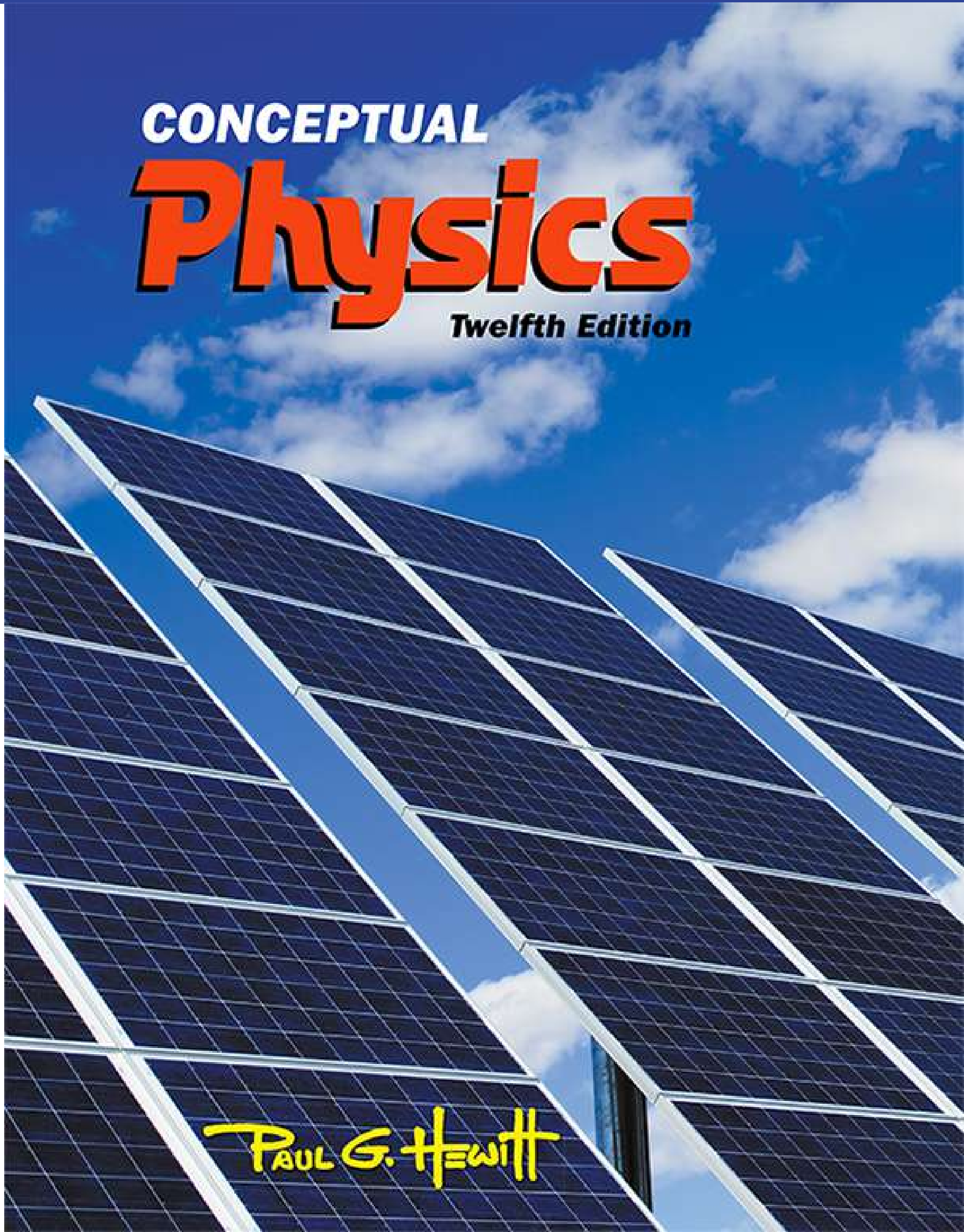
Lecture Outline

Chapter 20: Sound

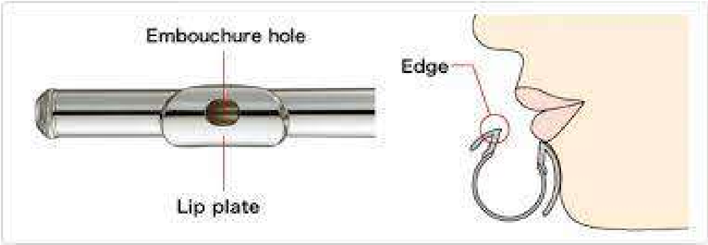


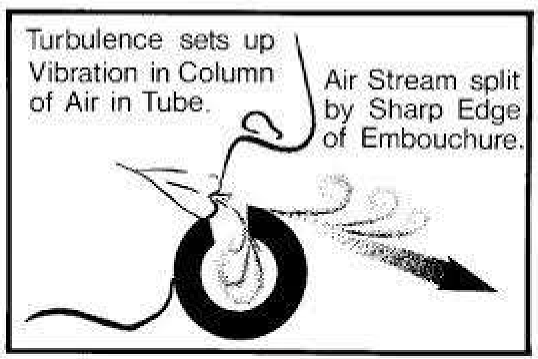
Nature of Sound

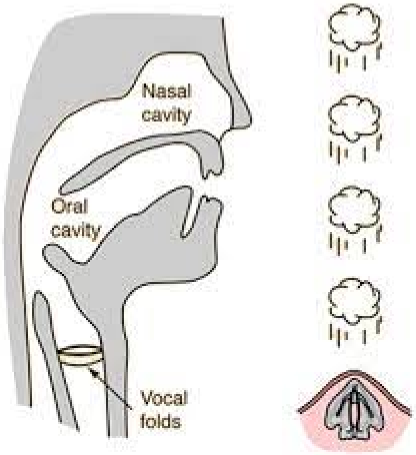
- Sound is a form of energy that exists whether or not it is heard.

Origin of Sound

- Most sounds are waves produced by the vibrations of matter.
  - For example:
    - In a piano, a violin, and a guitar, the sound is produced by the vibrating strings;
    - in a saxophone, by a vibrating reed;
    - in a flute, by a fluttering column of air at the mouthpiece;
    - in your voice due to the vibration of your vocal chords.





