Topic 15: Vibration and Waves

Source: *Conceptual Physics* textbook, laboratory manual, concept-development book and CPO physics text and laboratory manual

Types of Material: Textbooks, laboratory manuals, demonstrations, worksheet and activities and website and science stories

Building on: Vibrations and waves begin many new ideas not yet presented such as simple harmonic motion, wave interference and resonance. Measuring skills, significant figures, vectors, motion and force, however, will be used to study mechanical waves. The study of transverse and longitudinal waves using the standard slinky is a great way to demonstrate period, frequency, amplitude, wave speed, reflection, transmission and interference. All topics will lead to future physics topics.

Leading to: When wave behavior has been studied, the study of optics will be greatly understood since reflection, refraction, diffraction and interference of mechanical wave mainly behave like visible light waves. Similar experiments for mechanical waves can be performed with light. One example is periodically tapping the surface of still water at two locations about two centimeters apart and observing the interference pattern created. For light, the student can observe the same type of interference by using Thomas Young's experiment. In quantum mechanics, the background of vibration and waves will help give a visual image of de Broglie waves.

Links to Physics: The study of vibrations and waves is needed to understand electromagnetic wave behavior, simple harmonic motion, the difference between transverse and longitudinal waves that distinguishes between light and sound. Optics uses vibrations and waves to explain many optical phenomena. The visualization of the deBroglie wave also needs the background of vibrations and waves.

Links to Chemistry: Knowledge of frequency and wavelength is needed for atomic spectra. Frequency understanding is needed for the photoelectric effect.

Links to Biology: Knowledge of frequency and wavelength is needed for atomic spectra. Sound wave knowledge allows discussion of how the ear works and converts sound waves (mechanical) to nerve impulses (electrical).

Materials:

(a) Hewitt
1. Tick Tock
2. Grandfather's Clock
3. Catch a Wave

4. Ripple While You Work

(b) Hsu
1. Harmonic Motion
2. Natural Frequency
3. Waves
4. Resonance and Standing Waves

(c) My Lab
Referral only – Wave phenomena labs have been extensively written about and I have nothing better or anything to add. I like slinky labs and ripple tank (water) labs to study wave behavior. The computer simulation wave activities can also be outstanding.

(d) Worksheet
Vibration and Waves

(e) Demonstrations
1. 33-1/3 Record Projection and Bouncing Mass
2. Standing Wave Using a Jigsaw

(f) Websites and Videos
1. Wave Phun Lab Sims
2. The Doppler Effect and Sonic Boom Lab Sims
3. ESPN SportsFigures "Making Waves" Video Guide
4. ESPN SportsFigures "Cheering Energy" Video Guide
5. "Mystery of the Senses Hearing" Video Guide
6. PHet – The Listening Dude Lab Sim

(g) Good Stories
Hooke's Spring

Topic 15: Qualitative Vibration and Wave Lab

VIBRATIONS

A. 1. Period is the ‘time” to complete one cycle (we orbit the sun in 1 year). Set up a 50-cm-long pendulum. Set it vibrating. Time how long it takes to go over and back 10 cycles.

T = ______________________________s

2. How large is the period of this pendulum?

T = ______________________________s

3. Frequency is “how often something occurs in a given time.” Therefore, frequency is the opposite (inverse) of period. What is the frequency of the 50-cm pendulum?

F = ____________________________1/s (Hertz)

4. Make the pendulum longer than 50 cm. What happens to its period?

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5. What happens to the pendulum’s frequency for the longer pendulum?

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WAVE TYPES

B. 1. Waves are of two types. Transverse waves have a motion similar to rolling water waves moving up and down as they travel. The particles of the medium are moving perpendicular to the wave motion. Longitudinal waves can be visualized with dominos standing upright with a small space between them and one domino falls into the next and so on. This shows the particles of the medium moving parallel to the wave motion.

