Waves and Sound

- What is a wave?
- What are the main properties of waves?
- What two things do all waves transport?

Waves in Water

Vibration

What sets waves into motion?

How does the vibration frequency relate to the frequency of the wave created?

DEMO - Harmonic Oscillator

Properties of a wave

Waves are a type of disturbance that can propagate or travel. Waves carry information and energy.

- Wavelength (λ)
- Amplitude (A)
- Velocity (v)
- Period (T): time between crest (or trough) passages
- Frequency (f): rate of passage of crests (or troughs), $f = \frac{1}{T}$ (units: Hertz or cycles/sec)
- Wave speed = wavelength/period = wavelength * frequency ($v = \lambda * f$)

Types of Waves

- Longitudinal Waves
  - Waves of compression
  - Disturbance propagates along direction of travel
  - Sound waves
- Transverse Waves
  - Disturbance is perpendicular to the direction of travel
  - Water waves, light
- How does the medium that supports a wave move?

DEMO - making waves

Sound Waves

- Caused by alternating "compressions" and "rarefactions" in some medium, usually air.
  - Frequency of waves same as frequency of source
  - Heard as pitch or tone
  - Human ear ~ 20 to 20,000 hertz
- Loudness determined by amplitude of waves
- Requires a medium to propagate

DEMO - Tuning Fork

DEMO - Bell Jar in Vacuum
Speed of Sound
- In dry air at 0°C, sound travels at 330 m/s (740 mph)
  - travels faster through warm air
  - travels faster through dense air
- In water, sound travels at about 1300 m/s (3000 mph)

Clicker Question:
Suppose the sound from a 50-Hz razor spreads out at 340 m/s. The frequency is:
A: 20 Hz
B: 25 Hz
C: 50 Hz
D: 200 Hz

Clicker Question:
Suppose the sound from a 50-Hz razor spreads out at 340 m/s. The period is:
A: 0.02 seconds
B: 2 seconds
C: 20 seconds
D: 50 seconds

Clicker Question:
Suppose the sound from a 50-Hz razor spreads out at 350 m/s. The wavelength is:
A: 1 m
B: 7 m
C: 50 m
D: 350 m

Resonance
- Any elastic object will vibrate at its own set of frequencies when disturbed
  - Called natural frequencies
    - Determined by elasticity and shape
    - Bells, violin strings, idling cars
- Resonance
  - Dramatic increase in amplitude when frequency of forced vibrations matches natural frequency of object
  - Pumping a swing

Tacoma Narrows Bridge
- Wind blowing through bridge induced a resonant vibration at ~0.2 Hz, (both longitudinal waves, and then fatally, torsional vibration)

Tacoma Narrows Bridge Collapse on November 7, 1940
link to more footage
Waves bend when they pass through material of different densities.

- **Reflection & Transmission of Waves**
  - **SONAR**
    - Used by Dolphins
    - Ships
  - **Ultrasound**
  - **Earthquakes**

- **Diffraction**
  - Waves will diffract at edges

- **Interference**
  - **Constructive interference**
    - When the peaks of two waves coincide
    - Amplitude increases
    - Ex. Sonic Boom
  - **Destructive interference**
    - When the peak of one wave "fills in" the trough of another
    - Waves cancel
    - Ex. Noise Cancellation
Interference
- Constructive interference - Bow shock

Standing Waves
- Constructive interference
  - When the peaks of reflected waves coincide
  - Nodal points don’t move

Shock Waves
- Sonic Boom
- Bow Waves

Noise vs Music

Spitzer infrared telescope
Fourier Analysis

The Doppler Effect

- How does the pitch or tone of a sound wave change when the source of the sound is moving towards or away from you?

- What about when you are moving towards or away from the source?

- Does this effect occur for all types of waves or just for sound waves?

TABLE 27.1

<table>
<thead>
<tr>
<th>Source of Sound</th>
<th>Intensity (W/m²)</th>
<th>Sound Level (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jet airplane 30 m away</td>
<td>$10^2$</td>
<td>140</td>
</tr>
<tr>
<td>Air-raid siren, nearby</td>
<td>1</td>
<td>120</td>
</tr>
<tr>
<td>Disco music, amplified</td>
<td>$10^{-1}$</td>
<td>115</td>
</tr>
<tr>
<td>Rooster</td>
<td>$10^{-3}$</td>
<td>100</td>
</tr>
<tr>
<td>Busy street traffic</td>
<td>$10^{-3}$</td>
<td>70</td>
</tr>
<tr>
<td>Conversation in home</td>
<td>$10^{-4}$</td>
<td>60</td>
</tr>
<tr>
<td>Quiet radio in home</td>
<td>$10^{-5}$</td>
<td>40</td>
</tr>
<tr>
<td>Whisper</td>
<td>$10^{-10}$</td>
<td>20</td>
</tr>
<tr>
<td>Rattle of leaves</td>
<td>$10^{-11}$</td>
<td>10</td>
</tr>
<tr>
<td>Threshold of hearing</td>
<td>$10^{-15}$</td>
<td>0</td>
</tr>
</tbody>
</table>

Clicker Question:

True or False? Due to diffraction, at long wavelengths it is possible to see around corners.
A: True
B: False

Clicker Question:

Compared to the sound it makes when at rest, a siren approaching us rapidly will:
A: have a longer wavelength
B: have a louder sound
C: have a higher frequency
D: have a longer period

The frequency or wavelength of a wave depends on the relative motion of the source and the observer. (Shockwave Demo) (Web Link)
Clicker Question:

The Tacoma-Narrows bridge was destroyed by:
A: hurricane force winds
B: strong winds that resonated with the natural frequency of the bridge.
C: overloading the maximum weight that the bridge could support on a windy day.
D: thermal expansion on an unusually warm day in November.