Ch#11:

Heat & Thermodynamics

M.C.Q	2	2
S/R	4	8
L/R	1	5/3
		15/13

Heat:

It is a form of energy which transfer from hotter place/objects to the colder place/objects.

Temperature:

degree of hotness or coldness is called temperature.

Thermodynamics:-

The branch of physics in which we deals with the transformation of heat en

mechan

is calle

Kinetic

M.C.Q

Page #

L/R

Imp

Pressur

The r

exerted

molecul

is calle

Gas.

P=

- Its un

1

rmodynamics

M.C.Q	2	2
S/R	4	8
L/R	1	5/3
		15/13

rm of energy
er from hotter
to the colder

.

:-

f hotness or
called temperature.

mics:-

anch of physics in
als with the transformation

2

of heat energy into mechanical energy (work). is called Thermodynamics.

Kinetic Theory of Gases:-

M.C.Q / S/R

Page # 237.

L/R
Imp

Pressure of Gas:-

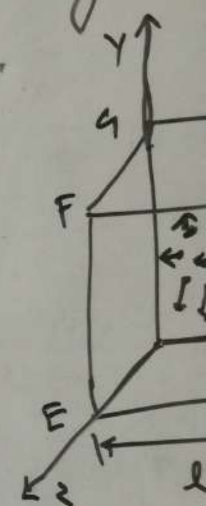
The normal force exerted by the gas molecules per unit area is called pressure of Gas.

$$P = \frac{F}{A}$$

• Its unit is Nm^{-2}

Explanation:-

Consider
vessel, ha
of length



• 'N' numb
present in
So

Area of The

Volum of Th

• we co
The each m
Now consid

having thre

velocities $\vec{V}_{1}$

2

ergy into
cal energy (work).
l Thermodynamics.

Theory of Gases:-

/SIR

237.

e of Gas:-

ormal force
by the gas

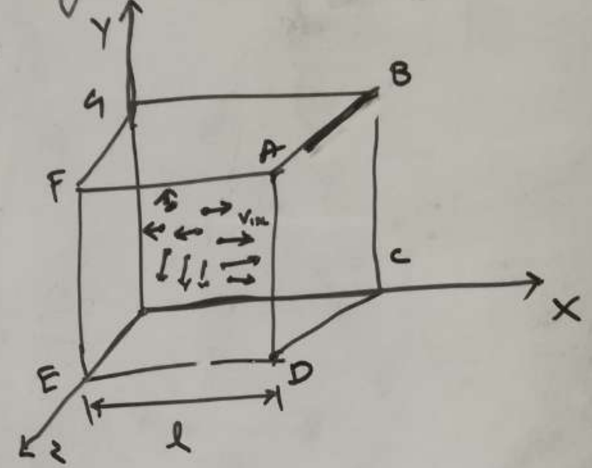
es per unit area
d pressure of

$= \frac{F}{A}$

nit is Nm^{-2}

Explanation:-

Consider a Cubical vessel, having each side of length 'l' as shown.



· 'N' number of molecules are present in the vessel as shown.

So

Area of the vessel = $A = l \times l = l^2$

Volum of the vessel = $V = l \times l \times l = l^3$

· we consider the mass the each molecule is 'm'

Now consider a single molecule having three components of velocities $\vec{V}_{1x}, \vec{V}_{1y}, \vec{V}_{1z}$ along

x, y & z axi
Simplicity w
x-axis

We see
Momentum o
before strik
is

$P_i = m$

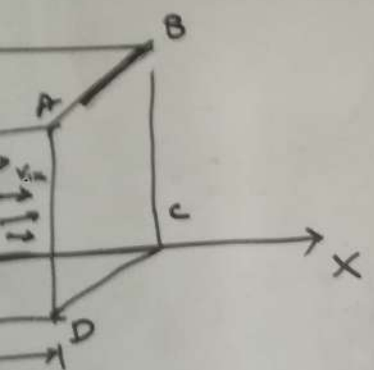
. we Conside
perfectly e
momentum
collision ar
in direction
of K.E as u

$P_f = -m$

Now
Change in Mo

3

Cubical
each side
'l' as shown.



of molecules are
e vessel as shown.

