



# Sound Waves

## and their characteristics


# 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*

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

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

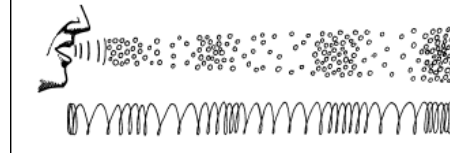
at  $20^\circ \text{ C}$  the velocity of sound would be?

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

therefore, at  $20^\circ \text{ C}$ ,

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

## 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

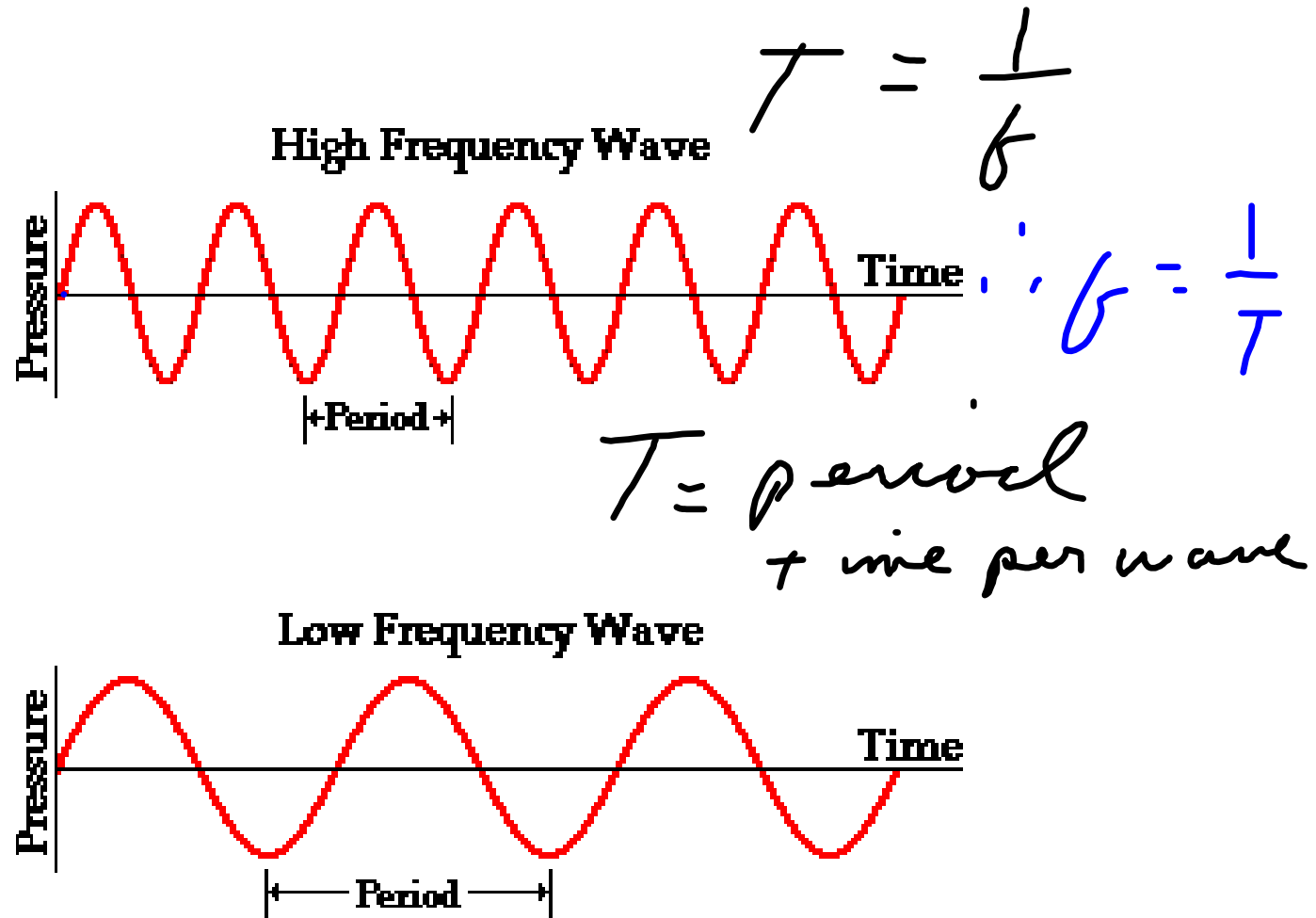
$$\lambda = \frac{v}{f} = \frac{340 \text{ m/s}}{20 \text{ Hz}} = \underline{\underline{17 \text{ m}}}$$

