11 PHYSICS

Unit 5: Light + Sound

Booklet 2

June 9th - June 16th

NAME: Filled

(adapted from www.physicsclassroom.com)

U5:L3 Speed of Sounds + Doppler

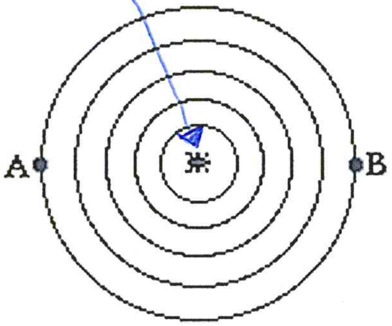
Scenario 1: Same Frequencies Observed

Suppose that there is a happy bug in the center of a circular water puddle. The bug is periodically shaking its legs in order to produce disturbances that travel through the water.

If these disturbances start at a point, then they would travel outward from that point in all directions.

Since each disturbance is traveling in the same medium (water), they would all travel in every direction at the same speed.

The pattern produced by the bug's *shaking* would be a series of concentric circles as shown in the diagram at the right.



A stationary bug producing disturbances in water.

→ means shaped as circles

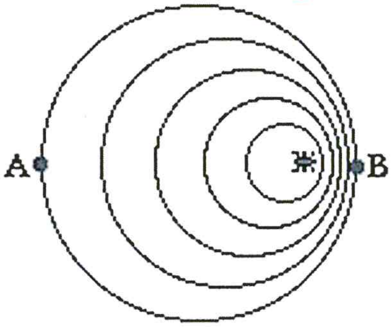
These circles would reach the edges of the water puddle at the same frequency. An observer at point A (the left edge of the puddle) would observe the disturbances to strike the puddle's edge at the same frequency that would be observed by an observer at point B (at the right edge of the puddle).

Scenario 2: Different Frequencies Observed →

Now suppose that our bug is moving to the right across the puddle of water and producing disturbances at the same frequency.

Since the bug is moving towards the right, each consecutive disturbance starts from a position that is closer to observer B and farther from observer A.

Therefore, each next disturbance has a shorter distance to travel before reaching observer B and thus takes less time to reach observer B.



A bug moving to the right and producing disturbances.

Person B observes that the frequency of arrival of the disturbances is higher than the frequency at which disturbances are produced.

On the other hand, each consecutive disturbance has a further distance to travel before reaching observer A. For this reason, observer A observes a frequency of arrival that is less than the frequency at which the disturbances are produced.

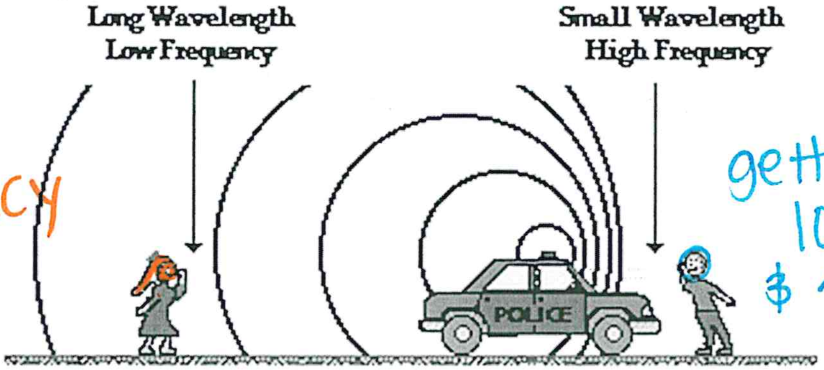
The Doppler Effect is observed whenever the source of waves is moving with respect to an observer.

(adapted from www.physicsclassroom.com)

The Doppler Effect can be observed for any type of wave - water wave, sound wave, light wave, etc. We are most familiar with the Doppler Effect because of our experiences with sound waves.

