UG-(I) Dr S. Roy

INTENSITY OF SOUND WAVES

The intensity of sound wave is defined as the amount of energy falling per second on unit area placed normal to the direction of travel of the sound.

Consider a progressive wave of amplitude a and travelling along x-axis with a velocity v. It is expressed by the equation

$$y = a \sin \frac{2\pi}{\lambda}(vt - x) \quad \text{----- (1)}$$

Differentiating equation (1) with respect to time t, we have

$$\frac{dy}{dt} = \frac{2\pi a v}{\lambda} \cos \frac{2\pi}{\lambda}(vt - x) \quad \text{——— (2)}$$

Let ρ be the density of the medium. The instantaneous kinetic energy of the wave per unit volume of the medium is therefore

$$\frac{1}{2}\rho\left(\frac{dy}{dt}\right)^2$$

$$= \frac{2\pi^2 a^2 v^2 \rho}{\lambda^2} \cos^2 \frac{2\pi}{\lambda}(vt - x) \quad \text{——— (3)}$$

The maximum value of $\cos^2 \frac{2\pi}{\lambda}(vt-x)$ is 1. Therefore the maximum kinetic energy per unit volume is $\frac{2\pi^2 a^2 v^2 \rho}{\lambda^2}$ with zero potential energy.

$\therefore$ Total energy per unit vol^m

$= \text{Maximum K.E} + \text{Minimum P.E (0)}$

$= \frac{2\pi^2 a^2 v^2 \rho}{\lambda^2}$

$= 2\pi^2 a^2 n^2 \rho$ and is "energy density"

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UG-(I) (Intensity....)

The energy density is the total energy contained in unit length of wave per unit area of cross-section. Now, as the wave travels a distance v in one sec, the rate of energy flow per unit area of cross-section of the medium is given by

$$= 2\pi^2 a^2 n^2 \rho \times v$$

This may be regarded as the "intensity of waves." The intensity of sound waves, however, diminishes with distance due to energy loss in a given medium.

Let I_1 and I_2 be the intensities of sound at distances r_1 and r_2 from a point source S of sound respectively. Let E be the total energy given out per second by the source, Let us draw two concentric spheres with S as centre and r_1 and r_2 as radii as shown in fig (1).

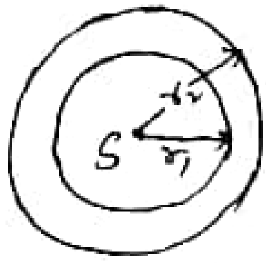

fig (1)

Now from the definition of intensity of sound waves

$$I_1 = \frac{E}{4\pi r_1^2} \quad \therefore E = 4\pi r_1^2 I_1 \longrightarrow (4)$$

and $$I_2 = \frac{E}{4\pi r_2^2} \quad \therefore E = 4\pi r_2^2 I_2 \longrightarrow (5)$$

From (4) and (5), we get

$$4\pi r_1^2 I_1 = 4\pi r_2^2 I_2$$

$$\therefore \frac{I_1}{I_2} = \frac{r_2^2}{r_1^2} \quad \text{i.e } I \propto \frac{1}{r^2}$$

Thus the intensity of sound at a point is inversely proportional to the square of the distance of the point from the source.

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The absolute sound intensity is measured in "watts per square centimetre". But, in practice it is the relative intensity which is more important than the absolute intensity. The ratio of intensities of two sounds is expressed in terms of "intensity level."

If two sounds have intensities I_1 and I_2, then the difference in intensity level is said to be

$$\log \frac{I_1}{I_2} \text{ bels.}$$

or,
$$\log \frac{I_1}{I_2} \text{ bels} = 10 \times \log \frac{I_1}{I_2} \cdot \frac{1}{10} \text{ bels}$$
$$= 10 \log \frac{I_1}{I_2} \text{ decibels.}$$

Thus if one sound has an intensity 10 times that of the other, there difference in level is

$$\log_{10} \frac{10}{1} = 1 \text{ bel}.$$

Similarly, if the intensity of one is 100 times that of the other, the difference in intensity level is 2 bel and so on.

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