Waves, Light, & Sound

Student Learning Objectives

- Analyze wave motion
- Recall attributes of electromagnetic waves & sound waves
- Explain resonance

What are the basic properties of waves?

A wave is a traveling disturbance that carries energy from place to place.

Question: When a ship that is 100 feet from a sailboat passes the sailboat, does the water travel with the wave from the ship to the sailboat?
All waves begin as a vibration!
When something moves back and forth repeatedly, this is vibration.
There are two basic types of waves. (vibration vs motion)
- Transverse (perpendicular)
- Longitudinal (parallel)

Question: What do you think the vibrational motion is for a water wave?

Transverse and longitudinal wave properties determine the characteristics of the wave.
- Wavelength (distance/one cycle)
- Period (time)
- Frequency (cycles per second)

Practice: While fishing, you notice that 2 foot high crests of a water wave hit your boat every 1.5 seconds. The distance between crests is 5 meters. Determine the wavelength, period, frequency, speed, and amplitude.
What is an electromagnetic wave?

- Electromagnetic radiation is a self-propagating wave.
- Changing E field produces self-propagating
- Changing M field produces

Type of "light" | λ | f | Energy
---|---|---|---
Gamma rays | | | |
X-rays | | | |
Ultraviolet | | | |
Visible | | | |
Infrared | | | |
Radio | | | |

http://www.chromoscope.net/

All electromagnetic waves travel at the same speed in a vacuum (in space).

<table>
<thead>
<tr>
<th>IN METRICS</th>
<th>IN MILES</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 x 10^8 m/s</td>
<td>186,000 miles/sec</td>
</tr>
<tr>
<td>3 x 10^8 km/s</td>
<td>670 x 10^6 mph</td>
</tr>
</tbody>
</table>

The energy we are now observing from objects in space was generated in the past.

<table>
<thead>
<tr>
<th>Sun</th>
<th>8 min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proxima Centauri</td>
<td>4.2 LY</td>
</tr>
<tr>
<td>Sirius</td>
<td>8.6 LY</td>
</tr>
<tr>
<td>Andromeda Galaxy</td>
<td>2.5 x 10^6 LY</td>
</tr>
</tbody>
</table>
EM wave speed is related to wavelength and frequency.

\[ c = \lambda f \]

**Practice**

1) A particular ray of red light has a frequency of \(4.2 \times 10^{14}\) Hz. What is the wavelength of this red light?

2) Which would have a longer wavelength, radio waves broadcast at 95.1 MHz or radio waves broadcast at 1220 MHz? Calculate the wavelength of each of these waves.

We interpret particular wavelengths of visible light as particular colors.

Each color of the visible spectrum corresponds to a specific wavelength, frequency, energy, and temperature.

<table>
<thead>
<tr>
<th>Color</th>
<th>Wavelength (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td>650</td>
</tr>
<tr>
<td>Yellow</td>
<td>575</td>
</tr>
<tr>
<td>Blue</td>
<td>475</td>
</tr>
</tbody>
</table>

The primary source of infrared radiation is heat or thermal radiation.

A particle of electromagnetic radiation is called a photon.

What are the basic attributes of a sound wave?

A sound wave is a longitudinal wave traveling through matter.

- Vibrations cause compressions and rarefactions.
- Molecules vibrate “side-to-side” (molecules collide)

**In Metrics**

- 343 m/s

**In Miles**

- 770 mph
**Tuning Fork**

- As the end of the fork moves outward, it compresses the air. When the fork moves back it produces an area of low pressure.

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**Practice**

1) If you see lightening and then hear the thunder 3 seconds later, how far away is the storm?

2) In a science fiction movie, when a spaceship explodes, we see and hear the explosion at the same time. What is wrong with this scenario?

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- Pitch is an interpretation of sound frequency.

<table>
<thead>
<tr>
<th>Animal</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humans</td>
<td>20-20,000 Hz</td>
</tr>
<tr>
<td>Dog</td>
<td>67-45,000 Hz</td>
</tr>
<tr>
<td>Cat</td>
<td>45-64,000 Hz</td>
</tr>
<tr>
<td>Guinea Pig</td>
<td>54-50,000 Hz</td>
</tr>
<tr>
<td>Bat</td>
<td>2,000-110,000 Hz</td>
</tr>
<tr>
<td>Goldfish</td>
<td>20-3,000 Hz</td>
</tr>
</tbody>
</table>

- Decibels measure the intensity of sound, or the loudness.

<table>
<thead>
<tr>
<th>Sound Level</th>
<th>Decibels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whisper</td>
<td>20 dB</td>
</tr>
<tr>
<td>Conversational Speech</td>
<td>60 dB</td>
</tr>
<tr>
<td>Biodegradable Sun Chip Bag</td>
<td>95 dB</td>
</tr>
<tr>
<td>Artillery Fire</td>
<td>140 dB</td>
</tr>
</tbody>
</table>

http://www.freemosquitoringtones.org/hearing_test/
An echo is a reflected wave.

Example: Ultrasound (f = 20,000 Hz)

[Link to Ultrasound Video]

Reverberations are the mixing of multiple reflected waves.

Louder volume or Random Mixing

Refraction (Δν) of sound wave occurs when density changes.

[Link to Refraction of Sound Wave Video]

Sound Intensity decreases inversely to the square of the distance from source (I ∝ 1/r²).

Why does the sound of a train whistle change?

[Link to Train Whistle Video]

When there is relative motion between a wave source and an observer, wavelengths are altered. Doppler Effect

Object moving towards observer, the wave is blue shifted.
- λ is shortened
- f is increased (higher pitch)

Object moving away from observer, the wave is red shifted.
- λ is lengthened
- f is decreased (lower pitch)
The Doppler Effect Illustrated

- Approach – the waves are bunched up → higher frequency (f)
- Behind – waves are spread out → lower frequency (f)

What is a sonic boom?

- A sonic boom is caused by a large change in pressure.
- The compression waves in a fluid stack up when an object travels at the speed of the waves or faster. (Shock Wave)
  → Stacked compression spheres
  → Sonic boom

Bow Waves and Sonic Boom

- As a plane exceeds the speed of sound it forms a high-pressure shock wave, heard as a ‘sonic boom.’
Practice

1) Why don’t we hear a sonic boom every time a jet passes overhead?

2) Why are there two booms in a sonic boom?

What happens when waves interfere with each other?

- Vibrational amplitudes add together.
- **Constructive interference**: increase in amplitude.
- **Destructive interference**: decrease in amplitude, or complete cancellation of the wave.

- Sound waves that are out slightly of phase produce **beats**.
  - [Link to beat phenomenon](http://hyperphysics.phy-astr.gsu.edu/hbase/sound/beat.html#c1)
  - [Link to online tone generator](http://onlinetonegenerator.com/)
- A wave and its reflection can add to produce a **standing wave**.
  - [Link to standing wave animation](http://physics.usask.ca/~hirose/ep225/animations/standing/anim-stwave1.htm)
Standing Waves

• Standing waves are formed only when the string is vibrated at particular frequencies.

Resonance

✓ Resonance occurs when incoming wave vibrations match an object's natural frequency.
  ➢ Vibrational energy increases.
  ➢ Amplitude increases.

✓ Each material has its own natural frequency.

✓ When there is resonance, the incoming energy is transferred to the object.

✓ https://www.youtube.com/watch?v=Q3oItpV9f6

Practice: What are some examples of resonance?