

GATE IES MENTOR

GATE IES MECH

SPECIAL HANDWRITING NOTES

4.104 ic engine



**TARGET
GATE/IES 2021**

2021

IC ENGINE

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* I.C. Engines *

Book - Automotive Mechanics

by Joseph Heitner. (Theory)

- IC Engines by V. Ganeshav. (Questions)
- IC Engines by Mathur & sharma

Thermodynamics - It is the field of science which deal with energy causes by gasses and pressure. It conversion in term of Heat and work and it's relationship with be various properties of system.

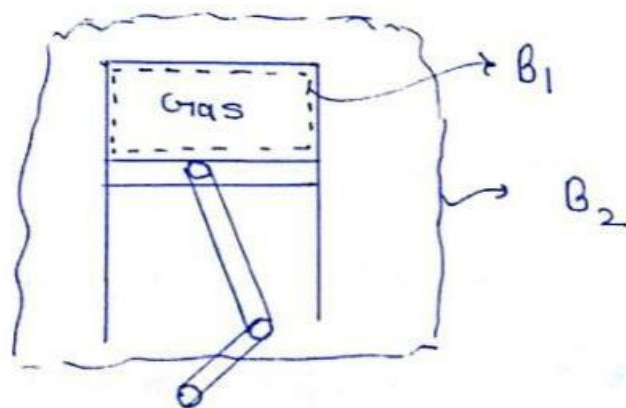
Properties:- Property of a system is that quantity which belong to the system and without which system can not exists. Thus P, V, T are the fundamental properties of system.
Heat & work are not the property of system.

System:- Reference to any space a matter or a group of matter within a definite boundary whether real or ~~img~~ imaginary is define a system. In the fig. shown, The gas inside the piston cylinder arrangement is a system for both the boundaries B_1 & B_2 . In the case of the cylinder. It is a surrounding for boundary B_1 and a system for boundary B_2 .

Surrounding:- Any matter that is outside the boundary and affect the behaviours of system is define as surrounding.

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In the fig. The cylinder is a surrounding for boundary B_1 for the region if the cylinder will not exist The gas Flow in all direction



piston cylinder arrangement

Types of system:-

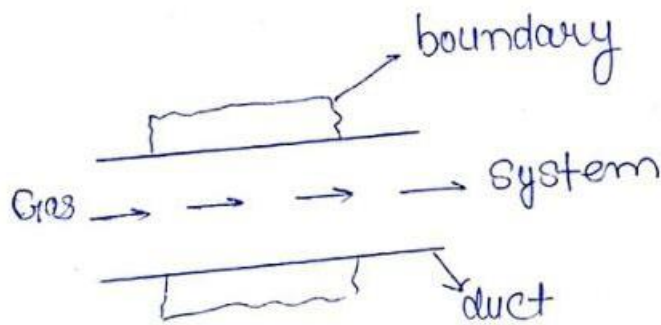
close system:- when no mass transfer by only energy transfer taking place across the boundary then the system is known as close system.

Eg:- A Gas inside a piston cylinder arrangement.

Open/Flow System:- when there is both mass and energy transfer taking place across the boundary the system is known as open or flow system.

Eg. Flow of a fluid through a duct.

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Isolated system:- It is the system which is completely separated or isolated from the surrounding. In this case, neither mass nor energy transfer taking place across the boundary.

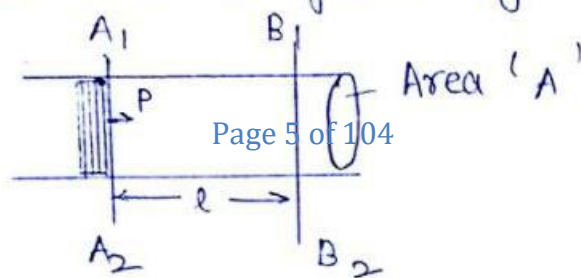
Eg. Gas inside a thermos flask.



work done for a Flow System:

let us consider fluid flowing through a duct as shown in fig.

