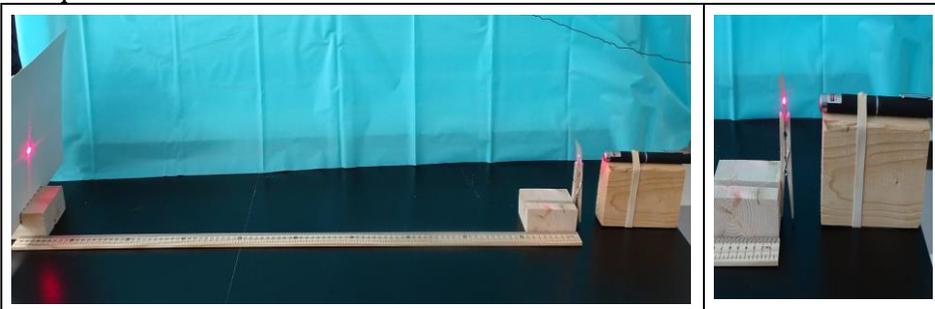


Diffraction Teacher Activity Guide

Activity 1: Wire Mesh

Set-up:



Section One: Measuring the Mesh

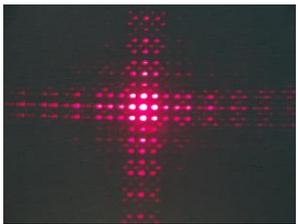
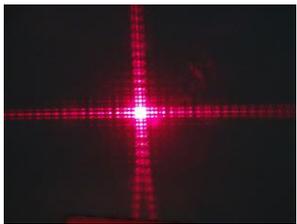
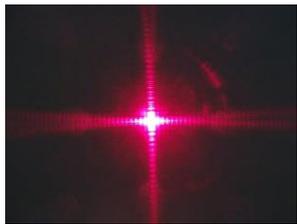
Fine Mesh	Medium Mesh	Large Mesh
<i>Distance along ruler = 1mm</i>	<i>Distance along ruler = 1mm</i>	<i>Distance along ruler = 1mm</i>
<i>Number of wires = 8</i>	<i>Number of wires = 4</i>	<i>Number of wires = 2</i>
<i>Distance Between Wires</i>	<i>Distance Between Wires</i>	<i>Distance Between Wires</i>
<i>d = 0.125 mm</i> <i>d = 1.25 x 10⁻⁴ m</i>	<i>d = 0.25 mm</i> <i>d = 2.5 x 10⁻⁴ m</i>	<i>d = 0.5 mm</i> <i>d = 5.0 x 10⁻⁴ m</i>

Section Two: Predicting the Pattern

Fine Mesh	Medium Mesh	Large Mesh
Diffraction Pattern Spacing $w = L \times \lambda/d$	Diffraction Pattern Spacing $w = L \times \lambda/d$	Diffraction Pattern Spacing $w = L \times \lambda/d$
<i>w = 0.0052 meters</i>	<i>w = 0.0026 meters</i>	<i>w = 0.0013 meters</i>
<i>w = 5.2 mm</i>	<i>w = 2.6 mm</i>	<i>w = 1.3 mm</i>

Section Three: Measuring Diffraction Patterns



Fine Mesh	Medium Mesh	Large Mesh
		
$w =$ Distance between spots $w \approx 8-9 \text{ mm}$	$w =$ Distance between spots $w \approx 2-3 \text{ mm}$	$w =$ Distance between spots $w \approx 1-2 \text{ mm}$

Section Four: Questions

1) Which mesh produced a larger diffraction pattern, medium, or fine mesh?

The fine mesh produced a larger diffraction pattern (see images from section 3).

2) Write a hypothesis predicting whether the fine mesh will produce a larger or smaller diffraction pattern spacing than large mesh?