highest sound = 20,000 Hz

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

lower or higher frequency  $\rightarrow$  pitch

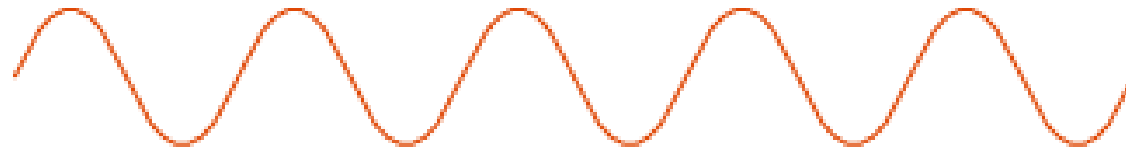
Difference between a high frequency sound and a low frequency sound.



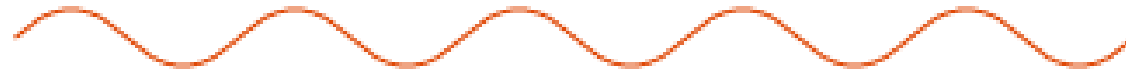
# Difference in amplitudes- loudness

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Higher  
Amplitude



Lower  
Amplitude



Higher  
Amplitude



Lower  
Amplitude

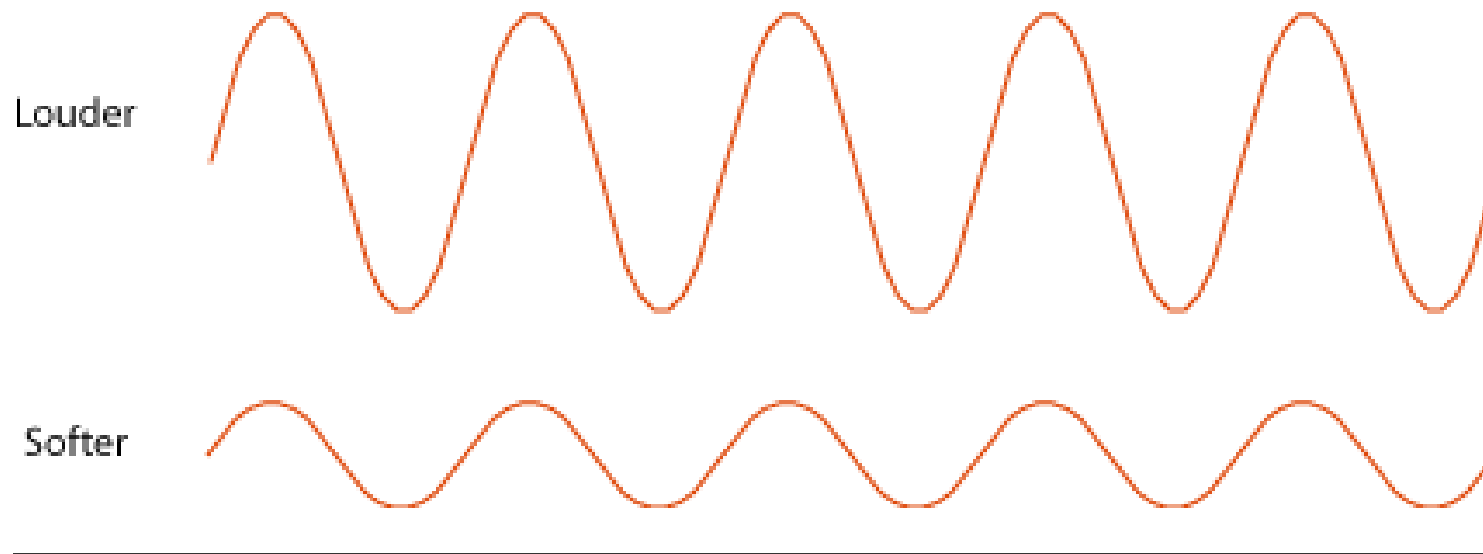


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**Figure 2:** It's easier to spot differences in amplitude at a glance when figures use TRANSVERSE waves.

