How Thick is Your Hair? GUIDE

INTRODUCTION: In the last experiment we saw what happened when laser light was passed through fabric to find its wavelength as long as we knew how far apart the threads were. Now we can use wavelength to find the width of a hair.

KEY QUESTION: How can a laser be used to measure the width of a human hair?

MATERIALS:

- Laser pointer
- Tape
- Large sheet of paper
- Human hair
  (Ask nicely before plucking this from your friend's head)
- Binder Clips (2)
- Scissors
- Pencil
- Index card
- Ruler

BEFORE THE ACTIVITY, STUDENTS KNOW:

- Light can act like a wave.
- A laser pointer is a beam of light that is coherent and all the same color.

AFTER THE ACTIVITY, STUDENTS SHOULD BE ABLE TO:

- Describe how wave interact
- Explain the pattern formed on the wall when a laser is shined on a human hair
- Explain how to use this pattern to measure the width of a small obstacle such as a human hair.

THE SCIENCE BEHIND DIFFRACTION

Light is both a particle and a wave, or better yet, light has both wave properties and particle properties. In this kit we will do experiments that will show both sides of light. This experiment is one that shows that light has wave This is tricky thing to comprehend.

Lets start by thinking about what happens when waves interact. We will assume that we are dealing with two waves that have the same wavelength. When two waves come together they add up to make a resultant wave. If the two waves have crests and troughs at the same points, they add up to make a wave that is twice as big as the two individual waves. This is called "constructive interference." When two waves have crests and troughs at the same points they are said to be "in phase." If two waves are completely "out of phase" which means one wave is up while the other is down, they cancel each other out. This is called "destructive interference."

When water waves flow around a pylon because they spread out on the other side of the pylon they will come back together and interact with each other. Sometimes they constructively interfere and sometime they destructively interfere. If we were to measure the height of the waves on the other side of the pylon we would sometimes see big waves and sometimes see no waves at all.

You have always heard that light always goes in a straight line. Well it does. Except when it doesn't. When light encounters and obstacle that is really small, only slightly larger than the wavelength of light, it will spread out again as it passes the obstacle, just like water flowing around a pylon. This is called diffraction. So light behaves just like the example of water flowing around the pylon that we talked about before. But what does this have to do with finding the thickness of a hair? Well, as the light goes around the hair it is going to come back together at different points based on the thickness of the hair and the wavelength of light. (Figure 2) Sometimes the light waves will cross when they are both up, sometimes they will cross when one is up and one is down. It will depend on the wavelength of light and how far it has traveled. (Fig. 3) If the wavelength of light is smaller, say, blue or green light, then the pattern you would see would have the bright spots closer together. What do you think you would see if you could do this with white light?

So far we know the pattern on the wall depends on at least two different things, the thickness of the hair and the wavelength of the laser Does it depend on anything else? Imagine what would happen if you moved the hair closer to the wall. The pattern would change. In fact, the spots would get closer together. The mathematical way of saying all this is: thickness of hair=((wavelength of laser) * (Distance from hair to wall))/(average spacing between bright spots).

So to find the thickness of the hair, we need to know the wavelength of the laser. If you have done activity one you can use the value of wavelength you found there. If not, or if you are not sure of your answer to activity one, the wavelength of your laser is 670nm. In doing this experiment it is going to be necessary to pay close attention to units of distance. I would recommend changing everything to meters and then changing micrometers to determine your final answer. This will allow students to get practice in unit conversion.

KEY TERMS:

Wavelength: The distance from one wave peak to the next.

Diffraction: When light goes around an obstacle or through a single slit the light rays interact with each other. When they do, a patterns of dark and bright spots is created.

Interference: When light passes through two slits and the light rays from each of the slits interacts. It is like diffraction but involves more than one slit or obstacle.

Constructive Interference: When two waves come together and make a bigger wave

Destructive Interference: When two waves come together and cancel each other out

In Phase: When two waves are going up and down together

Out of Phase: When one wave is going up as the other is going down

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EXPERIMENT 2

How Thick is Your Hair?

TEACHER'S GUIDE

■ SAFETY:

Review these guidelines closely with students before the activity and outline consequences for failure to follow them! Warn students very strongly about the dangers of looking directly into the laser beam. Shining the beam into their eyes of the eyes of their classmates an cause serious injury and damage. Consequences for student recklessly playing with the lasers should be outlined before giving out the supplies for the activity. If you are concerned, you may prefer to complete the portions of the procedure with the laser for your students and have them do the analysis.