Taking into account, a particular layer of fluid, flowing from section A_1A_2 to section B_1B_2 for which the displacement is l and if it is imagined that the flow takes place due to the pressure exerted by an imaginary piston formed by the different layer of fluid and if this pressure is equal to P , then the work done for the flow will be given by



$$W = \text{Force (F)} \times \text{displacement (l)}$$

$$= \text{pressure (P)} \times (A) \times l$$

$$= P \times (A \times l)$$

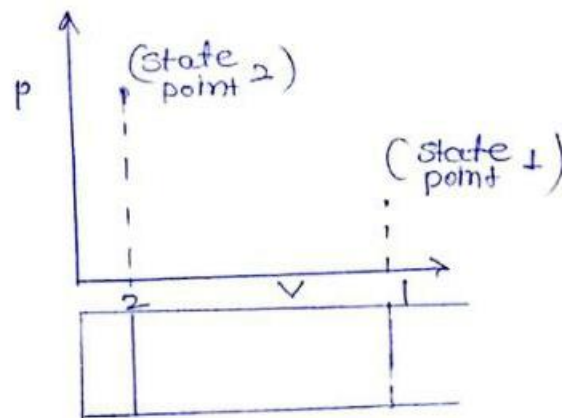
$$\boxed{W = P \times \text{Vol.}}$$

↓
Const.

$$\Rightarrow \boxed{W = P V}$$

↓
Const.

P-V diagram: - The P-V or pressure-volume diagram is the diagram the pressure is given by the height of diagram and volume is given by length of diagram. The P-V diagram is known as indication diagram. The state of the gas (inside the cylinder) is given by a point in P-V Diag. Thus this point is known as state point of the gas.



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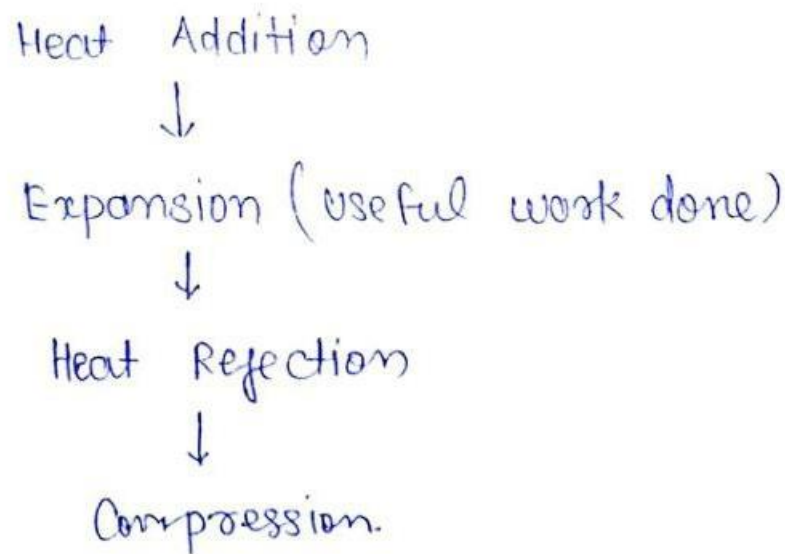
Process: - when a system undergoes changes from one condition to another condition it is then said to have completed a process (one state point to another state point.)

Cycle: - when a system after undergoing a number of processes is able to attain its original condition (original P, V, T) It is then said to have completed a cycle.

If the cycle is not completed, Then continuous work will not be obtain.

The different operation require for complete cycle.
Heat addition - Heat rejection - Expansion (work done) - compression

The order in which different operation carried out is as follows.



Ideal Cycle:- for an ideal cycle, the expansion and the compression processes should be reversible and adiabatic (isentropic processes)

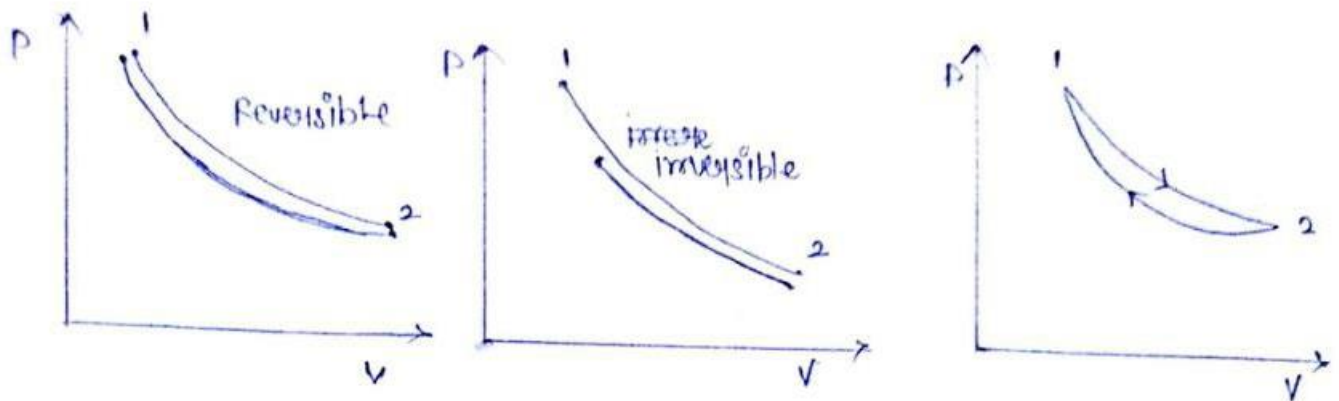
Reversible/irreversible process.

