Waves and Sound

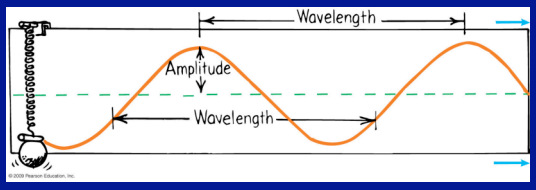
- What is a wave?
- What are the main properties of waves?
- What two things do all waves transport?

Waves in Water

Vibration

What sets waves into motion?

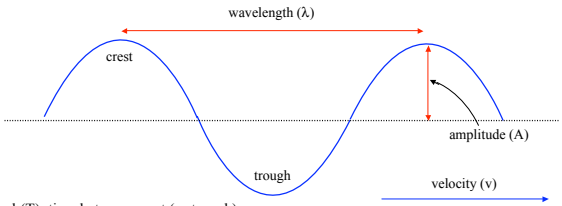
How does the vibration frequency relate to the frequency of the wave created?



DEMO - Harmonic Oscillator

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

Properties of a wave



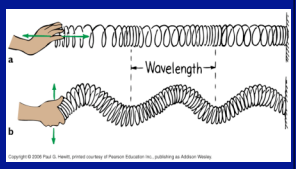
Period (T): time between crest (or trough) passages

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?

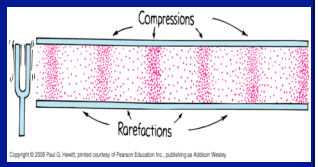


DEMO - making waves

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

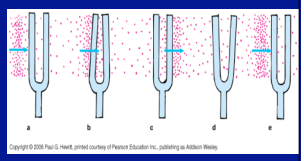
B: 7 m

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



Resonance occurs when compressions and rarefactions are timed to the natural frequency of the tuning fork.

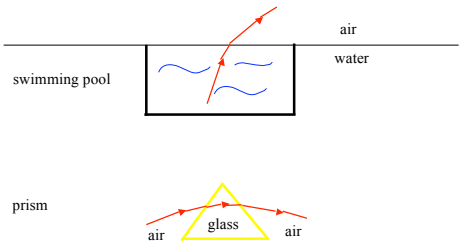
Tacoma Narrows Bridge

- 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

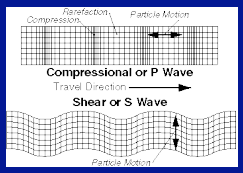
link to more footage

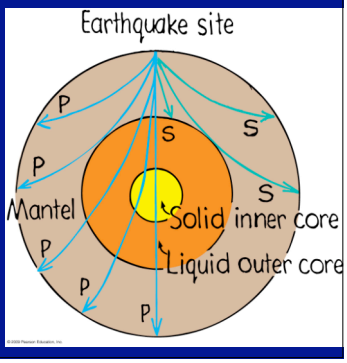
Waves bend when they pass through material of different densities.



Reflection & Transmission of Waves

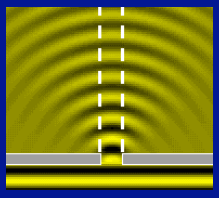
- SONAR
  - Used by Dolphins
  - Ships
- Ultrasound
- Earthquakes

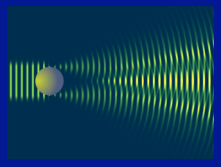




Diffraction

- Waves will diffract at edges

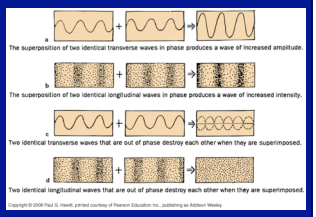


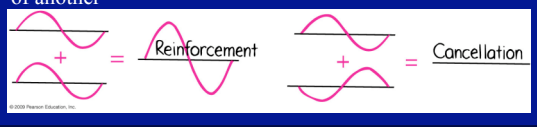


web link

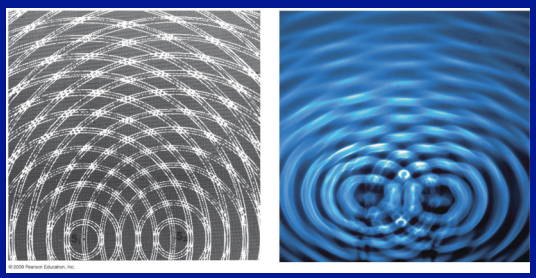
Interference

- 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





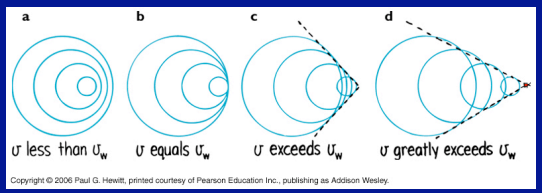
Interference



- Waves cancel
  - Ex. Noise Cancellation

Interference

- Constructive interference
  - Waves from the same object can add up when the velocity of an object making waves exceeds the speed of the waves

