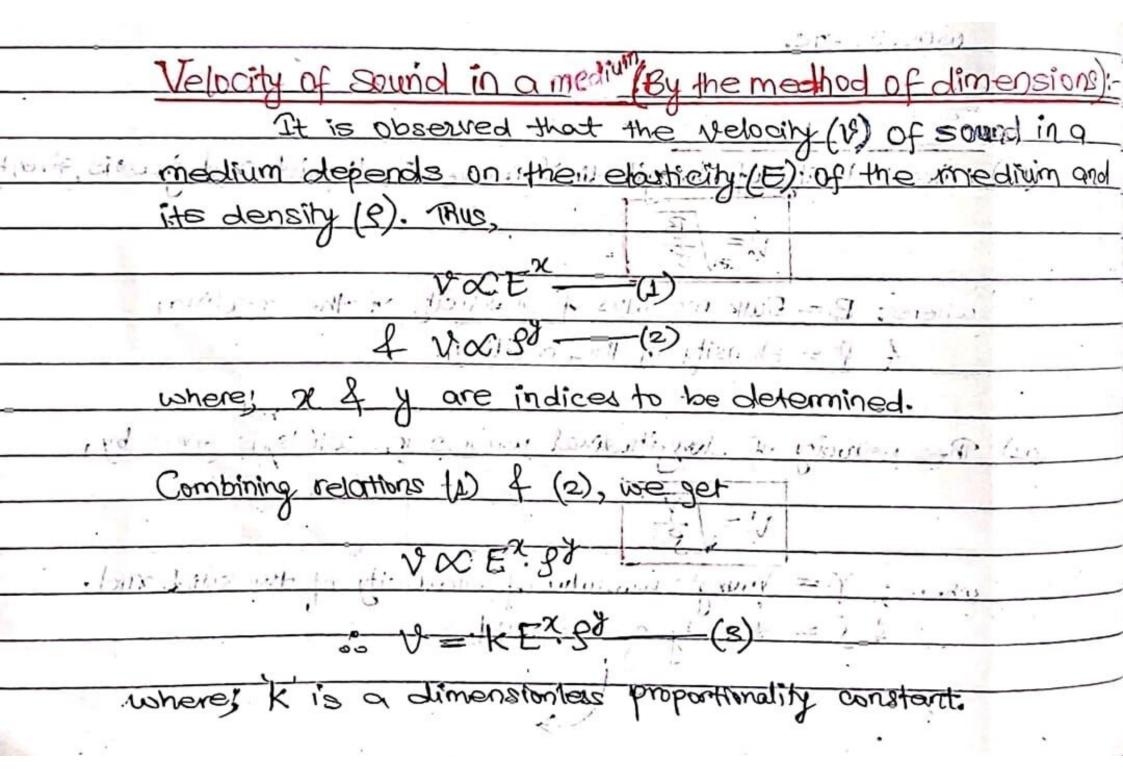
MECHANICAL WAVES

Mechanical Waves:

Mechanical waves are those waves which require material medium for their propagation from one point to another.

- > Mechanical waves are also called elastic waves because their propagation depends upon the elastic properties of the medium.
- > The mechanical waves exist in all three states of matter: solid, liquid and gas.
- => The mechanical waves may be transverse or longitudinal in nature.
- eg: Sound waves, waves on the surface of water, seismic waves, waves in pipes, waves in strings, etc.



2

Now,

Substituting the corresponding dimensions in
$$eq^{\Omega}$$
 (3), we get $\left[M^{0}LT^{-1}\right] = \left[M^{-1}T^{-2}\right]^{2} \left[M^{-3}T^{0}\right]^{\frac{1}{2}}$

