




particle motion

<http://positron.ps.uci.edu/~dkirkby/music/html/demos/PlaneWave/SoundWave.html>


sound waves and the ear drum

<http://www.glenbrook.k12.il.us/gbssci/phys/mmedia/waves/edl.html>


sound as a pressure wave

<http://www.glenbrook.k12.il.us/gbssci/phys/Class/sound/u1111c.html>


Sound

the speed of sound

$$v_s = 331 \text{ m/s at } 0^\circ \text{ C}$$

$$+ .6 \text{ m/s per } ^\circ \text{ C}$$

at 20° C the velocity of sound would be?

$$20^\circ \text{ C } (.6 \text{ m/s/ } ^\circ \text{ C}) = 12 \text{ m/s}$$

therefore, at 20° C ,

$$331 \text{ m/s} + 12 \text{ m/s} = 343 \text{ m/s}$$

Sound is a longitudinal (compressional) wave

the base wave equation is $v_s = f\lambda$

characteristics:

1) Frequency (pitch)

humans hear between 20 Hz - 20,000 Hz

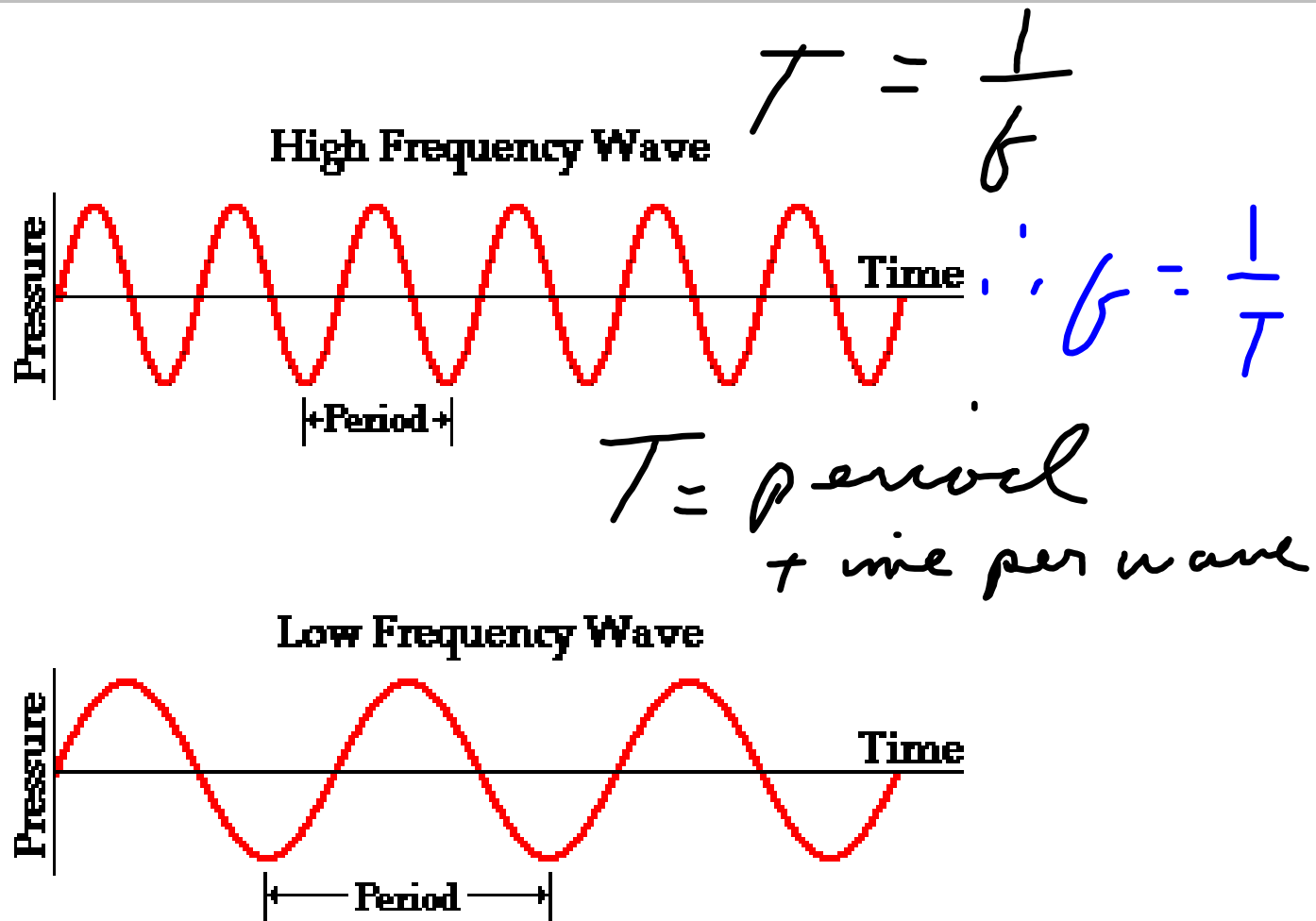
lowest sound = 20 Hz

$$\lambda = v_s / f = 340 \text{ m/s} / 20 \text{ Hz} = 17 \text{ m}$$

highest sound = 20,000 Hz

$$\lambda = v_s / f = 340 \text{ m/s} / 20,000 \text{ Hz} = .017 \text{ m}$$

frequency usually refers to the oscillation wave
and *pitch* to the sensation of hearing



