S = m \cdot C_v (T_3 - T_2)$

$Q_R = m C_p (T_2 - T_1)$

$Q_{12} = - m C_p (T_1 - T_2)$

$Q_R = m C_p (T_1 - T_2)$

$$\eta = 1 - \frac{m C_p (T_1 - T_2)}{m C_v (T_3 - T_2)}$$

$$\eta = 1 - \frac{\gamma \cancel{T_1} \left(\frac{T_1}{T_2} - 1 \right)}{\cancel{T_2} \left(\frac{T_3}{T_2} - 1 \right)}$$

$$\boxed{\eta = 1 - \frac{\gamma \left(\frac{T_1}{T_2} - 1 \right)}{\frac{T_3}{T_2} - 1}}$$

Rejection
(initial - final)

$Q_{12} = - m C_p (T_1 - T_2)$

1-2
$PV = mRT$
$V \propto T$
$\frac{V_1}{V_2} = \frac{T_1}{T_2}$

2-3
$PV = mRT$
$P \propto T$
$\frac{P_3}{P_2} = \frac{T_3}{T_2}$

$$\eta = 1 - \frac{\gamma \left[\frac{V_1}{V_2} - 1 \right]}{\left(\frac{P_3}{P_2} - 1 \right)}$$

(3-1) $PV^{\gamma} = C$

$P_3 V_3^{\gamma} = P_1 V_1^{\gamma}$

$400 \times (1)^{1.4} = 100 (V_1)^{1.4}$

$V_1 = 2.69$

$$\eta = 1 - \frac{1.4\left(\frac{2.69}{1} - 1\right)}{\frac{400}{100} - 1}$$

ⓐ

$$\boxed{\eta = 21.1\%}$$

③③ old work problem → ⓑ

③④ $P_1 = 100$

$P_2 = 125$ → find in ③③

$V_1 = 0.002$

$V_2 = 0.003$

ⓒ

$$(S_2 - S_1) = C_p \ln \frac{V_2}{V_1} + C_v \ln \frac{P_2}{P_1}$$

$$(S_2 - S_1) = 1.005 \times \ln \frac{0.003}{0.002} + 0.718 \ln \frac{125}{100}$$

$$\boxed{(S_2 - S_1) = 0.567} \text{ KJ/kg-K}$$

②
Incompressible

$\rho = \text{const}$

$\rho = \frac{m}{Vol}$ — const, const

$$\boxed{Tds = du + Pdv}$$

$Tds = du$ $\boxed{dv = 0}$

$S = C$ (Given)

$dS = 0$

$dU = 0$

$T = \text{Const}$

For liquid only C → C_v, C_p not

$dU = 0$

$C_v dT = 0$

$C\,dT = 0$

$$\boxed{T = \text{Const.}}$$

(U, V, h) → Const

V = C

$$\boxed{\begin{matrix} S = C \\ U = C \\ T\ C \end{matrix}}$$

④ C

① d ⑪ c ③ b ④ a ⑤ d ⑥ c ⑦ a *⑧ b *⑨ c
⑩ d ⑪ d ⑫ c ⑬ a ⑭ a ⑮ a ⑯ d
⑰ a ⑱ b ⑲ b ⑳ d ㉑ b ㉒ d **㉓ d ㉔ 4
㉕ c ㉖ a ㉗ b ㉘ a ㉙ b ㉚ b ㉛ c ㉜ a
㉝ b ㉞ d

Avilable energy, Avilablity & Irrsibility

Avilable energy :-

It is the maximum possible amount of work that can be obtained in a cycle is known as avileable energy.

Maxi. work is possible when the cycle is reversible.

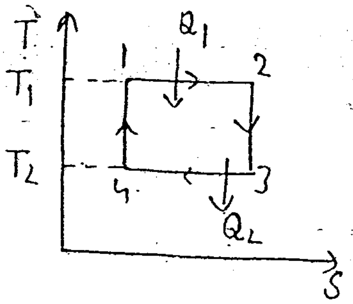
$$\eta = \frac{W}{Q_1}$$

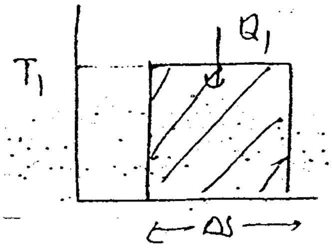
$$\eta_{max} = \frac{W_{max}}{Q_1}$$

$$\eta_{max} = 1 - \frac{T_2}{T_1}$$

$$\frac{W_{max}}{Q_1} = 1 - \frac{T_2}{T_1}$$

$$W_{max} = Q_1 \underbrace{\left(1 - \frac{T_2}{T_1}\right)}_{}\xrightarrow{} \text{len}$$





$Q_1 = T \times \Delta S$

this work is further maximum for siven source temp. T_1 and for an siven heat input Q_1 when T_2 is minimum. the lowest possible temp of head rejection is detn of Surrouding (T_0) and this maximum work is known as avilable energy.

when $\boxed{T_2 = T_0}$

$$A \cdot E = W_{max} = Q_1 \left(1 - \frac{T_0}{T_1}\right)$$

$$\boxed{A \cdot E = Q_1 \left(1 - \frac{T_0}{T_1}\right)}$$

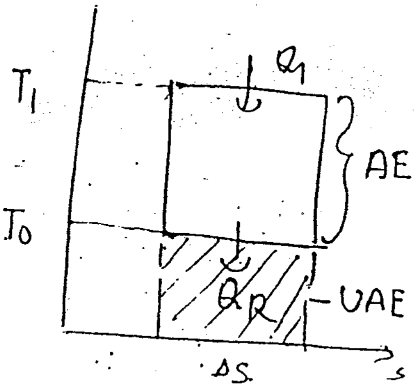
T_0 = Atmospheric temp.

Q_1 = Source energy

$Q_1 = T_1 \Delta S$

$\frac{Q_1}{T_1} = \Delta S$

$Q_2 = T_0 \Delta S$ ↓ Heat rejection



$$A \cdot E = Q_1 - \frac{Q_1}{T_1} T_0$$

$$A \cdot E = Q_1 - T_0 \Delta S$$

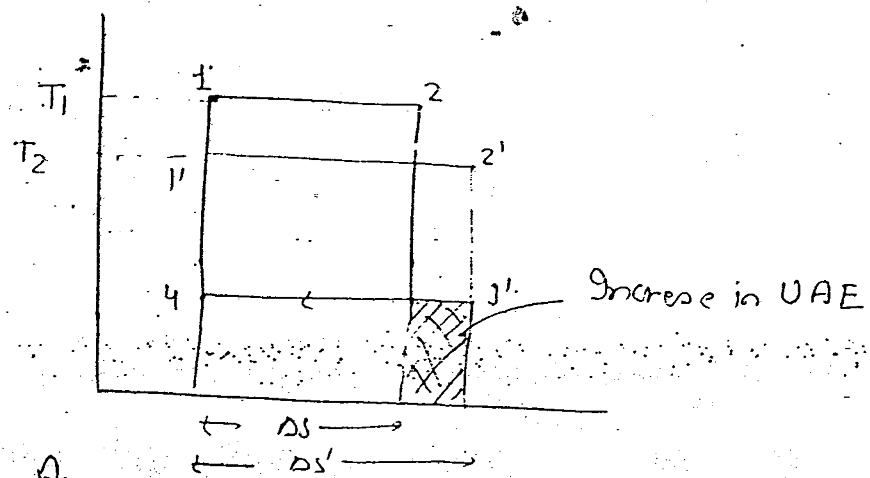
$$Q_1 = \underset{\text{max}}{A \cdot E} + \underset{\text{min (unavilable energy)}}{T_0 \Delta S}$$

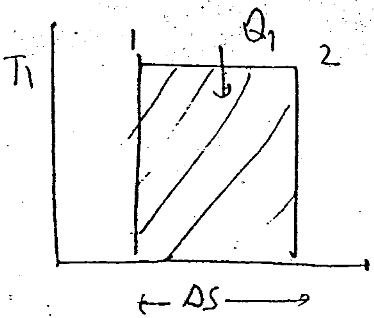
$$\boxed{Q_1 = A \cdot E + U A \cdot E}$$

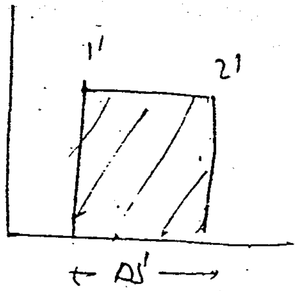
The minimum heat rejection ($T_0 \Delta S$) is known as unavileable Energy. The area below T_0 always represents unavilable enegy.

58

Loss of avileable Energy when heat is transfer through a finit temp. diffrence :-







$$Q_1 = T_1 \Delta S$$

$$\Delta S = \frac{Q_1}{T_1}$$

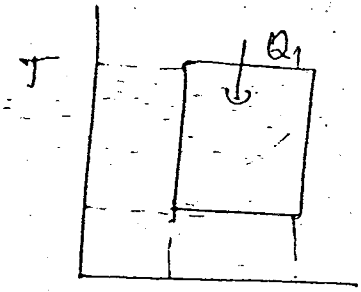
$$Q_1 = T_2 \Delta S'$$

$$\Delta S' = \frac{Q_1}{T_2}$$

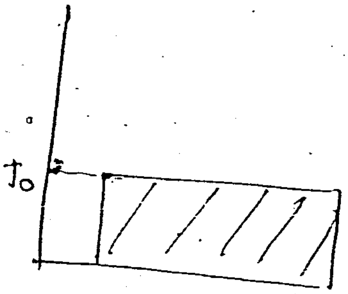
Increse in UAE = $T_0 (\Delta S' - \Delta S)$

$$\uparrow \text{in UAE} = T_0 \left[\frac{Q_1}{T_2} - \frac{Q_1}{T_1} \right]$$

$$\boxed{\uparrow \text{in UAE} = Q_1 T_0 \left(\frac{T_1 - T_2}{T_1 T_2} \right)}$$



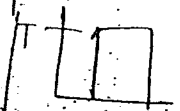
Meanis ful high Quality because produce work



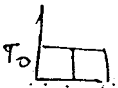
Meanis less low Quality Not produce work

if temp. less on same Q_1 ~~work~~ inverses the UAE

+ Above the atmosph temp. produce work.



meanis ful high Quality



meaning less | low Qual

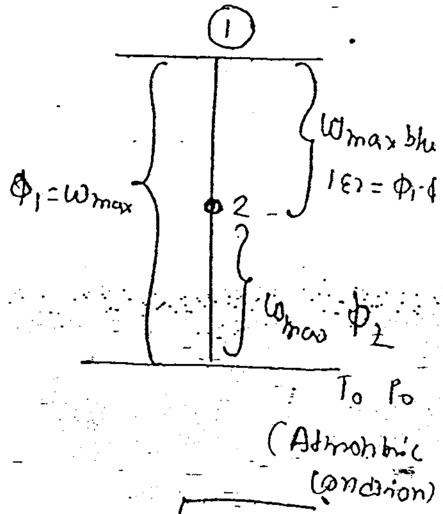
Note :- According to Ist law of thermodynamic thermal energy at higher temp have same meanins when Capairer to same amount of thermal enegy at lower temp. and hense Ist law is known as Quantitative law.

According to IInd law of thermodynamics thermal energy at higher temp has greater signifians when Compair to same amout of thermal enegy at lower temp because thermal energy at higher temp. is capable of producing power and hense IInd law is knows Qualitative law.

~~Availeablity~~

Avileablity :- It is the maximum work obtain in a process in which the system comes in to be equlibrium with surroundings.

Maxi work in any two point = Change in Avileablity



Avileabilty for Closed system :-

Sys T_0

$$(\Delta S)_{surr} = \left(\frac{dQ}{T}\right)_{surr}$$

$$(\Delta S)_{surr} = \frac{(\text{đ}Q)_{surr}}{T_0}$$

$$(\text{đ}Q)_{surr} = T_0 (\Delta S)_{surr}$$

Sys → dQ

$$(\text{đ}Q)_{sys} = -\text{đ}Q$$

$$\text{đ}Q_{surr} = +\text{đ}Q$$

$$(\text{đ}Q)_{sys} = -\text{đ}Q_{surr}$$

$$(\Delta S)_{uni} \geq 0$$

$$(\Delta S)_{univ} = 0$$

(Rem)

$$(\Delta S)_{sys} + (\Delta S)_{surr} = 0$$

$$(\Delta S)_{sys} = -(\Delta S)_{surr}$$

Reversible means = W_{max}

$\Delta S = 0$

$$\text{đ}Q_{sys} = dU_{sys} + \text{đ}W_{sys}$$

$$\text{đ}W_{sys} = \text{đ}Q_{sys} - dU_{sys}$$

$$\text{đ}W_{sys} = -\text{đ}Q_{surr} - dU_{sys}$$

$$\text{đ}W_{(sys)} = -T_0 (\Delta S)_{surr} - dU_{sys}$$

$$(\text{đ}W)_{sys} = T_0 (\Delta S)_{sys} - dU_{sys}$$

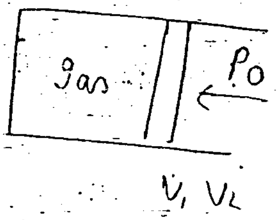
$$W_{max} = T_0 (S_2 - S_1) - (U_2 - U_1)$$

$$W_{max} = T_0(S_2-S_1) - U_2 + U_1$$

$$\boxed{W_{max} = (U_1 - U_2) - T_0(S_1 - S_2)}$$

↳ For closed sys maximum work is

$$\boxed{W_{max\,useful} = W_{max} - W_{atm}}$$



$$W_{max} = U_1 - U_2 - T_0(S_1 - S_2)$$

$$W_{max\,useful} = W_{max} - W_{atm}$$

$$W_{atm} = P_0(V_2 - V_1)$$

$$W_{max\,useful} = U_1 - U_2 - T_0(S_1 - S_2) - P_0(V_2 - V_1)$$

$$\boxed{W_{max\,useful} = U_1 - T_0S_1 + P_0V_1 - (U_2 - T_0S_2 + P_0V_2)}$$

$$\boxed{W_{max\,useful} = \phi_1 - \phi_2}$$

$$\phi_1 = U_1 - T_0S_1 + P_0V_1$$

* $\boxed{\phi = U - T_0S + P_0V}$ → Avilable function for closed system

R,O

Avalibity for open system :- ($P_{atm} = 0$ (not used))

$W_{max} =$

$$h_1 + \frac{C_1^2}{2} + Z_1 g + Q = h_2 + \frac{C_2^2}{2} + Z_2 g + W$$

$$h_1 + Q = h_2 + W$$

$$Q = h_2 - h_1 + W$$

$$\boxed{Q = dh + W}$$

$$\boxed{W_{max} = h_1 - h_2 - T_0 (S_1 - S_2)}$$

~~Irreversibility~~ :-

$$W_{max} = h_1 - h_2 - T_0 (S_1 - S_2)$$

$$h_1 - h_2 - T_0 S_1 + T_0 S_2$$

$$W_{max} = \underbrace{(h_1 - T_0 S_1)}_{\phi_1} - \underbrace{(h_2 - T_0 S_2)}_{\phi_2}$$

$$W_{max} = \phi_1 - \phi_2$$

$$\boxed{\phi_1 = h_1 - T_0 S_1}$$

$\boxed{\phi = h - T_0 S}$ → Availabilty function for open system

Irreversiblity :- (For both closed and open)

$$I = W_{max} - W_{act}$$

$$I = T_0 \left[(\Delta S)_{sys} + (\Delta S)_{surr} \right]$$

$$\cancel{I} \neq I.$$

$$* \boxed{I = T_0 (\Delta S)_{univ}}$$

A Irreversiblity is equal to (maximum work — Actual work)

* this eqn is valid for closed as will as open system

✡ Guoy theorem :-

According to this theorem rate of incrses of irreversiblity is proportional to rate of entropy change of univers.

