# The LIGO Cyberspace Explorer

Welcome to the LIGO Cyberspace Explorer! These Web-based activities connect to some of the exhibits at the LIGO Observatories. Perhaps you haven't visited a LIGO facility yet? Don't worry – you can still enjoy learning more about wave behavior, light and color, gravity and outer space as you do these virtual experiments!

Teachers can obtain a teacher's guide by sending an email to outreach@ligo-wa.caltech.edu

Scoping the Stars

In the same way that your fingerprint uniquely identifies you, a chemical element's spectrum identifies the element. At LIGO, you used a diffraction grating to look at light from the elements sodium and neon. You noticed the patterns of colored lines (the spectra) of each element. Astronomers hunt for the spectral patterns of chemical elements in star light. By matching the spectra of stars to the spectral patterns of the elements, astronomers can identify the elements in a star's atmosphere. Using the applet below, you will determine the elements in the atmospheres of a few mystery stars. Keep trying until you know which elements are present in the atmosphere of the first mystery star. List those elements on your Cyberspace Explorer Log. Try other stars. Your skill will increase as you analyze more stars.
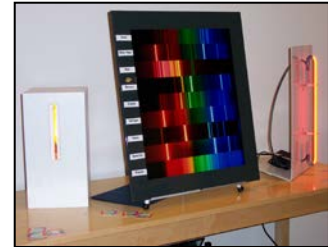
http://www.learner.org/teacherslab/science/light/color/spectra/spectra_1.html

Colored Shadows

Do you remember standing in the LIGO auditorium and casting shadows in multiple colors? Here you will change the color of two lights then observe the shadows created by a square that blocks parts of the light. Use your Explorer Log to explain what you think you would observe if there were three different colored lights (red, blue, and green) in this applet.

http://www.learner.org/teacherslab/science/light/color/shadows/index.html

Adding Colors

The retina of the human eye has three receptors for colored light. One is most sensitive to red light, another to green light, and the third to blue light. With these three receptors we are able to perceive more than a million different shades of color. Use this applet to mix the three primary colors at
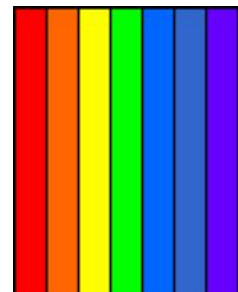
various intensities. When you're done experimenting, describe in your Explorer Log how to create the colors white and orange.

http://mysite.verizon.net/vzeoacw1/coloradd.html

Energy and Waves

At LIGO you explored a number of wave properties.   The applet below allows you to observe how the energy of a light wave can affect its properties. Will you be able to accurately measure the frequency and wavelength of the simulated light waves that you produce? Good luck!

http://amazing-space.stsci.edu/resources/explorations/light/makewaves-frames.html
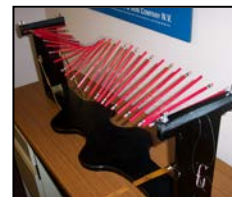
Compression Waves

The following applet simulates sound waves. These types of waves are called compression waves or longitudinal waves. They cause particles of the medium to vibrate back and forth in a direction that is parallel to the direction in which the wave propagates. Do you think air molecules must travel all the way from a sound source to your ear? Now you'll find out!

http://positron.ps.uci.edu/~dkirkby/music/html/demos/PlaneWave/Highlighted.html
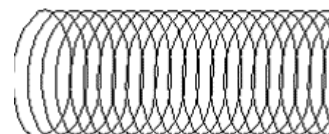
Transverse Waves

A transverse wave is a wave in which particles of the medium move in a direction perpendicular to the direction which the wave moves. Light is an example of this type of wave. Try adjusting the amplitude, wave length and frequency of the following transverse wave. Before you finish, describe the shape of a transverse wave that has small amplitude and a short wavelength.

http://www.ngsir.netfirms.com/englishhtm/TwaveA.htm
I
Resonance

Do you remember using the tuning forks at LIGO's sound wave station? Tuning forks are resonators – they don't vibrate at just any frequency; they prefer certain frequencies. This is why they produce pure sounds – they vibrate at pure frequencies (resonant frequencies). In this applet you'll need

to imagine that you are holding the spring by the red ball at the top. The controls let you shake the spring up and down at different frequencies. At what frequency can you make the spring and mass resonate? (At the resonance frequency, the mass will jump all the way up and down as the spring gets fully stretched and compressed.) Change the value of the "angular frequency" setting. On the scatter plot, try to move the tiny red ball to the top of the curve. Then start the spring and watch how it bounces.

http://www.walter-fendt.de/ph11e/resonance.htm

Wave Combination

Several of the wave activities at LIGO, such as the little Michelson Interferometer, involve a combination of waves. The fancy word for wave combination is *superposition*. The following applet provides a nice way to make a wave by combining two other waves. Below the applet graphing screen, you'll see some control buttons and two boxes with "Change" buttons next to them. The boxes contain the math equations that produce the top two waves. When the computer adds these two wave graphs together, the bottom wave graph is produced. Don't worry if the equations look complicated. Just start changing the numbers in the boxes, click the "change" button, and observe how the waves change.

Really cool hint: The wave equations probably read 2.5*sin(2.0*x-8.0*t) when the applet comes up. Add the magic math number "pi" to the top equation so it reads like this:

2.5*sin(2.0*x-8.0*t+3.14159)

Watch what happens to the combination wave (the bottom graph)! This is an example of destructive interference.

Here's the applet:

http://kingfish.coastal.edu/physics/physlets/Waves/superposition.html

Standing Waves

At LIGO you made standing waves on a string that was tied to an electric motor. Standing waves are easy to see when you make them, but understanding how they are produced can be tricky. This applet gives you a nice view of a single wave reflecting and creating standing waves. Change the display features to focus on different aspects of the wave system. Can you see the combination (superposition) of the transmitted and reflected waves?

http://www.walter-fendt.de/ph14e/stwaverefl.htm

Falling Objects

Suppose you dropped two objects from shoulder height. Would they fall at the same speed? Would this depend on their weight, size or other factors? The following applet helps you to solve the mystery that took mankind thousands of years to figure out!

http://www.eoascientific.com/campus/science/multimedia/weight_mass/view_interactive

Pendulum

A pendulum is a type of falling object. You experimented with a couple of pendulums at LIGO. Use this applet to control the string length and mass of the pendulum. Observe how the pendulum responds when you change these variables. Also observe the cool graphs that the applet provides as the pendulum swings!

http://www.walter-fendt.de/ph11e/pendulum.htm

Orbiting Planets

The planets in our solar system have orbits around the sun that are not perfect circles. An oval shape is called an ellipse; nearly all orbits are at least slightly elliptical. Use this applet to control the orbits of planetary bodies. Can you create stable orbits that prevent a planet from crashing into the sun? In your Explorer Log, describe how to safely launch the blue planet into a large elliptical orbit
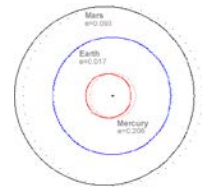
http://library.thinkquest.org/27585/lab/sim_solar.html