## Amplitude is Loudness

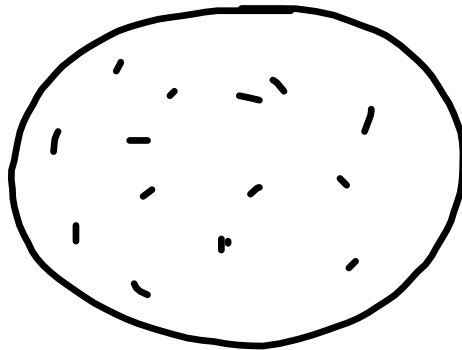
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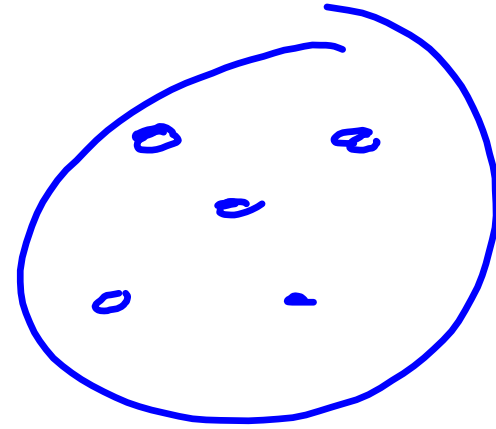
**Figure 3:** The size of a wave (how much it is "piled up" at the high points) is its **amplitude**. For sound waves, the bigger the amplitude, the louder the sound.

# Difference in Intensities

Hotgun



↑ I



↓ I

Intensity ~  $I = \frac{\# \text{ pellets}}{\text{area}}$

# Range of Intensities

we hear

softest  $10^{-12} \text{ W/m}^2$   
threshold of hearing

loudest  $1 \text{ W/m}^2$   
threshold of pain

$10^{12}$  range in intensities

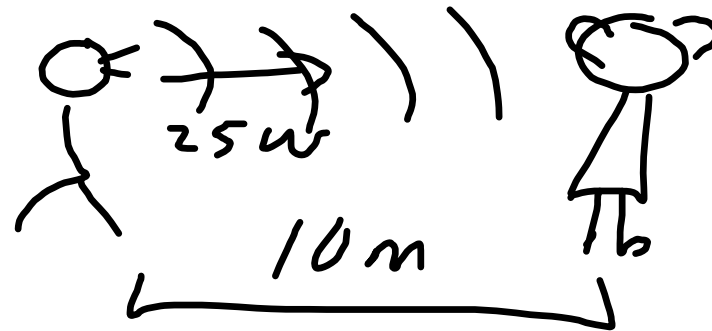
→ That's a lot!

## Loudness

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?

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

$$I = .02 \text{ W/m}^2$$



$$\text{Power} = P = \frac{W}{t} \text{ or } \frac{E}{t} = \frac{F d}{t} = Fv$$

Loudness: measured in  
relative Intensity " $\beta$ "

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

relative intensity

intensity of the sound

"threshold of hearing"

Loudness:

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

*intensity of the sound you're hearing*

*threshold of hearing*

*relative intensity of*

$$I = \frac{25 \text{ W}}{4\pi (10 \text{ m})^2} = .02 \text{ W/m}^2 \rightarrow 2 \times 10^{-2} \text{ W/m}^2$$

*What's the relative intensity of our example ( $\beta$ )?*

$$\beta = 10 \log \frac{I}{I_0}$$
$$\beta = 10 \log \left( \frac{2 \times 10^{-2} \text{ W/m}^2}{10^{-12} \text{ W/m}^2} \right)$$