Gibbs function :- $\boxed{G = H - TS}$

Helmlotz function :- (F)

Closed → $\boxed{F = U - TS}$

3-8-2011

Q find the loss of available enersy assoiated in the transfer of 1000 kJ of heat from a constant from a constant temp sys at 600°K to another at 400°K when the abient temp is 300°K

$$UA = Q \cdot T_0 \left[\frac{T_1 - T_2}{T_1 T_2} \right]$$

$$= 1000 \times \cancel{18} \times 300 \left[\frac{600-400}{600 \times 400} \right] = 250\ KJ\ A$$

Q. For a study flow procen from state 1 to state 2 enthalpy changes from $h_1 = 400$ kJ/kg to $h_2 = 100$ kJ/kg and entropy chonses from $S_1 = 1.1$ kJ/kg-K to $S_2 = 0.7$ kJ/kg-K and the amibent temp. is 300 K find the change in avilablity?

Am $\phi_1 - \phi_2 = W_{max} = h_1 - h_2 - T_0(s_1 - s_2)$

$$= (400-100) - 300(1.1-0.7)$$

$$= 180\ kJ/kg$$

Q. Steam flow steadly in an adibatic turbine the enthalpy at entrace is 412 kJ/kg at the exit is 2585 kJ/kg the vallues of flow availablity at the entirence and exit are 1787 kJ/kg and 140 kJ/kg respectivly the amibent temp is 300°K find

(I) actual work ?

(II) maxi. work ?

(III) Change in entropy of system (neslected K.E and P.E)

Ans :-

$h_1 = 4142$

$h_2 = 2585$

$\phi_1 = 1787$

$\phi_2 = 140$

$T_0 = 300$

$$h_1 + \cancel{\frac{C_1^2}{2}}^{0} + \cancel{Z_1 g}^{0} + \cancel{Q}^{0} = h_2 + \cancel{\frac{C_2^2}{2}}^{0} + \cancel{Z_2 g}^{0} + W$$

$$h_1 = h_2 + W$$

$$W = h_1 - h_2$$

$$W_{act} = 4142 - 2585$$

$$W_{act} = 1557\ kJ/kg$$

$$W_{max} = h_1 - h_2 - T_0(S_1 - S_2)$$

$$W_{max} = \phi_1 - \phi_2$$

$$= 1787 - 140 = 1647 \text{ kJ/kg}$$

$$1647 = (4142 - 2585) - 300(S_1 - S_2)$$

$$\boxed{(S_1 - S_2) = -0.3 \text{ kJ/kg}}$$

Es (10 marks)

Q. find the irreversibilty associated with the expansion of air to a very small opening in a pipe from prem and temp. of 8 bar 600k to a pressure of 1.2 bar assuming A to B an ideal gas and take temp. of surroundings as 298 K

Ans:- As the fluid is going to a very small opening it undergoes throttling process. and in throttling there is no heat transfer therefor entropy change for surrounding is zero.

$P_1 = 8$ bar $P_2 = 1.2$ bar

$T_1 = 600$K

$$(S_2 - S_1) = (\Delta S)_{sys} = C_p \ln \frac{T_2}{T_1} - R \ln \frac{P_2}{P_1}$$

$$= \quad h_1 = h_2 \text{ (throttling)}$$

$$C_p T_1 = C_p T_2$$

$$\boxed{T_1 = T_2}$$

$$\frac{T_2}{T_1} = 1 \Rightarrow \ln 1 = 0$$

$$(\Delta S)_{sys} = -R \ln \frac{P_2}{P_1}$$

$$(\Delta S)_{sys} = R \ln \frac{P_1}{P_2} \Rightarrow 0.287 \times \ln\left(\frac{8}{1.2}\right) = 0.544$$

But $I = T_0[(\Delta S)_{sy} + \overset{=0}{(\Delta S)_{surrou}}]$

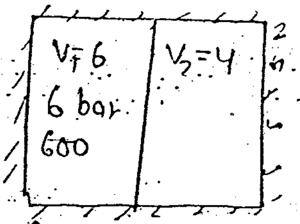
$I = T_0[(\Delta S)_{sys}]$

$I = T_0 \times 0.544$

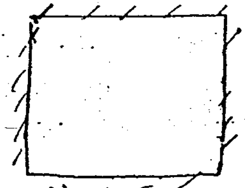
$= 298 \times 0.544 = 162.25$ kJ/kg

$\boxed{\text{Irreversiblity} = 162.25 \text{ kJ/kg}}$ → always (+ve)

Q. An adibatic Cylinder of 10m³ volume is divided into two Compartment A and B each of volume 6 m³ and 4 m³ by a thin partian initially the compartment A is filled with air at 6 bar, 600K while thir is vaccume in Combartment B. Suddenly the partician is removed and fluid in Compartment A. expands freely and fills both the compartm Calculate the irreversiblity of the process in KJ. and take Po = 1b and To = 300°K



$P_1 = 6$ bar
$V_1 = 6$ m³
$T_1 = 600$ K



Ans:- $P_0 = 1$ bar

$T_0 = 300°$K

$V = 10 \text{ m}^3 \rightarrow V_1 + V_2$
$6 + 4$

$V_1 \rightarrow P_1 = 6$ bar

$T_1 = 600$ k

$I = T_0[(\Delta S)_{sys} + \overset{=0 \text{ (insulated)}}{(\Delta S)_{surr.}}]$

$I = T_0[(\Delta S)_{sys}]$

air = ideal gas

$$(\Delta S)_{sys} = C_v \ln \frac{T_2}{T_1} + R \ln \frac{V_2}{V_1}$$

$$T_1 = T_2 \Rightarrow \ln 1 = 0$$

ideal gas in free expansion so $T_1 = T_2$

$$(\Delta S)_{sys} = R \ln \frac{V_2}{V_1}$$

$$\boxed{I = T_0 \, (\Delta S)_{sys}} = T_0 R \ln \frac{V_2}{V_1}$$

$$= 300 \times 0.287 \times \ln\left(\frac{10}{6}\right)$$

$$= 43.98 \text{ KJ/kg}$$ But Ans In KJ only

$PV = mRT$

$$m = \frac{\overset{\to \text{KPa}}{P}V}{\underset{\searrow \text{KJ than P in KPa}}{R}T} = \frac{6 \times 100 \times 6}{0.287 \times 600} = 20.9 \text{ kg}$$

total $I = 43.98 \times 20.9 = 919$ KJ

Q - A solid alumium ~~shaft~~ sphere of 0.1 m diameter and intialy at 200°C is Cooled to ambient temp. of 25°C the density of aluminum is 2700 kg/m³ and specific heat is 0.9 KJ/kg-K find the irreversiblity associated with this Process in KJ?

Ans-

$D = 0.1$ m

$T_i = 200°C$

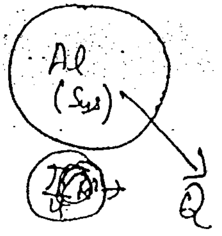
$T_0 = 25°C$

$\rho = 2700$ kg/m³

$C = 0.9$ KJ/kg-K

$$\rho = \frac{m}{V} = 2700$$
$$= \frac{m}{A \times L}$$
$$=$$

this is concept of finit body



heat transfered to surrounding

$$\therefore \boxed{(\Delta s)_{sys} = mc \ln \frac{T_f}{T_i}} \leftarrow \text{(for finit body)}$$

$$\rho = \frac{m}{V} = \quad m = \rho V \qquad (V = \text{sphere})$$

$$= \rho \times \frac{4}{3} \pi R^3$$

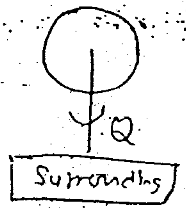
$$= 2700 \times \frac{4}{3} \times \left(\frac{0.1}{2}\right)^3$$

$$\boxed{m = 1.414 \text{ kg}}$$

$$(\Delta s)_{sys} = 1.414 \times 0.9 \times \ln\left(\frac{298}{473}\right)$$

$$(\Delta s)_{sys} = -0.587 \text{ kJ/K}$$

$$(\Delta s)_{surroundings} = +\frac{Q}{T_0}$$



$$Q = mc\Delta T$$

$$= 1.414 \times 0.9 \times (473 - 298)$$

$$= 222.4 \text{ kJ} = Q$$

Ela

$$(\Delta s)_{surr} = \frac{Q}{T_0} = \frac{222.4}{298} = 0.746 \text{ kJ/K}$$

$$I = T_0 \left[(\Delta s)_{sys} + (\Delta s)_{surr}\right]$$

$$= 298\left[-0.587 + 0.746\right] = 47.4 \text{ kJ}$$

$$\boxed{I = 47.4 \text{ kJ}}$$

Q. find the maxi work per kg of air that can be Obtain in a piston cylinder arransement the air expands from intial state of 9 bar, 400k to a final state of 1.5 bar, 300 k assume atmospheric Press $P_0 = 1$ bar and Atmosph Temp. T_0 of 288 K also find maxi useful work.

Ans $m = 1\ kg$

$P_1 = 9\ bar \quad P_2 = 1.5\ bar$

$T_1 = 400\ K \quad T_2 = 300\ K$

$P_0 = 1\ bar = 1 \times 100\ kPa = 100\ kPa$

$T_0 = 288K$

$$W_{max} = (U_1 - U_2) - T_0(S_1 - S_2)$$

$$= (C_vT_1 - C_vT_2) - T_0(S_1 - S_2)$$

$U_1 = m C_v dT$

↳ 1 kg

$$W_{max} = C_v(T_1 - T_2) - T_0\underline{(S_1 - S_2)}$$

ideal (air) But $(S_2 - S_1) = C_p \ln \frac{T_2}{T_1} - R \ln \frac{P_2}{P_1}$

For air $C_p = 1.005$

$$= 1.005 \times \ln \frac{300}{400} - 0.287 \times \ln\left(\frac{1.5}{9}\right)$$

$(S_2 - S_1) = 0.225\ kJ/kg\,K$

$* \ S_1 - S_2 = -0.225$

$$W_{max} = 0.718(400 - 300) - 288(-0.225)$$

$C_v = 0.718$ For air

$$\boxed{W_{max} = 136.6\ kJ/kg}$$

$\boxed{9\ bar = 900\ kPa}$

$$W_{useful} = W_{max} - P_0(V_2 - V_1)$$

$$= \overset{kJ/kg}{136.6} - \overset{kPa}{100}(0.574 - 0.1275)$$

$$\boxed{W_{useful} = 91.5\ kJ/kg}$$

$$P_1V_1 = mRT_1$$

$$V_1 = \frac{mRT_1}{P_1}$$

$$= \frac{1 \times 0.287 \times 400}{900}$$

$$V_1 = 0.1275$$

$$P_2V_2 = mRT_2$$

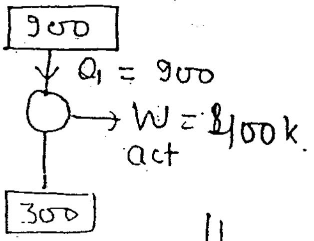
$$V_2 = \frac{1 \times 0.283 \times 300}{150}$$

$$V_2 = \underline{\underline{0.574}}$$

Imp ***

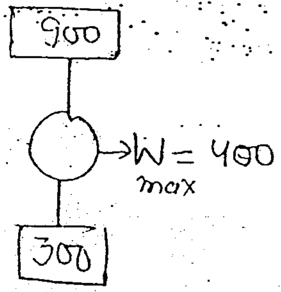
Q A system operates b/w two resirviours 900 K and 300 K & it produces net work of 400 KJ if the heat supply is 900 KJ then find the irreversiblity in KJ?

Ans:-
$T_1 = 900\ K$
$T_2 = 300\ K$
$W = 400\ kJ$
$Q_1 = 900\ kJ$



$$\int \frac{dQ}{T}$$

⇓ take reversible cycle



For W_{max} reversible

$$\frac{900}{900} = \frac{Q_2}{300}$$

$$\boxed{Q_2 = 300}$$

$$W_{max} = 900 - 300$$
$$= 600$$

$$I = W_{max} - W_{act}$$

$$= 600 - 400 = 200$$

$$\boxed{I = 200}$$

Mixture of Ideal gasses

Mole fraction (χ) :-

Mixture of Ideal Gases

Mole fraction (x) :-

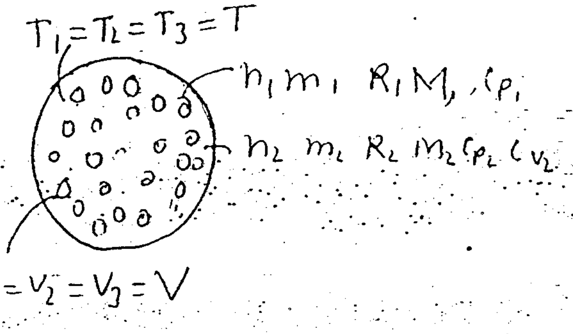
It is defined as the ratio of no. of moles to be total number of mole

$$X = \frac{n}{\Sigma n}$$

$$X_1 = \frac{n_1}{\cancel{\Sigma} n_1 + n_2}$$

$$X_2 = \frac{n_2}{n_1 + n_2 + \text{-----}}$$

$$\boxed{X_1 + X_2 + X_n + \text{-------} = 1}$$



$$P = P_1 + P_2 + P_3$$

$$PV = n\bar{R}T$$

$$P_1 V_1 = n_1 \bar{R} T_1$$

$$P_1 V = n_1 \bar{R} T \quad \text{— ①}$$

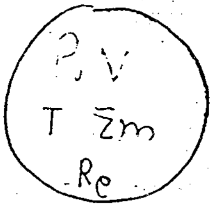
$$PV = \Sigma n \bar{R} T \quad \text{— (II)}$$

$$\frac{①}{(II)} \quad \frac{P_1 V}{PV} = \frac{n_1 \bar{R} T}{\Sigma n \bar{R} T}$$

$$\frac{P_1}{P} = \frac{n_1}{\Sigma n} \Rightarrow \frac{P_1}{P} = x_1$$

$$\boxed{\begin{aligned} P_1 &= x_1 P \\ P_2 &= x_2 P \end{aligned}}$$

Equivalent Gas Constant R_e :-



$$PV = \Sigma m R_e T \quad — Ⓐ$$

$$PV = mRT$$

$$P_1 V = m_1 R_1 T$$

$$P_2 V = m_2 R_2 T$$

$$(P_1 + P_2 + \ldots) V = (m_1 R_1 + m_2 R_2 + \ldots) T$$

$$(P_1 + P_2 + P_3 + \ldots) \Downarrow P$$

$$PV = (m_1 R_1 + m_2 R_2 + \ldots) T \quad — \text{by Ⓐ}$$

$$\Sigma m R_e \cancel{T} = (m_1 R_1 + m_2 R_2 + \ldots) \cancel{T}$$

$$R_e = \frac{m_1 R_1 + m_2 R_2 + \ldots}{\Sigma m}$$

$$\boxed{R_e = \frac{m_1 R_1 + m_2 R_2 + \ldots}{m_1 + m_2 + \ldots}}$$

Note :- similarly $\boxed{C_{pe} = \frac{m_1 C_{p_1} + m_2 C_{p_2} + \ldots}{m_1 + m_2 + \ldots}}$

$$\boxed{C_{ve} = \frac{m_1 C_{v_1} + m_2 C_{v_2} + \ldots}{m_1 + m_2 + \ldots}}$$

$$\boxed{C_{pe} - C_{ve} = R_e}$$

(66)