2) Loudness

- Related to the amplitude of the wave.
- a measure of the *intensity* of the wave.

$$I \sim A^2$$

A is amplitude
└ particle displacement
 I is intensity

- Intensity = P/A

in this formula "P" is power in watts and "A" is area

I intensity
P power

$$I = \frac{P}{A} = \frac{P}{4\pi r^2} = \frac{W}{m^2}$$

(shape)
The area of a sound wave as it leaves a source is the surface area of a sphere: $A = 4\pi r^2$

Amplitude is Loudness

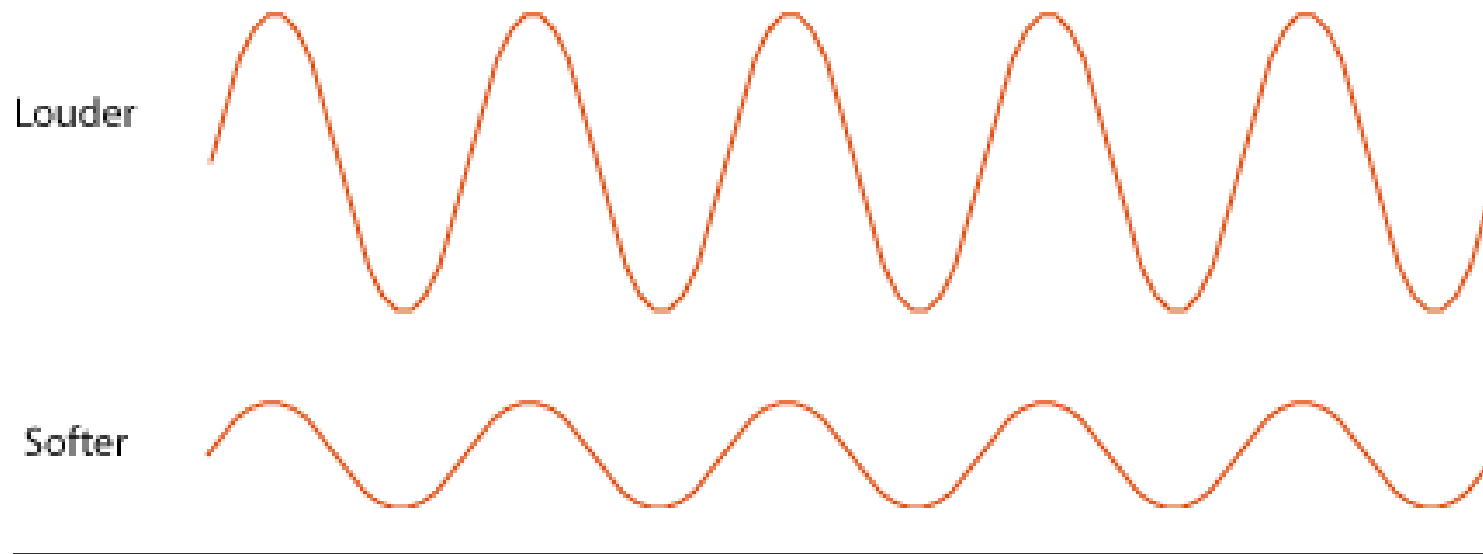
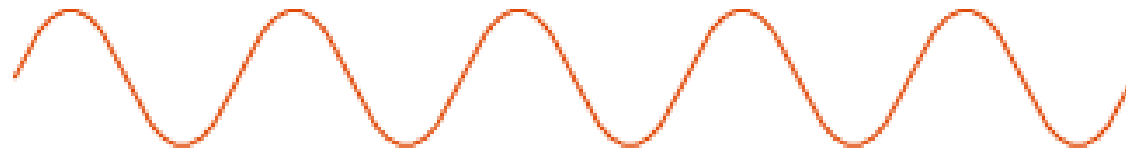
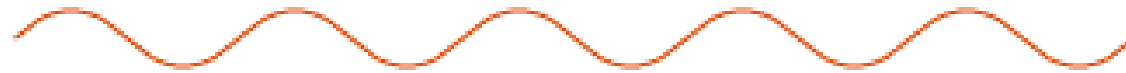


Figure 3: The size of a wave (how much it is "piled up" at the high points) is its **amplitude**. For sound waves, the bigger the amplitude, the louder the sound.

