

Numerical Problems**Important formulas:**➤ **Intensity Level of Sound**

$$\text{Intensity level} = 10 \log \frac{I}{I_0}$$

➤ **Speed of wave** $v = f\lambda$ ➤ **Time period** $T = \frac{1}{f}$ ➤ **Frequency** $f = \frac{n}{t}$ ➤ **Speed** $v = \frac{d}{t}$ ➤ **Distance** $S = vt$

11.1 A normal conversation involves sound intensities of about $3.0 \times 10^{-6} \text{ Wm}^{-2}$. What is the decibel level for this intensity? What is the intensity of the sound for 100 dB? (ALP)

Given Data

$$\text{Intensity of sound} = I = 3.0 \times 10^{-6} \text{ Wm}^{-2}$$

$$\text{Int. of faintest sound} = I_0 = 10^{-12} \text{ Wm}^{-2}$$

$$\text{Sound level} = L - L_0 = 100 \text{ dB}$$

To Find

$$\text{Intensity level} = L - L_0 = ?$$

$$\text{Intensity of sound} = I = ?$$

Solution

By using formula of intensity level of sound

$$L - L_0 = 10 \log \frac{I}{I_0}$$

$$L - L_0 = 10 \log \frac{3.0 \times 10^{-6}}{10^{-12}}$$

$$L - L_0 = 10 \log 3.0 \times 10^{-6+12}$$

$$L - L_0 = 10 \log 3.0 \times 10^6$$

$$L - L_0 = 10 \times 6.477$$

$$L - L_0 = 64.77 \text{ dB}$$

Now, again by using formula of intensity level of sound

$$L - L_0 = 10 \log \frac{I}{I_0}$$

$$100 = 10 \log \frac{I}{10^{-12}}$$

$$\frac{100}{10} = \log \frac{I}{10^{-12}}$$

$$10 = \log \frac{I}{10^{-12}}$$

$$\text{Antilog}(10) = \text{Antilog} \left(\log \frac{I}{10^{-12}} \right)$$

$$1 \times 10^{10} = \frac{I}{10^{-12}}$$

$$1 \times 10^{10} \times 10^{-12} = I$$

$$1 \times 10^{10-12} = I$$

$$1 \times 10^{-2} = I$$

$$0.01 = I$$

$$I = 0.01 \text{ Wm}^{-2}$$

11.2 If at Anarkali Bazar Lahore, intensity level of sound is 80 dB, what will be the intensity of sound there? (ALP)

Given Data

$$\text{Sound level} = L - L_0 = 80 \text{ dB}$$

$$\text{Intensity of faintest sound} = I_0 = 10^{-12} \text{ Wm}^{-2}$$

To Find

$$\text{Intensity of sound} = I = ?$$

Solution

By using formula of intensity level of sound

$$L - L_0 = 10 \log \frac{I}{I_0}$$

$$80 = 10 \log \frac{I}{10^{-12}}$$

$$\frac{80}{10} = \log \frac{I}{10^{-12}}$$

$$8 = \log \frac{I}{10^{-12}}$$

$$\text{Antilog}(8) = \text{Antilog} \left(\log \frac{I}{10^{-12}} \right)$$

$$1 \times 10^8 = \frac{I}{10^{-12}}$$

$$1 \times 10^8 \times 10^{-12} = I$$

$$1 \times 10^{8-12} = I$$

$$1 \times 10^{-4} = I$$

$$I = 10^{-4} \text{ Wm}^{-2}$$

11.3 At a particular temperature, the speed of sound in air is 330 ms^{-1} . If the wavelength of a note is 5 cm, calculate the frequency of the sound wave. Is this frequency in the audible range of the human ear? (ALP)

Given Data

$$\text{Speed of sound} = v = 330 \text{ ms}^{-1}$$

$$\text{Wavelength} = \lambda = 5 \text{ cm}$$

$$\lambda = 5 \times 10^{-2} \text{ m}$$

$$\lambda = 0.05 \text{ m}$$

To Find

$$\text{Frequency} = f = ?$$

Solution

By using formula of speed of wave

$$v = f\lambda$$

$$330 = (f)(0.05)$$

$$\frac{330}{0.05} = f$$

$$6600 = f$$

$$f = 6600 \text{ Hz}$$

$$f = 6.6 \times 10^3 \text{ Hz}$$

Yes, the frequency lies in the audible range of human ear.