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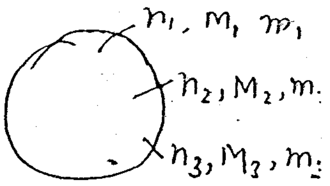
Equivalent Molecular Weight M_e :-



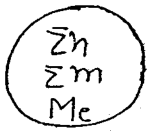
$$n = \frac{m}{M}$$

$$m = nM$$

$$m_1 = n_1 M_1$$

$$m_2 = n_2 M_2$$

$$\vdots \quad \vdots \quad \vdots$$



$$\Sigma m = \Sigma n M_e \quad \text{—(A)}$$

$$(m_1 + m_2 + \cdots) = (\cancel{n_1 + n_2 + n_3 + \cdots})$$

$$= n_1 M_1 + n_2 M_2 + n_3 M_3 + \cdots$$

$$\Sigma m = n_1 M_1 + n_2 M_2 + \cdots$$

By —(A)

$$\Sigma n \, M_e = n_1 M_1 + n_2 M_2 + \cdots$$

$$M_e = \frac{n_1 M_1 + n_2 M_2 + \cdots}{\Sigma n}$$

$$M_e = \frac{n_1}{\Sigma n} M_1 + \frac{n_2}{\Sigma n} M_2 + \cdots$$

$$\boxed{M_e = x_1 M_1 + x_2 M_2 + \cdots}$$

Equation to be remembered :-

1) $PV = mRT$ $PV = n\bar{R}T$

$\boxed{n = \frac{m}{M}}$

2) $R = \bar{R}/M$

3) $x_1 = \frac{n_1}{\sum n}$

4) $P_1 = x_1 P$, $P_2 = x_2 P$

5) $R_e = \frac{m_1 R_1 + m_2 R_2 + --}{m_1 + m_2}$

6) $C_{pe} = \frac{m_1 C_{p_1} + m_2 C_{p_2} + ---}{m_1 + m_2 + ----}$

7) $C_{ve} = \frac{m_1 C_{v_1} + m_2 C_{v_2} + ---}{m_1 + m_2 + ---}$

8) $M_e = x_1 M_1 + x_2 M_2 + ---$

(67)

Q. A mixture of ideal gases consists of 3 kg of nitrogen, 5 kg CO_2 at a pressure of 300 kPa and a Temp. of 20°C find (I) mole fraction of each consistuent (II) Equivlent mole Weght (III) Equivlent gas Const. (IV) Partial Pressure each constituent (V) total Volume of the mixture (VI) density of the mixture (VII) Cp and Cp of the mixture VIII if this mixture heated at const. Volume to 40°c find the changes in internal energy, enthalpy and entropy of mixture (IX) If the mixture is heated to 40°c at const. Pressure find changes in internal energy, enthalpy and entropy, $\gamma_{CO_2} = 1.286$ $\gamma_{N_2} = 1.4$

Ans :- $N_2 - 1$ $\quad CO_2 - 2$

$m_1 = 3\,kg$

$M_1 = 28$

$n_1 = \frac{m_1}{M_1}$

$n_1 = \frac{3}{28}$

$x_1 = \frac{n_1}{n_1+n_2}$

$= \frac{3/28}{\frac{3}{28}+\frac{5}{44}}$

$\boxed{X_1 = 0.485}$

$m_2 = 5\,kg$

$M_2 = 44$

$n_2 = \frac{m_2}{M_2}$

$n_2 = \frac{5}{44}$

$x_2 = \frac{n_2}{n_1+n_2}$

$\boxed{x_2 = 0.515}$

$M_e = x_1 M_1 + x_2 M_2$

$= 0.485 \times 28 + 0.515 \times 44$

$\boxed{M_e = 36.25}$

$R_e = \frac{\bar{R}}{M_e} = R_e = \frac{8.314}{36.25}$

$R_e = 0.229\ kJ/kg \cdot K$

$P_1 = x_1 P \Rightarrow P_1 = 0.485 \times 300$

$\boxed{P_1 = 145.5\ kPa}$

$P_2 = x_2 P \Rightarrow 0.515 \times 300$

$\boxed{P_2 \Rightarrow 154.5\ kPa}$

$P = 300\ kPa$
$V = ?$ $3+5=8$
$m =$ [redacted]
$R_e = 0.229$
$T = 293\ K$

$$PV = mR_eT$$

$$V = \frac{mR_eT}{P}$$

$$V = \frac{8 \times 0.229 \times 293}{300} = 1.789\ m^3$$

$$\rho = \frac{m}{V} = \frac{8}{1.789} = 4.471$$

$$\boxed{\rho = 4.471\ kg/m^3}$$

$N_2 \to 1$ $CO_2 \to 2$

$$C_{pe} = \frac{m_1C_{p_1} + m_2C_{p_2}}{m_1+m_2}$$

$$C_{p_1} = \frac{\gamma_1R_1}{\gamma_1-1} = \gamma_1 = 1.4$$

$$R_1 = \frac{\bar{R}}{M_1} = \frac{8.314}{28}$$

$$R_1 = 0.296$$

$$C_{p_1} = \frac{\gamma_1R_1}{\gamma_1-1} = \frac{1.4\times0.296}{1.4-1}$$

$$\boxed{C_{p_1} = 1.036}$$

$$C_{p_2} = \frac{\gamma_2R_2}{\gamma_2-1} = R_2 = \frac{\bar{R}}{M_2}$$

$$R_2 = \frac{8.314}{44}$$

$$\boxed{R_2 = 0.1889}$$

$$C_{p_2} = \frac{1.286\times0.1889}{1.286-1}$$

$$C_{p_2} = 0.849$$

$$C_{pe} = \frac{m_1C_{p_1} + m_2C_{p_2}}{m_1+m_2}$$

$$= \frac{3\times1.036 + 5\times0.849}{3+5}$$

$$\boxed{C_{pe} = 0.919\ kJ/kg}$$

$$\boxed{C_{pe} - C_{ve} = R_e}$$

$$0.919 - C_{ve} = 0.229$$

$$\boxed{C_{ve} = 0.690}$$

$m = 8$
$M_e = 36.25$
$R_e = 0.229$
$C_{pe} = 0.919$
$C_{ve} = 0.69$
$T_1 = 293K$
$T_2 = 313$

$$dU = m\,C_{ve}(T_2 - T_1)$$
$$= 8 \times 0.69(313 - 293)$$
$$\boxed{dU = 110.4\,KJ}$$

$$dH = mC_p\,dT$$
$$= 8 \times 0.519 \times (313 - 293)$$
$$\boxed{dH = 8 \times 147\,KJ}$$

ideal

$$\boxed{S_2 - S_1 = C_v \ln\frac{T_2}{T_1} + R \ln\frac{V_2}{V_1}}$$

Const Volume so

$V_1 = V_2$

KJ/Kg-K

$$\frac{V_2}{V_1} = \ln\frac{V_2}{V_1} = 0$$

$$S_2 - S_1 = C_v \cdot \ln\frac{T_2}{T_1}$$
$$= 0.69 \cdot \ln\left[\frac{313}{293}\right]$$
$$S_2 - S_1 = 0.045\ \text{KJ/Kg-K}$$

For total entropy change

$$S_2 - S_1 = 8 \times 0.045$$
$$\boxed{\Delta S = 0.364\ \text{KJ/K}}$$

For Const. Pressure

$$\boxed{S_2 - S_1 = C_v \ln\frac{T_2}{T_1} - R \ln\frac{P_2}{P_1}}$$

Thermodynamics Relations

Th. 1

The eqn $dz = M\,dx + N\,dy$ is exact when

$$\boxed{\left(\frac{\partial M}{\partial y}\right)_x = \left(\frac{\partial N}{\partial x}\right)_y}$$

Th. 2

if $f = \phi(x, y, z)$

$$\boxed{\left(\frac{\partial x}{\partial y}\right)_f \left(\frac{\partial y}{\partial z}\right)_f \left(\frac{\partial z}{\partial x}\right)_f = 1}$$

Th. 3 :-

$z = \phi(x, y)$

$$\boxed{\left(\frac{\partial x}{\partial y}\right)_z \left(\frac{\partial y}{\partial z}\right)_x \left(\frac{\partial z}{\partial x}\right)_y = -1}$$

Maxwell Equation :-

$$\left(\frac{\partial M}{\partial y}\right)_x = \left(\frac{\partial N}{\partial x}\right)_y ,$$

ⓐ $Tds = du + Pdv$

$du = Tds - Pdv$

$dz = Mdx + Ndy$

$M = T,\ x = s,\ N = -P,\ y = v$

$$\boxed{\left(\frac{\partial T}{\partial v}\right)_s = \left(\frac{-\partial P}{\partial s}\right)_V} \text{ — } ①$$

ⓑ $Tds = dh - vdp$

$dh = Tds + vdp$

$dz = Mdx + Ndy$

$M = T,\ x = s\ ,\ N = v,\ y = p$

$$\left(\frac{\partial M}{\partial y}\right)_x = \left(\frac{\partial N}{\partial x}\right)_y$$

$$\boxed{\left(\frac{\partial T}{\partial P}\right)_s = \left(\frac{\partial v}{\partial s}\right)_p}$$ — (II) Maxwell Eqn

ⓒ $G = H - TS$

$dG = dH - [Tds + SdT]$

$dG = \underbrace{dH - Tds}\, - SdT$ | $Tds = dH - vdp$; $dH - Tds = vdp$

$dG = vdP - SdT$

$dz = mdx + Ndy$

$m = v,\ x = P.\ N = -S,\ y = T$

$$\left(\frac{\partial m}{\partial y}\right)_x = \left(\frac{\partial N}{\partial x}\right)_y$$

$$\boxed{\left(\frac{dv}{\partial T}\right)_p = \left(-\frac{\partial s}{\partial P}\right)_T}$$ — (III) Maxwell Eqn

(IV) $F = U - TS$

$dF = dU - [TdS + SdT]$

$dF = \underbrace{dU - TdS} - SdT$

$TdS = dU + PdV$
$dU - TdS = -PdV$

$dF = -PdV - SdT$

$dZ = Mdx + Ndy$

$M = -P,\ x = V \qquad N = -S,\ y = T$

$$\left(\frac{\partial M}{\partial y}\right)_x = \left(\frac{\partial N}{\partial x}\right)_y$$

$$\boxed{\left(\frac{\partial P}{\partial T}\right)_V = \left(-\frac{\partial S}{\partial V}\right)_T}$$

Maxwell Eqn

(I) $$\boxed{\left(\frac{\partial T}{\partial V}\right)_S = \left(-\frac{\partial P}{\partial S}\right)_V}$$

(II) $$\boxed{\left(\frac{\partial T}{\partial P}\right)_S = \left(\frac{\partial V}{\partial S}\right)_P}$$

(III) $$\boxed{\left(\frac{\partial V}{\partial T}\right)_P = \left(-\frac{\partial S}{\partial P}\right)_T}$$

(IV) $$\boxed{\left(\frac{\partial P}{\partial T}\right)_V = \left(-\frac{\partial S}{\partial V}\right)_T}$$

***

Tds Equation :-

**

$$T\left(\frac{\partial s}{\partial T}\right)_p = T\left(\frac{\partial s}{\partial T}\right)_V$$

$$C_p - C_v = R$$

(Tds) - I eq^n

$$S = f(T, V)$$

$$ds = \left(\frac{\partial s}{\partial T}\right)_V dT + \left(\frac{\partial s}{\partial v}\right)_T dV$$

$$Tds = \underbrace{T\left(\frac{\partial s}{\partial T}\right)_V}_{C_v} dT + \underbrace{T\left(\frac{\partial s}{\partial v}\right)_T}_{\left(\frac{\partial P}{\partial T}\right)_V} dV$$

$$\boxed{Tds = C_v dT + T\left(\frac{\partial P}{\partial T}\right)_V dV}$$

Tds eq^n ①

(Tds) - II eq^n

$$S = f(T, P)$$

$$ds = \left(\frac{\partial s}{\partial T}\right)_P dT + \left(\frac{\partial s}{\partial P}\right)_T dP$$

$$Tds = \underbrace{T\left(\frac{\partial s}{\partial T}\right)_P}_{C_p} dT + T\underbrace{\left(\frac{\partial s}{\partial P}\right)_T}_{\left(-\frac{\partial v}{\partial T}\right)_P} dP$$

Tds - II eq^n

$$\boxed{Tds = C_p dT - T\left(\frac{\partial v}{\partial T}\right)_P dP}$$

$$\boxed{P = C}$$

$$\frac{\partial T}{ds} = \frac{T}{C_p}$$

$$\left(\frac{\partial T}{\partial s}\right)_P = \frac{T}{C_p} \Rightarrow C_p = T\left(\frac{\partial s}{\partial T}\right)_P$$

$$\left(\frac{\partial T}{\partial s}\right)_V = \frac{T}{C_V} = C_V = T\left(\frac{\partial s}{\partial T}\right)_V$$

$$Tds = Tds$$

$$C_v dT + T\left(\frac{\partial P}{\partial T}\right)_V dV = C_p dT - T\left(\frac{\partial V}{\partial T}\right)_P \partial P$$

$$T\left(\frac{\partial V}{\partial T}\right)_P dP + T\left(\frac{\partial P}{\partial T}\right)_V dV = (C_p - C_v)\, dT$$

$$dT = \boxed{\frac{T}{C_p - C_v}\left(\frac{\partial V}{\partial T}\right)_P} \partial P + \boxed{\frac{T}{C_p - C_v}\left(\frac{\partial P}{\partial T}\right)_V} dV \quad — \text{①}$$

$$T = f(P, \bar{V})$$

$$dT = \left(\frac{\partial T}{\partial P}\right)_V \partial P + \left(\frac{\partial T}{\partial V}\right)_P dV \quad — \text{(II)}$$