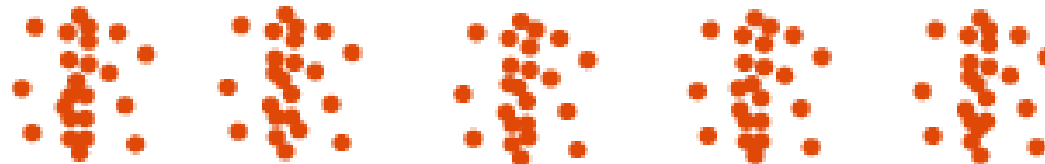
Higher
Amplitude



Lower
Amplitude



Higher
Amplitude



Lower
Amplitude



Figure 2: It's easier to spot differences in amplitude at a glance when figures use TRANSVERSE waves.

Loudness cont.

$$I = \frac{P}{4\pi r^2} = \frac{25 \text{ W}}{4\pi (10 \text{ m})^2} = 0.02 \text{ W/m}^2$$

ex: a sound is radiated from a source at 25 watts of power and is 10 m away. What is the intensity of the sound?

we hear between 10^{-12} W/m^2
and 1 W/m^2 of intensity

↑
"threshold
of pain"

↑
softest sound
you hear
"threshold
of hearing"

There is a 10^{12}
range of intensities your
ear can detect

Because of this vast
range we use a
"logarithmic" scale

$$\beta = 10 \log \frac{I}{I_0}$$

intensity of the sound

relative intensity

"threshold of hearing"

sound wave field from speaker

<http://www.mediacollege.com/audio/01/sound-waves.html>



<http://www.kettering.edu/~drussell/Demos/rad2/mdq.html>



Reflected sound wave

<http://www.phy.ntnu.edu.tw/java/propagation/propagation.html>

Noise



Tone



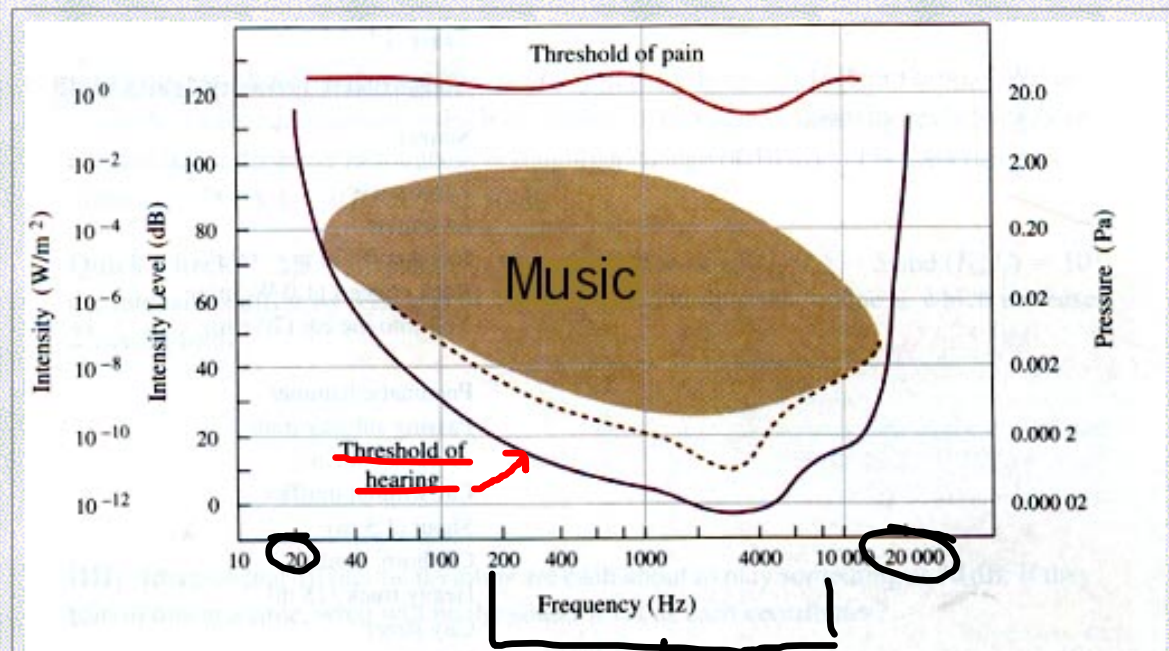
Doppler Shift

<http://www.kettering.edu/~drussell/Demos/doppler/doppler.html>



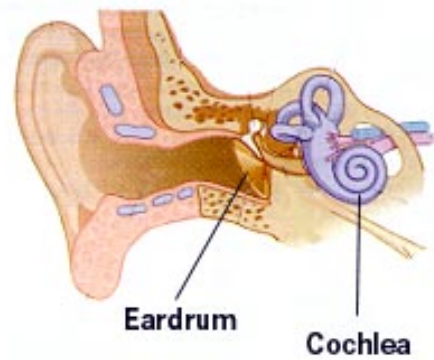
$$f' = f_0 \left(\frac{v \pm v_o}{v \pm v_s} \right)$$