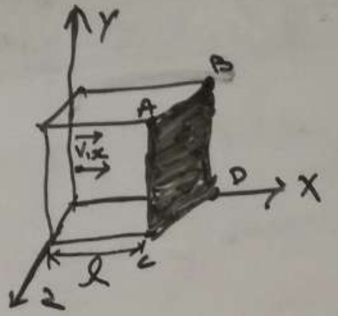
essel = $A = l \times l = l^2$

vessel = $V = l \times l \times l = l^3$

nsider The mass
olecule is 'm'
a single molecule
Components of
, $\vec{V}_{1y}$, $\vec{V}_{12}$ along

4

x, y & z axis respectively, For Simplicity we consider only x-axis



We see
Momentum of The Molecule before striking The side 'ABCDA' is

$$P_i = m\vec{V}_{1x}$$

. we Consider, collision is perfectly elastic So momentum before & after collision are same but opposite in direction & also no loss of K.E as well hence.

$$P_f = -m\vec{V}_{1x}$$

Now
Change in Moment $= P_f - P_i$

So

change in Mome

We Know

Force =

F_{1x} =

This is Th
ABCDA on
Now
. After
the molecu
position in
distance

$S = V$
$2l =$

$\Delta t =$

So

change in Momentum $= -mV_{1x} - mV_{1x}$

$= -2mV_{1x}$

We Know That

$$\text{Force} = \frac{\text{change in Momentum}}{\text{time}}$$

$$F_{1x} = \frac{-2mV_{1x}}{\Delta t} \rightarrow (1)$$

This is The force exerted by the side ABCDA on 1st molecule.

Now. After striking The side ABCDA, the molecule come back its original position in time 'Δt' & it covers The distance '$s = 2l$' so now

$$S = Vt \qquad V = V_{1x}$$

$$2l = V_{1x}\Delta t \qquad t = \Delta t$$

$$\Delta t = \frac{2l}{V_{1x}} \rightarrow (2)$$

Now put ② in eq ① we get

$$F_{1x} = - \frac{2mV_{1x}}{\frac{2l}{V_{1x}}}$$

$$F_{1x} = - \frac{mV_{1x}^2}{l} \rightarrow ③$$

As already discussed, This is is the force exerted by The side ABCDA on 1st molecule.

. According to newton's 3rd law

The force exerted by the molecule on the side ABCDA is same but opposite in direction

so That will be

$$F_{1x} = - \left[- \frac{mV_{1x}^2}{l} \right]$$

$$F_{1x} = \frac{mV_{1x}^2}{l}$$

Similarly the othe
exerted force o

$$F_{2x} = \frac{mV_{2x}^2}{l}$$

$$F_{3x} = \frac{mV_{3x}^2}{l}$$

$$\vdots$$

$$F_{nx} = \frac{mV_{nx}^2}{l}$$

The total x-
force due to
molecules is

$$F_x = F_{1x} + F_{2x} + F_{3x}$$

$$= \frac{mV_{1x}^2}{l} + \frac{mV_{2x}^2}{l} + \frac{m}{}$$

$$F_x = \frac{m}{l} \left[V_{1x}^2 + V_{2x}^2 + V_{3x}^2 \right.$$

divided both si

$\sqrt{1}$ we get

$\rightarrow$ (3)

ssed, This is

ted by The

molecule.

ton's 3rd law

d by The molecule

CDA is

site in direction

1x]

Similarly the other molecules exerted force on side is

$$F_{2x} = \frac{mV_{2x}^2}{l}$$

$$F_{3x} = \frac{mV_{3x}^2}{l}$$

$$\vdots$$

$$F_{nx} = \frac{mV_{nx}^2}{l}$$

The total x-directed force due to N-number of molecules is

$$F_x = F_{1x} + F_{2x} + F_{3x} + \cdots\cdots + F_{nx}$$

$$= \frac{mV_{1x}^2}{l} + \frac{mV_{2x}^2}{l} + \frac{mV_{3x}^2}{l} + \cdots\cdots + \frac{mV_{nx}^2}{l}$$

$$F_x = \frac{m}{l}\left[V_{1x}^2 + V_{2x}^2 + V_{3x}^2 + \cdots\cdots + V_{nx}^2\right]$$

divided both side with 'l^2' we get

$$\frac{F_x}{l^2} = \frac{m}{l^3}\left[V_{1x}^2 + V_{2x}^2 + \right.$$

As we know

$$\frac{F_x}{l^2} = \frac{F_x}{A} = P_x =$$

So eq (4) become

$$P_x = \frac{m}{l^3}\left[V_{1x}^2 + V_{2x}^2 + \cdots\right.$$

we also know that

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

$$\rho = \frac{m}{V}.$$

we have 'N' nu

in a vessel so

mass = N

& $V = l^3$

So

$$\rho = \frac{Nm}{l^3}$$

$$\frac{\rho}{N} = \frac{m}{l^3}$$

er molecules
on side is

directed.
N-number of

$_{3x}+\cdots+F_{nx}$

$\frac{mV_{3x}^2}{l}+\cdots+\frac{mV_{nx}^2}{l}$

$_{3x}^2+\cdots+V_{nx}^2]$

side with 'l^2' we get

$$\frac{F_x}{l^2} = \frac{m}{l^3}\left[v_{1x}^2+v_{2x}^2+v_{3x}^2+\cdots\cdots+v_{nx}^2\right] \quad (4)$$