Comparing -(I) and (II)

$$\left(\frac{\partial T}{\partial P}\right)_V = \frac{T}{C_p - C_v}\left(\frac{\partial V}{\partial T}\right)_P$$

$$C_p - C_v = T\left(\frac{\partial V}{\partial T}\right)_P \boxed{\left(\frac{\partial P}{\partial T}\right)_V} \quad — \text{(III)}$$

$$T \; \phi(P, V)$$

$$\left(\frac{\partial P}{\partial V}\right)_T \left(\frac{\partial V}{\partial T}\right)_P \left(\frac{\partial T}{\partial P}\right)_V = -1 \quad — \text{(IV)}$$

$$\left(\frac{\partial P}{\partial T}\right)_V = -\left(\frac{\partial P}{\partial V}\right)_T \left(\frac{\partial V}{\partial T}\right)_P \quad — \text{(5)}$$

⑤ in ⑦

$$C_p - C_v = T\left(\frac{\partial v}{\partial T}\right)_p \left[-\left(\frac{\partial p}{\partial v}\right)_T \left(\frac{\partial v}{\partial T}\right)_p\right]$$

$$\boxed{C_p - C_v = -\underbrace{T}_{+ve}\underbrace{\left[\left(\frac{\partial v}{\partial T}\right)_p\right]^2}_{+ve}\underbrace{\left[\frac{\partial p}{\partial v}\right]_T}_{-ve}} \leftarrow \text{9 times}$$

We know that $\left[\frac{dp}{\partial v}\right]_T$ is $= -ve$

and hences. $C_p - C_v$ is always (+ve)

therefor $\boxed{C_p > C_v}$

$pv = c$

$pdv + vdp = 0$

$pdv = -vdp$

$\frac{\partial p}{\partial v} = -\frac{p}{V}$

$C_p - C_v > 0$

$\boxed{C_p > C_v}$

Coefficient of volume expansivity (β) :-

It shows variation of volume with respect to temp. under isobaric condition

$$\boxed{\beta = \frac{1}{V}\left(\frac{\partial v}{\partial T}\right)_p}$$

$P = C$

$T \to \uparrow$

$\underbrace{V \to \text{change}}_{\text{Volume Expan}}$

(17) 2/2

Isothermal Compressibilty (K_T) :-

It shows variation of volume with respect to Pressure under isothermal Conditions.

$$\boxed{K_T = -\frac{1}{V}\left(\frac{\partial V}{\partial P}\right)_T}$$

$$(C_p - C_v) = -T\left[\left(\frac{\partial V}{\partial T}\right)_P\right]^2\left[\frac{\partial P}{\partial V}\right]_T$$

$$(C_p - C_v) = -T[\beta V]^3 \cdot \left[-\frac{1}{K_T V}\right]$$

$$(C_p - C_v) = T \cdot \beta^2 V^2 \cdot \frac{1}{K_T V}$$

$$**\ \boxed{C_p - C_V = \frac{TV\beta^2}{K_T}}$$ 13 times

$$K_T = -\frac{1}{V}\left(\frac{\partial V}{\partial P}\right)_T$$

$$\left(\frac{\partial P}{\partial V}\right)_T = \frac{-1}{K_T V}$$

$$\beta = \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_P \Rightarrow$$

$$\left(\frac{\partial V}{\partial T}\right)_P = \beta V$$

Energy Equation :-

Energy Equation :-

$$T\,ds \Rightarrow du + P\,dV$$

$$du = \underbrace{T\,ds}_{I^{st}} - P\,dV$$

$$du = C_v\,dT + T\left(\frac{\partial P}{\partial T}\right)_V dV - P\,dV$$

$$\boxed{du = C_v\,dT + \left[T\left(\frac{\partial P}{\partial T}\right)_V - P\right]dV} \quad \text{— ①}$$

energy eqn

$$U = f(T, V)$$

$$du = \left(\frac{\partial U}{\partial T}\right)_V dT + \left(\frac{\partial U}{\partial V}\right)_T dV \quad \text{— (II)}$$

Comparing ① and ②

$$C_V = \left(\frac{\partial U}{\partial T}\right)_V, \quad \left(\frac{\partial U}{\partial V}\right)_T = T\left(\frac{\partial P}{\partial T}\right)_V - P$$

For an ideal gas

$$PV = mRT \Rightarrow P = \frac{mR}{V}\cdot T \Rightarrow \frac{mR}{V} = \frac{P}{T}$$

$$\left(\frac{\partial P}{\partial T}\right)_V = \frac{mR}{V} = \frac{P}{T}$$

$$\left(\frac{\partial P}{\partial T}\right)_V = \frac{P}{T} \Rightarrow T\left(\frac{\partial P}{\partial T}\right)_V = P$$

$$T\left(\frac{\partial P}{\partial T}\right)_V - P = 0$$

So put in (I)

$$\boxed{dU = C_V\, dT} \leftarrow \text{For ideal gas}$$

$$\left(\frac{\partial U}{\partial V}\right)_T = \left(T\left(\frac{\partial P}{\partial V}\right)_T - P\right) = 0 \text{ for ideal gas}$$

$$\boxed{\left(\frac{\partial U}{\partial V}\right)_T = 0} \leftarrow \text{for an ideal gas}$$

For an ideal gas there is no change of internal energy with respect to volume under isothermal condition and hence internal energy of an ideal gas is independent of volume.

$$U = f(P, T, V)$$

$$T = \phi(U, P, V)$$

$$\left(\frac{\partial U}{\partial P}\right)_T \left(\frac{\partial P}{\partial V}\right)_T \left(\frac{\partial V}{\partial U}\right)_T = 1$$

$$\left(\frac{\partial U}{\partial P}\right)_T \left(\frac{\partial P}{\partial V}\right)_T = \left(\frac{\partial U}{\partial V}\right)_T$$

for an ideal gas $\left(\frac{\partial U}{\partial V}\right)_T = 0$

$$\left(\frac{\partial U}{\partial P}\right)_T \underset{(-ve)}{\left(\frac{\partial P}{\partial V}\right)_T} = 0$$

So

$$\boxed{\left(\frac{\partial U}{\partial P}\right)_T = 0}$$

It shows for an ideal gas internal energy does not varry with respect to pressure. therefor It is Internal energy of ideal gas depends on temp only.

Joules thomson ~~Equation~~ Coeffient (μ) :-

$$Tds = dh - Vdp$$

$$dh = \underbrace{Tds} + Vdp$$

$$dh = C_p dT - T\left(\frac{\partial V}{\partial T}\right)_p dp + Vdp$$

$$dh = C_p dT - \underbrace{\left[T\left(\frac{\partial V}{\partial T}\right)_p - V\right]}_{0} dp$$

$$\boxed{dh = C_p\, dT}$$

therfore for an ideal gas

$$\boxed{dh = C_p\, dT}$$

For an ideal gas

$$PV = mRT \Rightarrow \frac{mR}{P} = \frac{V}{T}$$

$$V = \frac{mR}{P} \cdot T$$

$$\left(\frac{\partial V}{\partial T}\right)_p = \frac{mR}{P} = \frac{V}{T}$$

$$\left(\frac{\partial V}{\partial T}\right)_p = \frac{V}{T} \Rightarrow$$

$$\boxed{T\left(\frac{\partial V}{\partial T}\right)_p - V = 0}$$

Joules thomson Coeffient (μ) :-

It shows variation of temp with respect to Pressure under isenthalpic condition. It ~~shows~~ variation ~~of temp.~~

$$\boxed{\mu = \left(\frac{\partial T}{\partial p}\right)_h}$$

(throtting)

For throttling $h = \text{const} \Rightarrow dh = 0$

$$0 = C_p dT - \left[T\left(\frac{\partial v}{\partial T}\right)_p - v\right] dp$$

$$C_p dT = \left[T\left(\frac{\partial v}{\partial T}\right)_p - v\right] dp$$

$$\frac{dT}{\partial p} = \frac{1}{C_p}\left[T\left(\frac{dv}{\partial T}\right)_p - v\right]$$

$$\left(\frac{\partial T}{\partial p}\right)_h = \frac{1}{C_p}\left[T\left(\frac{\partial v}{\partial T}\right)_p - v\right]$$

$$\boxed{\mu = \frac{1}{C_p}\left[T\left(\frac{\partial v}{\partial T}\right)_p - V\right]} \quad \left\{\left(\frac{\partial T}{\partial p}\right)_h = \mu\right.$$

For an ideal gas $\left(T\left(\frac{\partial v}{\partial T}\right)_p - v\right) = 0$

$**\ \boxed{\mu = 0}$ ← for an ideal gas.

$$\boxed{\mu = \left(\frac{\partial T}{\partial p}\right)_h = 0}$$

For an ideal gas under throttling condition their is no change of temp. w.r.s to pressure

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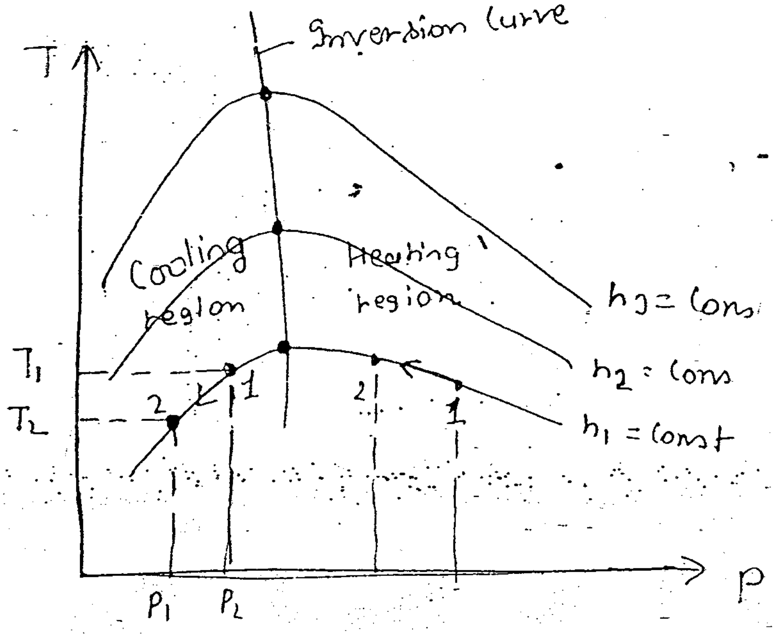
* throttling occur
in Direction of
Pressure drop.
due to friction
throttling gives
Cooling effect



$$\boxed{\mu = \left(\frac{\overset{(-ve)}{\partial T}}{\underset{(-ve)}{\partial p}}\right)_h = \text{Slope}}$$

The slope of isenthalpic curves ~~[illegible]~~ on T-p diagram is (+ve) in cooling region or Joule thomson coefficient is (+ve) in cooling region.

Joule thomson coefficient is (-ve) or the slope of isenthalpic curves on T-p diagram is (-ve) in Heating region.

~~Slope of~~
Joule thomson coefficient for an ideal gas is zero.

Highlights

(I) Maxwell relations are –

$$\boxed{\left(\frac{\partial T}{\partial v}\right)_S = -\left(\frac{\partial P}{\partial s}\right)_v}$$

$$\boxed{\left(\frac{\partial T}{\partial P}\right)_S = \left(\frac{\partial v}{\partial s}\right)_P}$$

$$\boxed{-\left(\frac{\partial P}{\partial T}\right)_v = \left(\frac{\partial s}{\partial v}\right)_T}$$

$$\boxed{\left(\frac{\partial v}{\partial T}\right)_P = -\left(\frac{\partial s}{\partial P}\right)_T}$$

(II) The specific heat relation are –

$$\boxed{C_p - C_v = \frac{VT\beta^2}{K}}$$

$$\boxed{C_V = T\left(\frac{\partial s}{\partial T}\right)_v}$$

$$\boxed{C_p = T\left(\frac{\partial s}{\partial T}\right)_P}$$

(III) Joule thomson co-efficient is expressed are –

$$\boxed{\mu = \left(\frac{\partial T}{\partial p}\right)_h}$$

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④ Entropy equation (Tds equation) :-

$$\boxed{Tds = C_v dT + T\left(\frac{\partial P}{\partial T}\right)_V dV}$$

$$\boxed{Tds = C_p dT - T\left(\frac{\partial V}{\partial T}\right)_P dP}$$

⑤ Equation for internal energy and entholpy :-

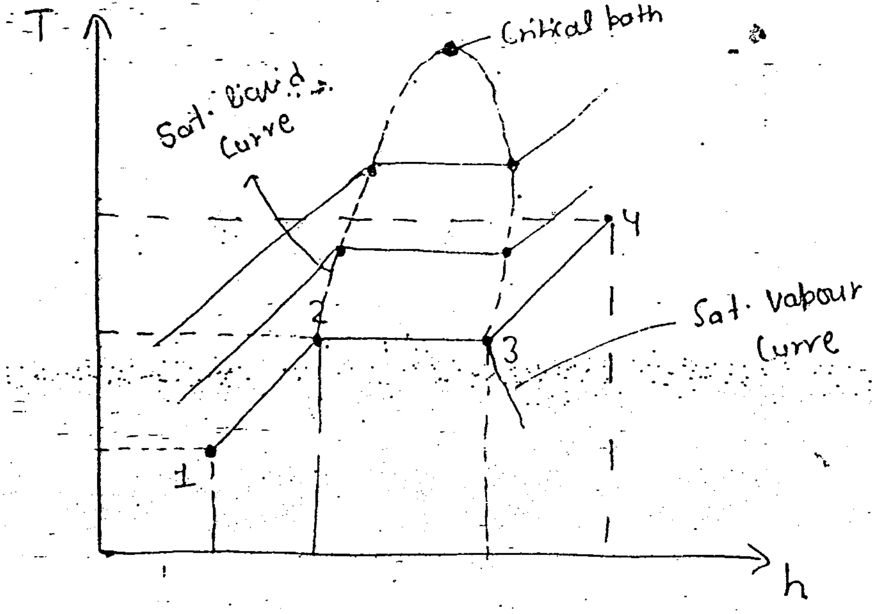
$$\boxed{\left(\frac{\partial U}{\partial V}\right)_T = T\left(\frac{\partial P}{\partial T}\right)_V - P}$$

$$\boxed{dU = C_v dT + \left\{T\left(\frac{\partial P}{\partial T}\right)_V - P\right\} dV}$$

$$\boxed{\left(\frac{\partial h}{\partial P}\right)_T = V - T\left(\frac{\partial V}{\partial T}\right)_P}$$

$$\boxed{dh = C_p dT + \left\{V - T\left(\frac{\partial V}{\partial T}\right)_P\right\} dP}$$

Properties of pure Substances



liquid V = small
vapour V = large
$h = U + pv$
$h \neq U = CT$

H_2O at 40° to Steam at 200°C

I) H_2O at 40° ——— H_2O at 100°C

II) H_2O at 100°C ——— Steam at 100°C

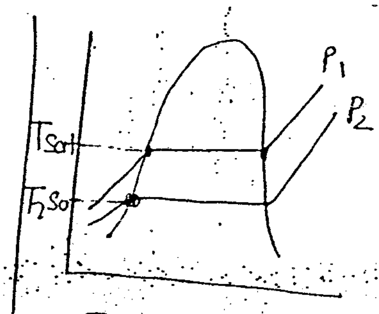
III) Steam at 100°C ——— Steam at 200°C

Critical point :- It is the point at which the sat. liquid and saturated vapour curves meet

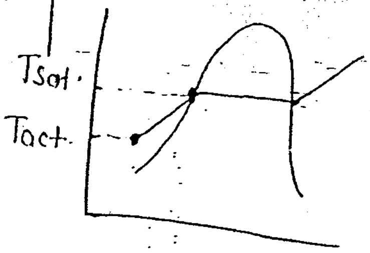
Sub cooled or under cooled region :-

It is the region in which the actual temp. is less than saturation temp. corrosponing to that pressure.