Sensitivity of the Human Ear: Part I



Note: threshold is much lower at 3000 Hz than it is at 15,000 Hz.

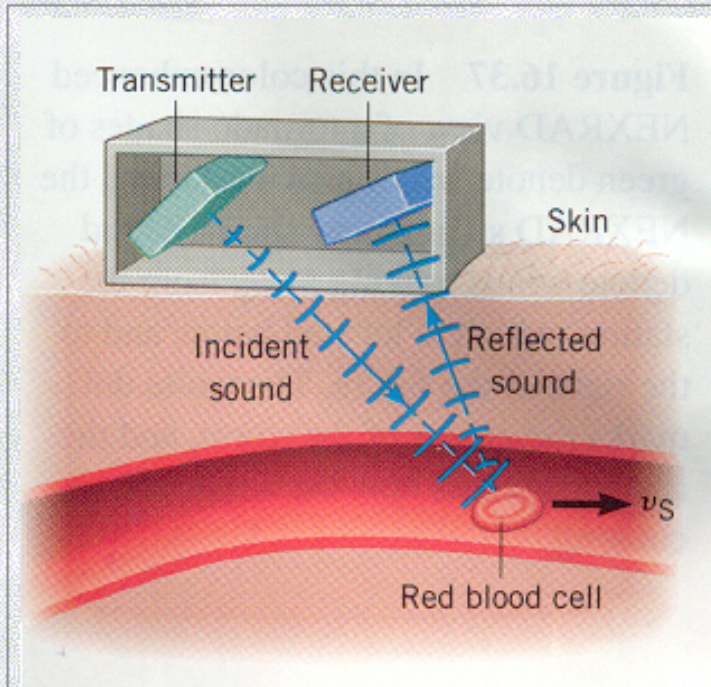
Speech



Outer ear collects sound energy, bones in middle ear transmit vibrations to fluid in canals (the inner ear).

Canals in cochlea separated by a flexible partition which flexes at different points depending on the frequency; nerve hairs in canals send information to the brain.

Doppler Flow Meter



Used to locate narrowed blood vessels where the speed is greater.

Typical blood speed: 0.10 m/s

Transmitter frequency: $f = 5$ megahertz
 $= 5 \times 10^6$ Hz

Use moving source Doppler equation:

$$f' = f / (1 + v_s / v)$$

$$f' = (5 \times 10^6) / (1 + 0.10 / 343)$$
$$= 4.99854 \times 10^6 \text{ Hz}$$

Change = 1460 Hz

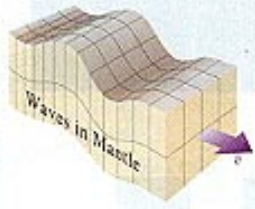
Transverse Seismic Waves

Shear waves--called S-waves.
Molten core can't vibrate transversely

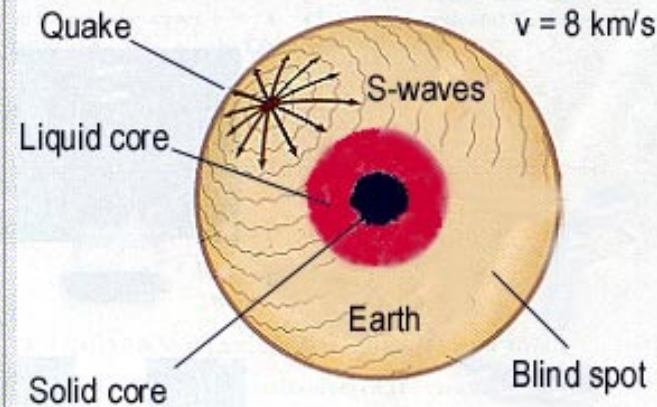
Primary waves --P-waves are longitudinal (not shown): they arrive first



Compression Waves
(Primary Waves: P-waves)



Transverse Waves
(Shear Waves: S-waves)



Compression waves arrive at seismic stations before the S-waves, so they're called "primary waves".

P-waves predominate in underground nuclear explosions.