Diffraction Lab: Grooves on a CD & Width of a Hair

The purpose of this lab is to use the diffraction properties of light to measure some extremely small lengths: the spacing of grooves on a CD and the width of a human hair.

# Background

According to *Huygen’s Principle* each point on the wavefront (crest) of a wave can be considered to be a source of a new wave, expanding out in all directions. Thus, when waves pass through a narrow opening (slit), waves expand in concentric circles on the other side of the slit. If you have more than one slit, the circularly expanding waves with interfere with one another. Where the two waves are in phase (crest-meets-crest, trough-meets-trough) the two waves *constructively interfere* and the wave intensity is increased. Where the two waves are out of phase (crest-meets-trough) the two waves *destructively interfere* and cancel each other out. This is why, when light is passed through two (or more) slits, a pattern of light and dark spots appears – the light spots correspond to locations where the waves passing through the slits constructively interfere; the dark spots correspond to destructive interference.

Figure 1: A wave whose wavefronts are

 parallel to each other pass

 through two slits. Circularly

 expanding wavefronts emerge

 on the far side of the slits.

 Notice that you can draw

 straight lines, connecting

 locations where crest-meets-

 crest. Constructive inter-

 ference thus occurs along the

 three arrows shown between

 the slits and the screen.

 These arrows show where bright spots will appear on the

 screen.

Consider the situation below:

Light with wavelength λ passes through slits distance *d* apart. Distance *L* behind the slits is a screen. The central bright spot appears at point *P0* . The next bright spot appears distance *x* away at point P1.

Figure 2:

P1

x

S1

d

P0

S2

L

Since the distance from *S1* to *Po* is equal to the distance from *S2* to *Po*, waves from both slits arrive at *Po* in phase, so a bright spot appears. Similarly, if the distance from *S2* to *P1* is exactly one wavelength longer than the distance from *S1* to *P1* , then waves from both slits will also arrive at *P1* in phase, and a bright spot will appear there as well.

Using geometry, one can show that the following relationship must be true:

λ = xd/L

This formula also holds if you have *many* slits. By passing light through tiny slits, and *carefully* measuring *L*, *x*, and *d*, Young was the first person to calculate the wavelength of visible light.

# Part I: How Many Grooves are on a CD?

The grooves on a CD can act like tiny slits, diffracting light. By reflecting laser light off of a CD, we will observe a diffraction pattern and measure the spacing between the grooves.

1. Use some modeling clay to stand a CD upright on your table. Shine your laser onto the CD so that the laser reflects at an angle as shown below. Use an 8.5x11 sheet of paper (taped to a binder, stood vertically) to catch the reflected beam about 30 cm from the CD. *Make sure your paper is oriented perpendicular to the reflected beam, or the lengths you measure will be incorrect!* Set it up so that one of the next bright spots on either side of the central bright spot also appears on your paper.

8.5 x 11 paper taped to binder

Figure 3:

Central bright spot

Next bright spot

Laser

Main reflected beam strikes the paper at a perpendicular angle.

CD (held up by modeling clay)

1. Carefully measure the distance (in meters) from the CD to the central bright spot. (Is this L or x, according to Figure 2?). Record this information in Table 1.
2. Carefully measure the distance (in meters) along the paper from the central bright spot to the next bright spot. (Is this L or x, according to Figure 2?). Record this information in Table 1.
3. The light shined by the laser has a wavelength of roughly 632 nm

(6.32 x 10-7 m). Use this information, along with your values for *x* and *L* to calculate the distance *d* between the grooves on the CD.

1. Repeat steps 1-4, slightly changing the angle at which the laser strikes the CD each time.
2. Find the average of your calculated values for *d*. Record this in Table 1.

Table 1

|  |  |  |  |
| --- | --- | --- | --- |
| Trial | L (meters) | x (meters) | d (meters) |
| Trial #1 |  |  |  |
| Trial #2 |  |  |  |
| Trial #3 |  |  |  |
| Average | \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* | \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* |  |

Analysis Question:

1. How many grooves are in the 3 cm ring of a CD?

# Part II: Width of a Human Hair

In this activity, we will diffract laser light around a human hair to measure its width. Each student should find the width of his/her own hair.

1. Obtain a hair from your head. Tape the hair at either end to a microscope slide like so:

Figure 4:

Microscope slide

Tape

Hair (lined up with the slide)

1. Stand the slide up with a piece of modeling clay and shine a laser through it so that the laser is hitting the hair. (Make sure the laser is NOT striking the tape, or any piece of dust or smudge on the slide). When the laser goes around the hair, it will diffract slightly like it’s going through a double-slit.
2. *On the far side of the room,* catch the diffraction pattern on a piece of paper. Carefully measure the distance (in meters) from the slide to the paper. (Is this *x* or *L?)* Record this number in Table 2.
3. Carefully measure the distance (in meters) from the center of the central bright spot to the center of the next bright spot. (This may be a little difficult to see. Just do your best!) Is this *x* or *L*? Record this number in Table 2.
4. Calculate the width *d* of your hair.

6. Repeat steps 1-5 for all people in your lab group.

Table 2

|  |  |  |  |
| --- | --- | --- | --- |
| Student | L (meters) | x (meters) | d (meters) |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |

Analysis Question:

1. In your lab group, who had the thickest hair? How thick was it? Who had the thinnest hair? How thin was it?

When you are finished, please throw away the hair and tape, wash the modeling clay off of your microscope slides and CD’s, and return all lab materials to their proper locations.

Write a complete lab report for this activity. Be sure to include, among other things, sample calculations, and a summary listing your major results, and any possible sources of error.