Example
*If we shine a laser at the fine and large mesh,
 Then the fine mesh will produce a larger diffraction pattern spacing
 Because our results showed that the medium mesh had a smaller diffraction pattern spacing than the fine mesh.*

4) Observe the diffraction pattern for the large mesh. Was your hypothesis correct? Why?

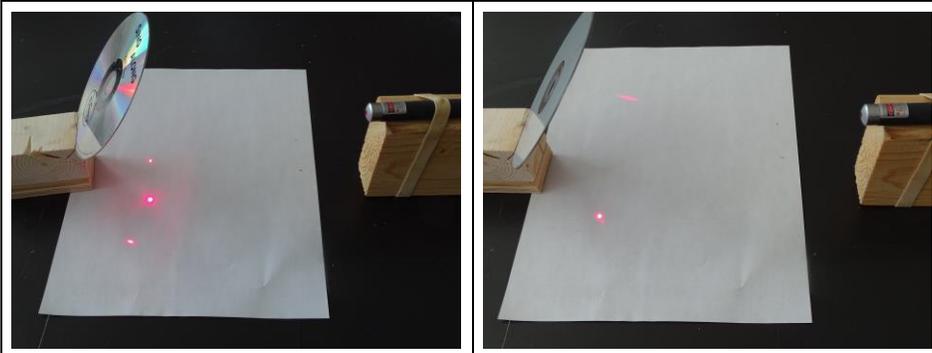
Students should notice that distance between spots is much smaller on the large mesh. It is difficult to measure from 1 meter. If you have room, you can try them at 2 meters.

Activity 2: CD/DVD

Set-up:

CD	DVD
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Section One: Polychromatic Light

1) Note at least two observations about the CD and DVD.

The CD and DVD split white light into a spectrum of color.

The colors that are seen in the CD and DVD are different.

2) What are the differences you notice between the CD and DVD?

The DVD sprays the colors over wider angles because the lines on it are far closer.

Section Two: Measuring Track Spacing

CD Track Spacing		DVD Track Spacing	
L =	9 cm	L =	9 cm



$w =$	<i>Will vary between 4.5 - 6.0 cm</i>	$w =$	<i>Will vary between 16 - 21 cm</i>
$d =$	distance between CD tracks $L \times \lambda \div w$ $9 \times 0.000065/4.5$ $= 0.00013 \text{ cm}$	$d =$	distance between CD tracks $L \times \lambda \div w$ $9 \times 0.000065/16$ $= 0.00003656 \text{ cm}$
	$1.3 \times 10^{-6} \text{ m}$		$3.656 \times 10^{-7} \text{ m}$
	0.0013 mm		0.0003656 mm
<i>Accepted track spacing is 1.6 microns (0.0016 mm)</i>		<i>Accepted track spacing is 0.74 microns (0.00074 mm)</i>	

Number of CD Tracks per millimeter = $1/d$	Number of DVD Tracks per millimeter = $1/d$
= 769	= 2,735
<i>Measurements can vary greatly in this activity. One common place of error is that the CD/DVD is not exactly at 45°. This can drastically change the w measurement.</i>	



CD/DVD Data

	CD	DVD
Diameter (mm)	120	120
Disk Thickness (mm)	1.2	1.2
Substrate Thickness (mm)	1.2	0.6



Track Pitch (micrometers)	1.6	0.74
Minimum Pit Size (micrometers)	0.83	0.4
Wavelength of Laser Reader (nm)	780	635/650
Data Stored on One Layer (Gigabytes)	0.65	4.7

Activity 3: Hair Thickness

Set-up:

A simple and cheap hair mounting device can be made with cardboard and double sided tape. Thin wire can also be used as a substitute for hair.





Section One: Measuring Hair Thickness

Measurements can be made from the center of diffraction minima or maxima.