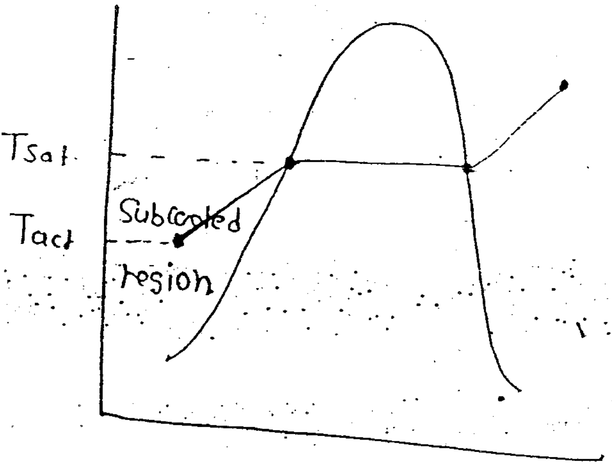
Degree of Subccoling is equal to (Tsat − Tact)



Tsaturation



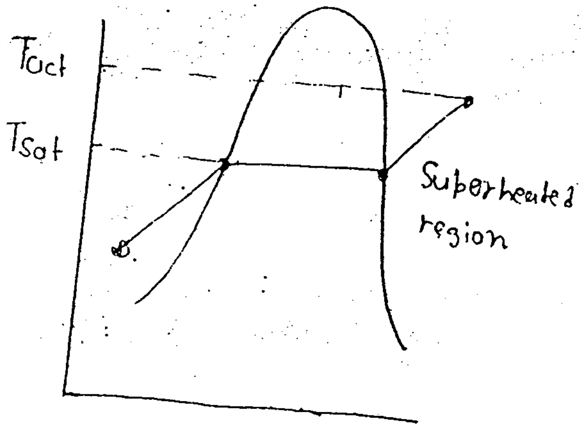
Tsat > Tactual
↓
Sub cooled



Degree of subcooling = Tsat − Tact

Super heated region :-

It is a region in which the actual temp. is grater than saturation temp. corresbhg to that pressure



Degree of superheat = Tact − Tsat

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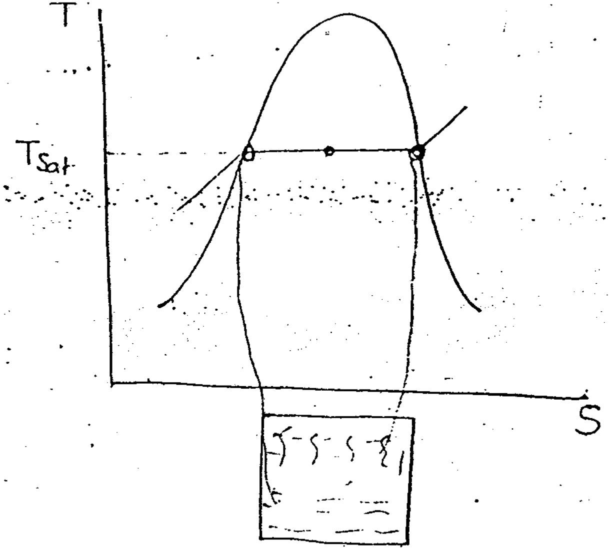
Wet region :-

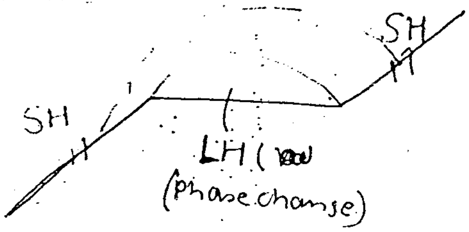
It is the region in which both liquid and vapour ~~exit~~ exists in equibrium, when the point is in wet region it will be at its corresponding saturation temp.



~~Sensible heat~~

Sensible region :-

The heat transfer associated with temp. differences is known as sensible heat



Latent heat :-

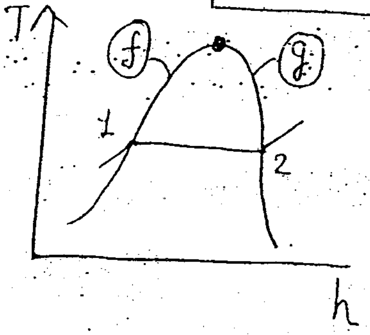
The heat transfer associated during phase change is known as latent heat.

$$LH = Q_{12} = Q_{\underset{const}{Press}} = dh$$

$$\boxed{LH = h_2 - h_1}$$

$$\boxed{LH = h_g - h_f = h_{fg}}$$

$LH = Q_P$
$= Q_{\text{during phase change or const. Press.}}$
$dQ_p = dH$

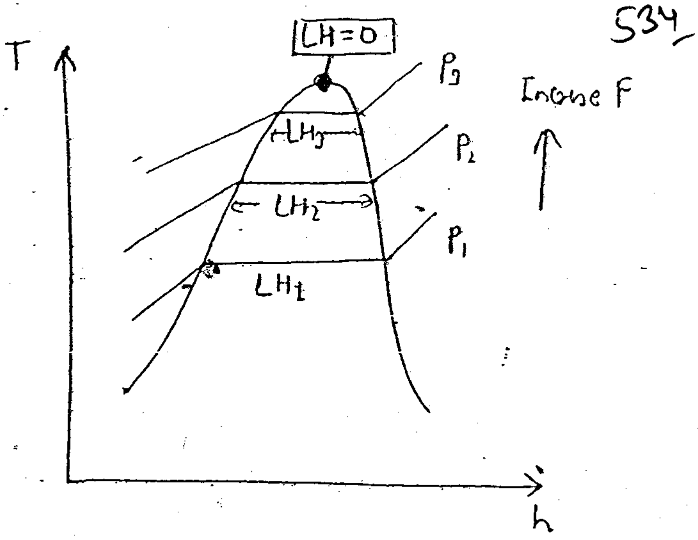


We know that phase change occurs at const pressure and hence heat transfer at const. pressure is change in enthalpy.

h_g = enthalpy of saturated vapour.

h_f = enthalpy of saturated liquid

* when increse in presur the Latent heat of vabourigation decrsed and at the critical point latent heat of vabourigation is zero.



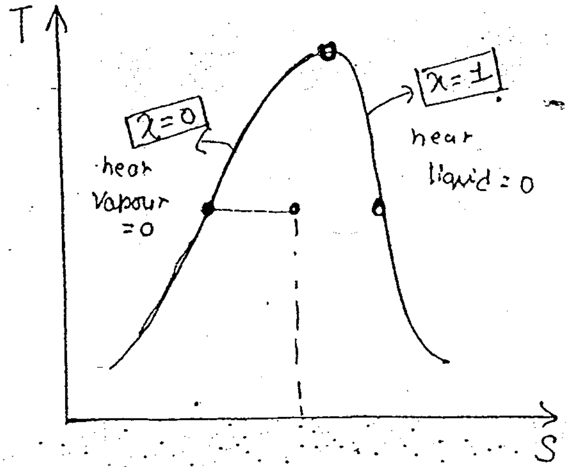
Dryness fraction (x) :-

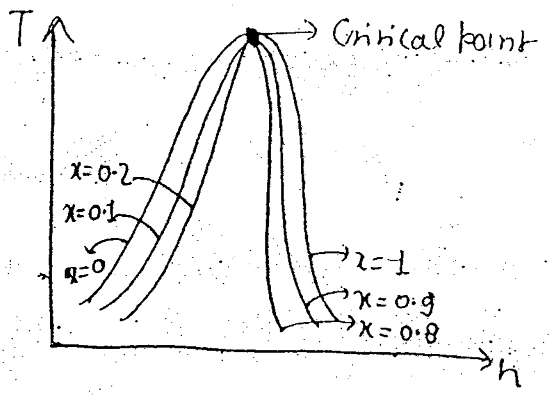
It is defined as the ratio of mass of vapour to the total mass

The dryness fraction along saturated liquid curve is zero

and dryness fraction alonge saturated vabour curve is $\boxed{x=1}$

All dryness fraction line converses at critical point.





$$\boxed{x = \frac{m_v}{m_v + m_l}}$$

Specific volume of mixture :-

$$V = V_v + V_l$$

$$mv = m_v v_v + m_l v_l$$

$$v = \frac{m_v v_v}{m} + \frac{m_l v_l}{m}$$

$$v = \frac{m_v v_v}{m_v + m_l} + \frac{m_l v_l}{m_v + m_l}$$

$$v = x v_v + (1-x) v_l$$

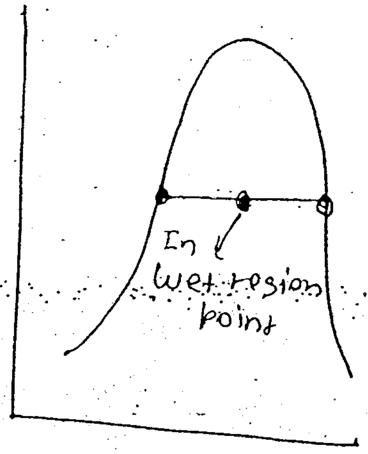
$$v = x v_v + v_l - x v_l$$

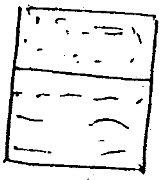
$$\boxed{v = v_l + x(v_v - v_l)}$$

$$\boxed{v = v_f + x(v_g - v_f)}$$ ← Specific Volume

→ Wet region

$$\boxed{\begin{aligned} h &= h_f + x(h_g - h_f) = h_f + x h_{fg} \\ U &= U_f + x(U_g - U_f) = U_f + x U_{fg} \\ S &= S_f + x(S_g - S_f) = S_f + x S_{fg} \end{aligned}}$$ → When point in wet region





$$v = \frac{V}{m}$$

$$V = mv$$

$$\boxed{m = m_v + m_l}$$

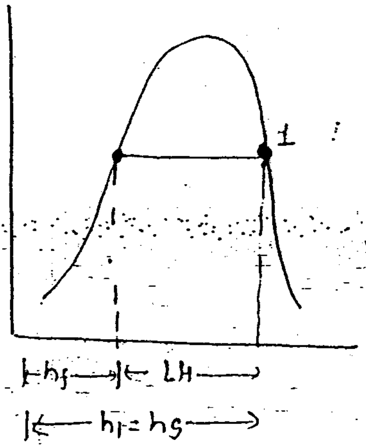
Enthalpy at various point :-

Case-I - When the point is on saturated vapour curve

$$h_1 = h_f + LH$$

$$h_g = h_f + LH$$

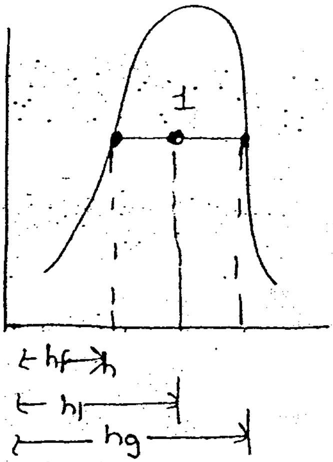
$$LH = h_g - h_f = h_{fg}$$



Case-II - When the point is on wet region

$$h_1 = h_f + x(h_g - h_f)$$

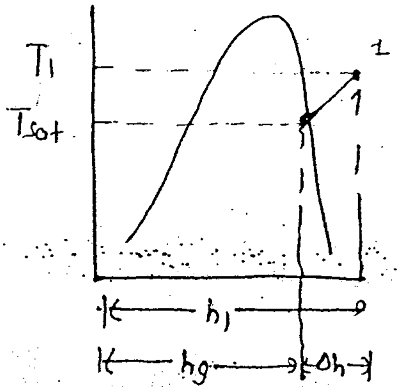
$$\boxed{h_1 = h_f + x(LH)}$$



Case-III :- when the point is in superheated region :-

$$h_1 = h_g + \Delta h$$

$$\boxed{h_1 = h_g + C_{p_{vapour}}(T_1 - T_{sat.})}$$



* Treat as ideal gas in superheated region.