Equating the corresponding indices, we get

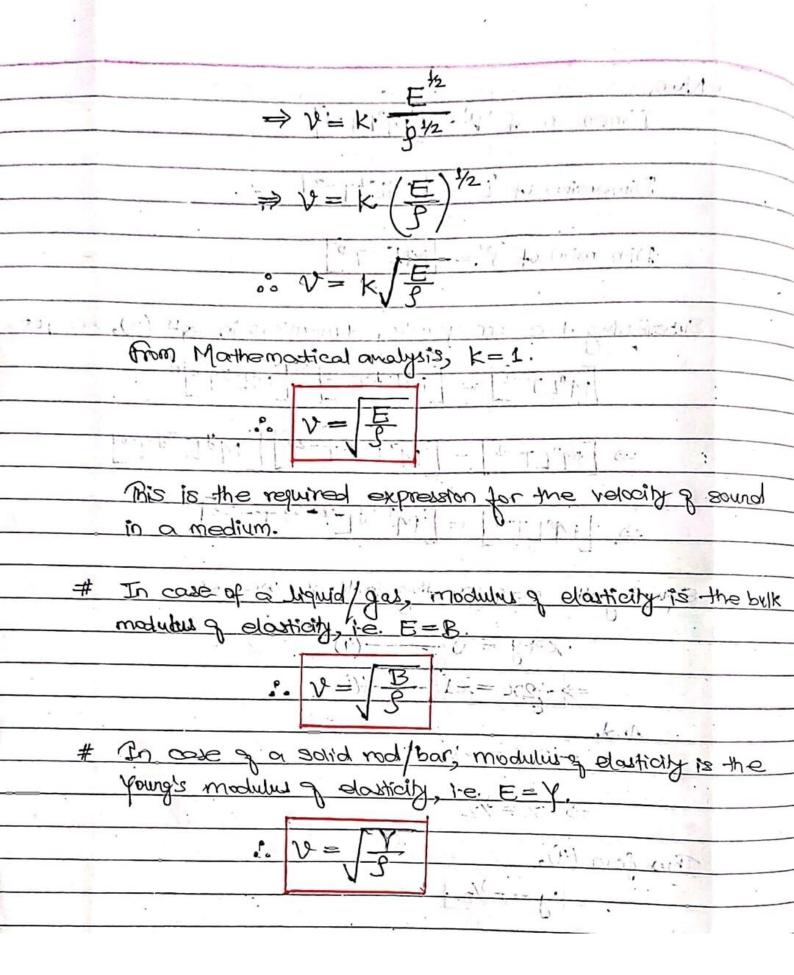
$$\Rightarrow y = -x$$

$$\Rightarrow y = -x$$

$$\Rightarrow (4)$$

Ru from (4),

Substituting the values of X f y in eq 1 (3), we get $V = k E^{1/2} \cdot g^{-1/2}$



Newton's formula for velocity of sound in gas:-The velocity of sound wants in a gou is given by, where: B= Bulk-modulis q elasticity q the gas. Newton assumed that when sound waves propagate through air, compressions and rarefactions are formed. He argued that the change in pressure and volume in these regions is so slow that the heat produced during compression is given to the summaring air while the heat lost during rarefaction is gained from the sumounding gas. so, the temperature of the medium remains constant. Thus, according 21 is always some bunds of nother paged of the sold of an isothermal process. . For an isothermal process, PV= constant - (2) where; P = pressure of the god ... +V= volume of the gal. On differentiating equ (2), we get where; - dt = B, the bulk modulus of air.

This is Newton's formula for the velocity of sound in a got, At NTP, P = 760 mm g Hg $= 1.01 \times 10^5 \text{ N/m}^2$ L S = 1.293 kg/m3 Thus, from og ? (4), $V = \sqrt{\frac{1.01 \times 10^5}{1.293}}$ > V ~ 280 m/s

According to Newton's formula, the velocity of sound in air at NTP is 280 m/s. However, the velocity of sound in oir at NTP is found to be 332 m/s, which is quite greater than the value calculated by Newton's formula. This is due to some discrepancies in Newton's assumption and it needs to be corrected.

Discrepancy of Newton's Formula - Laphce Correction:

More than one century later the Newton's derivation, Laplace in 1816, corrected this formula. He pointed out that Newton's assumption of propagation of sound in gas as a isothermal process was a mistake!

According to Laplace, the process of compression framefaction occur so rapidly that neither heat is transferred to the surroundings during compression nor heat is taken from the surrounding during rarefaction. So, the temperature is different regions does not remain constant. Thus, the propagation of sound waves through air is an adiabatic process.

for an adiabatic process,

where; $N = \frac{C}{C}$, the ratio of molar heat capacities of air.

111/1.

