Name______________________________________

Period________

Lesson 13: Waves

13.1 Experiment: Wave Types

A wave is a traveling disturbance. We are all familiar with waves in the water and with "the wave" in a baseball stadium. We begin our study of waves by examining energy and matter in a slinky.

(a) Stretch a slinky *loosely* across the table between two of you and send a wave pulse across to your lab partner by stretching some of the coils to the side a little and plucking. How does the wave travel?
Draw a picture of the slinky showing how the wave moves.

(b) Focus on one of the coils of the spring and try again. Does the coil you released travel all the way from one end of the slinky to the other? Watch carefully!

(c) What moves all the way from one side of the slinky to the other?

(d) Refer back to your diagram from (a). Does the wave pulse move horizontally or vertically in your diagram?

Focusing on one coil of the slinky, does the coil move horizontally or vertically in your diagram?

(e) Now send a wave pulse across differently. This time gather some of the slinky toward you by pulling it slightly back horizontally and let the compression pulse fly.
Draw a picture showing how the wave moves this time.

(f) Focus on one of the coils of the spring and try again.
Does the coil move all the way from your side of the slinky to your lab partner?

What moves all the way from one end of the slinky to the other?

(g) Refer back to your diagram from (e). Does the wave pulse move horizontally or vertically in your diagram?

Focusing on one coil of the slinky, does the coil move horizontally or vertically in your diagram?

(h) In any case, do waves carry matter or energy or both from one place to another through the material? Provide evidence for your answer.

*Waves come in different types. When the particles of the medium (the material) move perpendicular to the direction the wave moves, the wave is called a *transverse* wave (just like the plucked example you just tried). When the particles move parallel to the direction the wave moves (or *along* the same direction), the wave is called a *longitudinal* wave (just like the compression example you just tried).
Light is a transverse wave and sound is a longitudinal wave.

13.2 <u>Exercise: Wave Transmission</u>

(a) We have just observed that waves can travel through a slinky.
List at least 3 other examples of things that waves can travel through:

(b) Can a wave travel through empty space?

Explain.

(c) Does sound require a medium (a material) to travel through?

(d) What can sound travel through?

(e) What do the rings of Saturn sound like? Why?

(f) Light waves are vibrations of the electric field, also known as "electromagnetic waves".
Do electromagnetic waves travel through empty space?

How can you tell?

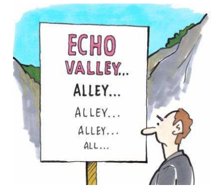
(g) Circle the correct underlined words in the statement below:

Electromagnetic waves <u>are/are not</u> an exception to the rule that waves must have a medium to travel through because light and other electromagnetic waves <u>can/can not</u> travel through empty space.

*Electromagnetic waves travel at a speed of $c = 3.0 \times 10^8$ *m/s.*

*Electromagnetic waves come in a wide range of wavelengths, each with their own uses and sources, that comprise ***the electromagnetic spectrum***. The longest waves are called
radio waves (as long as you like down to about 1 m – used in communications), followed by
microwaves (from 1m down to 1mm – yes these are the ones you cook with, also cellphones and broadband signals),
infrared waves (from 1mm down to about 700 nm [700×10^{-9}m] - "heat waves", humans glow with this kind of light that you can see with "heat vision" goggles),
visible light (around 700nm down to around 400nm – what we can see: only a tiny amount of what there is),
ultraviolet light (400nm [4×10^{-5}m] down to 10^{-9}m – can be dangerous, from the sun),
x-rays (10^{-9}m down to 10^{-11}m – prolonged exposure can be dangerous to living tissue), and
gamma rays (10^{-11}m down to as small as you like – most dangerous to living tissue, from high energy astronomical processes and nuclear explosions, etc).

*Electromagnetic waves are the only type of wave that doesn't require something to travel through.



13.3 Experiment: Wave Reflection

(a) Lay the slinky on the tabletop or floor and have one person hold the end secure. This end, not allowed to move, is called a "fixed end". Send horizontal (sideways) wave pulses to your "fixed end" partner.
<u>PREDICT</u>: What will happen to waves when they reach the end of the material?