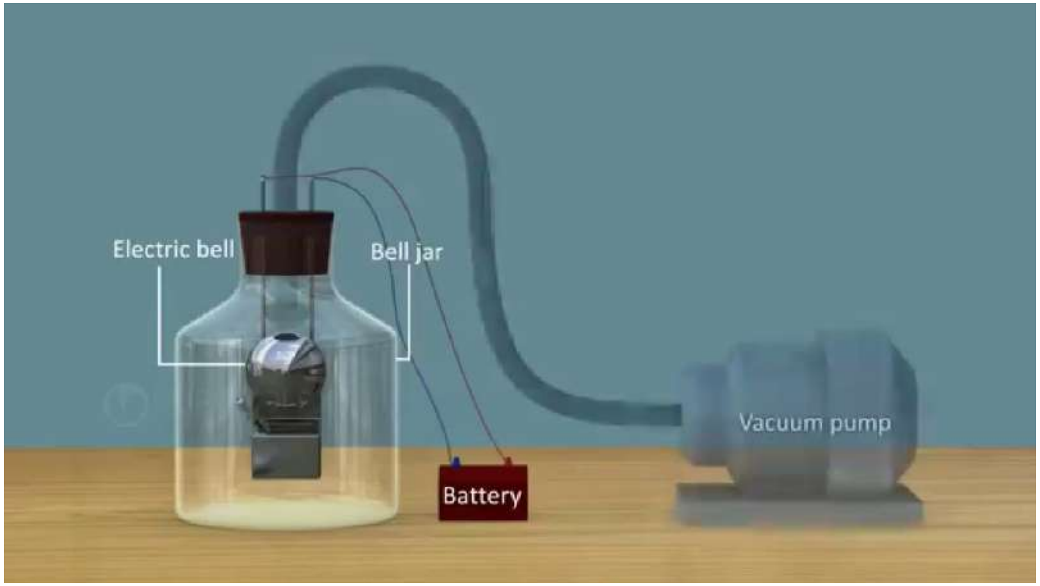


Origin of Sound, Continued

- The original vibration stimulates the vibration of something larger or more massive, such as
  - the sounding board of a stringed instrument,
  - the air column within a reed or wind instrument, or
  - the air in the throat and mouth of a singer.
- This vibrating material then sends a disturbance through the surrounding medium, usually air, in the form of longitudinal sound waves.
- → Sound is a *mechanical* wave—the energy is propagated (moved along) by moving particles

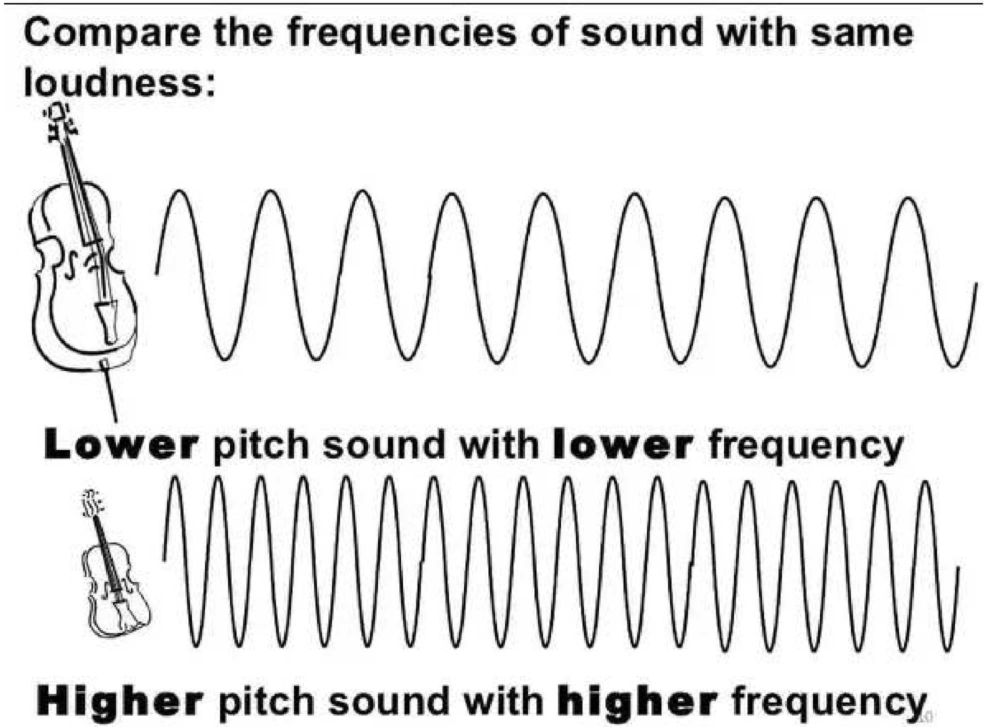
In space, no one can hear you scream.

- A *vacuum* has no air molecules.
- But sound requires a medium.
- Sound cannot travel in a vacuum.
- As air is pumped from a jar containing a loud electric bell, you hear it less and less.
- See
- the
- video.



Pitch

- Under ordinary conditions, the frequencies of the vibrating source and sound waves are the same.
- The subjective impression about the frequency of sound is called **pitch.**



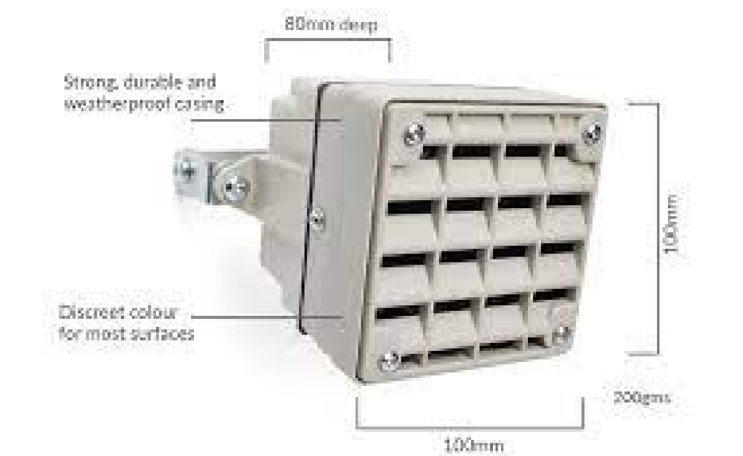
Pitch and hearing

- The ear of a young person can normally hear pitches corresponding to the range of frequencies between about 20 and 20,000 Hertz.

- As we grow older, the limits of this human hearing range shrink, especially at the high-frequency end.