* In superheat state treat as ideal gas

$\Delta h = C_p\, dT$

Entropy at various point :-

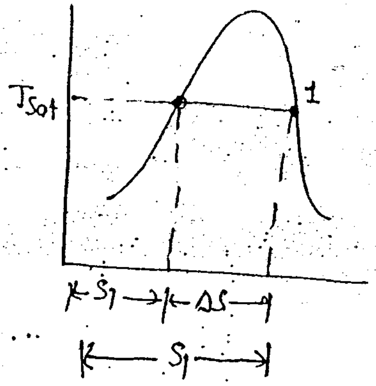
Case I :- when the point is on saturated vapour curve

$$S_1 = S_f + \Delta S$$

$$S_1 = S_f + \frac{LH}{T_{sat}}$$

$$S_g = S_f + \frac{LH}{T_{sat}}$$

$$\boxed{S_g - S_f = \frac{LH}{T_{sat}}}$$



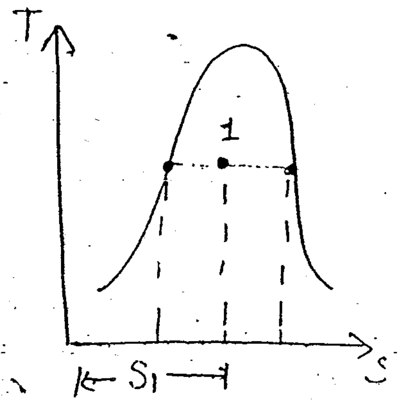
$ds = \frac{dQ}{T}$ (reversible)

$ds = \frac{LH}{T_{sat}}$

Case-II :- When the boint is in wet region –

$$S_1 = S_f + x(S_g - S_f)$$

$$\boxed{S_g = S_f + x\left(\frac{LH}{T_{sat}}\right)}$$



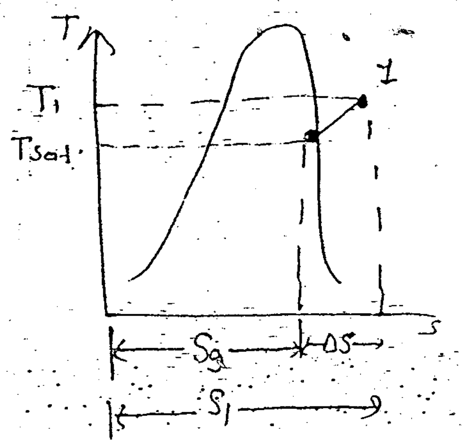
Case-III when the boint is in superheated region

$$S_2 - S_1 = C_p \ln\frac{T_2}{T_1} - R \ln\frac{P_2}{P_1} \to 0$$

P = C then ln P = 0

$$\Delta S = C_p \ln\frac{T_2}{T_1}$$

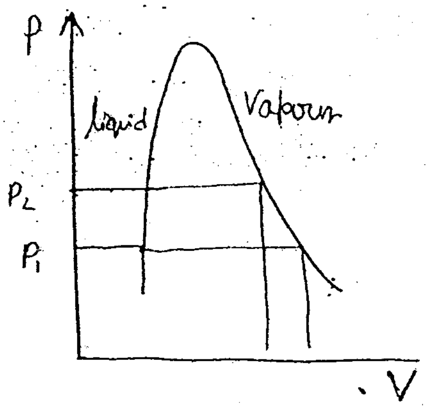
$$\Delta S = C_{p_{vapour}} \ln\frac{T_1}{T_{sat}} \quad \text{——} \quad Ⓐ$$



$$S_1 = S_g + \Delta S$$

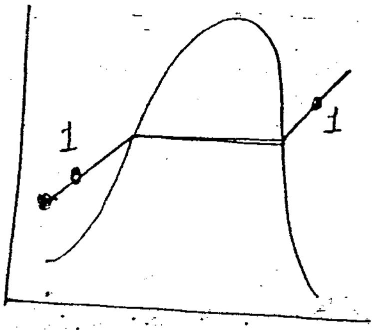
$$\boxed{S_1 = S_g + C_{p_{vap}} \ln\frac{T_1}{T_{sat}}}$$

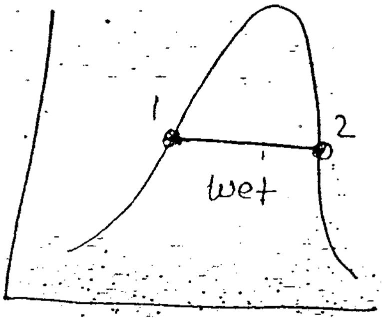
P-V diagram :-



Mollier diagram :-

Note :- In superheaded and subcooled regions the degree of freedom is two because both temp. and pressure can be varied independently. But in wet region both constant T and const. p ~~an~~ line goes inside and hence they can not be varied independently





$P + F = C + 2$

$1 + F = 1 + 2$

$\boxed{F = 2}$

P, T → vary independ

$P + F = C + 2$

$2 + F = 1 + 2$

$\boxed{F = 1}$

T, P → const

Mollier diagram :

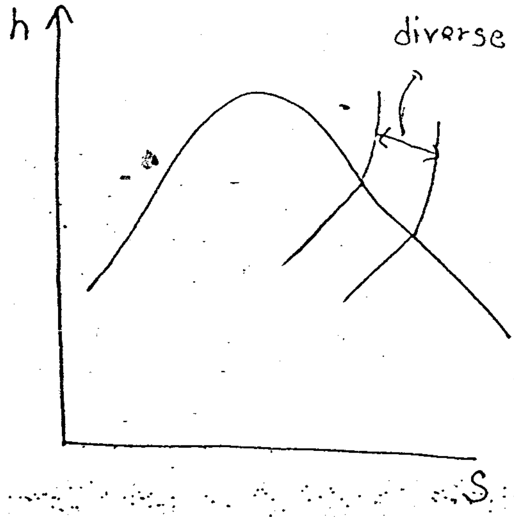
$$T\,ds = dh - v\,dp$$

P : const

$dP = 0$

$$T\,ds = dh$$

$$\boxed{\frac{dh}{ds} = T}$$



Slop of constant pressure lines on mollier diagram is equal to temp. In wet region during phase change as the temp. is constant. the slop is also const.

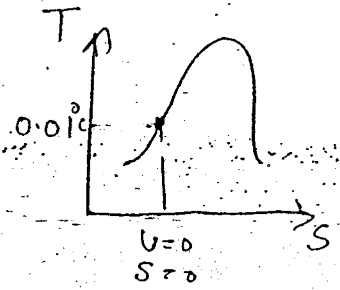
but in superheated region with incress in temp the slope increses and hence constant pressre line diverse in superheated region on mollier diagram.

Referense state in steam table :-

In steam table, the internal energy and entropy Of Saturated water at 0.01°c is arbitrarly taken as Zero.

$$\left.\begin{array}{l} U = 0 \\ S = 0 \end{array}\right\} \text{at } 0.01^\circ C$$

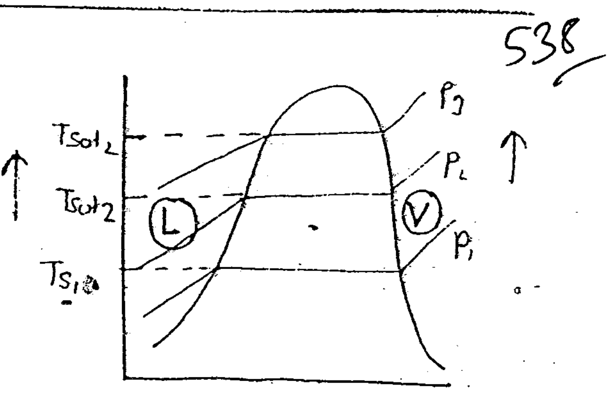
at Saturated water

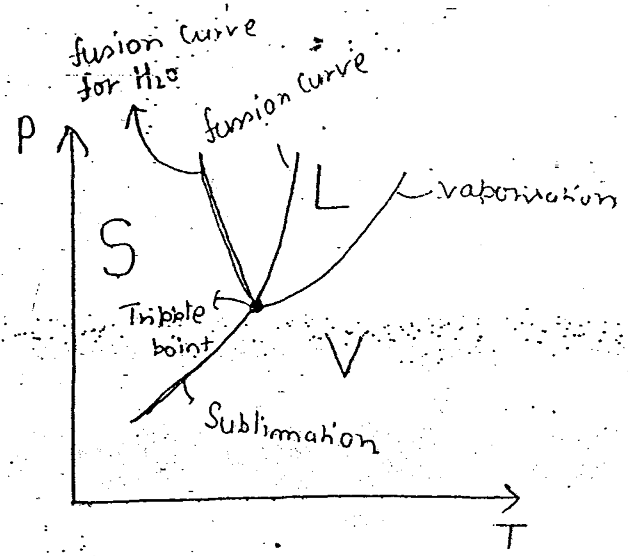


S-L = melting
L-S = frezzing
L-V = vaporisation
V-L - Condenation
S → V - Sublimation

Chemical substace	Water
S-L - melting - Expanding	S-L - meting - Contracting
L-S - frezzing - Contracting	L-S - frezzing - Expanding

with incrse in presure
the corrosponing saturation
temp. also increses

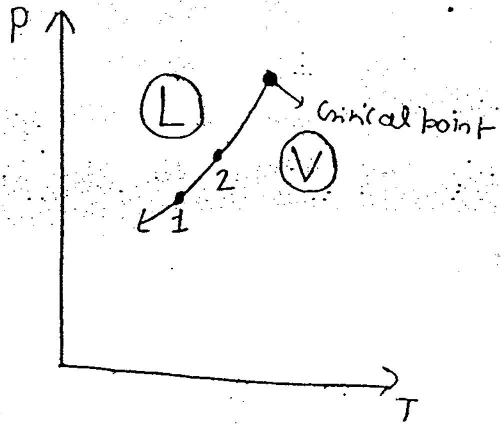




The slop of fusion curve on P,T diagram is (+ve) for genral substances, and its is negative for water

Slop of fusion curve = +ve
(genral substance)

Slop of fusion curve = −ve
(H_2O



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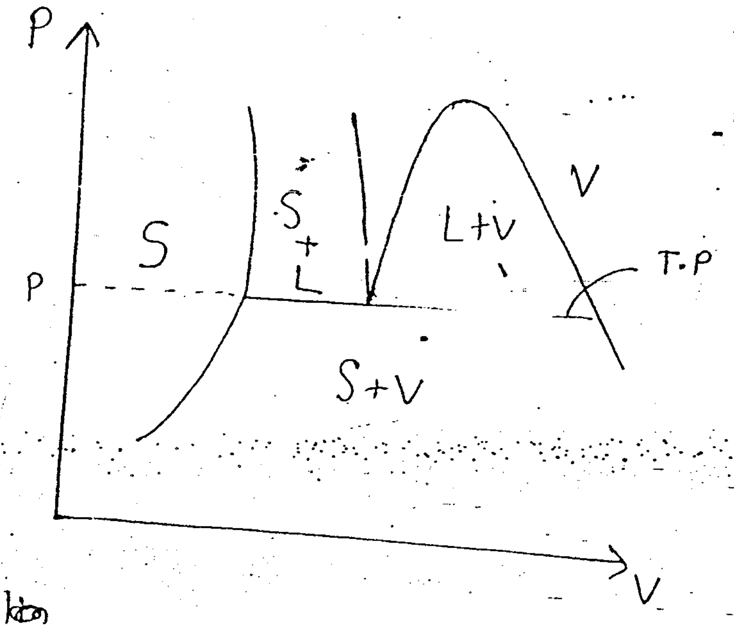
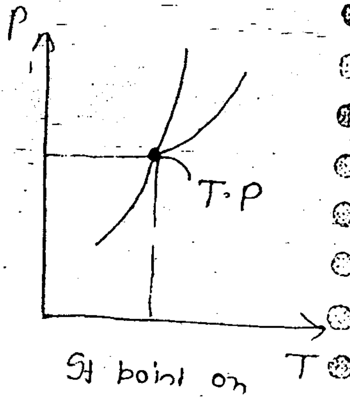


Gibs rule
takes about
intensive
proprty only
So P,T → const
V → variable

Triple point line on P-V diagram



St point on P,T

~~Triple point is a point on P-V diagram~~
~~It is a point on P-T diagram~~

Triple point is a point on P-T diagram and it is a line on P-V diagram according to Gibbs phase rule (F = 0). at triple point

no intansive variable vary but extensive variable varry.

Clausius-clapeyron Equation :-

From Maxiwell eq^n

$$\left(S_g - S_f = \frac{LH}{T_{sat}}\right)$$

$$\left(\frac{\partial P}{\partial T}\right)_V = \left(\frac{\partial s}{\partial v}\right)_T$$

$$\frac{dP}{dT} = \frac{S_g - S_f}{V_g - V_f}$$

$$S_g - S_f = \frac{LH}{T_{sat}}$$

$$\boxed{\frac{dP}{dT} = \frac{LH}{T_{sat}\cdot(V_g - V_f)}}$$ — Clapeyron Eq^n

But $V_g >>> V_f$

$$\frac{dP}{dT} = \frac{LH}{T_{sat}\, V_g}$$

$$PV = mRT$$

$$\frac{V}{m} = \frac{RT}{P}$$

$$v = \frac{RT}{P}$$

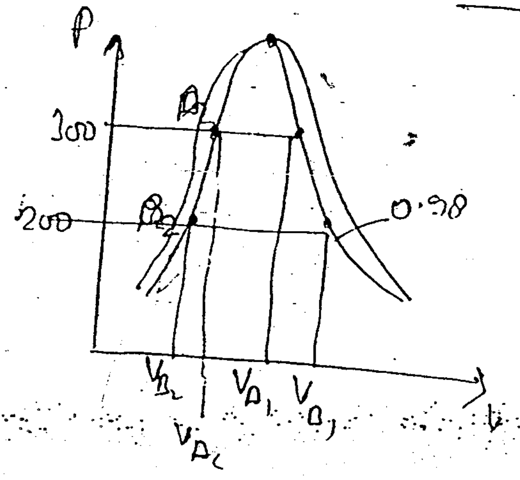
$$\frac{dP}{dT} = \frac{LH}{T_{sat}\cdot \frac{R\,T_{sat}}{P}}$$

$$\frac{dP}{dT} = \frac{P(LH)}{R(T_{sat})^2}$$

$$\boxed{\frac{dP}{dT} = \frac{P(LH)}{R(T_{sat})^2}}$$ — ~~Cal~~- Clausius clapeyron Eq^n

Chapter-6

① (d)



$V_{A_1} < V_{B_1}$ and $V_{A_2} > V_{B_2}$

⑪ $T = 100^\circ C$ ⓐ

$V_v = 8 V_l$

$v_l = 0.001044\ m^3/kg$

$v_g = 1.6729\ m^3/kg$

quality $= x$

$$x = \frac{m_v}{m_v + m_l}$$

$$x = \frac{m_v}{m_v\left[1 + \frac{m_l}{m_v}\right]}$$

$$x = \frac{1}{1 + \frac{m_l}{m_v}}$$

$m_l = \frac{V_l}{v_L}$

$m_v = \frac{V_v}{v_v}$

$$x = \frac{1}{1 + \frac{V_L}{v_L} \Big/ \frac{V_v}{v_v}}$$

$$x = \frac{1}{1 + \frac{V_l}{v_l} \times \frac{v_v}{V_v}} = \frac{1}{1 + \frac{\cancel{V_l} \times 1.6724}{0.001044 \times 8\cancel{V_l}}}$$

$\boxed{x = 0.005}$

⑭ $u_f = 251.2\ kJ/kg$

$v_A = v_B$ (given)

$m_A u_A = m_B u_B$

$$\frac{m_A}{m_B} = \frac{u_B}{u_A}$$

$$= \frac{u_f + x_B(u_g - u_f)}{u_f + x_A(u_g - u_f)}$$

$$u = u_f + x(v_g - v_f)$$

$$= u_f$$

Q5 540

⑦ $\rho = 36.12 \ \text{kg/m}^3$

$T = -20^\circ C$

$\rho_l = 1377$

$\rho_v = 7.379$

$x = ?$

$v_l = \frac{1}{\rho_l}$

$v_v = \frac{1}{\rho_v}$

$\rho = \frac{m}{V}$

$v = \frac{V}{m}$

$v = \frac{1}{\frac{m}{V}}$

$v = \frac{1}{\rho}$

(b)