When a system undergoes a process in such a manner that it is able to retain its original condition by following some path in reverse direction, the process is then known as reversible process.

On the other hand if the system is unable to return to its original condition by following the reverse path the process is then known as an irreversible process.

Also, if a system is able to retain its original

Condition by following a different path the process is still ~~is~~ irreversible process.

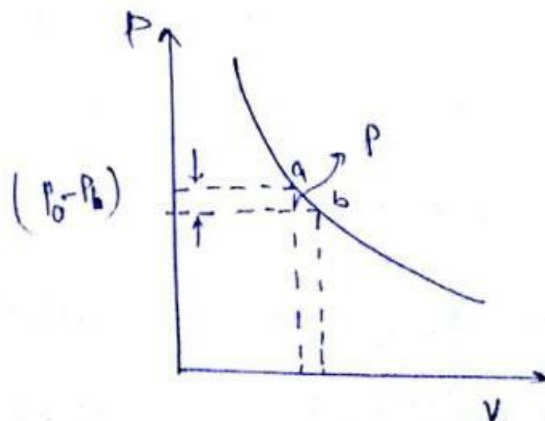


Quasi-static process:— When a system undergoes a process in such a manner that the final condition is nearest to original and equilibrium condition the process is then known as quasi-static process.

A quasi static process is same as differentially small change in calculus.

It is used under condition when any value that is remain constant remains constant.

A quasi-static process can be use only for a irreversible process



$$W = P \times V$$

↓
Const.

$$\int dw = \int_1^2 P \times dV$$

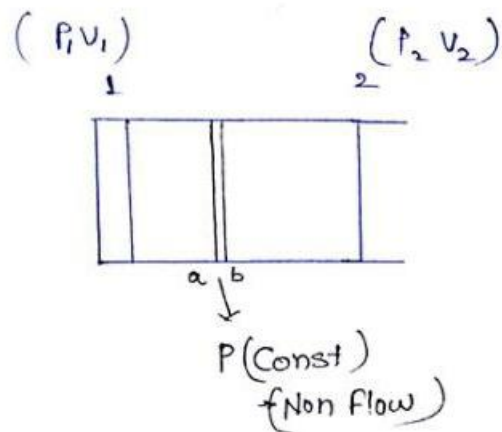
$$W = \int_1^2 P dV$$

* To calculate work done always consider quasi-static process.

Work done for close system (Non p_f Flow system)

⇒ A quasi-static process taken in consideration

Let us considering a gas expanding from state point 1 to 2 in such a manner then the pressure and volume change from P_1, V_1 to P_2, V_2 .



* whenever $P = \text{constant}$
take quasi-static
process.

For the non flow system there is no energy available outside. then the ^{Page 9 of 104} energy taken from the system it self due to this pressure of gas decreasing (P not const.). We thus consider a quasi-static process for which change in pressure is negligible and the change in volume dv . If the imaginary constant pressure for the quasi-static process ' P ' the work done for quasi static process will be

$$dw = P \times dv$$

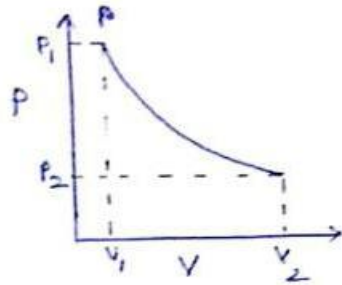
the work done for entire process will be

$$W = \int_1^2 P dv.$$

Types of process: -

- 1) Constant-Volume process (or isochoric or isometric process)
- 2) Constant-Pressure process (or isobaric process)
- 3) Constant-temp. process (or isothermal or hyperbolic process)

4)



$$V \propto \frac{1}{P} \Rightarrow V = C/P$$
$$\Rightarrow PV = \text{Constant}$$

Use only for Gas not for vapour,

- 4) Adiabatic process (No heat transfer)
- 5) Polytropic process (P, V & T changes, Heat transfer also takes place)

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Question Determine work done for different process undergoes by a close system as per above condition.