As we know

$\frac{F_x}{l^2} = \frac{F_x}{A} = P_x$ = Normal Force per unit Area

So eq (4) becomes

$$P_x = \frac{m}{l^3}\left[v_{1x}^2+v_{2x}^2+\cdots\cdots+v_{nx}^2\right] \quad (5)$$

we also know that

density = $\frac{\text{mass}}{\text{volume}}$

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

we have 'N' number of molecules in a vessel so

mass = Nm

& $V = l^3$

So

$$\rho = \frac{Nm}{l^3}$$

$$\frac{\rho}{N} = \frac{m}{l^3} \longrightarrow (6)$$

put eq (6) in (5

$P_x = \frac{\rho}{N}\left[v_{1x}^2+v_{2x}^2+\right.$

$P_x = \rho\left[\frac{v_{1x}^2+v_{2x}^2}{}\right.$

where

$\left[\frac{v_{1x}^2+v_{2x}^2+v_{3x}^2+\cdots}{N}\right.$

mean of Squ

called mean

directed

represente

So eq (7) b

$P_x = \rho\langle v_x^2$

This is the e

pressure ex

of molecule

Similarly we

put eq (6) in (5) we get

$$P_x = \frac{\rho}{N}\left[v_{1x}^2 + v_{2x}^2 + v_{3x}^2 + \cdots\cdots + v_{nx}^2\right]$$

$$P_x = \rho\left[\frac{v_{1x}^2 + v_{2x}^2 + v_{3x}^2 + \cdots + v_{nx}^2}{N}\right] \rightarrow (7)$$

Where

$$\left[\frac{v_{1x}^2 + v_{2x}^2 + v_{3x}^2 + \cdots\cdots + v_{nx}^2}{N}\right]$$ is the

mean of squared velocities

called mean squared velocity

directed along x-axis,

represented $\langle v_x^2 \rangle$

So eq (7) becomes

$$P_x = \rho\langle v_x^2 \rangle \longrightarrow (8)$$

This is the expression of total pressure exerted by the 'N' number of molecules on x-axis,

Similarly we consider the pressure

exerted by the N-number of molecules on 'y' & z-axis is

$$P_y = \rho \langle V_y^2 \rangle$$

& $$P_z = \rho \langle V_z^2 \rangle$$

we consider the collision is perfectly elastic so. all the components of mean square velocities are equal

Hence

$$\langle V_x^2 \rangle = \langle V_y^2 \rangle = \langle V_z^2 \rangle$$

from vector addition

$$\langle V^2 \rangle = \langle V_x^2 \rangle + \langle V_y^2 \rangle + \langle V_z^2 \rangle$$

$$\langle V^2 \rangle = \langle V_x^2 \rangle + \langle V_x^2 \rangle + \langle V_x^2 \rangle$$

$$\langle V^2 \rangle = 3 \langle V_x^2 \rangle$$

$$\frac{1}{3} \langle V^2 \rangle = \langle V_x^2 \rangle \rightarrow (9)$$

put eq (9) in eq (8) we get

$$P_x = \rho \times \frac{1}{3} \langle v^2 \rangle$$

$$P_x = \frac{\rho}{3} \langle v^2 \rangle$$

By pascal law, The pressure inside the vessel by the gas molecules are same so in general

$$P = \frac{\rho}{3} \langle v^2 \rangle \rightarrow (10)$$

we know That

$$\rho = \frac{Nm}{V}$$

put this in above eq

$$P = \frac{Nm}{3V} \langle v^2 \rangle$$

$$P = \frac{N}{3V} \langle mv^2 \rangle$$

$P = \frac{2N}{3V}$

$\frac{2N}{3V} =$

So

$P \propto <$

$P \propto <$

It shows

pressure

Gas m

directl

The aver

K.E of

11

eq (8) we

$v^2 >$

$^2 >$

w, The pressure

el by the gas

same So

$^2 > \rightarrow$ (10)

That

n above eq

$<v^2>$

$<mv^2>$

12

$$P = \frac{2N}{3V} < \frac{1}{2} m v^2 >$$

$$\frac{2N}{3V} = \text{Constant}$$

So

$$P \propto < \frac{1}{2} m v^2 >$$

$$P \propto < K.E >$$

It shows that the total pressure exerted by the Gas molecules is directly proportional to the average translational K.E of the molecules.

Interpretation

Ideal Gas:

The Gas i

having only k

ideal Gas.

For Ideal G

$PV = nRT$

where 'R' i

Constant, i

8.314 J mol

'T' is the a

'n' is the

of the Gas

volume 'V'

$$n = \frac{N}{N_A}$$

$N_A = 6.022$

12

$\frac{1}{2}mv^2>$

tant

$v^2>$

$>$

t The total

exerted by the

ules is

oportional to

translational

molecules.

13

Interpretation of temperature:-

Ideal Gas:.

The Gas in which molecules having only K.E called ideal Gas.

For Ideal Gas

$$PV = nRT \rightarrow (1)$$

where 'R' is the General Gas constant, its value is $8.314\ J\,mol^{-1}K^{-1}$.

'T' is the absolute temperature

'n' is the number of moles of the Gas contained in volume 'V'.

$$n = \frac{N}{N_A}$$

$$N_A = 6.022 \times 10^{23}$$

So eq(1) beco

$$PV = \frac{N}{N_A} RT$$

$$PV = N\frac{R}{N_A}$$

$$\frac{R}{N_A} = \frac{8.314}{6.022 \times 10^{23}}$$

$$\frac{R}{N_A} = K = \text{Bol}$$

Now eq(2)

$$PV = NK$$

$$P = \frac{N}{V}K$$

$\frac{N}{V}$ = Numb per U

$$\frac{N}{V} = N_0$$

So

$$P = N_0 K T$$

...emperature:-

...h molecules
...called

$\rightarrow (1)$
General Gas
...alue is

...lute temperature
...ber of moles
...tained in

So eq (1) becomes

$$PV = \frac{N}{N_A} RT$$

$$PV = N\frac{R}{N_A} T \rightarrow (2)$$

$$\frac{R}{N_A} = \frac{8.314}{6.022\times10^{23}} = 1.38\times10^{-23}\ JK^{-1}$$

$\frac{R}{N_A} = K =$ Boltzmann's Constant

Now eq (2) becomes

$$PV = NKT$$

$$P = \frac{N}{V} KT$$

$\frac{N}{V} =$ Number of Molecules per Unit volume

$$\frac{N}{V} = N_0$$

So

$$P = N_0 KT \rightarrow (3)$$

We know that

$P = \frac{2N}{3V} <\frac{1}{2}m$...

Here $\frac{N}{V} = N_0$...

So

$P = \frac{2}{3} N_0 <\frac{1}{2}$...

Compare eq (3)...

$\cancel{N_0}KT = \frac{2}{3}$...

$T = \frac{2}{3K} <$...

$\frac{2}{3K} =$ Con...

So

$T =$ Const...

$T \propto <$...

$T \propto <$...

It shows that t...
is directly propo...

$\rightarrow ②$

$\times 10^{-23}\ JK^{-1}$

...n's Constant

...comes

Molecules

volume

$\rightarrow ③$

15

We know that

$$P = \frac{2N}{3V}\left\langle \frac{1}{2}mv^2 \right\rangle$$

Here $\frac{N}{V} = N_0$

So

$$P = \frac{2}{3}N_0\left\langle \frac{1}{2}mV^2 \right\rangle \rightarrow ④$$

Compare eq ③ & ④ we get

$$\cancel{N_0}KT = \frac{2}{3}\cancel{N_0}\left\langle \frac{1}{2}mV^2 \right\rangle$$

$$T = \frac{2}{3K}\left\langle \frac{1}{2}mv^2 \right\rangle \rightarrow ⑤$$

$$\frac{2}{3K} = \text{Constant}$$

So

$$T = \text{Constant}\left\langle \frac{1}{2}mv^2 \right\rangle$$

$$T \propto \left\langle \frac{1}{2}mv^2 \right\rangle$$

$$T \propto \langle K.E \rangle$$

It shows that temperature of the gas molecules is directly proportional to the average translational K.E of the gas molecules.

Q. Derive boyle's law from Kinetic molecular theory of Gases.

Ans:.

Boyle's law :.