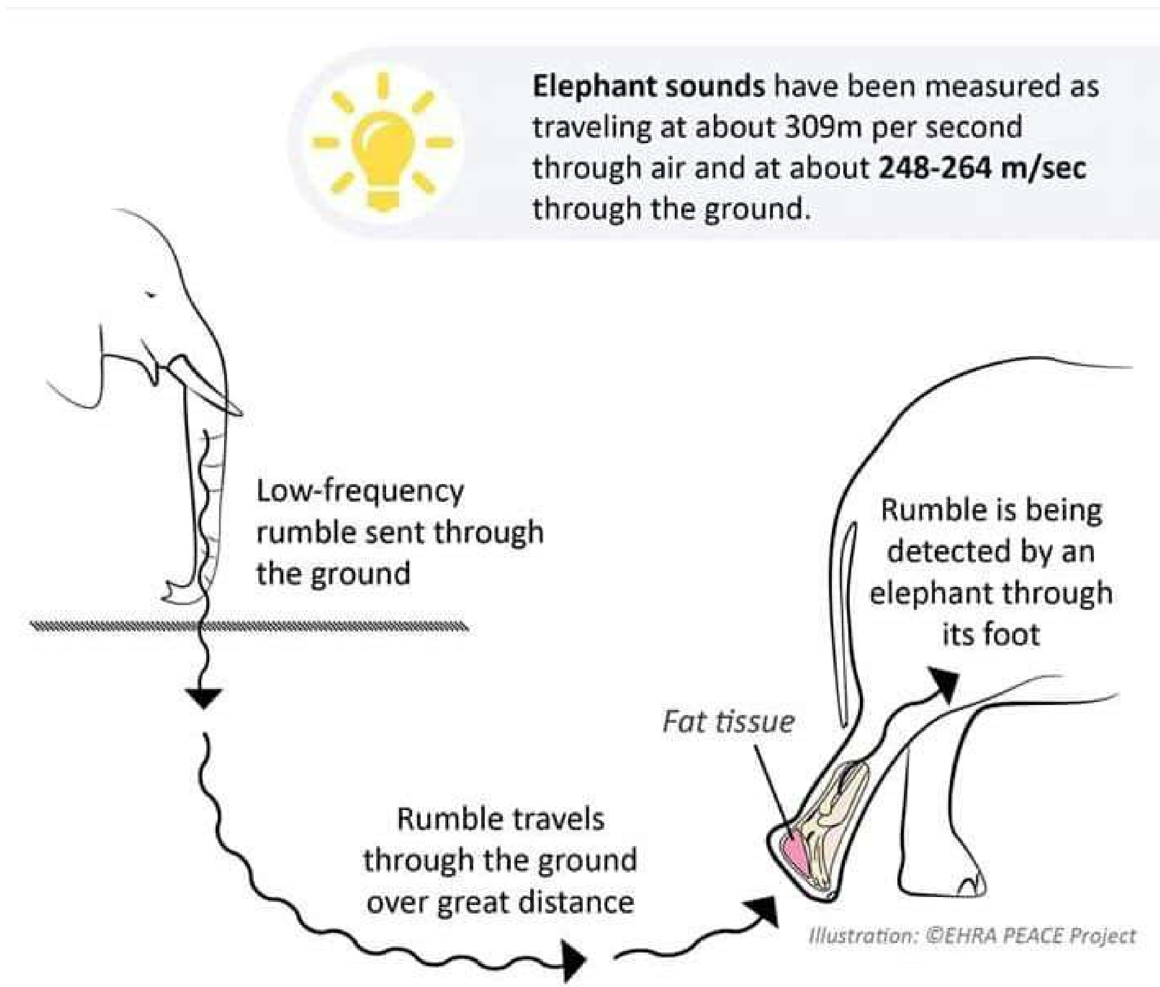
Mosquito noise box:

- Keeps those pesky teenagers away!

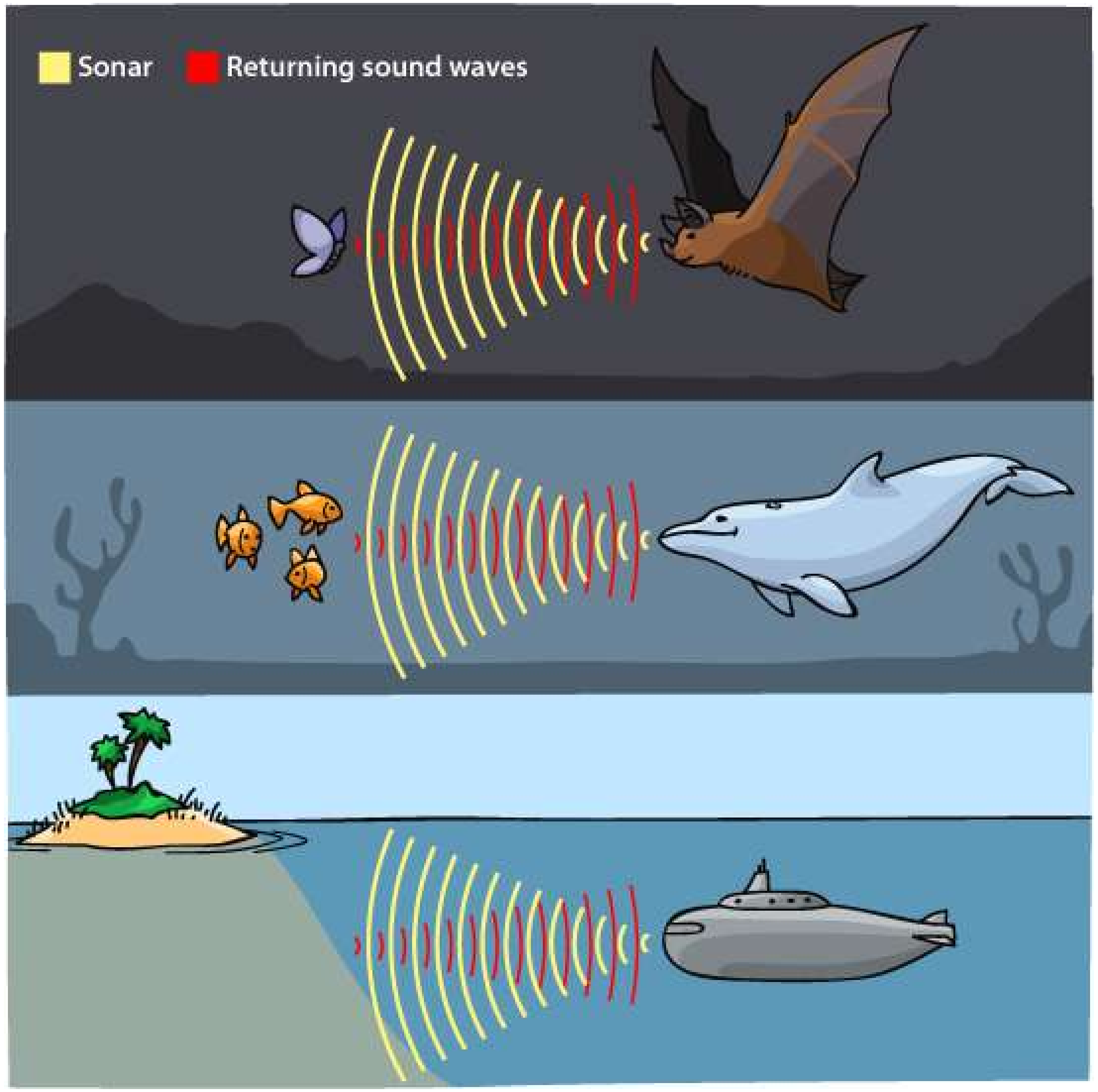


- Let's test your hearing!