① Constant Volume Process: -

when $v = \text{const.}$

then $dv = 0$

$$\therefore p \times dv = p \times 0 = 0$$

$$W = \int_1^2 P dv = \int_1^2 0 = [C]_1^2 = C - C = 0$$

$$\therefore \boxed{W = 0}$$

② constant - pressure ^{Process} ~~Pressure~~:-

$$P = \text{Const.}$$
$$W = \int_1^2 P dV = P \int_1^2 dV = P[V]_1^2$$

$$\therefore \boxed{W = P(V_2 - V_1)}$$

③ constant temp. ^{Process.} ~~Pressure~~:-

$$T = \text{constant}$$

$$P \times V = C \quad \text{or} \quad P = \frac{C}{V}$$

$$W = \int_1^2 P dV = \int_1^2 \frac{C}{V} dV = C \int_1^2 \frac{dV}{V}$$

$$W = C (\ln V)_1^2$$

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

$$\boxed{W = P_1 V_1 \ln \left(\frac{V_2}{V_1} \right)}$$

④ Adiabatic process:-

$$P V^{\gamma} = C, \text{ or } P = \frac{C}{V^{\gamma}} = C \times V^{-\gamma}$$

$$W = \int_1^2 P dV = \int_1^2 C V^{-\gamma} dV = C \left[\frac{V^{-\gamma+1}}{-\gamma+1} \right]_1^2$$

$$W = \left(\frac{P V^{\gamma} \cdot V^{-\gamma+1}}{-\gamma+1} \right)_1^2 = \left(\frac{P V}{-\gamma+1} \right)_1^2$$

$$\text{or } W = \frac{P_2 V_2 - P_1 V_1}{-\gamma + 1}$$

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

⑤ Polytropic process:-

$$\therefore W = \frac{P_1 V_1 - P_2 V_2}{n - 1}$$

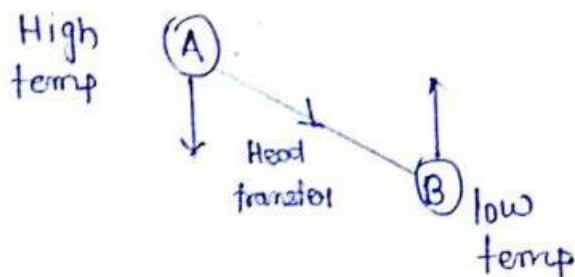
$$P V^n = C$$

Thermal equilibrium:-

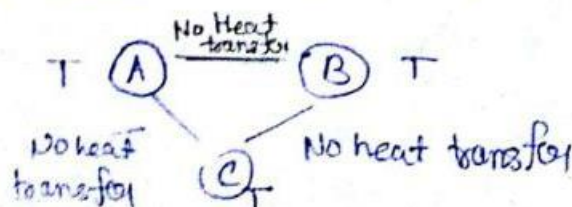
When there is no heat transfer between two bodies, then they are then said to be in thermal equilibrium with one another.

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Under ideal conditions, the temp of two bodies will be same when they are in thermal equilibrium with one another.



Zeroth law when two bodies are separately in thermal equilibrium with a third body then first two bodies will also be in thermal equilibrium.



Gas:- The state obtain after complete evaporation of liquid is defined as gas.

Ideal Gas:- An ideal gas is the one which obey all the gas law.