$$\beta = 10 \log (2 \times 10^{10})$$

$$\beta = 10 (10.3)$$

$$\beta = \underline{\underline{103 \text{ dB}}}$$

$I$  in  $\text{W/m}^2$

sound at threshold of pain

$\beta = ?$

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

$$\beta = 10 \log \frac{10^0 \text{ W/m}^2}{10^{-12} \text{ W/m}^2}$$

$$\beta = 10 \log (10^{12})$$

$$\beta = 10(12)$$

$$\beta = \underline{120 \text{ dB}}$$

# 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>

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Noise



Tone



# Doppler Shift — *A frequency due to motion*

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

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



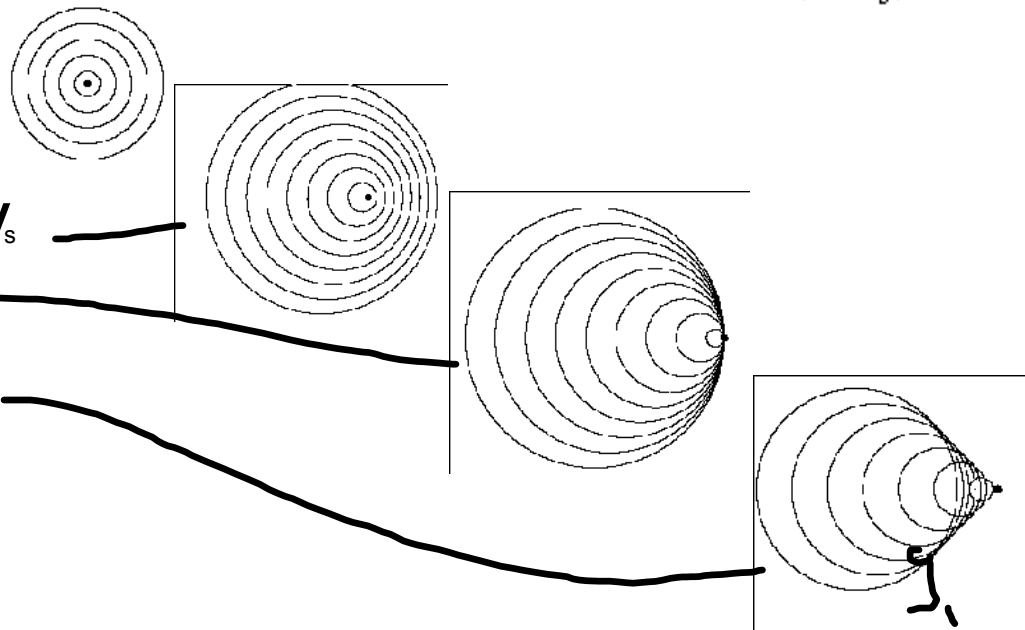
car horn

still

slower than  $v_s$

$v_s$

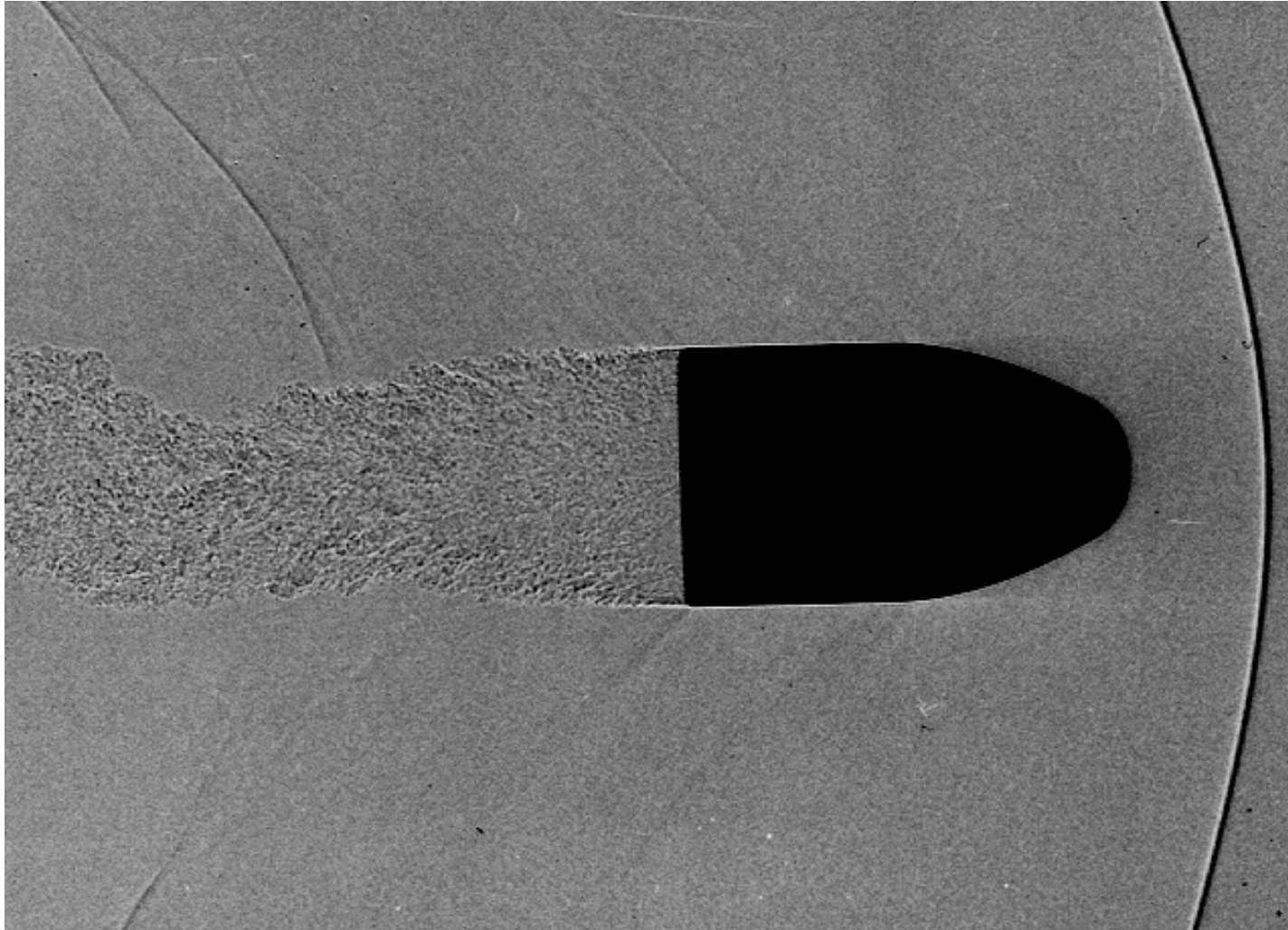
faster than  $v_s$



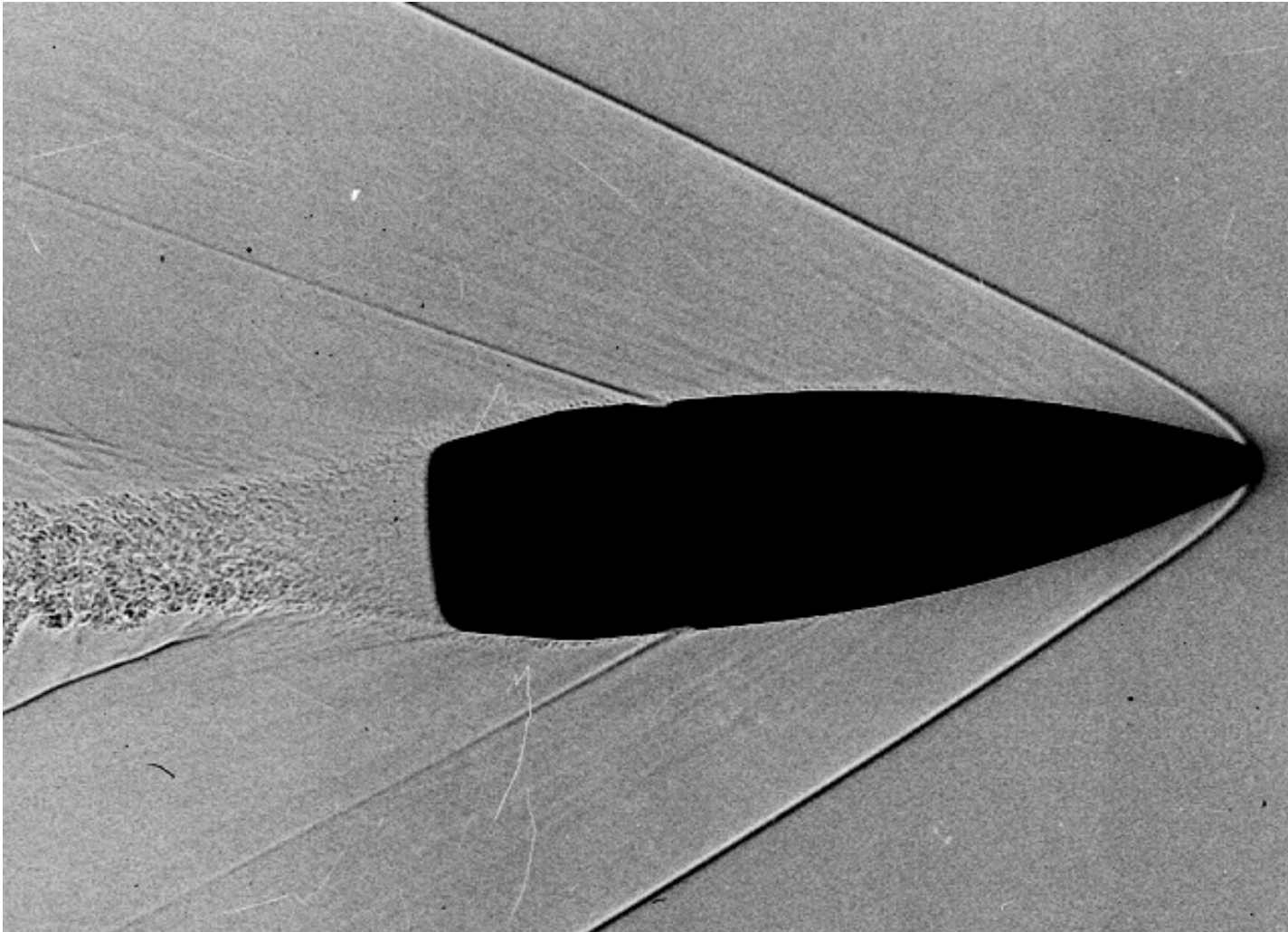


Title: May 10 - 9:33 AM (18 of 25)

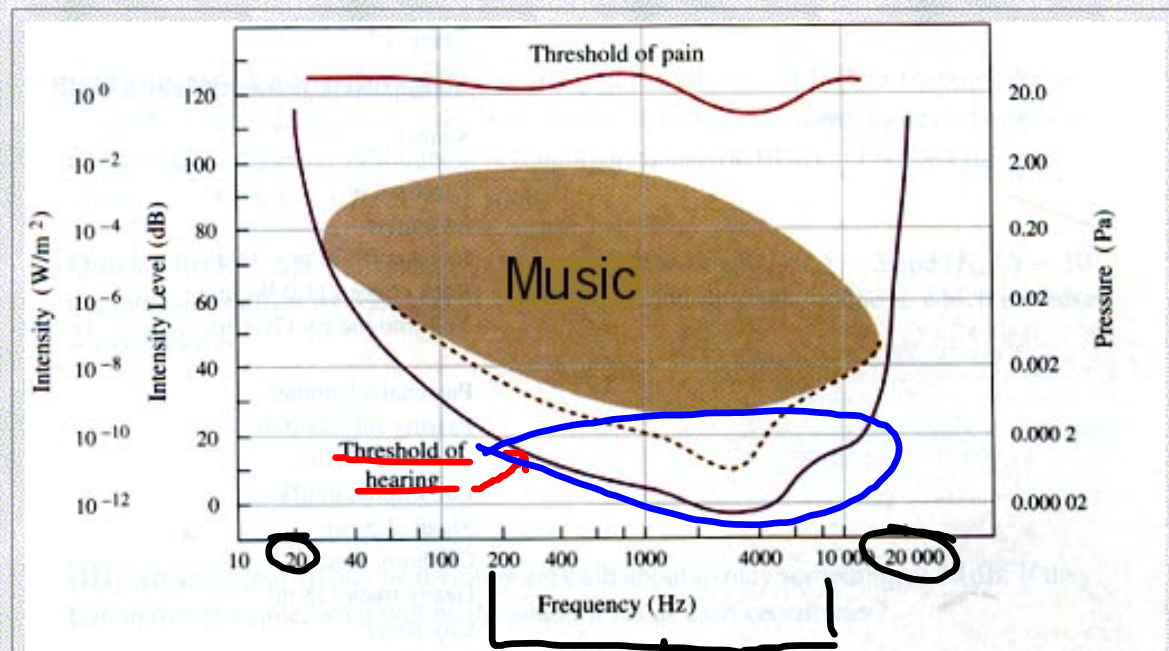
bullet at mach 1.01, note shock wave just in front of the bullet