2. To observe and study both types of waves, we will use a stretched slinky. You will need a partner or tie the other end of the slinky to something solid at floor level. Stretch the slinky on the floor so the coils are 2-3 cm apart and quickly snap your wrist to the side about a foot and return. Observe and record everything you see. (This should be more than one!)

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3. Was this pulse transverse or longitudinal?

4. Compress 10 or so coils of the stretched slinky and release. Observe and record everything you see.

5. Was this wave "pulse" transverse or longitudinal?

WAVE INTERACTION

C. Waves at the Same Place at the Same Time

1. Send a large pulse on one side of a stretched slinky and at the same time have a partner send a small pulse on the same side of the slinky. Describe everything you observe while they meet and after they depart.

2. Repeat #1 but send the large and small pulses on the opposite sides of the slinky.

3. In nature, name one type of longitudinal wave and one type of transverse wave.

Topic 15: Vibration and Waves Answer Sheet

A. 1. T about 1.4 s

2. 1.4 s

3. 0.71 s

4. Since $T \propto \sqrt{L}$ $L\uparrow$, then $T\uparrow$ is larger.

5. Since $f \propto 1/T$ as $T\uparrow$, $f\downarrow$.

B. 1. NA

2. Wave moves down medium at constant speed, $\perp$ to medium.
Wave gets smaller due to energy loss, however, retains the same shape.
Wave reflects at far end, and wave switches sides (phase change).

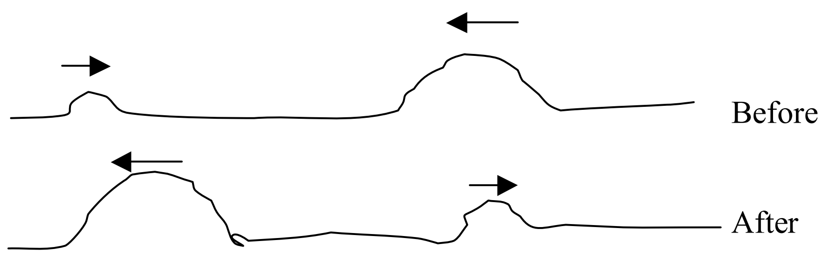
3. Transverse, $\perp$ to wave motion

4. Wave moves down medium at constant speed, $\parallel$ to the medium.
Wave reflects at far end and returns.
Energy of wave decreases.

5. Longitudinal, $\parallel$ to wave motion

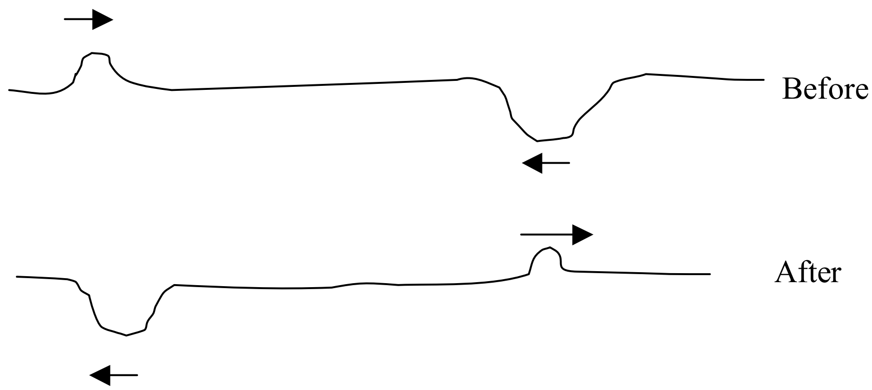
C. 1. When the large and small transverse pulse meet, they interact and reemerge keeping the same shape. Thus, the two pulses do not reflect but pass through each other.