Perhaps you recall an instance in which a police car or emergency vehicle was traveling towards you on the highway. As the car approached with its siren blasting, the pitch of the siren sound (a measure of the siren's frequency) was high; and then suddenly after the car passed by, the pitch of the siren sound was low. That was the Doppler Effect - an apparent shift in frequency for a sound wave produced by a moving source.

getting quieter
& ↓ frequency

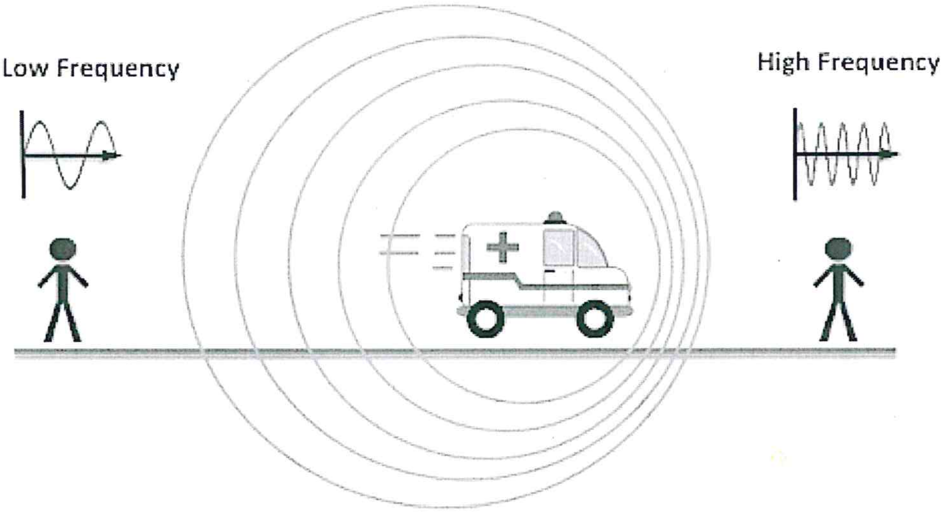


getting louder
& ↑ frequency

The Doppler Effect can be observed when the source of waves is moving with respect to the observer.

- There is an apparent upward shift in frequency when the observer and the source are approaching each other
- ...and an apparent downward shift in frequency when the observer and the source are moving away from each other.

Note that the Doppler Effect is not an actual change in the frequency of the source. The source of the sound always emits the same frequency. The observer only perceives a different frequency because of the relative motion between them.

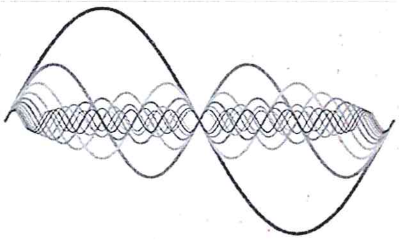


(adapted from www.physicsclassroom.com)

U5:L4 Musical Notes + Resonance

Musical instruments are set into vibrational motion at their natural frequency when a person hits, strikes, strums, plucks or somehow disturbs the object.

Each natural frequency of the object is associated with one of the many standing wave patterns by which that object could vibrate. The natural frequencies of a musical instrument are sometimes referred to as the harmonics of the instrument.



An instrument can be forced into vibrating at one of its harmonics (with one of its standing wave patterns) if another *interconnected* object pushes it with one of those frequencies.

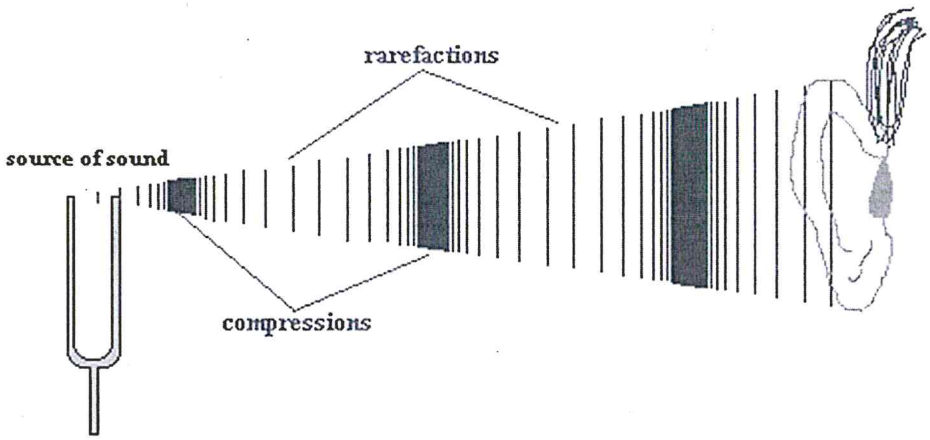
This is known as **resonance** - when one object vibrating at the same natural frequency of a second object forces that second object into vibrational motion.

The familiar *sound of the sea* that is heard when a seashell is placed up to your ear is also explained by resonance.

Even in an apparently quiet room, there are sound waves with a range of frequencies. These sounds are mostly inaudible due to their low intensity. This so-called background noise fills the seashell, causing vibrations within the seashell. But the seashell has a set of natural frequencies at which it will vibrate.