On differentiating eq 1 (5), we get

Dividing both sides by V 1-1, we get.

$$\frac{rPV^{r-1}}{V^{r-1}} dV + \frac{V^r}{V^{r-1}} = 0$$

$$\Rightarrow P = -VdP$$

$$\Rightarrow P = -VdP$$

$$\Rightarrow P = -dP$$

$$\Rightarrow P = B - (6)$$

$$V \Rightarrow P = B - (7)$$

$$\Rightarrow P = \frac{1}{\sqrt{P}} \Rightarrow P = \sqrt{7}$$
This is corrected Newton's Armula the velocity of sound in gas.

At NTP,
$$P = \frac{1}{\sqrt{P}} \Rightarrow P = \frac{1}{\sqrt{2}}$$

$$\Rightarrow P = \frac{1}{\sqrt{2}} \Rightarrow P = \frac{1}{\sqrt{2}}$$

This result is in close agreement with the experimental value. Thus, Laplace's formula gives the corred value of velocity of sound in air.

Factors Affecting the velocity of sound in Gas:

The velocity of sound in a gas is given by,

$$\mathcal{Y} = \sqrt{\frac{rP}{S}}$$

where; P= pressure of the gas P = density of the gas

Y = Sp, the ratio of molar heat capacities of the gas.

o for 'n' modes of gas, the equation of state is

But,
$$m = \frac{m}{M}$$

where; m= given mass of the gas

Rus, of 1 (2) becomes

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

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

8

$$\Rightarrow \frac{P}{m} = \frac{RT}{M}$$

$$\Rightarrow \frac{P}{S} = \frac{RT}{M} \qquad (3) \quad \left[\vdots S - \frac{m}{V_1} \right]$$

Using (B) in (1), we get

Now, let's discuss the factors affecting the velocity of sound in gas.

(O1) Effect of Pressure:

The increase in pressure of the gas causes an equivalent increase in the density of the gas so that the ratio of % is always constant. Hence from (1), the velocity of sound in gos is independent of the pressure of the gas at constant temperature.

(02) Effect of density:

From eqn (1), we have

For any two gases (say Gas I and Gas 2) having some atomicity (r=constant) and same pressure P,

$$V_1 = \sqrt{\frac{rP}{S_1}}$$

Thus,
$$\frac{\sqrt{P}}{\sqrt{S_1}}$$
 $\frac{\sqrt{P}}{\sqrt{S_1}}$

$$\Rightarrow \frac{V_2}{V_1} = \sqrt{\frac{rP}{s_2}} \times \sqrt{\frac{g_1}{rP}}$$

$$\Rightarrow \frac{V_2}{V_1} = \sqrt{\frac{S_1}{S_2}}$$

$$\Rightarrow v \propto \frac{1}{\sqrt{s}}$$

Thus, the velocity of sound in a gas is inversely proportional to the square root of the density of the gas, at constant pressure.

Alara H. Kr. L. Cont. Alara Tolk	<u>.</u>
(03) Effect of Humidity:	
The density of water vapour is smaller than	1 that of dry
air. Thus, the presence of moisture reduces the	density &
air. So, Smoist air < Say air. Since vocity, hence the	irelocity of
	The second secon
sound is greater in moist our than in dry our.	·
	A) a valoriby
Greater the humidity of air, higher is:	THE VENCING
of source.	11
(04) Effect of Pemperature:	
From eq 2 (4); it is elear that the velocity of	f of sound
in gos is directly proportional to the square root	of the absolute
temperature of the gas.	<u>.</u>
i.e. vast	4
If Vi and Vz be the velocities of a ?	as at
temperatures T_ & Tz respectively, then	Liza
	• • • • • • • • • • • • • • • • • • • •
$\frac{\sqrt{1}}{\sqrt{2}} = \sqrt{\frac{1}{T}}$	
V2 V 12	

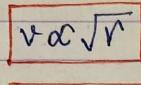
Effect of Wind:-The velocity of sound is greater in the direction of the wind and less in the opposite direction. The net velocity a sound is given by, where; V = velocity of sound.

V = velocity of wind. Effect of frequency, wavelength and amplitude: -The velocity of sound in air is independent of both frequency and wavelength. The velocity of sound is independent 9 amplifie as well.

(07) Effect of nature of gas:

from ego (4), we have

Thus at constant temperature T,



The velocity of sound in a gas depends upon the atomicity of the gas (vac Ir) and the molecular mass of the gas (vac Im).