Lab Handout

Lab 19. Wave Properties

How Do Frequency, Amplitude, and Wavelength of a Transverse Wave Affect Its Energy?

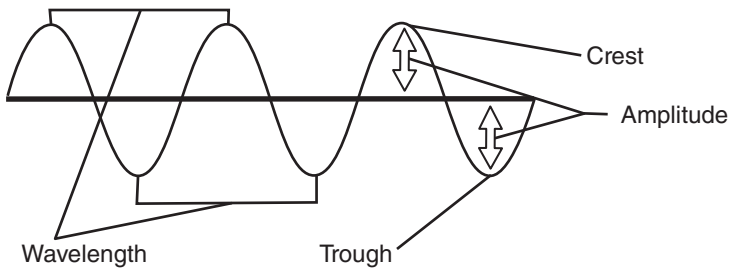
Introduction

Energy can be transported by waves. There are many forms of waves that exist in the world. Mechanical waves, such as sound waves or water waves, must travel through a medium, or matter. For example, when you speak, you create a pressure disturbance in the air that travels as a wave through the air molecules. You can also create a wave in a rope or string by moving one end from side to side. In each case, the wave travels through the medium, the air or the rope (or string). Electromagnetic waves, such as radio, ultraviolet, and visible light waves, don't require a medium to travel. Instead, the vibrations of perpendicular electric and magnetic fields form these waves.

Although waves may travel differently, some mechanical and electromagnetic waves can be represented by the same basic shape, or waveform. Electromagnetic waves and the waves you might make in a rope or string, for example, are called transverse waves. A drawing of a transverse wave is shown in Figure L19.1. The highest point of the wave is called the crest, and the lowest point is called the trough. The wavelength of the wave, a measure of how long the wave is, can be found by measuring the distance between the same point on a wave and the wave in front of or behind it. Usually, this is done by measuring crest to crest or trough to trough. The amplitude of a wave is the distance from the resting position (the horizontal line) to the crest or trough. The frequency of a wave is hard to show in a picture. A wave's frequency is a measure of how many times a wave passes a certain point in a certain amount of time. To measure frequency, scientists measure the number of wave cycles (trough to trough or crest to crest) that occur in 1 second, and they measure this value in hertz (Hz). One cycle per second is 1 Hz, two per second is 2 Hz, and so on.

FIGURE L19.1

Transverse wave



The properties of a wave contain information about the energy that wave is carrying and also determine its use. For example, electromagnetic radio waves are used to transmit the radio signals your car stereo picks up. Your favorite station numbers are actually measurements of the frequency at which that station broadcasts.

Your Task

Use what you know about waves and energy to design and carry out an investigation that will allow you to describe the relationship between a wave's energy and its amplitude, wavelength, and frequency.

The guiding question of this investigation is, **How do frequency, amplitude, and wavelength of a transverse wave affect its energy?**

Materials

You will use an online simulation called *Wave on a String* to conduct your investigation. You can access the simulation by going to the following website: *https://phet.colorado.edu/sims/html/wave-on-a-string/latest/wave-on-a-string_en.html*.

Safety Precautions

Follow all normal lab safety rules.

Investigation Proposal Required? ☐ Yes ☐ No

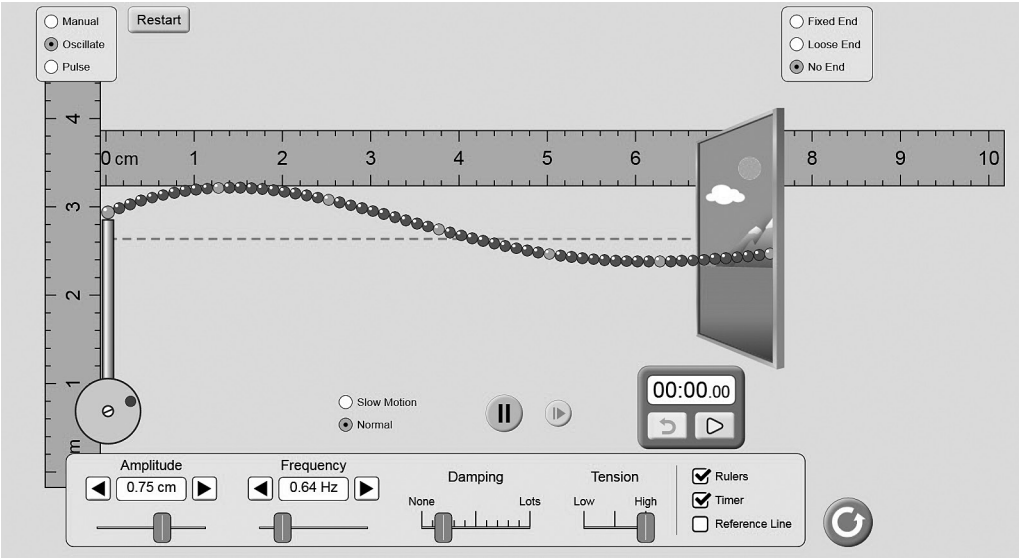
Getting Started

To answer the guiding question, you will need to design and carry out an experiment. To accomplish this task, you must determine what type of data you need to collect, how you will collect it, and how you will analyze it. The *Wave on a String* simulation allows you to propagate (start) and manipulate a wave on a virtual rope. The rope is shown as a series of red circles, with every ninth circle colored green (see Figure L19.2). This will make it easier for you to track and measure the properties of the various waves you create.

