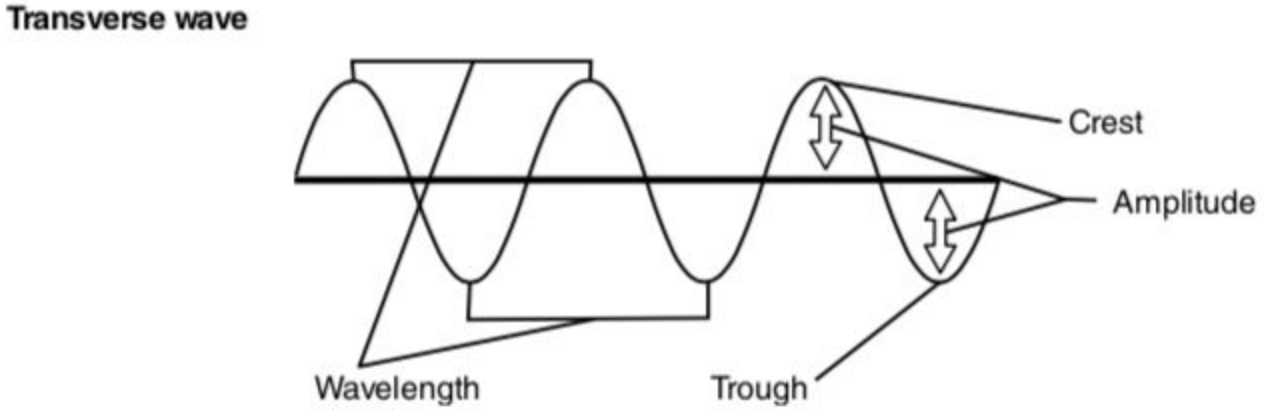
Wave Properties: How Do Frequency, Amplitude, and Wavelength of a Transverse Wave Affect Its Energy?

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 the figure below. 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.



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

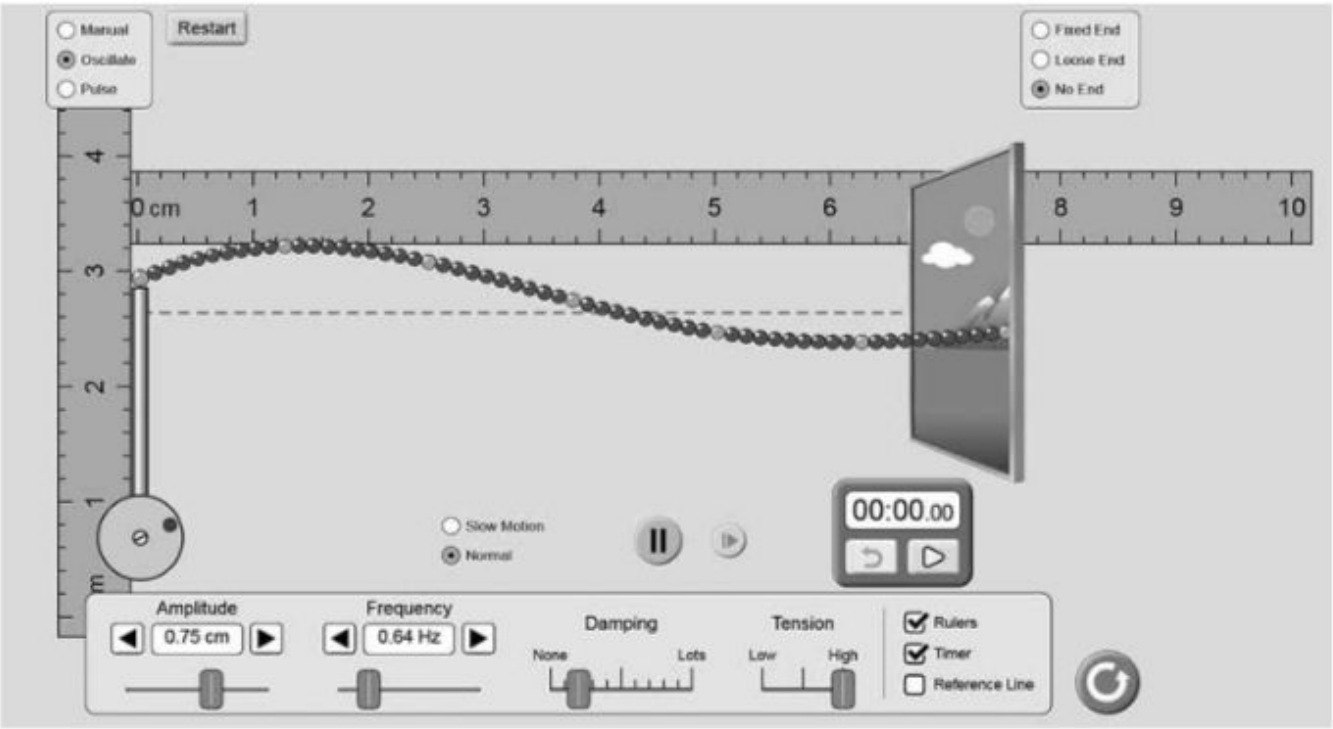
Use what you know about waves and energy to design and carry out an investigation that will allow you to describe the relationship between a wave's energy and its amplitude, wavelength, and frequency.

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

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 below). This will make it easier for you to track and measure the properties of the various waves you create.

A screenshot of the *Wave on a String* simulation



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 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 in 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?

Data table examples on next page

First option data table:

How Frequency, Amplitude, and Wavelength Affect Energy

	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
Frequency (Hz)					
Amplitude (cm)					
Wavelength (cm)					

Second option data tables:

How Frequency Affects Amplitude and Wavelength

**only change frequency and measure amplitude and wavelength*

	Trial 1	Trial 2	Trial 3
Frequency (Hz)			
Amplitude (cm)			
Wavelength (cm)			

How Amplitude Affects Frequency and Wavelength

**only change amplitude and measure frequency and wavelength*

	Trial 1	Trial 2	Trial 3
Frequency (Hz)			
Amplitude (cm)			
Wavelength (cm)			

Report

Once you have completed your research, you will need to prepare an investigation report that consists of four sections (be sure to have section headings):

1. Introduction: Give some background information on the topic. Explain what question you were trying to answer and include a hypothesis. (Background info, research question and hypothesis)
2. Procedure: What did you do during your investigation and why did you conduct your investigation in this way? (How you collected and analyzed data)
3. Data: Include a data table and/or graph to show your results. Be sure to include a title for your table or graph with labels for the variables.
4. Conclusion: What is your argument? (Claim - Evidence - Reasoning)

Your report should answer these questions in two pages or less. The report must be typed, and any diagrams, figures, or tables should be embedded into the document. Type your report on Google Docs (12 point font, double-spaced) and share it with your teacher. Your report will be graded based on the rubric in the class syllabus.