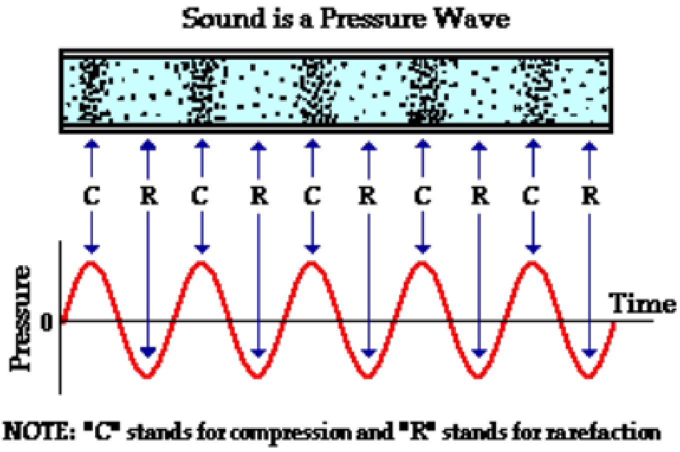
Ch. 12 Sound

Sound is a longitudinal wave (the vibration of the air molecules is parallel to the direction the wave is moving)

Produced through areas of **compression** and **rarefaction**.



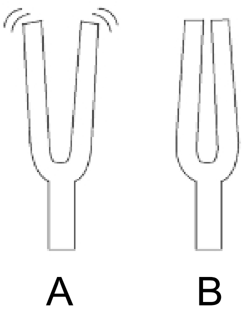
Compression - region of a longitudinal wave where density and pressure are at a maximum

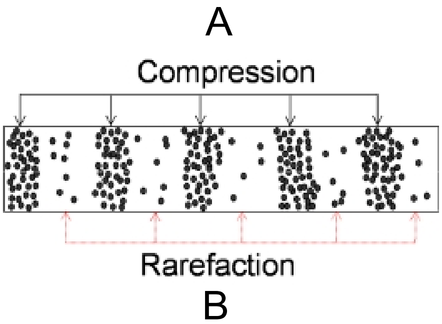
Rarefaction - region of a longitudinal wave where density and pressure are at a minimum

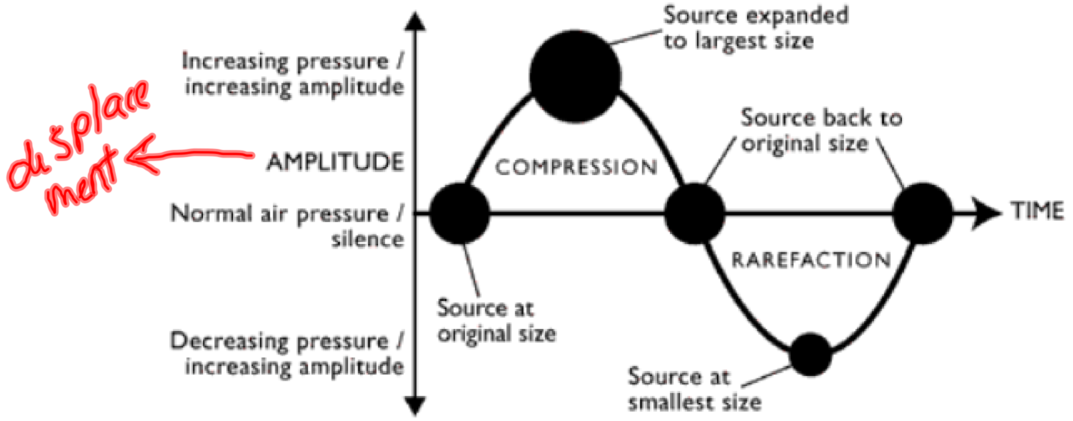
A vibrating tuning fork is capable of creating such a longitudinal wave. As the tines of the fork vibrate back and forth, they push on neighboring air particles.

