

Waves and Sound

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

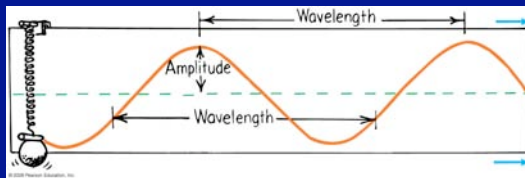
Waves in Water



Vibration

What sets waves into motion?

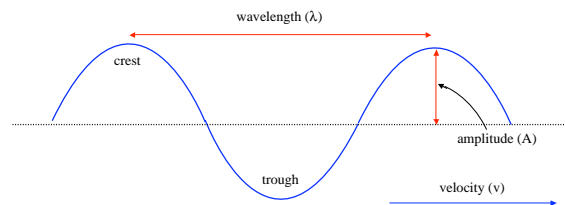
How does the vibration frequency relate to the frequency of the wave created?



DEMO - Harmonic Oscillator

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

Properties of a wave



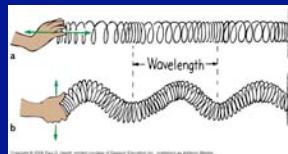
Period (T): time between crest (or trough) passages

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?

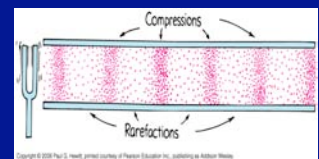


DEMO - making waves

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

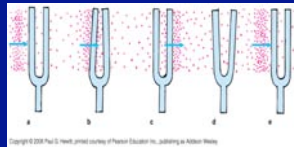
Clicker Question:

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.

swimming pool

prism

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

Reinforcement

Cancellation

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

u less than u_w

u equals u_w

u exceeds u_w

u greatly exceeds u_w

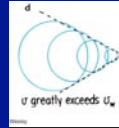
Interference

- Constructive interference - Bow shock



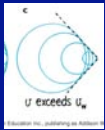
Interference

- Constructive interference - Bow shock



Interference

- Constructive interference - Bow shock

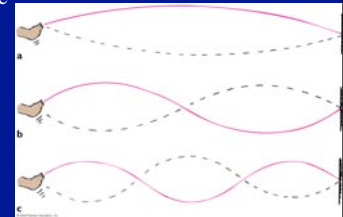


Spitzer infrared telescope

Standing Waves

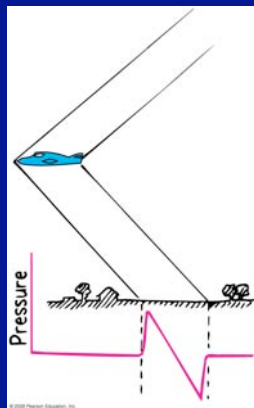
- Constructive interference
 - When the peaks of reflected waves coincide
 - Nodal points don't move

DEMO - Standing waves

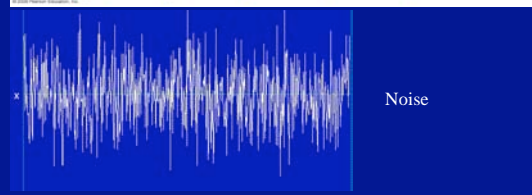
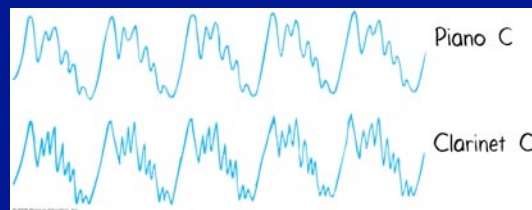


Shock Waves

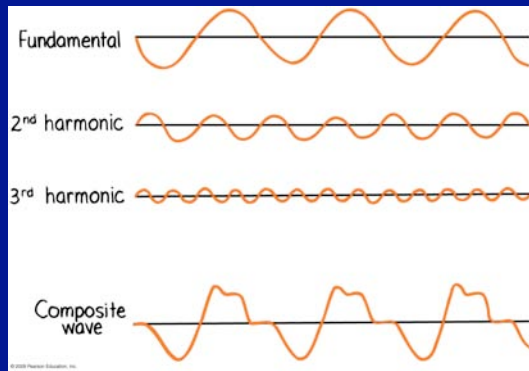
- Sonic Boom
- Bow Waves



Noise vs Music



Fourier Analysis



Sound Intensity

dB = decibel, factor of 100 = 20 dB

TABLE 21.1
Common Sources and Sound Intensities

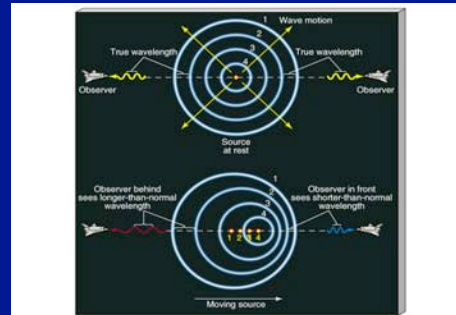
Source of Sound	Intensity (W/m^2)	Sound Level (dB)
Jet airplane 30 m away	10^2	140
Air-raid siren, nearby	1	120
Disco music, amplified	10^{-1}	115
Riveter	10^{-3}	100
Busy street traffic	10^{-5}	70
Conversation in home	10^{-6}	60
Quiet radio in home	10^{-8}	40
Whisper	10^{-10}	20
Rustle of leaves	10^{-11}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