11.4 A doctor counts 72 heartbeats in 1 min. Calculate the frequency and period of the heartbeats. (ALP)

Given Data

$$\text{Number of heartbeats} = n = 72$$

$$\text{Time} = t = 1 \text{ min}$$

$$t = 60 \text{ s}$$

To Find

$$\text{frequency} = f = ?$$

$$\text{Time period} = T = ?$$

Solution

For frequency, we use

$$f = \frac{n}{t}$$

$$f = \frac{72}{60}$$

$$f = 1.2 \text{ Hz}$$

For time period, we use

$$T = \frac{1}{f}$$

$$T = \frac{1}{1.2}$$

$$T = 0.833 \text{ s}$$

11.5 A marine survey ship sends a sound wave straight to the seabed. It receives an echo 1.5 s later. The speed of sound in seawater is 1500 ms^{-1} . Find the depth of the sea at this position.

Given Data

$$\text{Time taken} = t = 1.5 \text{ s}$$

$$\text{Speed} = v = 1500 \text{ ms}^{-1}$$

To Find

$$\text{Depth of seabed} = h = ?$$

Solution

By using formula of distance

$$S = vt$$

$$S = (1500)(1.5)$$

$$S = 2250 \text{ m}$$

The echo distance must be half, so

$$h = \frac{S}{2}$$

$$h = \frac{2250}{2}$$

$$h = 1150 \text{ m}$$

11.6 A student clapped his hands near a cliff and heard the echo after 5 s. What is the distance of the cliff from the student if the speed of the sound is taken as 346 ms^{-1} ? (ALP)

Given Data

$$\text{Time taken} = t = 5 \text{ s}$$

$$\text{Speed} = v = 346 \text{ ms}^{-1}$$

To Find

$$\text{Distance of cliff} = h = ?$$

Solution

By using formula of distance

$$S = vt$$

$$S = (346)(5)$$

$$S = 1730 \text{ m}$$

The echo distance must be half, so

$$h = \frac{S}{2}$$

$$h = \frac{1730}{2}$$

$$h = 865 \text{ m}$$

11.7 A ship sends out ultrasound that returns from the seabed and is detected after 3.42 s. If the speed of ultrasound through seawater is 1531 ms^{-1} , what is the distance of the seabed from the ship?

Given Data

$$\text{Time taken} = t = 3.42 \text{ s}$$

$$\text{Speed} = v = 1531 \text{ ms}^{-1}$$

To Find

$$\text{Distance of seabed} = h = ?$$

Solution

By using formula of distance

$$S = vt$$

$$S = (1531)(3.42)$$

$$S = 5236.02 \text{ m}$$

The echo distance must be half, so

$$h = \frac{S}{2}$$

$$h = \frac{5236.02}{2}$$

$$h = 2618.01 \text{ m}$$

11.8 The highest frequency sound humans can hear is about 20,000 Hz. What is the wavelength of sound in air at this frequency at a temperature of 20°C ? What is the wavelength of the lowest sounds we can hear of about 20 Hz? Assume the speed of sound in air at 20°C is 343 ms^{-1} .