Pressure is inversally proportional to the volume keeping the temperature constant.

$$P \propto \frac{1}{V} \text{ (at Constant Temp)}$$

$$P = \frac{\text{Constant}}{V}$$

$$PV = \text{Constant} \rightarrow (1)$$

Now

Consider

$$P = \frac{2N}{3V} \langle \tfrac{1}{2} m v^2 \rangle$$

$$PV = \frac{2N}{3} \langle \tfrac{1}{2} m v^2 \rangle$$

$$\frac{2N}{3} = \text{Constant}$$

$$PV = \text{Constant} \langle \tfrac{1}{2} m v^2 \rangle \rightarrow (2)$$

as we know that

Temperat

eq

$T \propto \langle \tfrac{1}{2} m$

So

$\langle \tfrac{1}{2} m v^2 \rangle$

Hence eq (2

$PV = \text{Const}$

from eq (5

See

$PV = \text{Con}$

$P \propto \frac{1}{V}$

SQ.

Derive cha

Kinetic mol

Gases.

Ans:- Charles l

Volume

a gas is di

from Kinetic
of Gases.

...sally proportional
...g the temperature

...Constant Temp)

... $\rightarrow$ ①

...$mv^2\rangle$

...$\frac{1}{2}mv^2\rangle$

...nt $\langle\frac{1}{2}mv^2\rangle \rightarrow$ ②

...at

Temperature is Constant

&

$T \propto \langle\frac{1}{2}mv^2\rangle$

So

$\langle\frac{1}{2}mv^2\rangle$ is also constant

Hence eq ② becomes

$PV = \text{Constant} \rightarrow$ ③

from eq ③ & ① we

see

$PV = \text{Constant}$

$P \propto \frac{1}{V}$

SQ:

Derive charles law from Kinetic molecular Theory of Gases.

Ans: Charles law:

Volume of a given mass of a gas is directly proportional

to the absolute tem...
the pressure const...

$V \propto T$ (at ...

$V = \text{Constant}$...

$\frac{V}{T} = \text{Constan}$...

Now Consider

$P = \frac{2N}{3V}\langle\frac{1}{2}m$...

$V = \frac{2N}{3P}\langle\frac{1}{2}$...

$\frac{2N}{3P} = \text{Constan}$...

$V = \text{Constant}$...

As we Know

$T \propto \langle\frac{1}{2}m$...

So

$V = \text{Const}$...

$V \propto T$

to the absolute temperature, keeping the pressure constant

$$V \propto T \quad \text{(at constant Pressure)}$$

$$V = \text{Constant } T$$

$$\frac{V}{T} = \text{Constant} \longrightarrow (1)$$

Now Consider

$$P = \frac{2N}{3V} \langle \tfrac{1}{2} m v^2 \rangle$$

$$V = \frac{2N}{3P} \langle \tfrac{1}{2} m v^2 \rangle$$

$$\frac{2N}{3P} = \text{Constant}$$

$$V = \text{Constant} \langle \tfrac{1}{2} m v^2 \rangle$$

As we Know

$$T \propto \langle \tfrac{1}{2} m v^2 \rangle$$

So

$$V = \text{Constant } T$$

$$V \propto T$$

Internal Energy:

The microscopic sum of all energies (K.E + P.E) of the Substance is called internal energy.

From book page #244

S|Q + M.C.Q's

sum
+ P.E) of
alled
's

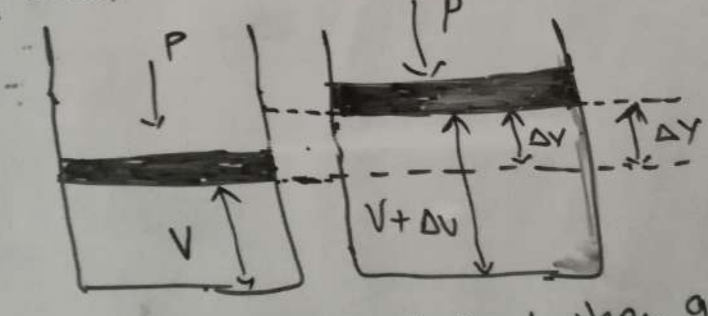
Work & Heat:

Heat is a form of energy which transform from one form to another form.

Explanation:

Consider a Gas in a Container having volume 'V' as shown.

- The Gas molecules exert pressure on the walls of the container & piston as well as shown.



- The piston moves upward when gas molecules exert pressure & doing some work

so $W = F\Delta Y$

$= PA\Delta Y$

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

$P = \frac{F}{A}$

$F = PA$

$A\Delta Y = \Delta V$