The upper-left-hand corner of the screen has a box with options for manual, oscillate, and pulse. These options allow you to choose how you will make the waves you will use for data. The "Manual" option requires that you move a wrench up and down to create a wave. The "Oscillate" option creates the wave for you, and you can adjust the frequency and amplitude of the waves using a slider that will appear at the bottom of the screen. Do not choose the "Pulse" option. Because this option only moves upward, it does not create a transverse wave and will not produce a wave that will be helpful for your investigation. You also have the option to use a rope with a fixed end, a loose end, or no end. The simulation provides rulers, a timer, and a reference line for you to use. To activate these tools, simply check the box next to each option. You can move the rulers by clicking

FIGURE L19.2

A screenshot of the *Wave on a String* simulation



and dragging them to different locations. You may start and pause the simulation at any time by selecting the play/pause button at the bottom of the screen. You can also view the simulation in normal time or in slow motion.

You will need to design and carry out at least three different experiments using the *Wave on a String* simulation in order to determine the relationship between frequency, amplitude, wavelength, and energy. You will need to conduct at least three different experiments, because you will need to be able to answer three specific questions before you will be able to develop an answer to the guiding question:

- How does changing the frequency affect the energy of the wave?
- How does changing the amplitude affect the energy of the wave?
- How does changing the wavelength affect the energy of the wave?

It will be important for you to determine what type of data you need to collect, how to collect the data you need, and how you will need to analyze your data for each experiment, because each experiment is slightly different.

To determine *what type of data you need to collect,* think about the following questions:

- What will serve as your independent variable in the investigation?
- What will serve as your dependent variable(s) in the investigation?
- How will you define and determine the amount of energy being put into the waves?

- How will you measure the various properties of the waves?

To determine *how you will collect your data,* think about the following questions:

- What simulation settings will you use to collect the data you need?
- How will you make sure that your data are of high quality (i.e., how will you reduce error)?
- How will you keep track of the data you collect?
- How will you organize your data?

To determine *how you will analyze your data,* think about the following questions:

- What type of calculations will you need to make?
- What type of table or graph could you create to help make sense of your data?
- How will you determine if there is a relationship between different variables?

Connections to Crosscutting Concepts, the Nature of Science, and the Nature of Scientific Inquiry

As you work through your investigation, be sure to think about

- how scientists work to explain the relationships between causes and effects;
- the importance of tracking how energy moves into, out of, and within systems;
- the difference between data and evidence in science; and
- methods used in scientific investigations.

Initial Argument

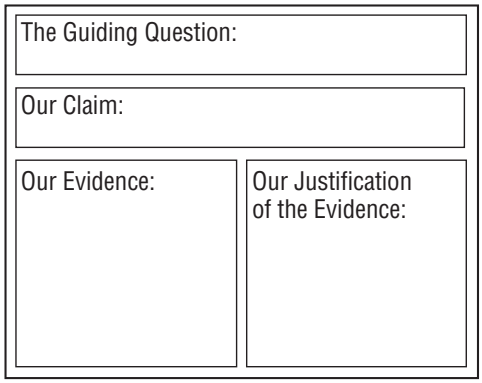
Once your group has finished collecting and analyzing your data, your group will need to develop an initial argument. Your initial argument needs to include a *claim*, *evidence* to support your claim, and a *justification* of the evidence. The claim is your group's answer to the guiding question. The evidence is an analysis and interpretation of your data. Finally, the justification of the evidence is why your group thinks the evidence matters. The justification of the evidence is important because scientists can use different kinds of evidence to support their claims. Your group will create your initial argument on a whiteboard. Your whiteboard should include all the information shown in Figure L19.3.

Argumentation Session

The argumentation session allows all of the groups to share their arguments. One member of each group will stay at the lab station to share that group's argument, while the other members of the group go to the other lab stations to listen to and critique the arguments developed by their classmates. This is similar to how scientists present their arguments

FIGURE L19.3

Argument presentation on a whiteboard



to other scientists at conferences. If you are responsible for critiquing your classmates' arguments, your goal is to look for mistakes so these mistakes can be fixed and they can make their argument better. The argumentation session is also a good time to think about ways you can make your initial argument better. Scientists must share and critique arguments like this to develop new ideas.

To critique an argument, you might need more information than what is included on the whiteboard. You will therefore need to ask the presenter lots of questions. Here are some good questions to ask:

- How did you collect your data? Why did you use that method? Why did you collect those data?
- What did you do to make sure the data you collected are reliable? What did you do to decrease measurement error?
- How did your group analyze the data? Why did you decide to do it that way? Did you check your calculations?
- Is that the only way to interpret the results of your analysis? How do you know that your interpretation of your analysis is appropriate?
- Why did your group decide to present your evidence in that way?
- What other claims did your group discuss before you decided on that one? Why did your group abandon those alternative ideas?
- How confident are you that your claim is valid? What could you do to increase your confidence?

Once the argumentation session is complete, you will have a chance to meet with your group and revise your initial argument. Your group might need to gather more data or design a way to test one or more alternative claims as part of this process. Remember, your goal at this stage of the investigation is to develop the most acceptable and valid answer to the research question!

Report

Once you have completed your research, you will need to prepare an *investigation report* that consists of three sections. Each section should provide an answer to the following questions:

1. What question were you trying to answer and why?
2. What did you do to answer your question and why?

3. What is your argument?

Your report should answer these questions in two pages or less. This report must be typed, and any diagrams, figures, or tables should be embedded into the document. Be sure to write in a persuasive style; you are trying to convince others that your claim is acceptable and valid!