- Sound waves with frequencies below 20 hertz are **infrasonic** (frequency too low for human hearing).
- **Elephants make and hear infrasonic:**

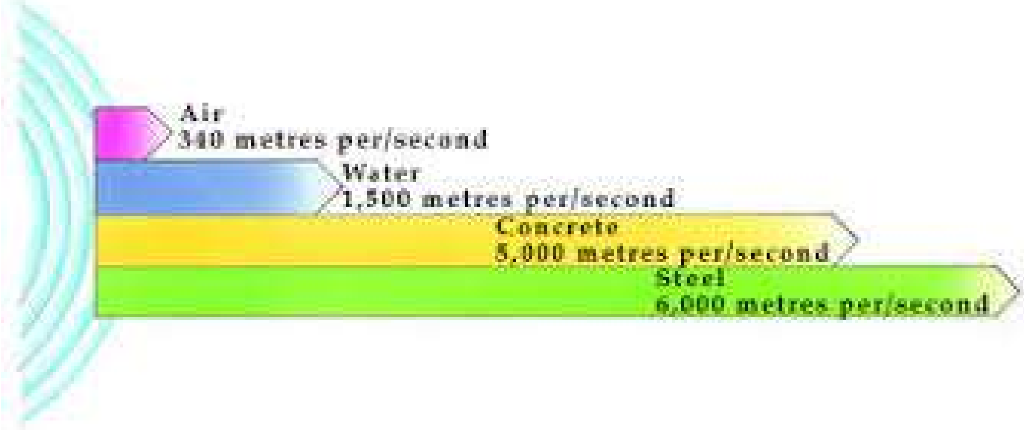


- Sound waves with frequencies above 20,000 hertz are called **ultrasonic** (frequency too high for human hearing).
- **Bats and porpoises make and hear ultrasonic**



Media That Transmit Sound

- Any elastic substance — solid, liquid, gas, or plasma — can transmit sound.
- In elastic liquids and solids, the atoms are relatively close together, respond quickly to one another's motions, and transmit energy with little loss.
- Sound travels about 4 times faster in water than in air and about 15 times faster in steel than in air.



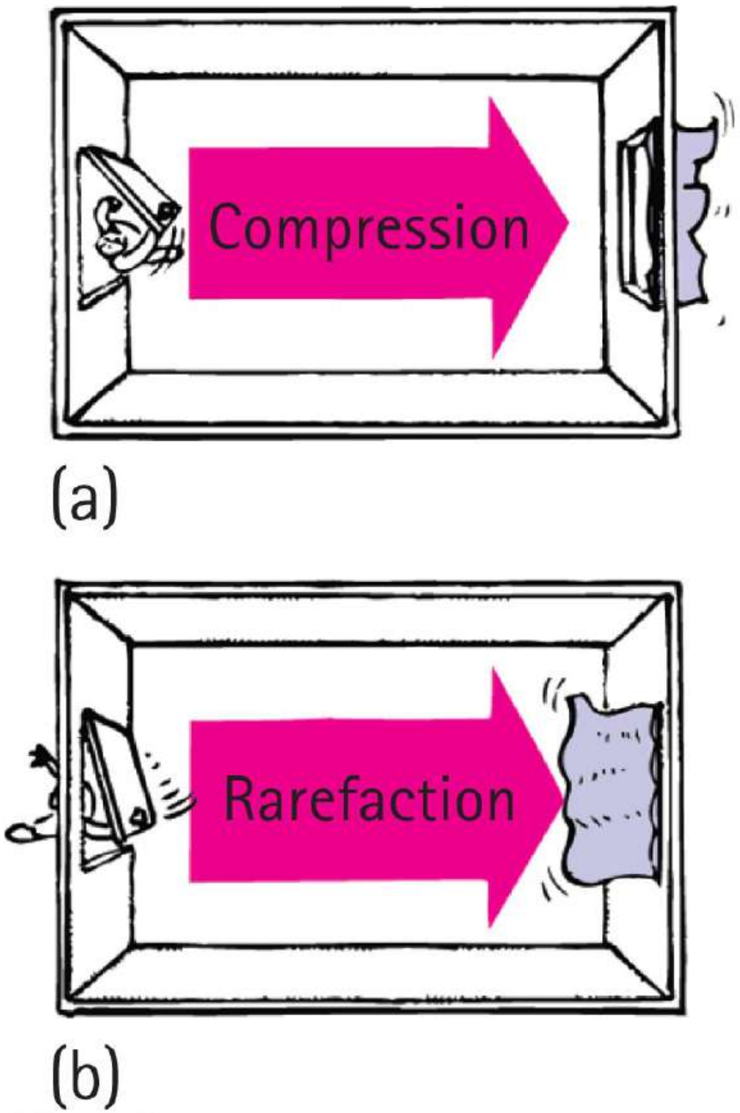
Sound is faster in a solid

It travels further before dying out.

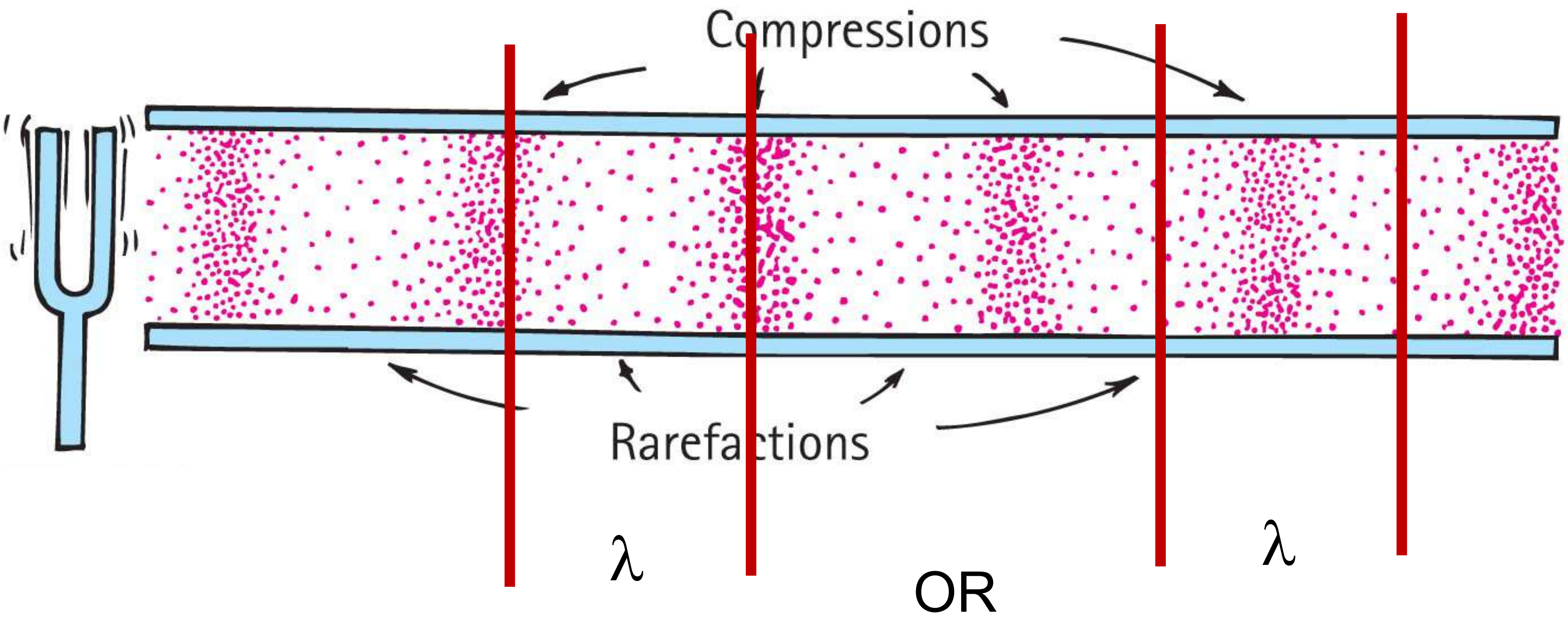
So you hear better.