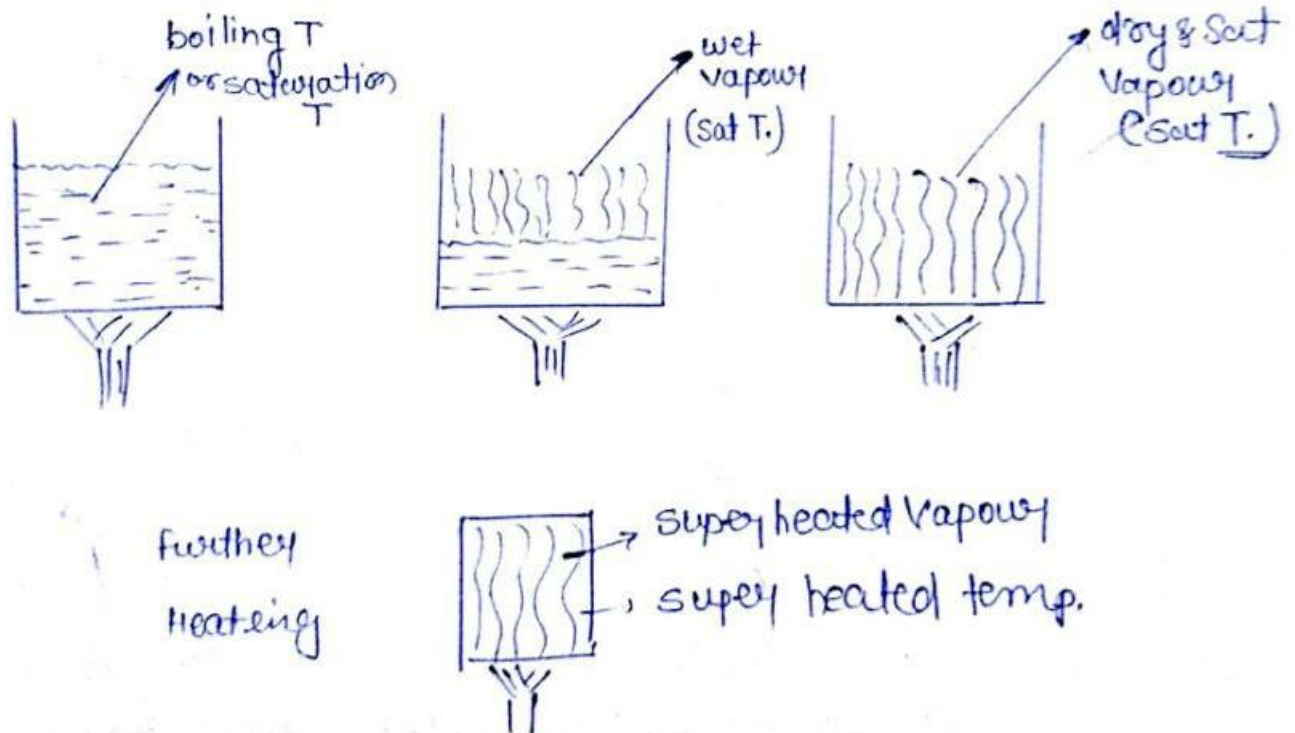
Real Gas:- No real gas is perfect as non obey the gas law. Under certain condition of temp & pressure some gasses behave like a perfect gas.

Ex- ~~A~~, O_2 , N_2 , H_2 etc.

Real gases are the gases that are available in practice.

Vapour:-

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Vapour:- The state existing due to incomplete evaporation of liquid is define as vapour

liquid will be present in the vapour given in the above definition such a vapour is known as wet vapour. The temp of wet vapour will be the boiling temp. that is also known as the saturation temp.

Heating the wet vapour, at one stage, will result in all the liquid being transferred in vapour. Such a vapour is known as dry and saturated vapour. The temp of this vapour will be the saturation temp. When the dry and saturated vapour is heated, ~~then~~ the vapour then available is known as superheated vapour. The temp. of superheated vapour is known as superheated temp.

Diff. Gas law

Boyle's law:- Temp. remaining constant. The Volume of the given mass of a gas is inversely proportional to its absolute pressure.

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when $T = \text{constant}$,

$$\text{then } V \propto \frac{1}{P} \quad \text{or} \quad V = \frac{C}{P} \quad \text{or} \quad P \times V = C$$

$$\therefore P_1 V_1 = P_2 V_2 = \dots = P_n V_n = C \quad \text{--- (1)}$$

Charles's law (1st statement)

when $P = \text{constant}$ the volume of given mass of a gas is directly proportional to its absolute temp.

when $P = \text{Const}$, then $V \propto T$

$$\text{or } V = CT \quad \therefore \frac{V}{T} = C$$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \quad \text{or} \quad \boxed{\frac{V_2}{V_1} = \frac{T_2}{T_1}} \quad - (2)$$

when $V = \text{Const}$, then $P \propto T$

$$\text{or } P = CT \quad \therefore \frac{P}{T} = C$$

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} \quad \text{or} \quad \boxed{\frac{P_2}{P_1} = \frac{T_2}{T_1}} \quad - (3)$$

Charl's law (2nd Statement) - Pressure remaining constant, The volume of the given mass of a gas, increase or decrease by $\frac{1}{273}$ of its original volume for every degree increase or decrease $^{\circ}\text{C}$ scale of Temp.