$v = v_f + x(v_g - v_f)$

$\frac{1}{\rho} = \frac{1}{\rho_f} + x\left(\frac{1}{\rho_g} - \frac{1}{\rho_f}\right)$

$\frac{1}{38.12} = \frac{1}{1377} + x\left(\frac{1}{7.329} - \frac{1}{1377}\right)$

$\boxed{x = 0.2}$

⑧ Po

$P_1 = 200 \ \text{kPa}$

$x = 0.4$

$V = 1 \ m^3$

$T_2 = 30^\circ C$

$Q = h_2 - h_1$

$h_2 = 125.73 \ \text{kJ/kg}$

$h_1 = h_f + x(h_g - h_f)$

$h_1 = 504.7 + 0.4(2706.7 - 504.7)$

$h_1 = 1385.5 \ \text{kJ/kg}$

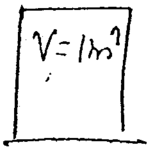
$Q = h_2 - h_1$

$= 125.7 - 1385.5$

$Q = -1259.7 \ \text{kJ/kg}$

but ans in KJ

then mass



$v = v_f + x(v_g - v_f)$

$= ~~0.001061 + 0.4(0.8857~~$

$v = v_f + x(v_g - v_f)$

$= 0.001061 + 0.4(0.8857 - 0.001061)$

$v = 0.3549$

$v = \frac{V}{m} = m = \frac{V}{v}$

$m = \frac{1}{0.3549}$

$\boxed{m = 2.819}$

(d)

$Q = -1259.7 \times 2.819 \ \frac{KJ}{kg} \times kg$

$= -3550 \ KJ$

⑨ $P = 1 \ \text{bar}$

$T_{sat} = 99.63^\circ C$

$S_g = ?$

$S_g - S_f = \frac{LH}{T_{sat}}$

(b)

$S_g - S_f = \frac{(h_g - h_f)}{T_{sat}}$

$S_g = 1.3026 + \frac{2675 - 417.5}{273 + 99.63}$

$\boxed{S_g = 7.362}$

⑩ $Q = U_2 - U_1$ (V=C)

ⓒ (12 - ?) P=C ⓒ
x=?

⑪ - ⓐ

(13) ⓑ

(14) $h_1 = h_2$

Adiabatic ($dQ = 0$)

Rev

$ds = \frac{dQ}{T}$

$ds = 0$

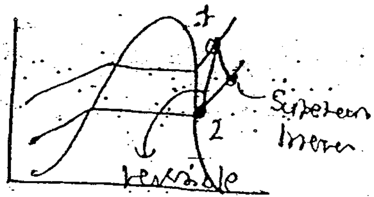
S = const

Irrev

$ds = \frac{dQ}{T} + \delta s$

$\underline{ds > 0}$

S → incresed so



15 ⓒ Hsid
V=C $\boxed{dQ = du}$

(16) ⓑ

(17) ⓓ U=0
S=0 trible point

(18) $v = 0.003155$ m³/kg

[illegible] $\boxed{V=C}$

$V = 0.025$ m³

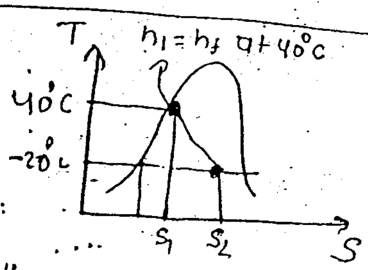
P = 0.1 MPa

$m = 10$ kg

$v_g = 0.003155$ m³/kg

1	p		s
t	190.2	u_f	
-20	1554.9	88.76	
40		318.74	

(26)



throtling = $Q = 0$
$\Delta Q = 0$

$h_1 = \underline{371.43}$

wet resion $h_2 = h_f + x(h_g - h_f)$

$h_2 = 89.05 + x(1418 - 89.05)$
(37141

Chapter -7

① $\frac{dP}{dT} = \frac{LH}{T(V_g - V_f)}$ ← enthalpy of Vaporisation

$$17.69 = \frac{LH}{(273+20)(0.0358-0.0008157)}$$

$$\boxed{LH = 181.5}$$

(II) (a)(b)

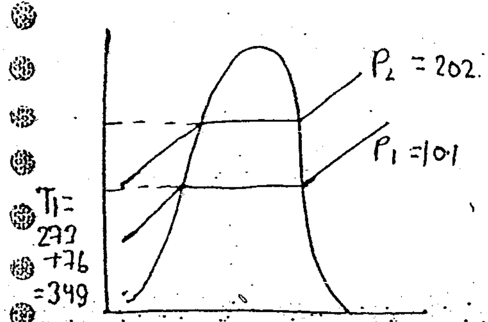
(III) T = 76°C

P = 101 kPa

LH = 195 kJ/kg

R = 0.055 kJ/kg

P_2 = 202 kPa ls.



$$\frac{dP}{dT} = \frac{P(LH)}{RT^2} \quad ⓑ$$

$$\int_1^2 \frac{dP}{P} = \frac{LH}{R}\int_1^2 \frac{dT}{T^2}$$

$$\ln\frac{P_2}{P_1} = \frac{LH}{R}\left[-\frac{1}{T}\right]_{T_1}^{T_2}$$

$$\ln\frac{202}{101} = \frac{195}{0.055}\left[-\left(\frac{1}{T_2} - \frac{1}{T_1}\right)\right]$$

$$\boxed{T_2 = 374.54\ k}$$

(IV) $G = H - TS$ ⓑ

$F = U - TS$

$(G-F) = (H-T\cancel{S}) - (U-T\cancel{S})$

$(G-F) = H - U$

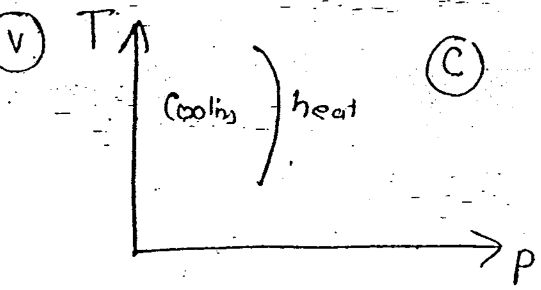
$(G-F) = f(T) - f(T)$

$G-F = PV = mRT$

$G-F = mRT$

$\boxed{G-F = F}$

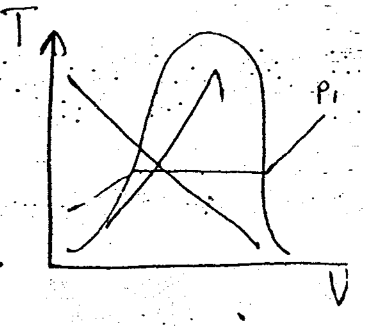
(V) ⓒ

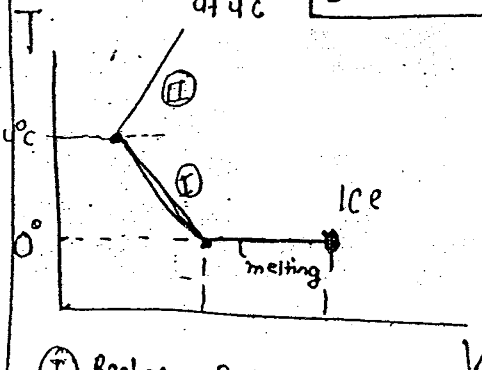


(VI) P = 1 atm

ρ = T = 4°C

$$\overset{max}{\uparrow}\rho = \frac{m \to C}{V \to min}$$ at 4°C





(I) Region $\left(\frac{\partial T}{\partial V}\right)_P$ = -ve slop

II reg $\left(\frac{dT}{dV}\right)_P$ = +ve slop from maxwell

$\left(\frac{dr}{dv}\right)$

$$\left(\frac{\partial S}{\partial P}\right)_T = \left(\frac{\partial v}{\partial T}\right)_P$$ ⓓ Ans

for 30

$$\left(\frac{\partial S}{\partial P}\right)_T = -[-ve] = +ve$$

$$\left(\frac{\partial S}{\partial P}\right)_T = -[+ve] = -ve$$

---

⑦ $\ln P_{sat} = A - \frac{B}{T_{sat}}$

$$\frac{dP}{dT} = \frac{LH}{T(V_g - V_f)}$$

$$\boxed{\frac{dP}{dT} = \frac{LH}{V_{fg}\,T}} - A$$

$$\ln P = A - \frac{B}{T_{sa}}$$

$$\frac{1}{P}\frac{dP}{dT} = 0 - B\left[-\frac{1}{T^2}\right]$$

$$\frac{1}{P}\frac{dP}{dT} = \frac{B}{T^2}$$

$$\frac{dP}{dT} = \frac{PB}{T^2}$$ By - Ⓐ

$$\frac{PB}{T^2} = \frac{LH}{TV_{fg}}$$ ⓑ

$$LH = \frac{PB\,V_{fg}}{T}$$

⑧ Slop constant $\overset{(+ve)}{}$ = cooling $\overset{T \text{ (decresed)}}{}$

Throttling = increasing

ⓐ

⑨ $\left(\frac{\partial S}{\partial V}\right)_T = \left(\frac{\partial P}{\partial T}\right)_V$

ⓑ

$$PV = mRT$$

$$\frac{P}{T} = \frac{mR}{V}$$

$(m=1)$

$$\frac{P}{T} = \frac{R}{V}$$

$$P = \frac{R}{V}T$$

⑩ c

⑪ Entropy change due to diffusion

$P_1 = x_1 P$ | $\frac{P_2}{P} = x_2$

$\frac{P_1}{P} = x_1$

O_2	N_2
$n_1 = 1$	$n_2 = 4$
200	200kP
300	300K

$$\Delta S = -m_1R_1\ln\left(\frac{P_1}{P}\right) - m_2R_2\ln\left(\frac{P_2}{P}\right)$$

$$\Delta S = -m_1R_1\ln(x_1) - m_2R_2\ln(x_2)$$

$$PV = mRT = n\bar{R}T$$

$$= mR\cancel{T} = n\bar{R}\cancel{T}$$

$$mR = n\bar{R}$$

$$m_2R_2 = n_2\bar{R}$$

$$\Delta S = -n_1\bar{R}\ln x_1 - n_2\bar{R}\ln x_2$$

$$x_1 = \frac{n_1}{n_1+n_2} \qquad x_2 = \frac{n_2}{n_1+n_2}$$

$$x_1 = \frac{1}{1+4} = 0.2 \qquad x_2 = \frac{4}{1+4}$$

$$\therefore x_2 = 0.8$$

$\Delta S = -1 \times 8.314 \times \ln 0.2 - 4 \times 8.314 \ln(0.8)$

$\boxed{\Delta S = \cancel{200}\ 20.8}$ ⓑ

⑫ ⓒ ⑮ ⓒ

⑬ ⓓ ⑯ a

⑭ ⓑ

⑰ $C_p - C_v = \frac{Tv\beta^2}{K_T}$

$C_p - C_v = \frac{(273+25) \times 0.000114 \ (5 \times 10^{-5})^2}{8.6 \times 10^{-12}}$

$C_p - C_v = 9.87$

$\frac{C_p}{C_v} = 1.024 \qquad C_v = \frac{C_p}{1.024}$

$C_p - \frac{C_p}{1.024} = \boxed{C_p = 421}$

⑱ $\left[T\left(\frac{\partial S}{\partial T}\right)_P - T\left(\frac{\partial S}{\partial T}\right)_V\right]$

$\Rightarrow T\left(\frac{\partial S}{\partial T}\right)_P - T\left(\frac{\partial S}{\partial T}\right)_V$

ⓓ $C_p - C_v = R$

⑲ ⓐ

Khushi Cyber Cafe]

Page - ⑮

⑭ $E = 25 + 0.25t \qquad \frac{dE}{dt} = 0.25$

$dQ = dE + dW \qquad \frac{dW}{dt} = 0.25$ given

$\frac{dQ}{dt} = \frac{dE}{dt} + \frac{dW}{dt}$

$\frac{dQ}{dt} = 0.25 + 0.25 = 1$

⑮ ⓐ

1-2	2-3
$V = C$	$P = C$
Q_{12} 170	$Q_{23} = -180$
$W_{12} = 0$	$W_{23} = -40$
$U_1 = 100$	$dQ_{23} = dU_{23} + dW_{23}$

$-180 = U_3 - U_2 + (-40$

$-180 = U_3 - 270 + (-40)$

$\boxed{U_3 = 130}$

$dQ_{12} = dU_2 + dW_{12}$

$dQ_{12} = U_2 - U_1 + dW_{12}$

$170 = U_2 - 100$

$U_2 = 270$

3-1

adiabatic

$\boxed{Q = 0}$

⑯ d

⑰ Q_P — U, W ⓑ

$\frac{dU}{Q_P} = \frac{dU}{dH} = \frac{\cancel{n} C_v dT}{\cancel{n} C_p dT}$

$\frac{dU}{Q_P} = \frac{1}{\gamma} = 5/7$

⑯ $h_1 = h_2$

$u_1 + P_1v_1 = u_2 + P_2v_2$

$u_2 - u_1 = P_1v_1 - P_2v_2$

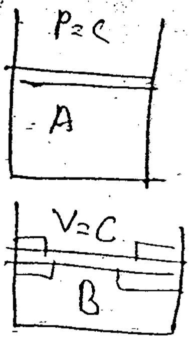
$du = P_1v_1 - \cancel{100\times2}\ P_2v_2$

$= 10\times100\times0.5 - 100\times2$

$= 300$

⑰ (d)

⑱ $Q_P = Q_V$ (given)



$mc_p dT_A = mc_v dT_B$

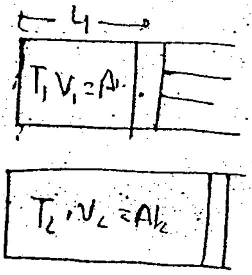
$\frac{c_p}{c_v} dT_A = dT_B$

$\gamma dT_A = dT_B$

$1.4(30) = dT_B$

$\boxed{dT_B = 42K}$ (d)

⑲ $\gamma = 5/3$



$T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$

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

$\left(\frac{T_1}{T_2}\right) = \left(\frac{A_2}{A_4}\right)^{\frac{5}{3}-1}$

$\frac{T_1}{T_2} = \left(\frac{2}{4}\right)^{2/3}$ (d)

⑳ $\delta W = 0$
$\delta Q < 0$ {then for the gas}

$\delta Q = dU + \delta W$

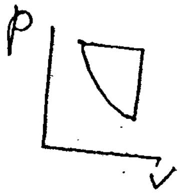
$\delta W = 0$ (given)

