Introduction to Physical Science

Sound

Presented by Robert Wagner

Sound

- Sound is a disturbance of matter from the source outward - a wave
  - Hearing is the perception of sound waves
  - Not all frequencies of sound can be heard - ultrasound for example
- Vibrating strings can produce sound waves
  - Create impressions and rarefactions that propagate outward in waves

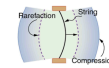

Figure 17.3 A vibrating string moving to the right compresses the air in front of it and expands the air behind it.

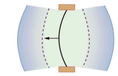

Figure 17.4 As the string moves to the left, it creates another compression and rarefaction as the ones on the right move away from the string.

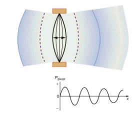

Figure 17.5 After many vibrations, there are a series of compressions and rarefactions moving out from the string as a sound wave. The graph shows gauge pressure versus distance from the source. Pressures vary only slightly from atmospheric for ordinary sounds.

Image Credit: OpenStax College Physics - Figure 17.3, 17.4, 17.5 CC BY 4.0

Speed of Sound

- Sound is a wave so it travels at a certain speed and has a frequency(pitch) and a wavelength
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- Speed of sound will vary depending on what it is traveling through
  - Fastest through solids
  - Slowest through gases
  - Cannot travel through a vacuum!

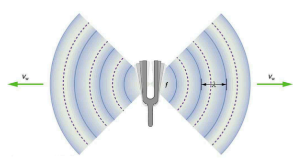

Figure 17.8 A sound wave emanates from a source vibrating at a frequency f, propagates at v_w, and has a wavelength λ.

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Sound Waves in Atmosphere

- Sound speed depends on temperature and pressure of atmosphere. At sea level, the speed of sound is
  -
- Examples
  - At 0ºC, the speed of sound is 331 m/s
  - At 20ºC, the speed of sound is 343 m/s
- Speed of sound is nearly independent of frequency.
  - Think what this might mean for music in a large stadium!

Example

- Calculate the wavelengths of sounds at the extremes of the audible range, 20 and 20,000 Hz (Consider each to have 2 significant figures), in 30.0ºC air.
    - Draw a sketch (if applicable)
    - Identify known values
    - Identify equation
    - Enter values in the equation and solve

$f_{min} = 20\ Hz\ ;\ f_{max} = 20{,}000\ Hz\ ;\ T = 30.0^oC$

$$v_w = (331\ m/s)\sqrt{\frac{T}{273\ K}}$$

$$v_w = (331\ m/s)\sqrt{\frac{303\ K}{273\ K}} = 348.7\ m/s$$

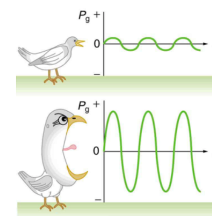
$$v_w = f\lambda\ ;\ \lambda = \frac{v_w}{f}$$

$$\lambda_{max} = \frac{348.7\ m/s}{20\ Hz} = 17\ m$$

$$\lambda_{min} = \frac{348.7\ m/s}{20000\ Hz} = 1.7\ cm$$

Sound Intensities

- Intensity depends on how energetically the source is vibrating
    - A more intense wave will have larger amplitude oscillations
- Sound intensities are often measured in decibels
    - Defined in terms of logarithms
    -
    -



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Decibel Scale

- Log scale shows a large range with small numbers

Sound intensity level β (dB)	Intensity I(W/m^2)	Example/effect
0	1×10^{-12}	Threshold of hearing at 1000 Hz
10	1×10^{-11}	Rustle of leaves
20	1×10^{-10}	Whisper at 1 m distance
30	1×10^{-9}	Quiet home
40	1×10^{-8}	Average home
50	1×10^{-7}	Average office, soft music
60	1×10^{-6}	Normal conversation
70	1×10^{-5}	Noisy office, busy traffic
80	1×10^{-4}	Loud radio, classroom lecture
90	1×10^{-3}	Inside a heavy truck; damage from prolonged exposure[1]
100	1×10^{-2}	Noisy factory, siren at 30 m; damage from 8 h per day exposure
110	1×10^{-1}	Damage from 30 min per day exposure
120	1	Loud rock concert, pneumatic chipper at 2 m; threshold of pain
140	1×10^{2}	Jet airplane at 30 m; severe pain, damage in seconds
160	1×10^{4}	Bursting of eardrums

Image Credit: OpenStax College Physics - Table 17.2 CC BY 4.0

Example

- A sound wave traveling in the atmosphere has an intensity of . What would this be in decibels?
    - Draw a sketch (if applicable)
    - Identify known values
    - Identify equation
    - Enter values in the equation and solve

$I = 5.04x10^{-4}\ W/m^2$

$$\beta(dB) = 10\ log_{10}\frac{I}{I_o}$$

$$\beta(dB) = 10\ log_{10}\frac{5.04x10^{-4}\ W/m^2}{10^{-12}\ W/m^2}$$

$$\beta(dB) = 87\ dB$$

Summary

- Sound waves are a disturbance of matter that propagates outward from a source at a frequency our ears are sensitive to
- The speed of sound depends on the medium through which it travel and the temperature
- We can measure the intensity of sound using the logarithmic scale - decibels