when $P = \text{a Constant}$

$$V = V_0 + \frac{t^{\circ}\text{C}}{273} V_0$$

$$\text{or } V = V_0 \left(1 + \frac{t^{\circ}\text{C}}{273} \right)$$

$$\therefore V = V_0 \left[\frac{273 + t^{\circ}\text{C}}{273} \right]$$

when the temp of gas is -273°C , then the volume of the Gas equal to zero

To have zero temp. when volume of Gas is zero. A new scale of temp is introduced known as the absolute or the kelvin a scale of temp such that zero temp in kelvin scale correspond to -273 in the $^{\circ}\text{C}$ scale of temp.

The change in temp is same in both the scale. Thus the relationship between the kelvin scale and $^{\circ}\text{C}$ scale will be as under $T_k = 273 + t^{\circ}\text{C}$

$$T_k = 273 + t^{\circ}\text{C} \quad - (a)$$

We have from equation (a) & (d)

$$\therefore V = V_0 + \left[\frac{T_k}{273} \right]$$

Thus, we have for the volumes V_1 & V_2

$$V_1 = V_0 \left[\frac{T_1 k}{273} \right] \quad - (b)$$

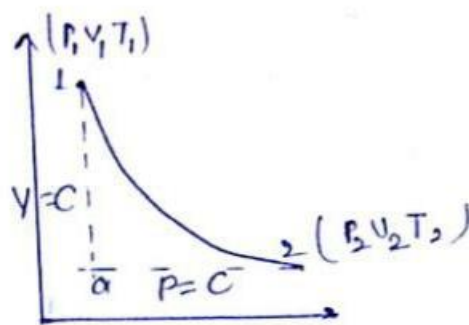
$$V_2 = V_0 \left[\frac{T_2 k}{273} \right] \quad - (c)$$

equation (b) divide by equation (c) gives

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

Which is in accordance with the first statement of Charles law. It is thus clear that the temp. applied for thermodynamic must be in the kelvin scale of Temp. only.

Universal Gas law:-



let us consider a system undergoing change from state point ① to state point ② in such a manner that P, V, T changes from P_1, V_1, T_1 to P_2, V_2, T_2 if the final condition is obtain by first taking a constant volume path 1-a and then by a constant pressure path, we that have for the constant volume process.

$$V_1 = V_a$$

$$\& \frac{T_a}{T_1} = \frac{P_a}{P_1} \quad \text{or} \quad T_a = T_1 \times \frac{P_a}{P_1} \quad - \text{①}$$

And for the Constant Pressure process^(9.2) we get

$$P_2 = P_1$$

$$\& \frac{V_1}{V_2} = \frac{P_1}{P_2} \therefore T_1 = T_2 \times \frac{V_1}{V_2} \quad \text{--- (2)}$$

From (1) & (2)

$$T_1 \times \frac{P_1}{P_1} = T_2 \times \frac{V_1}{V_2}$$

$$\text{or } T_1 \times \frac{P_2}{P_1} = T_2 \times \frac{V_1}{V_2}$$

$$\therefore \boxed{\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}}$$

$$\therefore \frac{PV}{T} = \text{a Constant } R$$

$$\therefore \boxed{PV = RT} \quad \text{Gas equation}$$

R - Gas Constant.

If the mass ' m ' is introduced in equation (Gas mass

$$\boxed{PV = m R_c T} \quad (\text{Characteristic gas equation})$$

R_c - characteristic Gas Constant.

Heat

Unit of heat:- one unit of heat is the amount of heat require to raise the temp. of

1 gram of air through 1°C .

- One unit of heat in the SI unit is ~~Not~~ know as 1 joule.

- Specific heat: Specific Heat of a substance is the amount of heat required to raise the temp. of 1 gram of that substance through 1°C

$$C = \frac{Q}{mt}$$

$$Q = m \times c \times t$$

let us consider a mass m of substance will heated until the raise in temp. t if the heat transfer for this purpose is Q , then we have from above definition the specific heat is given by

$$C = \frac{Q}{mt}$$

$$t \rightarrow \frac{Q}{m}$$

$$1 \rightarrow \frac{Q}{mt}$$

$$\text{or } Q = m \times c \times t$$

$$\therefore \text{Heat transferred} = (\text{mass} \times \text{specific heat} \times \text{change in temp.})$$

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