$\delta Q = dU$

$dQ < 0$

$dU < 0$

㉑ $Q = 5kJ$



$\Sigma Q = \Sigma W$

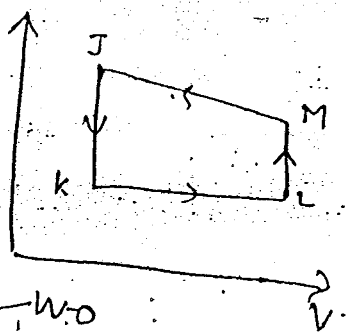
$\Sigma W = W_{AB} + 0 + W_{CA}$

$5 = W_{AB} + W_{CA}$

$5 = 10 + W_{CA}$

$\boxed{W_{CA} = -5}$

㉒



$PV = mRT$

$\downarrow P \propto \downarrow$

JK – V = C – W = 0
Q < 0

(a)

LM
V = C
W = 0
$\uparrow P \propto T \uparrow$
Q = supp
Q > 0

(23) $V = 2$ liter

$T_i = 27^\circ C$

$Q = 1\,KW = 1\,KJ/sec$

$W = 160\,J/sec \quad 0.16\,KJ/sec$

$1 - 0.16 = 0.84\,KJ/sec$

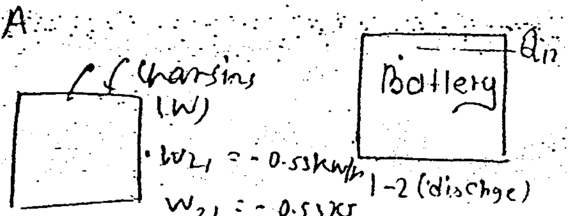
$Q = 0.84\,t$

$t = mc(\Delta t)$

$0.84\,t = 2 \times 4.20\,(77-27)$

$t\ 500\,sec = 88\,min\ 20\,sec$

(24) A



$W_{21} = -0.53\,kW/h$

$W_{21} = -0.53\,KJ/sec$

$Q_{12} = -250\,Kcal$

$W_{12} = 0$

$W_{21} = -1908\,KJ$ (5)

$\sum Q_{21} = \sum W.$

$Q_{12} + Q_{21} = W_{12} + W_{21}$

$-1045 + Q_{21} = 0 + (-1908)$

$Q_{21} = -863\,kJ$

(25) $T_2 = r\,T_1$

$T_2 = 1.4 \times 300 = \underline{\underline{420}}$

(26) C

(27) $dQ = du + dw$

$$\frac{dQ}{dt} = \frac{du}{dt} + \frac{dw}{dt}$$

$$\overset{\circ}{Q} = \frac{du}{dt} + \overset{\circ}{W}$$

$\overset{\circ}{W} = -260\,J/sec.$

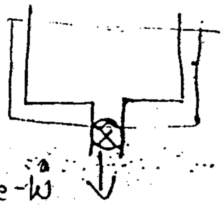
$\overset{\circ}{Q} = +10\,J/sec.$

$\frac{du}{dt} = 250\,J/sec.$

$= -250\,J/\cancel{sec} \times 3600\,\cancel{sec}$ (b)

$= 900 \times 10^3\,J = 900\,kJ$

(28)



$$\frac{du}{dt} = \overset{\circ}{m}_i h_i + \overset{\circ}{Q} - \overset{\circ}{m}_e h_e - \overset{\circ}{W}$$

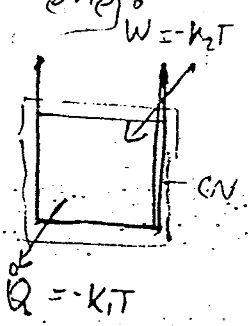
$$\frac{du}{dt} = -\overset{\circ}{m}_e h_e$$

$\overset{\circ}{m}_i = 0$

$$\frac{d}{dt}(mu) = -\overset{\circ}{m}_e h_e$$

9

(29)



$$\left(\frac{du}{dt}\right)_{CV} = \overset{\circ}{m}_i h_i + \overset{\circ}{Q} - \overset{\circ}{m}_e h_e - \overset{\circ}{W}$$

$$\left(\frac{du}{dt}\right)_{CV} = \overset{\circ}{Q} - \overset{\circ}{W}$$

$$\frac{du}{dt} = K_2T - K_1T$$

$$\frac{du}{dt} = (K_2 - K_1)\,T$$

~~$\frac{dT}{dt} = (d$~~

$$** \frac{dU}{dT}\cdot\frac{dT}{dt} = (K_2-K_1)T$$

$dU = C\,dT$

$\frac{dU}{dT} = C$ (b)

$C\cdot\frac{dT}{dt} = (K_2-K_1)T$

$\frac{dT}{T} = \frac{(K_2-K_1)}{C}\,dt$

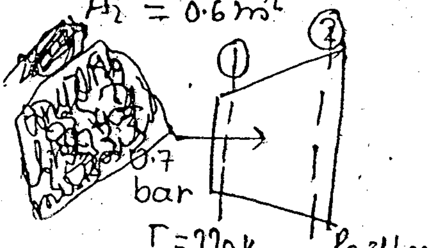
$\ln T = \frac{K_2-K_1}{C}\cdot t$

$$\boxed{T = e^{+\frac{K_2-K_1}{C}\cdot t}}$$

$T = e^{+ve} = +ve$

(30) 1MPa (c)
data mis

(31) $P = 0.7$ bar
$T = 57^\circ C$
$C = 200$ m/s
$A_1 = 0.4$ m²
$P_2 = 1$ bar
$A_2 = 0.6$ m²



$T = 330$K $P_2 = 1$bar
$P_1 = 0.7$ bar $A_2 = 0.6$
$C_1 = 200$
$A_1 = 0.4$

$\dot m = \rho AC$

$= \frac{m}{Vol}\times A\times C$

$= \frac{m}{A\times l}\times A\times C$

$\dot m = \frac{m}{t} = \frac{\rho AL}{t}$

$\dot m = \rho AC$

$\boxed{\dot m_1 = \dot m_2}$ → for study

$\rho_1 A_1 C_1 = \rho_2 A_2 C_2$

$\dot m_1 = \rho_1 A_1 C_1$

$PV = mRT$
$P = \frac{m}{V}RT$
$P = \rho RT$
$\rho = \frac{P}{RT}$

$\dot m = \frac{P_1}{RT_1}\times A_1 C_1$ kPa, kJ/kg K

$\rho_1 = \frac{0.7\times100}{0.287\times310}$

$\rho_1 = 0.739$

$\dot m = 0.735\times0.4\times200$

(a) $= 59.1$ kg/sec

(32) $PV^\gamma = const$

$P_1V_1^{\gamma-1} = P_2V_2^{\gamma-1}$

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

→ never use beau (d) drive when only it riversible adibatic so don't use it.

Valid riversible adibatic

$\dot m = \rho_2 A_2 C_2$

$59.1 = \rho_2 A_2 C_2$

$PV = mRT$

$P_2 = \rho_2 R T_2$

$\frac{P_2}{RT_1} = \rho_2$ (D)

$P_2 = 1$ bar
$A_2 = 0.6$ m²

$59.1 = \rho_2 A_2 C_2$

$59.1 = \frac{100}{0.287\,T_2}\times0.6\times C_2$

$$h_1 + \frac{C_1^2}{2000} = h_2 + \frac{C_2^2}{2000}$$

$$C_pT_1 + \frac{C_1^2}{2000} = C_pT_2 + \frac{C_2^2}{2000}$$

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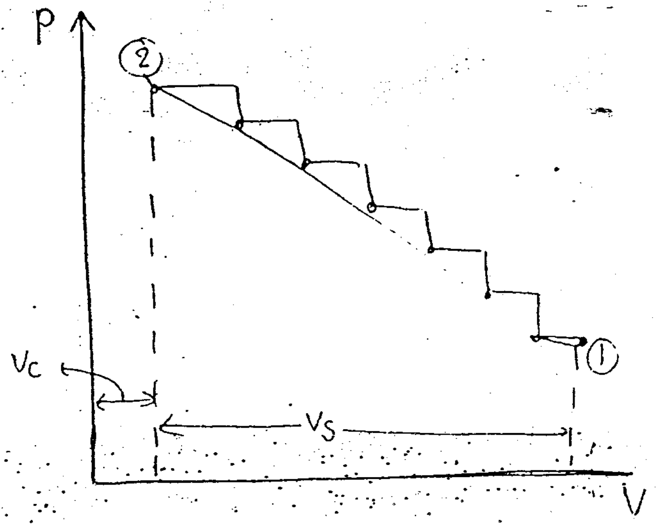
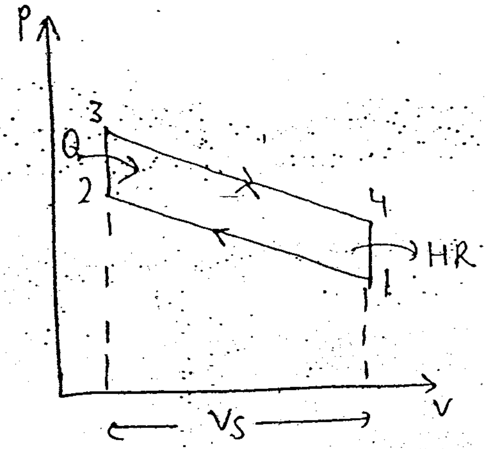
Otto Cycle :- In an otto cycle the heat addition takes place at Constant (V=C) Volume the other operations are common for all the cycle and are as follows [HA (V=C)]

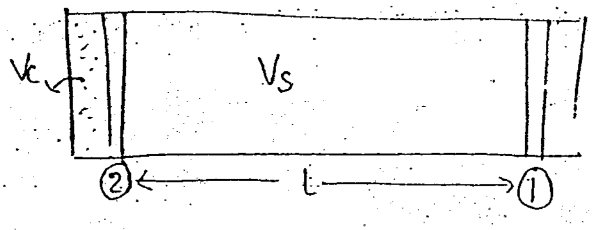
ⓐ heat rejection (V=C)
ⓑ Expansion (Reversible adibatic) (Isentropic)
ⓒ Compression (Isentropic)



(Ratio of vol.) $= \frac{\text{Larger V}}{\text{Lesser V}}$

$$\boxed{\text{Comp ratio} = \frac{V_1}{V_2}}$$





$r = \frac{V_1}{V_2}$

$HA = mC_v(T_3 - T_2)$

$V_3 = V_2$ & $V_4 = V_1$

Comp
HA (V=C)
Exp [Isen.
HR - V=C

$$\frac{V_4}{V_3} = \text{exp. ratio}$$

Also, $\frac{V_4}{V_3} = \frac{V_1}{V_2} = r$

$$H.R = m c_v (T_4 - T_1)$$

$$\eta = \frac{W.D}{HA} = \frac{HA - HR}{HA}$$

$$\boxed{\eta = 1 - \frac{HR}{HA}}$$

Efficency of Otto Cycle :-

$$\eta = 1 - \frac{HR}{HA}$$

$$\eta_v = 1 - \frac{m c_v (T_4 - T_1)}{m c_v (T_3 - T_2)}$$

$$\eta_v = 1 - \frac{(T_4 - T_1)}{(T_3 - T_2)}$$

$$\left(\frac{V_1}{V_2}\right)^{\gamma-1} = \frac{T_2}{T_1} \quad \therefore \frac{T_1}{T_2} = \left(\frac{V_2}{V_1}\right)^{\gamma-1} = \left(\frac{1}{r}\right)^{\gamma-1} \text{ — ⓐ}$$

$$\& \quad \frac{T_4}{T_3} = \left(\frac{V_3}{V_4}\right)^{\gamma-1} = \left(\frac{V_2}{V_1}\right)^{\gamma-1} = \left(\frac{1}{r}\right)^{\gamma-1} \text{ — ⓑ}$$

Eq -ⓐ = Eq ⓑ

$$\frac{T_4}{T_3} = \frac{T_1}{T_2} \Rightarrow \frac{T_4 - T_1}{T_3 - T_2}$$

from algebra

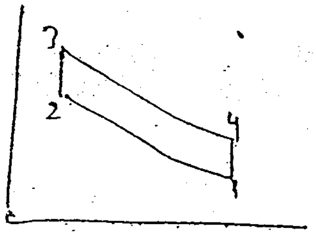
$$\frac{a}{b} = \frac{c}{d} = \frac{a-c}{b-d}$$

$$\therefore \frac{T_4-T_1}{T_3-T_2} = \left(\frac{1}{r}\right)^{\gamma-1} \quad \text{— (9)}$$

$$\therefore \boxed{\eta_v = 1-\left(\frac{1}{r}\right)^{\gamma-1}}$$

efficeiny of otto Cycle

Q Bore and stroke of the cylinder of 6 cylinder engine working on a otto cycle $d = 17\,cm$ $L = 30\,cm$ respectivily total Clearence volume is $V_c = 8225\,cm^3$ $r = ?$



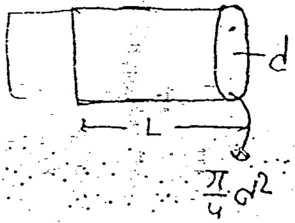
$n = 6$

$d = 17\,cm$

$L = 30\,cm$

$V_c = 9225\,cm^3$

$$r = \frac{V_1}{V_2} \quad [\text{Compression}]$$



$$r = \frac{V_c + V_s}{V_c}$$

$$V_s = \left(\frac{\pi}{4} \times d^2 \times L\right) \times n$$

$$V_s = \left[\frac{\pi}{4} \times (0.17)^2 \times (0.30)\right] \times 6$$

$$= 40856\,cm^3$$

$$r = \frac{9225 + 40856}{9225} = 5.4$$

gate-03
Q (59) W.b For an engine operating on air standard Otto cycle $V_c = 0.1 V_s$ and the $\gamma = 1.4$ determin the air stand efficu

$$r = \frac{V_c + V_s}{V_c} = \frac{0.1 V_s + V_s}{0.1 V_s} = 11$$

$$\eta = 1 - \left(\frac{1}{r}\right)^{\gamma - 1}$$

$$= 1 - \left(\frac{1}{11}\right)^{1.4-1}$$

$$\boxed{\eta = 61.6\,\%}$$

$$C = \frac{V_c}{V_s} = 0.1$$

Clearnes volume.

gate-04
Q An engine working on be Otto cycle as bore of 10 cm Stroke length 15 cm, $\gamma = 1.4$ the clerence volum = 196.3 cm³
$\frac{HA}{Kg}$ = 1800 kJ/kg Determin the work done per kg ?

An.

$$V_s = \left(\frac{\pi}{4} \times d^2 \times L\right) \Rightarrow \frac{\pi}{4} \times (10)^2 \times 15 =$$

$$\eta_v = 1 - \left(\frac{1}{r}\right)^{\gamma-1} = \frac{W.D}{HA}$$

$$W.D = HA\left[1 - \left(\frac{1}{r}\right)^{\gamma-1}\right]$$

$$= 973.5 \text{ kJ/kg}$$

IES-08
Q

THERMODYNAMICS BY
KULKARNI SIR

END