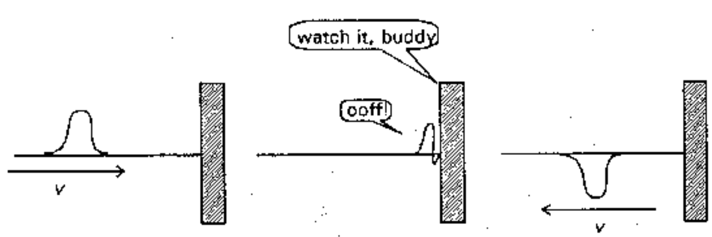
(b) Now try it. Which way does the pulse come back?

(c) How does this relate to sound? (Hint: We have a word describing a reflection of a sound wave against a wall.)

(d) Now tie a bit of string to the other end to make the end effectively a "free end" where that end of the slinky is free to go back and forth. Have one person hold the string end at the end of the slinky and the person at the other end send horizontal wave pulses to the "free end" lab partner.
<u>PREDICT</u>: How will it come back this time?

(e) Now try it. How did it come back?

(f) Write a simple rule describing how waves reflect based on whether the end is a fixed or free end.



13.4 Experiment: Determining Wave Speed

(a) Stretch a slinky loosely across the table between you and a lab partner and send a wave pulse across to the other person by stretching some of the coils gently to the side and plucking. (Don't overdo it this time: we're going to try a stronger pluck in part (b)!) Use a stopwatch to time how long it takes from when the pulse is released to when it returns to the end it was sent from.

$time_{round\_trip}$ = _______________ seconds

(b) Now try sending a stronger pulse without changing the tension in the slinky. To achieve this, increase the amplitude slightly by stretching a little more to the side before letting it go. Again, time the round trip of the pulse.

$time_{round\_trip}$ = _______________ seconds

(c) When you increased the amplitude, what happened to the speed of the wave?

(d) This time try changing the tension by pulling back a few coils and then sending the pulse the same way. Be careful not to overstretch the slinky past its elastic limit! Again, time the round trip of the pulse.

$time_{round\_trip}$ = _______________ seconds

(e) When you increased the tension, what happened to the speed of the wave?

(f) Now try shaking the slinky left and then right once quickly to increase the frequency of the wave. Time this the same way you timed the last two.

$time_{round\_trip}$ = _______________ seconds

(g) What happened to the speed of the wave when you changed the frequency?

(h) What can be done to change the speed of a wave?

*Wave speed can only be changed by changing something about the material the wave travels through, so wave speed will stay the same even if you change the wavelength, frequency, or amplitude. Wave speed is only caused by the properties of the medium. Changing the tension or the liner density (mass per unit length) will change the wave speed for a stretched object like a string or spring. Increasing the connective property between molecules will tend to increase the wave speed. Increasing the inertia property of the molecules, on the other hand, will tend to decrease the wave speed.
For a stretched string or spring, the wave speed is determined by the following equation:

$$v_{string} = \sqrt{\frac{Tension}{(mass/length)}}$$

13.5 Experiment: wave speed, frequency, and wavelength.

(a) Write the equation relating velocity to distance and time.

(b) What is the name for the period of time that it takes for a wave to pass by a given location?

(c) What is the distance that a wave moves in such a period of time called?

(d) Now rewrite the equation, only replace the distance with your answer to the last question and replace the time with your answer to two questions back.

(e) How is period related to frequency?

(f) Rewrite the equation, except multiply by the inverse of time instead of dividing.

(g) Replace the inverse of time with frequency and write the new equation.

(h) How does wave speed (the velocity) relate to wavelength and frequency?

13.6 Wave Terms

(a) Wave speed (v):

Unit:

(b) Frequency (f):

Unit:

(c) Period (T):

Unit:

(d) Wavelength (λ):

Unit:

(e) Amplitude (A):

Unit:

(f) Rules for wave speed:

(g) Circle the correct word in the statement below:

Sound is a transverse/longitudinal type of wave because air molecules move parallel/perpendicular to the direction the wave moves through the air.

13.7 Wave abilities:

(a) Reflection

fixed end:

free end:

(b) Superposition (or "Interference"):

Amplitudes _______________

Constructive

Destructive

Tsunami protection?

(c) Refraction

Example (of refraction):

(d) Diffraction

Example:

(e) Polarization

Example:

Can any kind of waves be polarized?

(f) Doppler effect

Examples: