CH21-2 – Sound

Important Ideas

- Intensity

$$I = \frac{P}{A} \qquad \text{for a spherical wave: } A = 4\pi r^2$$

- Absolute sound intensity level:

$$\beta = (10\text{ dB}) \log_{10}\left(\frac{I}{I_0}\right) \text{ where } I_0 = 1 \times 10^{-12}\text{ W/m}^2$$

- Relative sound intensity level:

$$\Delta\beta = (10\text{ dB}) \log_{10}\left(\frac{I_f}{I_i}\right)$$

- Doppler effect. v is the speed of sound in the medium, o is the observer (or listener or detector), and s is the source. The top sign is for the observer and source moving toward each other and the bottom sign is for the observer and source moving away from each other.

$$f' = f\left(\frac{v \pm v_o}{v \mp v_s}\right)$$

1. You tap the edge of the pool with a hammer. Friend A is under water 10 m from where you tapped. Friend B is out of the water 10 m from where you tapped. Who will hear the sound first?

   (a) Friend A
   (b) Friend B
   (c) Neither, because they will hear the sound at the same time.

   Speed of sound in water is 1500 $\frac{m}{s}$. Speed of sound in air is 343 $\frac{m}{s}$. Sound travels faster in water.

2. In experiment 1, you have a 100 W light bulb that emits light outward in all directions including onto a screen 5 m away from the bulb. In experiment 2, you use lenses and mirrors to focus all of the light from a 100 W light bulb onto a screen 1 m x 1 m that is 5 m away from the bulb. In which experiment is the intensity of the light on the screen the greatest?

   (a) Experiment 1
   (b) Experiment 2
   (c) The intensity is the same.

   Experiment 1: $I = \frac{P}{A} = \frac{100\text{ W}}{4\pi r^2} = \frac{100\text{ W}}{4\pi (5\text{ m})^2} = 0.318\text{ W}$

   Exp. 2: $I = \frac{P}{A} = \frac{100\text{ W}}{(1\text{ m})(1\text{ m})} = 100\ \frac{\text{W}}{\text{m}^2}$

3. To increase the sound level by 20 dB, by what factor must you increase the sound intensity?

(a) 20
(b) 10
(c) 100
(d) 200

$\Delta\beta = (10\,dB)\log_{10}\left(\frac{I_f}{I_i}\right)$

$20\,dB = 10\,dB\log_{10}\left(\frac{I_f}{I_i}\right)$

$2 = \log\left(\frac{I_f}{I_i}\right)$

$10^2 = \frac{I_f}{I_i}$

$\boxed{\frac{I_f}{I_i} = 100}$

4. What is the intensity of sound with a measured sound level of 100 dB?

$\beta = 10\,dB\log\left(\frac{I}{I_0}\right)$

$100\,dB = 10\,dB\log\left(\frac{I}{10^{-12}\frac{W}{m^2}}\right)$

$10 = \log\left(\frac{I}{10^{-12}\frac{W}{m^2}}\right)$

$10^{10} = \frac{I}{10^{-12}\frac{W}{m^2}}$

$I = (10^{10})\left(10^{-12}\frac{W}{m^2}\right) = \boxed{10^{-2}\frac{W}{m^2}}$

5. The sound level of a motorcycle is about 100 dB. The sound level of normal conversation is about 70 dB. How much more intense is the sound from a motorcycle than the sound from a persons voice during conversation?

(a) 30 times more intense
(b) 300 times more intense
(c) 3 times more intense
(d) 1000 times more intense

$100\,dB - 70\,dB = 30\,dB$

$\Delta\beta = (10\,dB)\log_{10}\left(\frac{I_f}{I_i}\right)$

$30 = 10\log_{10}\left(\frac{I_f}{I_i}\right)$

$3 = \log\left(\frac{I_f}{I_i}\right)$

$10^3 = I_f/I_i$

$\boxed{I_f = 1000\,I_i}$

6. An ambulance and a police rescue vehicle are traveling in the same direction toward the scene of an accident. The ambulance has its siren on.

Figure 1: Ambulance and police car

When the ambulance is going faster than the rescue vehicle, the siren frequency heard by the police officers in the rescue unit will be _____ when both vehicles are stationary.

(a) higher than
(b) the same as
(c) lower than

Source TS moving away from the observer

7. Sound of frequency 200 Hz is coming toward you with a velocity of 30 m/s. You are at rest. The speed of sound in air at room temperature is about 343 m/s. What frequency will you hear?

$f = 200\,Hz$

$V = 343\,\frac{m}{s}$

$f' = f\left(\frac{V \pm V_o}{V \mp V_s}\right)$

Source moving toward observer

$V_s = 30\,\frac{m}{s}$

$V_o = 0$ (at rest)

$f' = 200\,Hz\left(\frac{343}{343 - 30\,\frac{m}{s}}\right)$

$\boxed{f' = 219\,Hz}$