bullet at mach 2.45



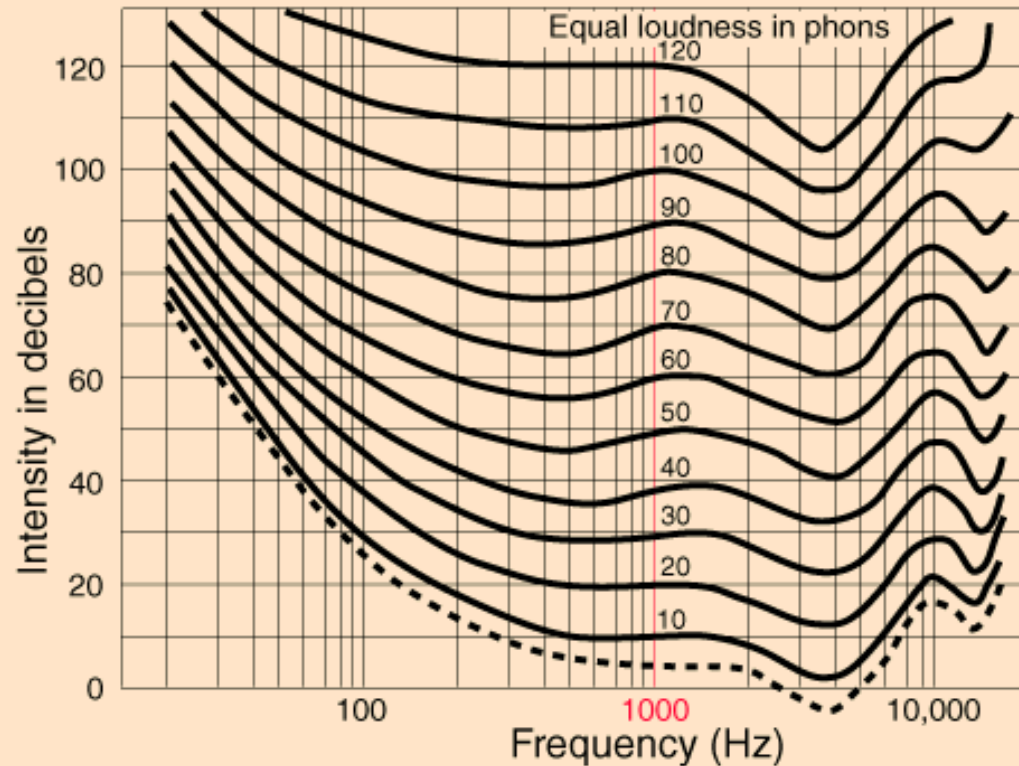
# Sensitivity of the Human Ear: Part I



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

*Speech*

# Equal Loudness Curves

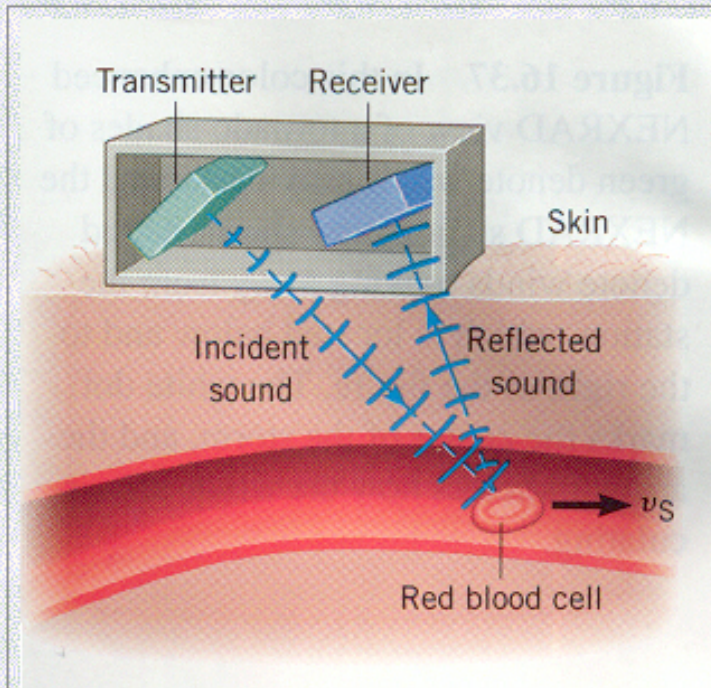


10 - 120 in middle of graph are called "phons"

They relate a sound at any frequency to a 1000 Hz sound at \_\_\_ db's

60 phons means "as loud as a 60 dB, 1000 Hz tone"