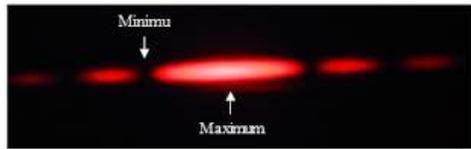


Figure 1 The bright spots are the maxima, the dark spots between them are the minima.

$$\begin{aligned}
 d &= L \times \lambda / w \\
 &= 2 \text{ m} \times 6.5 \times 10^{-7} \text{ m} / 0.025 \text{ m} \\
 &= 5.2 \times 10^{-5} \text{ m} \\
 &= 0.052 \text{ mm}
 \end{aligned}$$

Section Two: Questions

1) Measure several different hairs. Are all of your hairs the same thickness?

Hair thickness can vary even from the same person. The average human hair thickness is between 0.02 mm – 0.12 mm.

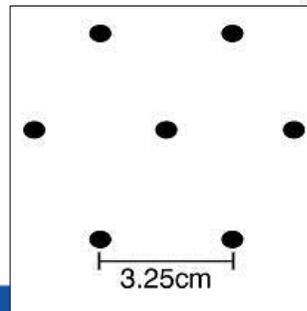
2) Are your hairs the same thickness as other people’s hairs?

Hair thickness varies greatly from person to person. The average human hair thickness is between 0.02 mm – 0.12 mm.

Further Questions

Question 1:

The membrane from a water purifier has millions of very small holes in it. A laser pointer was used to project the diffraction pattern from the membrane onto a screen. The screen was 1 m from the purifier membrane and produced a diffraction pattern with a spacing of 3.25 cm as shown to the right.



What is the average distance between the holes in the water purifier membrane?

Wavelength of laser pointer = 650 nm.

$$\begin{aligned} d &= L x \lambda / w \\ &= 1 \text{ m} x 6.5 \times 10^{-7} \text{ m} / 0.0325 \text{ m} \\ &= 0.00002 \text{ m or } 0.02 \text{ mm} \end{aligned}$$

Question 2:

Early in the morning, sunlight streams through an east facing kitchen window and projects an image of the window onto the western wall of the kitchen. The window is covered by a mesh security screen. The grid spacing of the security mesh is 1.3 mm. The distance between the western wall of the kitchen and the security mesh is 2.5 m.

- a) Assuming sunlight has a mean wavelength of $\lambda = 560$ nm, what is the spacing of the diffraction pattern projected onto the western wall?

$$\begin{aligned} w &= L x \lambda / d \\ &= 2.5 \text{ m} x 5.6 \times 10^{-7} \text{ m} / 0.0013 \text{ m} \\ &= 0.0011 \text{ m or } 1.1 \text{ mm} \end{aligned}$$

- b) The window is 1.3 m high and 0.85 m wide. Compare the spacing of the diffraction pattern to the size of the window. Would you be able to see diffraction at the edges of the image?

The diffraction pattern is only due to the security mesh and not the size of the window. In the first sentence, it states that you can see the image of the window on the western wall, therefore, you do see the diffraction at the edge of the window. (Hopefully I'm interpreting the question the right way)

- c) Suppose the security mesh is replaced with a much larger grill with a spacing of 1 cm between the wires? How large would the diffraction pattern be now? Could you see something this small?

$$\begin{aligned} d &= L x \lambda / w \\ &= 2.5 \text{ m} x 5.6 \times 10^{-7} \text{ m} / 0.01 \text{ m} \\ &= 0.00014 \text{ m or } 0.14 \text{ mm} \end{aligned}$$

Would not be able to see as it is 10X's smaller than 1 mm

Question 3:

Laser pointers often come with a little kit of holograms. One hologram, when illuminated with the laser, projects a smiley face onto a wall 3 m away. Using a red laser pointer ($\lambda = 630$ nm) the

Commented [1]: I think this is a pretty confusing question and not one they know how to deal with the information given.

