

INTENSITY OF SOUND

(BSC I SEMESTER)

(Unit V)

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PHYSICS DEPARTMENT

DEFINATION

- Intensity is defined to be the power per unit area carried by a wave. Power is the rate at which energy is transferred by the wave.
- In equation form, intensity I is
- $I = \frac{P}{A}$, where P is the power through an area A .
- The SI unit for I is W/m^2

- The intensity of a sound wave is related to its amplitude squared by the following relationship:
- $I = \frac{(\Delta p)^2}{2\rho v_w}$ here Δp is the pressure variation or pressure amplitude (half the difference between the maximum and minimum pressure in the sound wave) in units of pascals (Pa) or N/m^2

- The energy (as kinetic $mv^2 / 2$) of an oscillating element of air due to a travelling sound wave is proportional to its amplitude squared.
- In this equation, ρ is the density of the material in which the sound wave travels, in units of kg/m^3 , and v_w is the speed of sound in the medium, in units of m/s .
- The pressure variation is proportional to the amplitude of the oscillation, and so I varies as $(\Delta p)^2$
- This relationship is consistent with the fact that the sound wave is produced by some vibration; the greater its pressure amplitude, the more the air is compressed in the sound it creates.

- Sound intensity levels are quoted in decibels (dB) much more often than sound intensities in watts per meter squared. Decibels are the unit of choice. The reasons for this choice of units are related to how we perceive sounds. How our ears perceive sounds can be more accurately described by the logarithm of the intensity rather than directly to the intensity. One reason for doing this is the variation of sound intensities over a wide range (approximately 10^{-12} to 10 W/m^2) in our audible acoustical environment. The other reason is that our ear does not respond linearly to sound intensities. The sensation of hearing depends on the logarithm of intensities. The commonly used standard intensity for air borne sounds is 10^{-12} W/m^2 which approximately corresponds to the lower limit of intensity for audibility in air at a frequency of 1KHz.

- The intensity level (IL) of a sound of intensity I is defined by
- $IL = 10 \log_{10} \left(\frac{I}{I_0} \right) \dots \dots \dots (1)$
- Where IL is expressed in decibels (dB) and I_0 is the standard reference intensity. Bel is a large unit of IL.
- 1Bel=10 decibels

Most of the modern sound detectors like headphones, loudspeakers respond to the changes in acoustic pressure rather than to the intensity. Hence it would be more useful to express equation 1 in terms of sound pressures. Since $I = p_{rms}^2 / \rho_0 c$, we may define sound pressure level (SPL) in decibels by the equation

$$SPL = 20 \log_{10} \frac{p_{rms}}{p_0} \dots \dots \dots (2)$$

Where p_0 is the effective pressure of a standard sound. The commonly used reference pressure for specifying SPL in air is $2 \times 10^{-5} \text{ N/m}^2$.

It corresponds almost exactly to $I_0 = 10^{-12} \text{ W/m}^2$. Hence almost identical numerical values are obtained by using either of the above two equations for sound waves in air.

LOUDNESS

- Loudness of sound is the degree of auditory sensation produced by sound waves reaching the ear.
- It depends not only on the intensity of sound but also on the frequency and sensitiveness of the ear.
- Loudness is a physiological quantity rather than a physical quantity.
- Loudness depends on mental interpretation and hence cannot be measured exactly with an instrument. There is no absolute scale for the measurement of loudness. However, it has been found that there is fair agreement between observers as to when a pure tone of one frequency appears as loud as a tone of another frequency.

- Therefore , it is possible to make a quantitative measurement of loudness by comparing the sound under test with some standard sound. The standard is chosen to be a tone of frequency 1KHz and of acoustic pressure $2 \times 10^{-5} \text{ N/m}^2$.
- The unit of loudness level (LL) is phon.
- The intensity level of the standard tone is raised until it appears equally loud with the sound under test, then the rise of the intensity level of the standard tone is dB is said to be equivalent loudness of the sound in number of phons.

Example:

- Q. Show that if one sound is twice as intense as another, it has a sound level about 3dB higher
- Solution:
- The ratio of the two intensities is 2 to 1 ie
- $\frac{I_2}{I_1} = 2$
- We know
- $IL = 10 \log_{10} \left(\frac{I_2}{I_1} \right)$
- $= 10 \log_{10} 2.00$

- $=10(.301)\text{dB}$
- Thus $IL = 3.01 \text{ dB}$
- Discussion: this means that the two sound intensity levels differ by 3.01 dB. Note that only the ratio $\frac{I_2}{I_1}$ is given and not the actual intensities

Defination of bel

The threshold audibility, i.e. , the lower limit of audibility for a note of frequency 1000 c.p.s corresponds to an intensity equal to 10^{-16} watt/cm² and corresponding acoustic pressure being 0.0002 dyne/cm². This is taken as standard intensity I_0 . A Sound of intensity 10 times that of this threshold value is said to have intensity level 1 Bel or 10 decibels. The intensity level is defined in terms of this standard intensity using Weber-Fechner Law by a logarithmic relation as follows:

$$\text{Intensity level in bels} = \log_{10} \frac{I}{I_0}$$

or , Intensity level in decibels = $10 \cdot \log_{10} \frac{I}{I_0}$

- Defination of phon
- The loudness level of sound is not proportional to the intensity, but change in loudness is proportional to logarithm of the intensity expressed in terms of the standard intensity.
- Loudness level is expressed in terms of the loudness of standard tone of 1 kHz frequency and intensity 10^{-2} w/m^2 . For sound of intensity level of 1 bel or 10 decibels, the loudness level is said to be 1 phon. Thus, if $\frac{I}{I_0} = n$ decibels, the loudness level $\Delta L = 10 \log_{10} n$ is said to be n phons.

- Problems will be worked out in class