# Doppler Flow Meter



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

Typical blood speed: 0.10 m/s

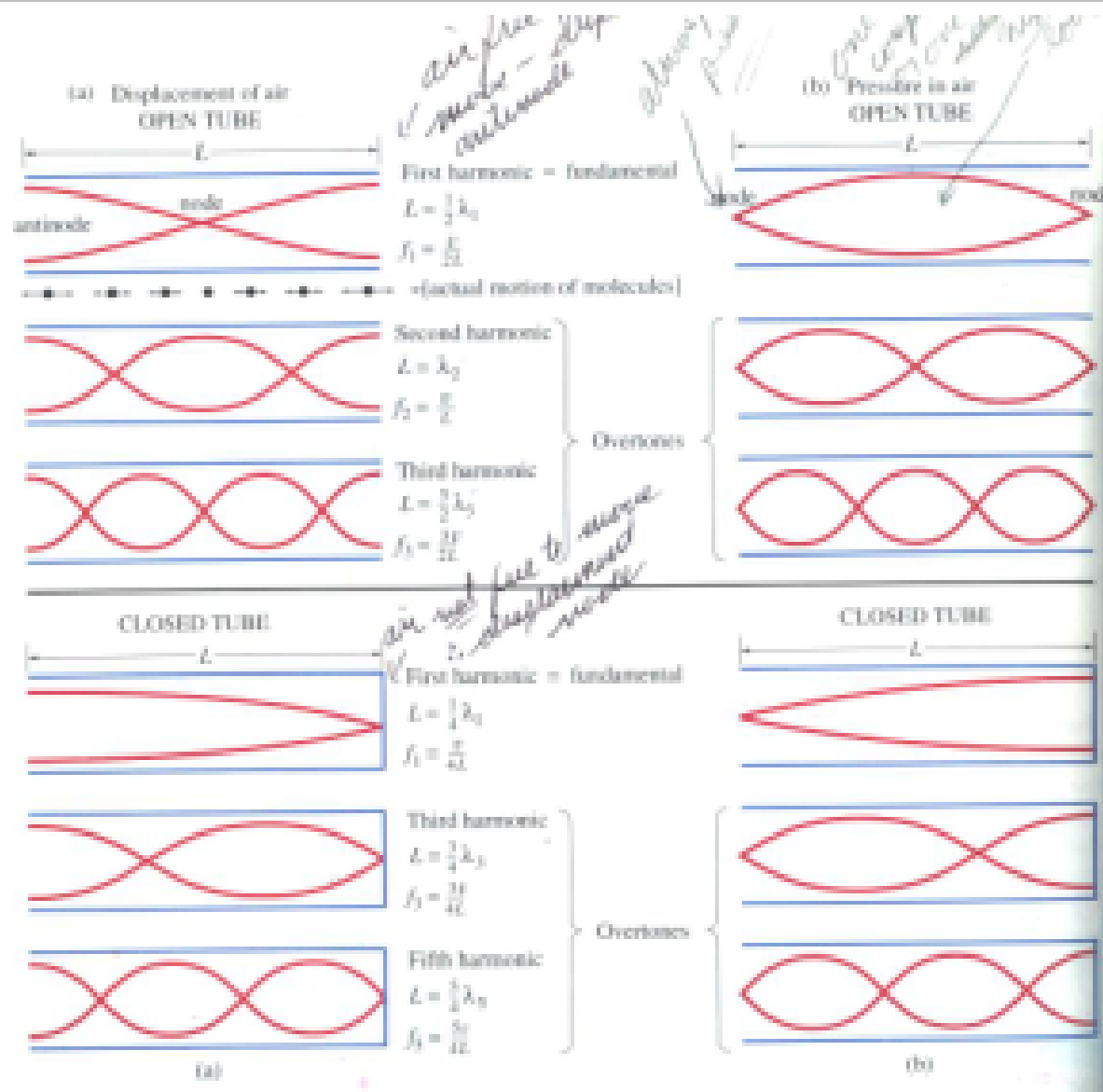
Transmitter frequency:  $f = 5$  megahertz  
 $= 5 \times 10^6$  Hz

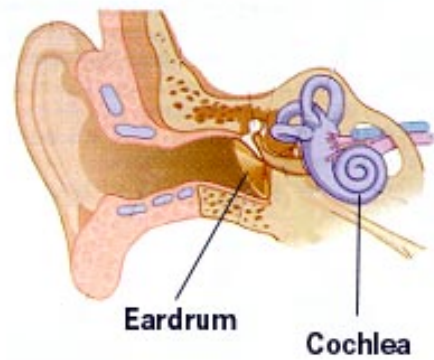
Use moving source Doppler equation:

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

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

Change = 1460 Hz





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.