I think the answer to this is that the wall is not far away enough in comparison to the window size to be in the "far field limit", so it's not coherent enough to give diffraction spots, but I don't think that's a good question for this work sheet. We should either get rid of it (maybe this whole problem!) or replace it with something they can do.



smiley face has a diameter of 63 cm. If a blue laser ($\lambda = 400 \text{ nm}$) were used to project the same hologram how large would the smiley face be?

$$\lambda_1/w_1 = \lambda_2/w_2$$

$$6.3 \times 10^{-7} \text{ m}/0.63 \text{ m} = 4.0 \times 10^{-7} \text{ m}/w_2$$

$$w_2 = 0.401 \text{ m or } 40 \text{ cm}$$

Question 4:

Shine the laser pointer onto the wall. Try to “pinch” off the beam with your finger and thumb. What do you see as the gap becomes smaller? Explain, using the concept of diffraction, why the spot doesn’t just “blink out.”

The diffraction spot should get larger, the smaller the gap becomes (the pinching of your finger and thumb). Diffraction is proportional to the wavelength and inversely proportional to the gap, as the gap gets smaller the diffraction spreads because there is less interference as light moves through the gap.

Question 5:

Long Play vinyl records also have circular tracks or grooves. Voyager, the spacecraft that visited all the planets, has a gold LP on it. LPs have 240 grooves per inch.

- a) Suppose you performed the CD/DVD experiment with the gold LP. What would be the spacing of the dots you would observe?

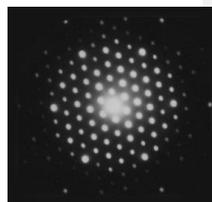
*LP has 94 grooves/cm, which is 1/8 of a CD (769/cm).
 Spacing for CD is 4.5 cm
 Gold LP spacing = 4.5 cm/8
 = .56 cm*

- b) Why can’t you store as much information on a vinyl record as a CD or DVD?

There are fewer tracks to store data.

Question 6:

In an electron microscope, a beam of electrons is accelerated to great energy (1 KeV or more) and fired through thin films of material. The beam is then projected onto a screen. Here is the pattern that forms when the beam passes through a thin sheet of aluminum.



a) Are the electrons behaving like a wave or a particle? Each atom in the aluminum film acts like a point on a mesh grid.

The answer is both. (Trick question). The electrons behave like waves when it diffracts the aluminum film leaving a diffraction pattern. However, it can also act like a particle when it scatters off the atom, where there is a transfer of linear momentum and the electrons are scattered to the specific diffraction spot.

b) Electrons with an energy of 10 KeV have a wavelength of $\lambda = 1.2 \times 10^{-11}$ m. This image was taken $L = 30$ cm back from the aluminum film and the spots are separated by a distance of 1.6 cm. What is the distance between the aluminum atoms?

$$\begin{aligned} d &= L \times \lambda / w \\ &= 0.3 \text{ m} \times 1.2 \times 10^{-11} \text{ m} / 0.016 \text{ m} \\ &= 2.25 \times 10^{-10} \text{ m} \text{ or } 2.25 \times 10^{-7} \text{ mm} \text{ (0.000000225 mm) or } 0.225 \text{ nm} \end{aligned}$$

c) Check that your answer is reasonable. One mole of aluminum atoms (6.02×10^{23}) occupies a volume of 10 milliliters. What is the average volume for each atom? If each atom were spherical, what radius would that correspond to?

$$10 \text{ mL} = 0.01 \text{ L}$$

$$\text{Volume of one aluminum atom} = 0.01 \text{ L} / 6.02 \times 10^{23} = 1.66 \times 10^{-26} \text{ L}$$

$$1.66 \times 10^{-26} \text{ L} = 1.66 \times 10^{-29} \text{ m}^3$$

$$\text{Radius} = (1.66 \times 10^{-29} \text{ m}^3)^{1/3} / 2 = 1.28 \times 10^{-10} \text{ m} = 0.128 \text{ nm}$$

$$\text{Diameter} = 2 \times 0.128 \text{ nm} = 0.256 \text{ nm. Similar to } d \text{ from diffraction!}$$