Example:



2. They interact and reemerge keeping the same shape. Thus, the two pulses do not reflect but pass through each other.

Example:

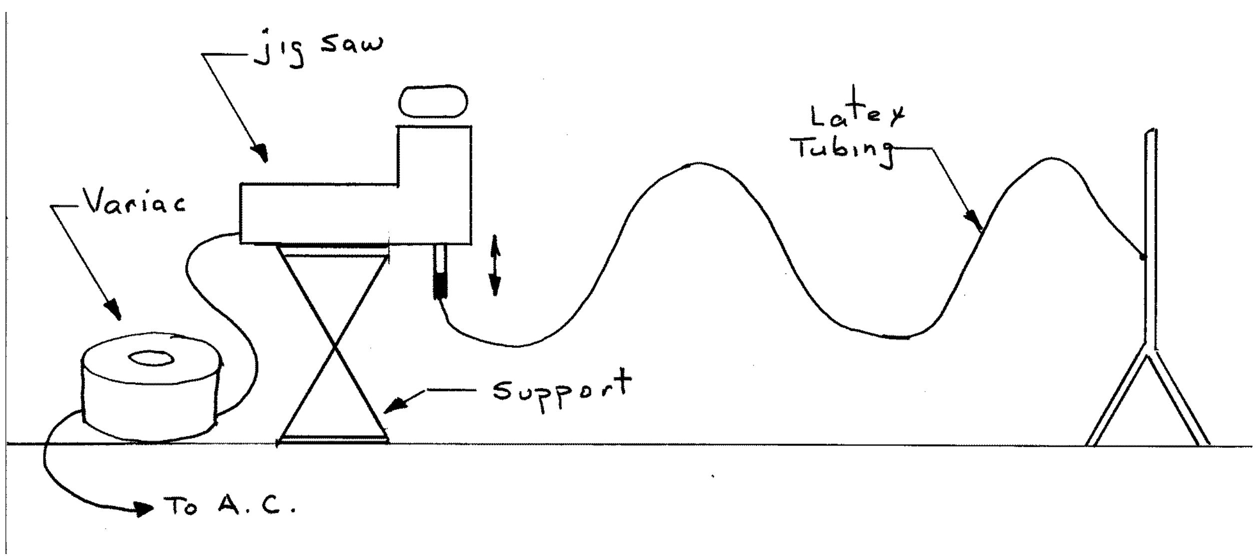


3. Longitudinal: Sound
   Transverse: Radio Waves

Demonstration: Waves on a String

Objective: To demonstrate wave properties; observations may include amplitude, wavelength, troughs, crests, nodes, antinodes, wave speed, standing waves, fundamental frequency, harmonics, and changes in medium density.

Equipment: Variable speed jigsaw with blade (or single speed jigsaw and Variac)
Latex tubing
Lab jack or similar support
Set up the apparatus as shown in the sketch, being sure to mount the jigsaw to a sturdy support.



By using the Variac to change the speed of the reciprocating blade, the relationship between frequency and wavelength can be observed.

Variation: Shorten the length of tubing (thus increasing the tension and changing the medium’ s density) and notice changes in the wave characteristics.

Variation: Attach two slightly different pieces of tubing and note differences in the wave’s appearance.

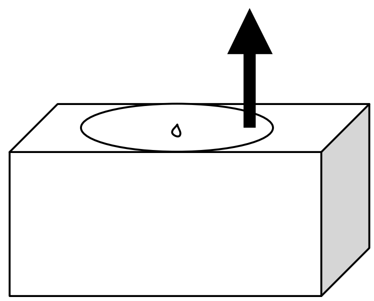
Variation: Slow down the blade speed (lower frequency) to produce a fundamental frequency (one-half wavelength). Increase the frequency to produce several harmonics.

Topic 15: Demonstration – Vibrations and Waves

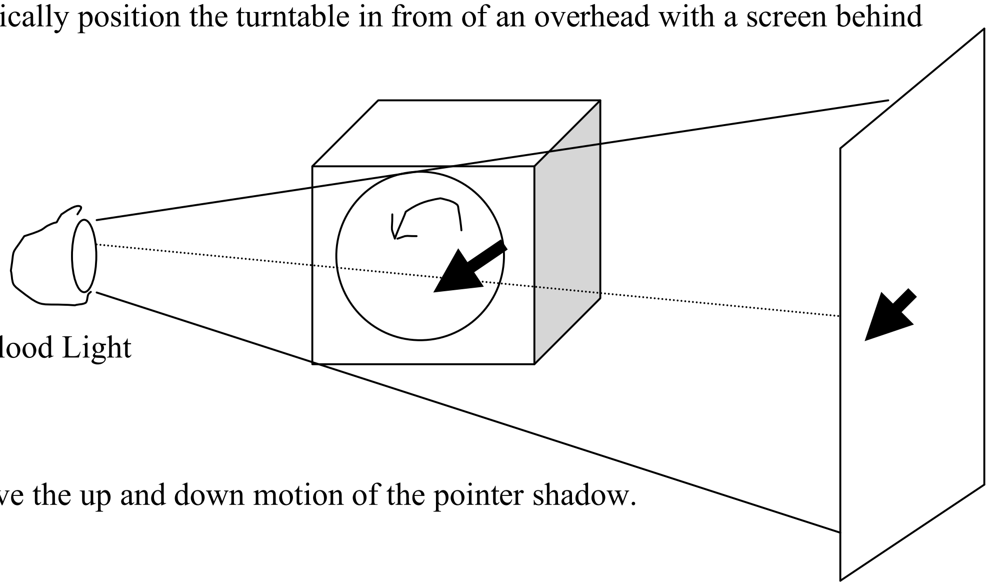
Purpose: To visually illustrate without using mathematics that the linear projection of 2-dimensional motion is the same as simple harmonic motion (SHM.)

Procedure:

1. Obtain a 33-1/3 rpm record player and mount a pointer facing upright on the outer edge of the turntable.



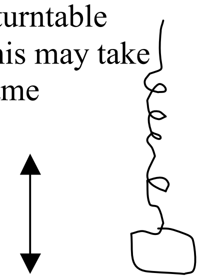
2. Vertically position the turntable in from of an overhead with a screen behind



Overhead/Flood Light

Observe the up and down motion of the pointer shadow.

3. Find a spring capable of moving up and down about the same amount as the turntable diameter (about 8 inches) with a correct size mass at the end of the spring. This may take some trial and error to find the right spring/mass combination to match the same frequency.



4. Once these two motions have the same frequency, viewers can see that the projected pointer moves like the mass on the spring.

   Things to ask about are the velocities and accelerations throughout the two motions:
   The maximum velocity for both the mass and projection occur at the center of the up and down motion. The velocity at the top and bottom is zero. The acceleration (the change in velocity in time) is at maximum at the top and bottom and zero at the center. The math to prove this true can be found in many physics textbooks.

Hooke’s Spring

For making maps, and especially for determining position on the earth’s surface, one of the key elements needed is an accurate and consistent time keeping device. Science was discovering that the pendulum was not reliable at all latitudes and, in addition, a pitching, rolling deck of a ship was no place for a gravity-driven device.

Two men emerged to advance the evolution of the mechanical clock Robert Hooke (1635-1703) and Christian Huygens (1629-1695). Both men realized that the device must be free of weights, pendulums and other gravity-dependent mechanics. Both men also conceived the concept of a coiled metallic strip, a spring, that could act as a power source as it unwinds and as a regulator for consistent timekeeping. At the age of ten years, Hooke had already made his first clock of wood. As early as 1658, Hooke proposed the coil spring for his marine clock but failed to produce such an instrument. His Dutch competitor, Christian Huygens, did make one using a balance spring in 1674. The following year an incensed Hooke produced a coil spring clock of his own, engraved it with an inscription claiming himself to be the inventor and presented it to the king.

As neither inventor’s clock was accurate enough for determining longitude at sea, the regulator still proved elusive. It took more than one hundred years (1761) when John Harrison perfected the “regulator” and built his marine clock, the H4. On a two-month journey to Jamaica, his “watch” lost only five seconds.

Although neither Hooke nor Huygens is recognized as the sole inventor of the marine clock, Hooke did discover the relationship between a spring’s displacement and the force put upon it, Hooke’s Law.