Sound in Air

- Sound waves
  - are vibrations made of compressions and rarefactions.
  - are longitudinal waves.
  - require a medium.
  - travel through solids, liquids, and gases.

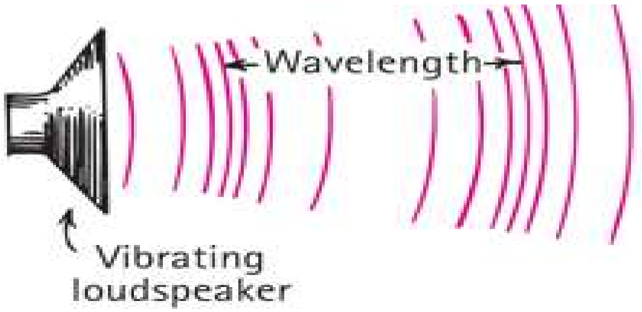


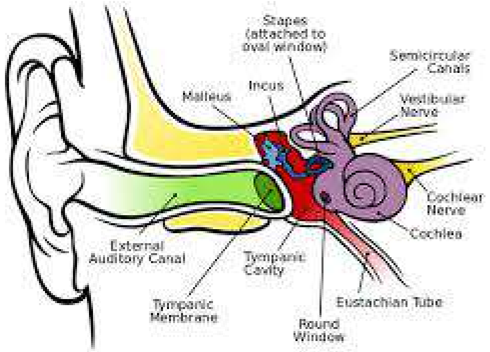
- Wavelength λ of sound
  - Distance between successive compressions or rarefactions



How sound is heard from a radio loudspeaker:

- Radio loudspeaker is a paper cone that vibrates.
- Air molecules next to the loudspeaker set into vibration.
- Produces compressions and rarefactions traveling in air.





- Sound waves reach your ears, setting your eardrums into vibration.
- Sound is heard.

- Speed of sound

  1. Depends on wind conditions, temperature, humidity
     - Speed in dry air at 0°C is about 330 m/s.
     - In water vapor slightly faster (closer particles).
     - Faster in warm air than cold air (faster particles).

  – Each degree rise in temperature above 0°C, speed of sound in air increases by 0.6 m/s

  2. It also depends on the medium:

  – Speed in water about 4 times speed in air.

  – Speed in steel about 15 times its speed in air.

  3. It does NOT depend on the frequency (pitch) or amplitude (loudness) of the sound.

Speed of Sound in Air
CHECK YOUR NEIGHBOR

You watch a person chopping wood and note that after the last chop you hear it 1 second later. How far away is the chopper?

A. 330 m
B. More than 330 m
C. Less than 330 m
D. There's no way to tell.

Speed of Sound in Air
CHECK YOUR ANSWER

You watch a person chopping wood and note that after the last chop you hear it 1 second later. How far away is the chopper?

A. 330 m

Speed of Sound in Air
CHECK YOUR NEIGHBOR, Continued

You hear thunder 2 seconds after you see a lightning flash. How far away is the lightning?

A. 340 m/s
B. 660 m/s
C. More than 660 m/s
D. There's no way to tell.

Speed of Sound in Air
CHECK YOUR NEIGHBOR, Continued

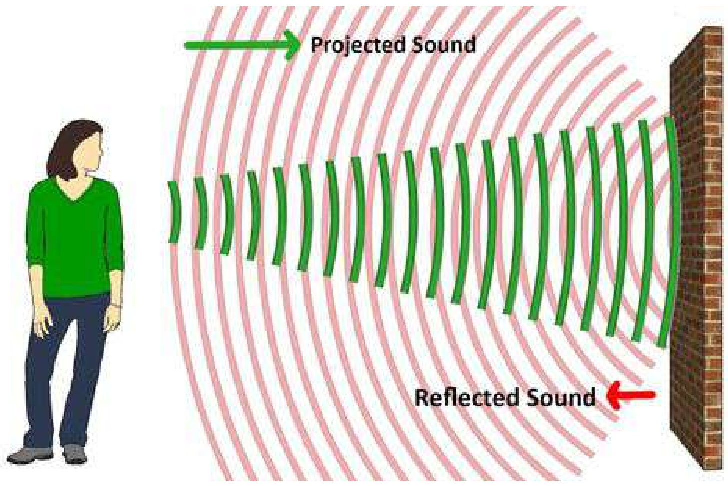
You hear thunder 2 seconds after you see a lightning flash. How far away is the lightning?

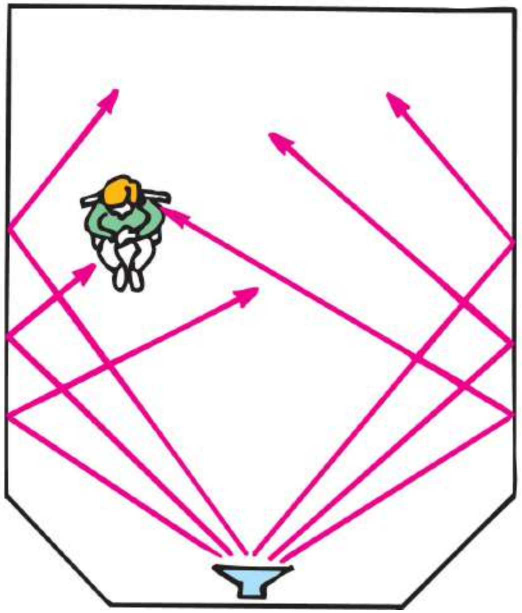
B. **660 m/s**

In 5 seconds, sound travels 5 x 330 m = 1650 m.
This is about 1 mile.
Light travels that distance almost instantly.
So, when you see lightning, start counting seconds until you hear thunder (sound).
For every 5 s you count, the storm is 1 mile away.

Reflection of Sound

- Reflection
  - Process in which sound encountering a surface is returned
  - Often called an *echo*
  - Multiple reflections—called *reverberations*





Reflection of Sound
CHECK YOUR NEIGHBOR

Reverberations are best heard when you sing in a room with

A. carpeted walls.
B. hard-surfaced walls.
C. open windows.
D. None of the above.

Reflection of Sound
CHECK YOUR ANSWER

Reverberations are best heard when you sing in a room with

B. **hard-surfaced walls.**

Explanation:

Rigid walls better reflect sound energy. Fabric is absorbent, and open windows let sound energy escape from the room.

Reflection of Sound A situation to ponder…

- Consider a person attending a concert that is being broadcast over the radio. The person sits about 45 m from the stage and listens to the radio broadcast on their cell phone over one ear and the direct sound signal with the other ear.

- Further suppose that the cell phone signal must travel all the way around the world before reaching the ear.

A situation to ponder…
CHECK YOUR NEIGHBOR

Which signal will be heard first?

A. cell phone signal
B. direct sound signal
C. Both at the same time.
D. None of the above.

A situation to ponder…
CHECK YOUR ANSWER

Which signal will be heard first?

C. **Both at the same time.**

Explanation:

Time to travel 45 m at 340 m/s ≈ 0.13 s.

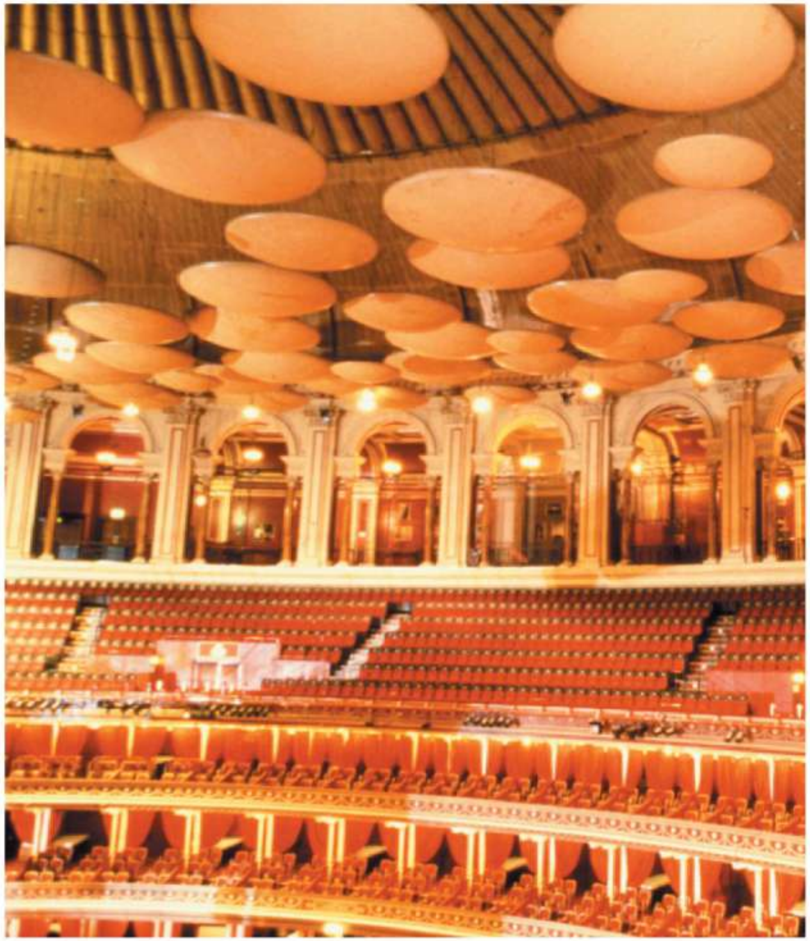
A cell phone radio signal travels at the speed of light, 3×10^8 m/s. Time to travel 4×10^7 m (Earth's circumference) at 3×10^8 m/s is also 0.13 s.

So if you sit further back than 45 m, the cell phone signal will reach you first.

Reflection of Sound, Continued

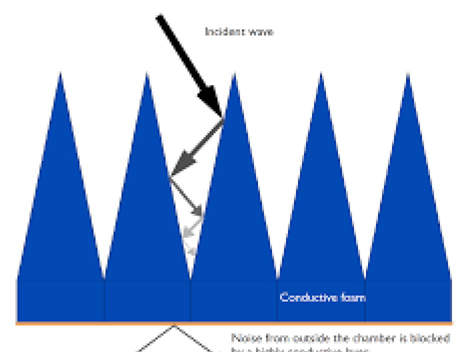
- Acoustics
  - Study of sound
  - Example:

A concert hall aims for a balance between reverberation and absorption. Some have reflectors to direct sound (which also reflect light—so what you see is what you hear).



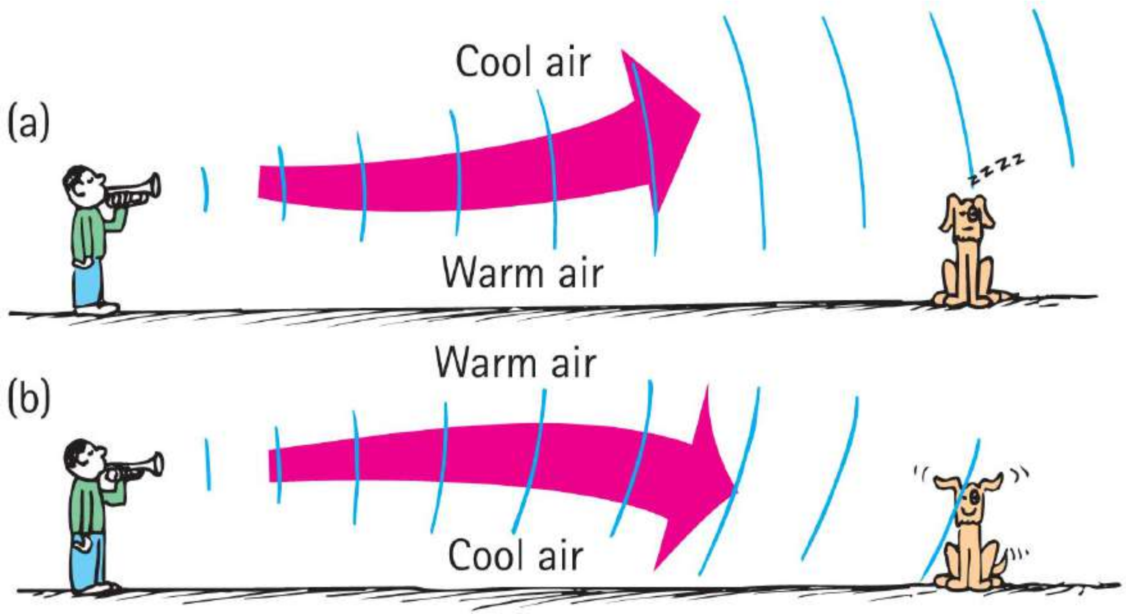
Anechoic chambers: “deaden” sounds

- Sound energy goes into space
- Reflects many times
- Loses energy each time
- Little energy comes out.



Refraction of Sound

- Refraction



  – Bending of waves—caused by changes in speed affected by
    - wind variations.
    - temperature variations.

Refraction of Sound
CHECK YOUR NEIGHBOR

When air near the ground on a warm day is warmed more than the air above, sound tends to bend

A. upward.
B. downward.
C. at right angles to the ground.
D. None of the above.

Refraction of Sound
CHECK YOUR ANSWER

When air near the ground on a warm day is warmed more than the air above, sound tends to bend

A. **upward.**

Refraction of Sound
CHECK YOUR NEIGHBOR, Continued

In the evening, when air directly above a pond is cooler than air above, sound across a pond tends to bend

A. upward.
B. downward.
C. at right angles to the ground.
D. None of the above.

Refraction of Sound
CHECK YOUR NEIGHBOR, Continued

In the evening, when air directly above a pond is cooler than air above, sound across a pond tends to bend

B. downward.

Explanation:

This is why sound from across a lake at night is easily heard.

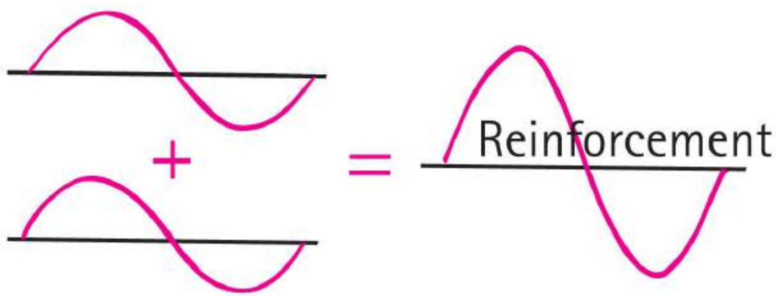
Reflection and Refraction of Sound

- Multiple reflection and refractions of *ultrasonic* waves
  - Device sends high-frequency sounds into the body and reflects the waves more strongly from the exterior of the organs, producing an image of the organs.
  - Used instead of X-rays to see interior of body.

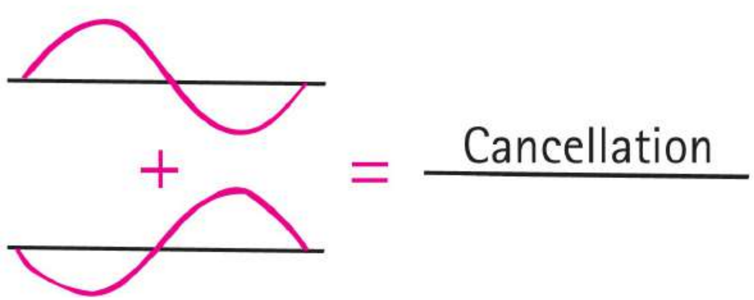
Reflection and Refraction of Sound, Continued

- Dolphins emit ultrasonic waves to enable them to locate objects in their environment.

- Interference
  - Property of all waves and wave motion
  - Superposition of waves that may either reinforce or cancel each other



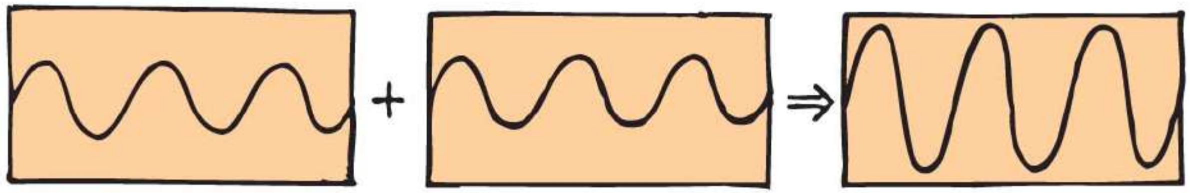
- constructive interference



- destructive interference

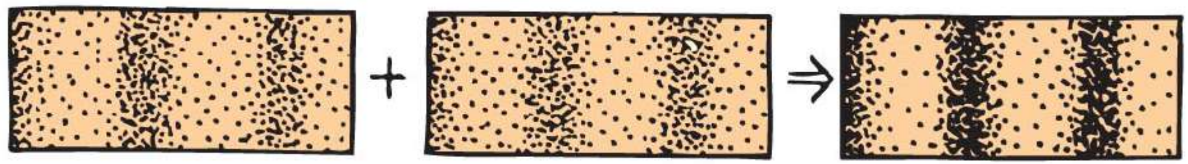
Interference, Continued-1

(a)



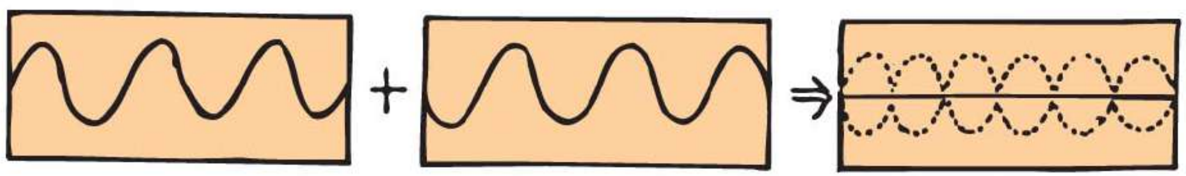
The superposition of two identical transverse waves in phase produces a wave of increased amplitude.

(b)



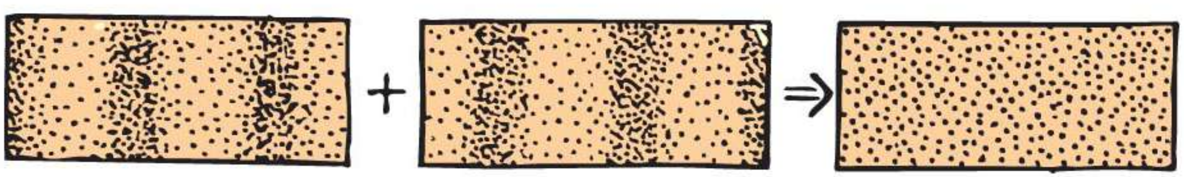
The superposition of two identical longitudinal waves in phase produces a wave of increased intensity.

(c)



Two identical transverse waves that are out of phase destroy each other when they are superimposed.

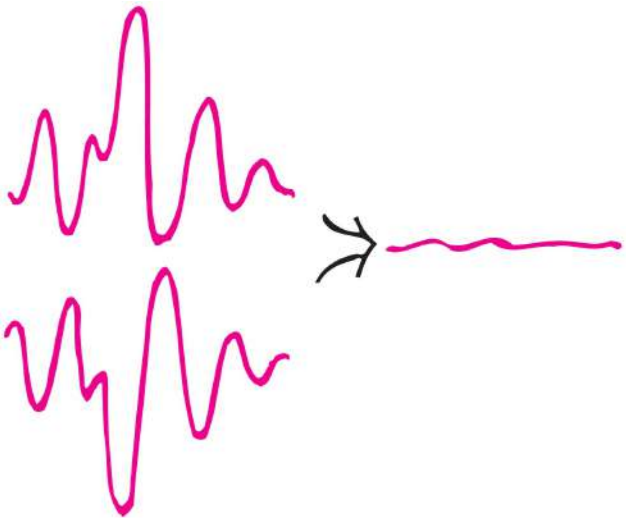
(d)



Two identical longitudinal waves that are out of phase destroy each other when they are superimposed.

