Name: Class:

WAVES
of matter

Visual Quantum Mechanics

ACTIVITY 3

Light and Waves

Goal
We will look at a property of light and learn how scientists conclude that light behaves as a wave.

The light from atoms indicates that only certain energy transitions occur in each atom. We were able to explain these results using energy diagrams. However, we have not yet explained why only certain energies occur in each atom or why these energies are different for different elements. To get to the reasons will take us a little time. We begin with a short diversion about the nature of light.

Interference of Light: Young's Experiment
Approximately 200 years ago, scientists (then called "natural philosophers") argued about the fundamental nature of light. In his book *Optiks*, Isaac Newton assumed that light consisted of a collection of minute particles. With this model, he explained most of the known optical experiments. Others thought that light must take the form of a wave. In 1801, Thomas Young completed an experiment that seemed to end this controversy.

In this activity, you will begin with an experiment very similar to one done by Young. Place a laser about two (2) meters from a sheet of white paper taped to a wall. With the room as dark as possible, aim the laser so that its beam is perpendicular to the paper. Remember: Never look directly into the beam coming from the laser. Then place a slide with two very small, closely spaced slits in the path of the laser beam, also perpendicular to the beam as shown in Figure 3-1.

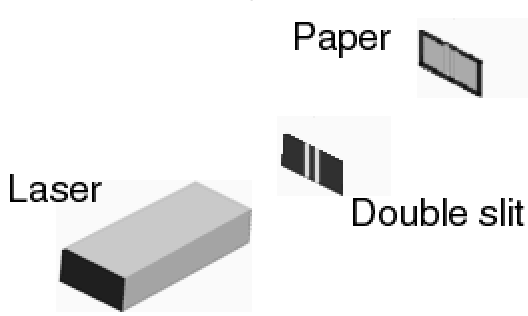

Figure 3-1: Diagram for Young's double-slit experiment.

 Visual Quantum Mechanics is supported by the National Science Foundation under grants ESI 945782 and DUE 965288. Opinions expressed are those of the authors and not necessarily of the Foundation.

You may have to adjust the position and orientation of the slits so that the laser light passes through both slits and forms a clear pattern on the wall.

In the space below, sketch and describe the pattern created by the light where it hits the screen.

We call such a pattern an *interference* pattern.

From these results Thomas Young concluded that light behaved like a wave and that Newton's particle model of light could not explain these observations. Even though Newton was an intellectual giant essentially everyone agreed with Young. To see why, we need to complete a couple of short experiments.

The first experiment involves a version of the two-slit experiment of Young. We will use something that we know is a wave. It's a wave drawn on a piece of plastic. Along the solid line mark with an X locations where the addition of the two waves is a maximum (constructive interference). Place zeros where the two waves cancel each other (destructive interference). Taping one end of the plastic waves to a wooden block will hold that location fixed and will serve as the two slits. Place the block with waves on the paper so that the two slits are approximately at the two dots below with the waves extending toward the bottom of the page.

Other groups used different amplitudes or wavelengths for this experiment. Compare your results with others in the class and answer the questions below.

How does the distance between zeros depend on

wavelength?

amplitude?

We will use this information soon.

Try a similar experiment with some particles. To simulate objects similar to Newton's particles of light you will use BBs. Place a blank piece of paper in a shallow pan. Over this paper place a sheet of carbon paper with the carbon side down.

To simulate the two slit experiment place the BBs in a small box with two holes in it. Over the carbon paper take your fingers off the holes and let the BBs drop. A carbon mark will appear where the BBs land. [Hint: A much better pattern appears if the carbon paper is placed on a hard surface that is angled so that when the BB's bounce they don't land back on the carbon paper.]

Describe the pattern of particle locations.

? You have now completed three two-slit experiments. One each with light, waves and particles. Use the results of these experiments to describe why Young concluded that light behaved as a wave.

As you see with these experiments, interference — the pattern of light and dark for light — only occurs for waves. Particles can't do it.

Now, you will complete a simulation of an experiment which at first thought seems rather strange. A double slit experiment using electrons. This type of experiment can be done, but the equipment is rather expensive. Open the *Double Slit* program and click on the source tube labeled *Electrons* on the left side of the screen. Click *Start* to see what happens. Describe the pattern below.

? Which pattern(s) — light, waves or BBs — does the pattern for electrons resemble?

? What can you conclude about the behavior of electrons in a Double Slit experiment?

Similar experiments resulted in a conclusion that electrons behave as waves. This result was surprising but inescapable. As we shall see, it is confirmed in many situations.

First, let us see how this pattern changes with the energy of the electron. Keeping other variables fixed try at least four different energies and record the distance between consecutive dark areas on the screen.

Electron Energy (eV)	**Distance between dark areas**

? How does the distance between dark areas change as the energy increases?

? For the plastic waves look at how the distance between zeros changed with wavelength. Use that information to describe below how the electron's wavelength changes as the energy increases.

In the next activity we will use all of the results from this one to connect the wave properties of electrons to other properties such as momentum and energy.