A. The forward motion of a tine pushes air molecules horizontally to the right **(COMPRESSION)**

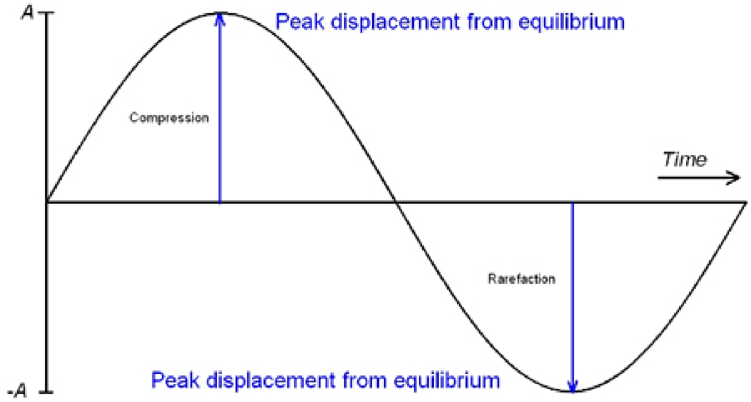
B. The backward retraction of the tine creates a low-pressure area allowing the air particles to move back to the left **(RAREFACTION)**







displacement
Increasing pressure / increasing amplitude
AMPLITUDE
Normal air pressure / silence
Decreasing pressure / increasing amplitude
Source expanded to largest size
COMPRESSION
Source back to original size
TIME
RAREFACTION
Source at original size
Source at smallest size



Sound is also a displacement wave. When the air molecules are compressed or rarefracted, they are at a maximum distance from the equilibrium

Frequency determines the pitch.

Pitch is a measure of how high or low a sound is perceived to be.

$$v = f \lambda$$

The speed of sound is dependent on temperature and the medium through which it travels.

at 0^{o}_{C} v_{air} = 331 m/s

at 25^{o}_{C} v_{air} = 346 m/s

at 25^{o}_{C} v_{water} = 1490 m/s

Sound travels faster in water because the particles are closer together in a liquid than a gas.

Higher temperature means more particle collisions = faster movement of sound

$$v_{(T)} = 331\sqrt{\frac{T}{273}}$$

* T is in KELVIN*

Intensity

Intensity is the rate at which energy flows through a unit area perpendicular to the direction of the wave.

$$I = \frac{P}{A}$$

I = Intensity (W/m^2)

P = Power (W)

A = area (m^2)

For a spherical wave:

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

r = distance from the source (m)

Example 1:

A speaker emits sound at 80 W. Find the intensity at a distance of 10 m.

$$I = \frac{P}{4\pi r^2} = \frac{80}{4\pi (10)^2}$$

$$I = 0.0637 \text{ W/m}^2$$

Example 2:

At what distance from a 50 W speaker is the intensity at the threshold of pain (1 W/m^2)

$$I = \frac{50}{4\pi r^2}$$

$$1 = \frac{50}{4\pi r^2}$$

$$r = 1.99 m$$

Decibels

$$\beta = 10 \log \left(\frac{I}{I_0}\right)$$

Decibels are a dimensionless unit that describes that ratio of two intensities of sound.

β = loudness in decibels

I = intensity

I_0 = 10^{-12} W/m^2 = threshold of hearing

dB

(10 ^ -12)

(1E-12)

Example 3:

Find β for the threshold of hearing.

$$\beta = 10 \log\left(\frac{10^{-12}}{10^{-12}}\right) = 0 \text{ dB}$$

Find β for the threshold of pain.

$$\beta = 10 \log\left(\frac{1}{10^{-12}}\right) = 120 \text{ dB}$$

Example 4:

Sound intensity of a machine is 1 x 10^{-5} W/m^2. Calculate the decibel level of this machine.

$$\beta = 10 \log\left(\frac{I}{I_0}\right)$$

$$\beta = 70 \text{ dB}$$

Example 5:

The decibel level of sound is 50 dB at a distance of 10 m from the source. Find the intensity of the sound and the power of the source.

$$5 = \log_{10}\left(\frac{I}{10^{-12}}\right)$$

$$10^5 = \frac{I}{10^{-12}}$$

$$I = 1 \times 10^{-7}\ W/m^2$$

$$1 \times 10^{-7} = \frac{P}{A} = \frac{P}{4\pi(10)^2} \rightarrow P = 1.3 \times 10^{-4}\ W$$