Ch 16 Sound

Key words: sound waves; pressure waves; intensity; decibels (dB); sound level β; resonance; vibrating strings, open/closed tube; fundamental frequency ($n = 1$), resonant frequencies; harmonics & overtones; interference; Doppler effect

Note: MasteringPhysics Homework (Ch 16+31) is due Monday (4/19) @11:59pm

Objective:

Solve a problem involving **sound level β** and **intensity I**

- ☐ By applying the **logarithmic relationship** between the two variables.
- ☐ By manipulating the equation using **log properties**.

Solve a problem involving the **Doppler Effect**

- ☐ By considering the motion of the **source of sound** and the **observer**.

Content Review: [10mins]

Sound Level β

- The **sound level** β of any sound is given by

$$\beta = 10 \log \frac{I}{I_0} \qquad \text{measured in decibels (dB)}$$

where I is the **intensity of the sound** and I_0 is the **reference intensity** (typically the human threshold of hearing $I_0 = 1 \times 10^{-12}\ \mathrm{W/m^2}$

- The **intensity** I is inversely proportional to the distance squared

$$I \propto \frac{1}{r^2}$$

- If there is more than one source of sound, then the total intensity is stacked linearly. In other words, if one source of sound has intensity I, then n identical sources would have total intensity $I_{\text{net}} = n\,I$

Doppler Effect

- The **Doppler Effect** is the result of the spatial distortion of sound waves due to a moving source and/or a moving observer.
  - ☐ This effect is the stretching/compressing of the spacing between wave peaks, resulting in a lower/higher perceived frequency.
- **Rule of Thumb:**

decreasing distance b/w source & observer $\longrightarrow$ higher observed frequency

and vice versa: increasing distance $\longrightarrow$ lower observed frequency

- The **observed frequency** f_{obs} is given by

$$f_{\text{obs}} = \left[\frac{v \pm v_{\text{obs}}}{v \mp v_{\text{src}}}\right] f_{\text{src}} \qquad \text{where } f_{\text{src}} \text{ is the source frequency}$$

The **sign** ($\pm$) of the velocities v_{obs} and v_{src} can be determined *qualitatively* based on our **Rule of Thumb** mentioned above, looking at the relative motion of the source and observer.

Guided Practice [10mins]

Two Firecrackers

If two firecrackers simultaneously produced a sound level of $95\,\mathrm{dB}$ when fired simultaneously at a certain place, what would the sound level be if only one exploded?

Solution

$\beta = 92\,\mathrm{dB}$ for a single firecracker.

Group Activity [10mins]

Standing Near Concert Speaker

At a rock concert, a dB meter registered $130\,\mathrm{dB}$ when placed $2.2\,\mathrm{m}$ in front of a loudspeaker on the stage.

- How far away would you have to stand so that the sound level will be a tolerable $85\,\mathrm{dB}$?
  Cool fact: the pain threshold of human hearing is around $130\,\mathrm{dB}$

Solution

$r = 390\,\mathrm{m}$

Group Activity [10mins]

Moving Firetruck Siren

A firetruck sounding a siren with a frequency of $1280\,\mathrm{Hz}$ is traveling at $120.0\,\mathrm{km/h}$.

(a) What frequencies does a (stationary) observer standing next to the road hear as the firetruck approaches and as it recedes?

(b) What frequencies does an observer sitting in a car moving at $90\,\mathrm{km/h}$ in the the opposite direction hear before and after passing the firetruck?

Solution

(a) $f_{\text{towards}} = 1420\,\mathrm{Hz}, \qquad f_{\text{away}} = 1170\,\mathrm{Hz}$

(b) $f_{\text{towards}} = 1520\,\mathrm{Hz}, \qquad f_{\text{away}} = 1080\,\mathrm{Hz}$