■ CORRESPONDING EXTENSION ACTIVITIES

- Spiraling CDs and DVDs
- Prisms
- Colors of Compact Florescent Bulbs

■ BIBLIOGRAPHY/SUGGESTED RESOURCES

http://www.exploratorium.edu/snacks/diffraction/index.html

Figure 1

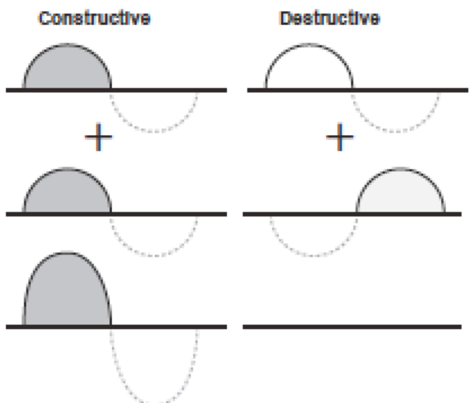


Figure 2

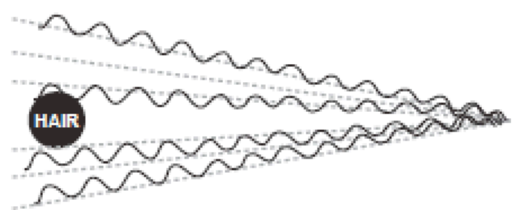


Figure 3

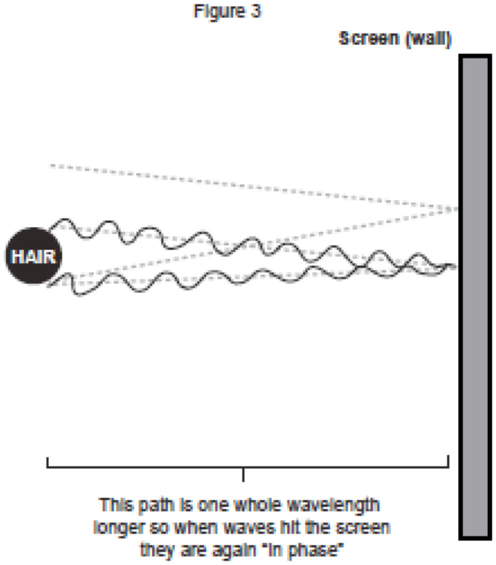
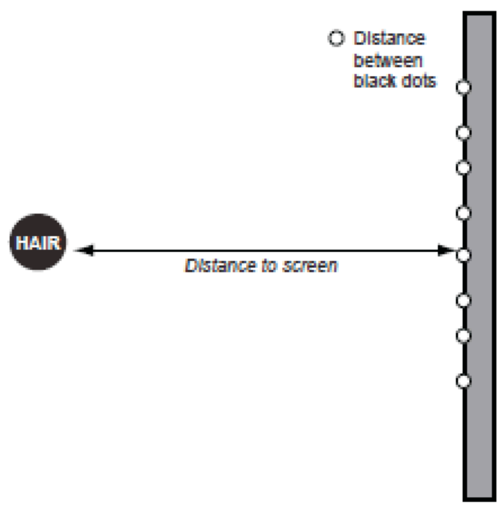


Figure 3



What is the width of a hair?
Do blondes have thinner hair?

To do and notice:

Pluck a hair from your head or ask someone to donate one of theirs to you. Tape the strand of hair on the index card. (Look at the sample.) Attach a binder clip to the side of the index card.

Stand the card in front of a laser. Align the LASER so that it shines directly on the hair. Look at the screen and notice the series of bright and dark spots. By measuring the distance between dark spots on either side of the central bright spot, you can measure the width of your hair!

Use the hair ruler and line up the edge of the ruler to the middle of a dark spot. The distance to the middle of the next dark spot tells the diameter of the strand of hair in micrometers.

What's going on?

Because light usually behaves like a wave, it bends around the edges of an object in a process called *diffraction*. When you shine light on a single strand of hair, the light that passes to either side will bend toward the middle of the strand. The thinner the width of the hair, the more the light diffracts around it. When the light waves from each side of the hair overlap they will add together to create bright and dark spots. This is called *interference*. The result is a series of bright and dark spots on the wall.

LIGO Connection: The interferometer uses a LASER to set up interference patterns to detect gravitational waves.