Given Data

$$\text{Highest frequency} = f_1 = 20000 \text{ Hz}$$

$$\text{Lowest frequency} = f_2 = 20 \text{ Hz}$$

$$\text{Speed of sound} = v = 343 \text{ ms}^{-1}$$

To Find

$$\text{Wavelength at } f_1 = \lambda_1 = ?$$

$$\text{Wavelength at } f_2 = \lambda_2 = ?$$

Solution

By using formula of speed of wave

$$v = f_1 \lambda_1$$

$$343 = (20000)(\lambda_1)$$

$$\frac{343}{20000} = \lambda_1$$

$$0.01715 = \lambda_1$$

$$\lambda_1 = 0.01715 \text{ m}$$

$$\lambda_1 = 1.715 \times 10^{-2} \text{ m}$$

Now again by using formula of speed of wave

$$v = f_2 \lambda_2$$

$$343 = (20)(\lambda_2)$$

$$\frac{343}{20} = \lambda_2$$

$$17.15 = \lambda_2$$

$$\lambda_2 = 17.15 \text{ m}$$

$$\lambda_2 = 1.715 \times 10^1 \text{ m}$$

11.9 A sound wave has a frequency of 2 kHz and wavelength 35 cm. How long will it take to travel 1.5 km? (ALP)

Given Data

$$\text{Frequency} = f = 2 \text{ kHz}$$

$$\text{Frequency} = f = 2 \times 10^3 \text{ Hz}$$

$$\text{Wavelength} = \lambda = 35 \text{ cm}$$

$$\lambda = 35 \times 10^{-2} \text{ m}$$

$$\lambda = 0.35 \text{ m}$$

$$\text{Distance} = S = 1.5 \text{ km}$$

$$S = 1.5 \times 10^3 \text{ m}$$

To Find

$$\text{Time} = t = ?$$

Solution

First, we find speed of wave

$$v = f\lambda$$

$$v = (2 \times 10^3)(0.35)$$

$$v = 700 \text{ ms}^{-1}$$

Now by using formula of distance

$$S = vt$$

$$1.5 \times 10^3 = (700)(t)$$

$$\frac{1.5 \times 10^3}{700} = t$$

$$2.14 = t$$

$$t = 2.14 \text{ s}$$

Examples

11. 1 Calculate the intensity levels of the (a) faintest audible sound (b) rustling of leaves. (ALP)

Solution

(a) Intensity level of faintest audible sound can be calculated by substituting $I = I_o = 10^{-12} \text{ Wm}^{-2}$. Therefore, by using formula of intensity level of sound

$$L - L_o = 10 \log \frac{I}{I_o}$$

$$L - L_o = 10 \log \frac{I_o}{I_o} \quad \because I = I_o$$

$$L - L_o = 10 \log 1$$

$$L - L_o = (10)(0)$$

$$L - L_o = 0 \text{ dB}$$

(b) As intensity of the rustle of leave is $I = 10^{-11} \text{ Wm}^{-2}$. Therefore, by using formula of intensity level of sound

$$L - L_o = 10 \log \frac{I}{I_o}$$

$$L - L_o = 10 \log \frac{10^{-11}}{10^{-12}}$$

$$L - L_o = 10 \log 10^{-11+12}$$

$$L - L_o = 10 \log 10$$

$$L - L_o = (10)(1)$$

$$L - L_o = 10 \text{ dB}$$

11.2 Calculate the frequency of a sound wave of speed 340 ms^{-1} and wavelength 0.5 m . (ALP)

Given Data

$$\text{Speed of sound} = v = 340 \text{ ms}^{-1}$$

$$\text{Wavelength} = \lambda = 0.5 \text{ m}$$

To Find

$$\text{Frequency} = f = ?$$

Solution

By using formula of speed of wave

$$v = f\lambda$$

$$340 = (f)(0.5)$$

$$\frac{340}{0.5} = f$$

$$680 = f$$

$$f = 680 \text{ Hz}$$

11. 3 Flash of lightning is seen 1.5 seconds earlier than the thunder. How far away is the cloud in which the flash has occurred? (speed of sound = 332 ms^{-1}).

Given Data

$$\text{Time taken} = t = 1.5 \text{ s}$$

$$\text{Speed} = v = 332 \text{ ms}^{-1}$$

To Find

$$\text{Distance} = S = ?$$

Solution

By using formula of distance

$$S = vt$$

$$S = (332)(1.5)$$

$$S = 498 \text{ m}$$