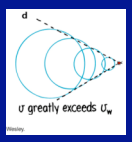


Interference

- Constructive interference - Bow shock

Interference

- Constructive interference - Bow shock



Interference

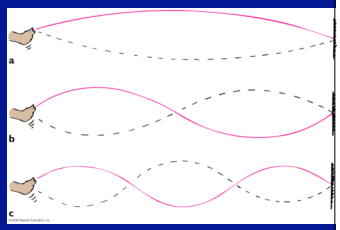
- Constructive interference - Bow shock

Spitzer infrared telescope

Standing Waves

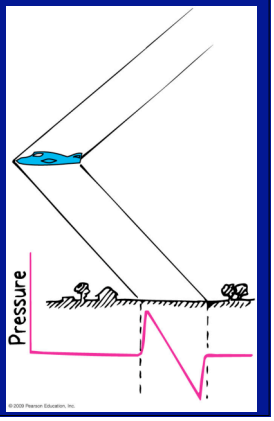
- Constructive interference
  - When the peaks of reflected waves coincide
  - Nodal points don't move

DEMO - Standing waves

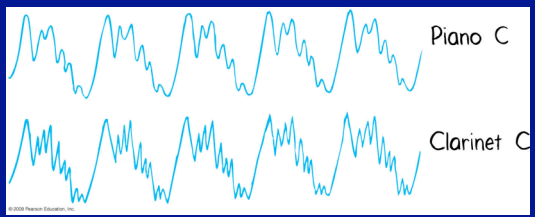


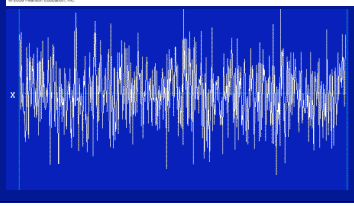
Shock Waves

- Sonic Boom
- Bow Waves



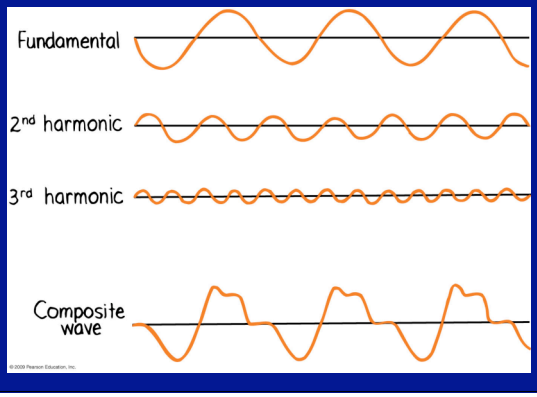
Noise vs Music





Noise

Fourier Analysis



Sound Intensity

dB = decibel, factor of 100 = 20 dB

TABLE 21.1
Common Sources and Sound Intensities

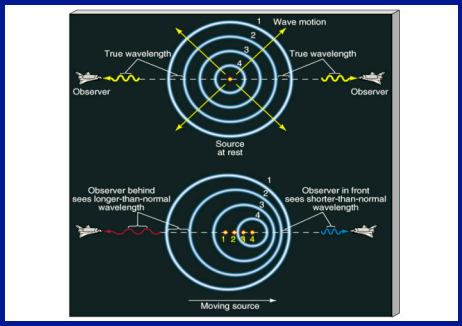
Source of Sound	*Intensity (W/m^2)*	*Sound Level (dB)*
Jet airplane 30 m away	10^{2}	140
Air-raid siren, nearby	1	120
Disco music, amplified	10^{-1}	115
Riveter	10^{-3}	100
Busy street traffic	10^{-5}	70
Conversation in home	10^{-6}	60
Quiet radio in home	10^{-8}	40
Whisper	10^{-10}	20
Rustle of leaves	10^{-11}	10
Threshold of hearing	10^{-12}	0

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?

DEMO - Doppler Arm

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



For visible light, the frequency (or wavelength) determines its color.

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

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.