If one of the frequencies in the room forces air within the seashell to vibrate at its natural frequency, a resonance situation is created. And always, the result of resonance is a big vibration - that is, a loud sound. In fact, the sound is loud enough to hear.

So the next time you hear the *sound of the sea* in a seashell, remember that all that you are hearing is the amplification of one of the many background frequencies in the room.



(adapted from www.physicsclassroom.com)

Musical Instruments

Musical instruments produce their selected sounds in the same manner. Brass instruments typically consist of a mouthpiece attached to a long tube filled with air. The tube is often curled in order to reduce the size of the instrument.

The metal tube merely serves as a container for a column of air. It is the vibrations of this column that produces the sounds that we hear. The length of the vibrating air column inside the tube can be adjusted either by sliding the tube to increase and decrease its length or by opening and closing holes located along the tube in order to control where the air enters and exits the tube.

Brass instruments involve the blowing of air into a mouthpiece. The vibrations of the lips against the mouthpiece produce a range of frequencies. One of the frequencies in the range of frequencies matches one of the natural frequencies of the air column inside of the brass instrument.

This forces the air inside of the column into resonance vibrations. The result of resonance is always a big vibration - that is, a loud sound.

Resonance Problem Solving

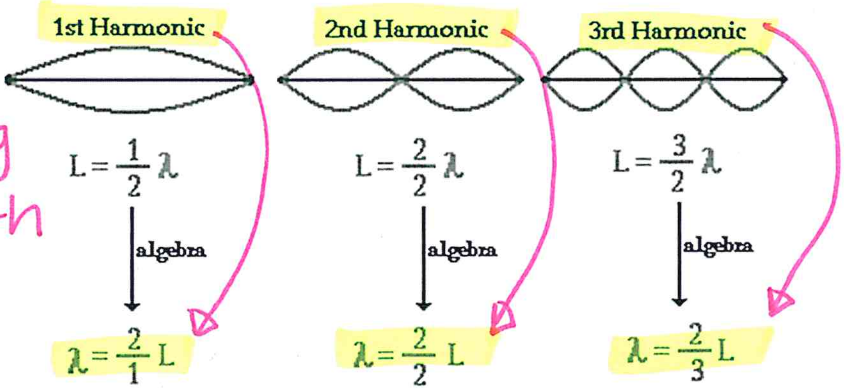
A guitar string has a number of frequencies at which it will naturally vibrate. These natural frequencies are known as the harmonics of the guitar string.

The natural frequency at which an object vibrates at depends upon the tension of the string, the linear density of the string and the length of the string. Each of these natural frequencies or harmonics is associated with a standing wave pattern.

The graphic below depicts the standing wave patterns for the lowest three harmonics or frequencies of a guitar string.

Ⓛ = length of string

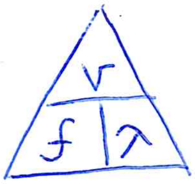
λ = wavelength



(adapted from www.physicsclassroom.com)

The wavelength of the standing wave for any given harmonic is related to the length of the string (and vice versa).

If the length of a guitar string is known, the wavelength associated with each of the harmonic frequencies can be found.
The length-wavelength relationships and the wave equation ($v = f\lambda$) can be combined to perform calculations predicting the length of string required to produce a given natural frequency.



Example 1:

v (speed)

The speed of waves in a particular guitar string is 425 m/s. Determine the fundamental frequency (1st harmonic) of the string if its length is 76.5 cm.

L (guitar string length) $= 0.765\text{m}$

- 1st harmonic $\lambda = 2L$

$\lambda = 2(0.765\text{m})$

$\lambda = 1.53\text{m}$

- $f = \dfrac{v}{\lambda}$

$f = \dfrac{425\text{ m/s}}{1.53\text{ m}}$

$\boxed{f = 278\text{ Hz}}$

Example 2:

f

Determine the length of guitar string required to produce a fundamental frequency (1st harmonic) of 256 Hz. The speed of waves in a particular guitar string is known to be 405 m/s.

v

- $\lambda = \dfrac{v}{f}$

$\lambda = \dfrac{405\text{ m/s}}{256\text{Hz}}$

$\lambda = 1.58\text{m}$

- 1st Harmonic $\lambda = 2L$ or $L = \dfrac{\lambda}{2}$

$L = \dfrac{\lambda}{2}$

$L = \dfrac{1.58\text{m}}{2}$

$\boxed{L = 0.791\text{m}}$

(adapted from www.physicsclassroom.com)