Interference, Continued-2

- Application of sound interference
  - Destructive sound interference in noisy devices such as jackhammers that are equipped with microphones to produce mirror-image wave patterns fed to operator's earphone, canceling the jackhammer's sound



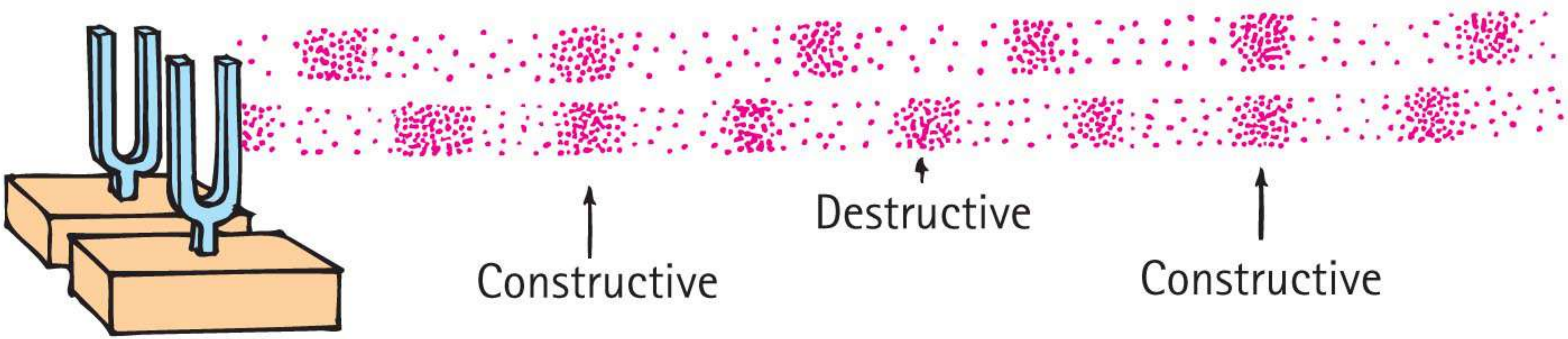
Interference, Continued-3

- Application of sound interference (continued)
  - Sound interference in stereo speakers out of phase sending a monoaural signal (one speaker sending compressions of sound and other sending rarefactions)

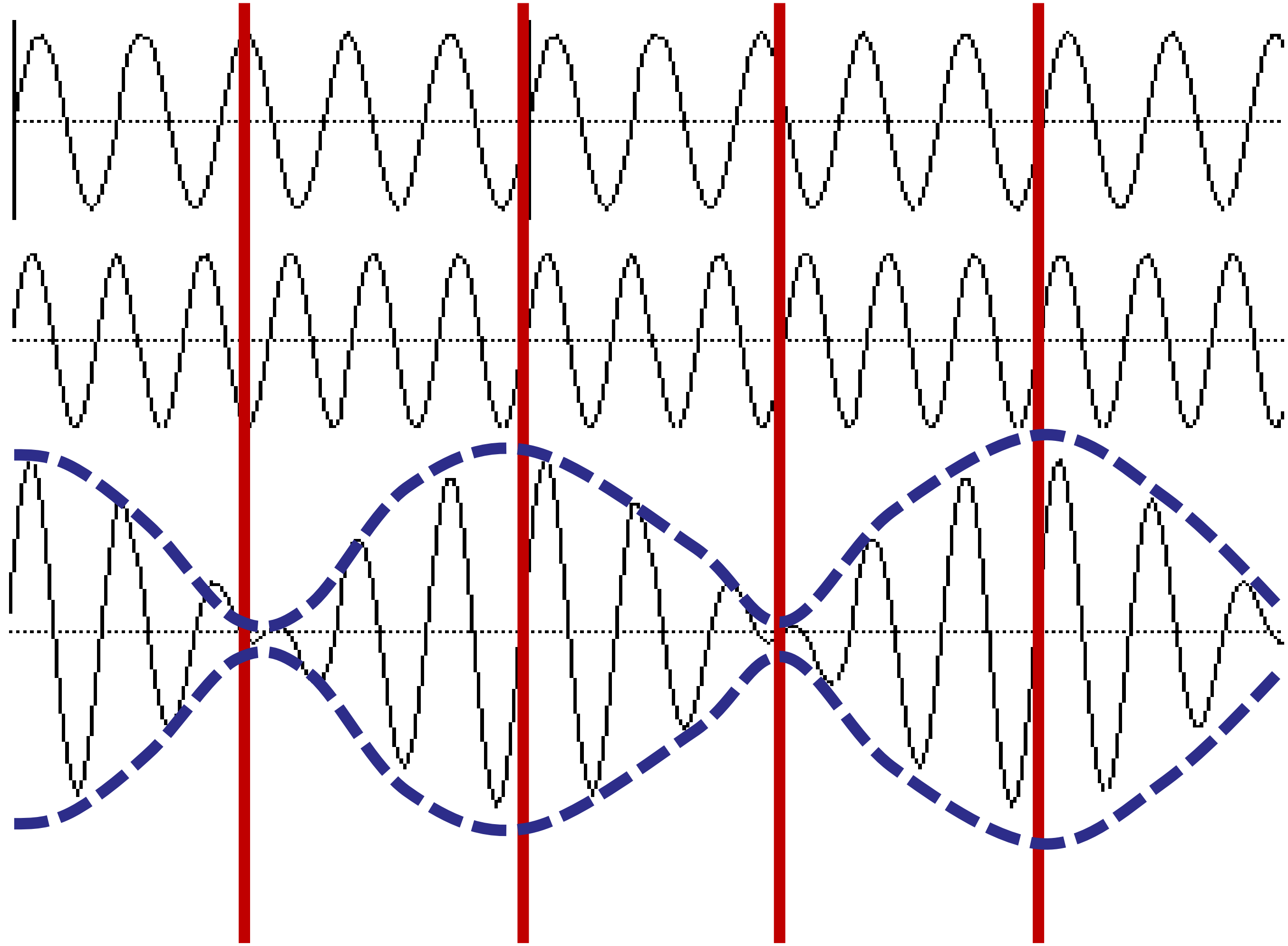
  - As speakers are brought closer to each other, sound is diminished.

Beats

- Periodic variations in the loudness of sound due to interference that occurs when 2 frequencies are close to each other.
- An example of wave interference
- Provide a comparison of frequencies



- lower f
- higher f
- beats:



D soft | C loud | D soft | C loud | ETC

- D = destructive
- C = constructive

Applications

- Piano tuning by listening to the disappearance of beats from a tuning fork and a piano key

- Tuning instruments in an orchestra by listening for beats between instruments (often the oboist usually plays a concert A = 440 Hz) and the other instruments are tuned to that.

Beat frequency

The beat frequency is found by subtracting the two frequencies:

beat frequency = higher f – lower f

Example: What is the beat frequency when a 262-Hz tuning fork and a 266-Hz tuning fork are sounded together?

beat frequency = higher f – lower f

Example: A violin player hears 3 beats when she plays at the same time as the oboist, who is playing at 440-Hz. What is the frequency of the violin?

If the violinist tightens her string, and the beats slow to 1 beat per second, what is her frequency?