Name:______________________________Date:_______________Class:________________

Student Worksheet

Uncertainty Measurements and the Wavelength of Light

Safety
Never look directly into a laser.
Never shine a laser into another person's eye.

Introduction

The closest star to the Earth, not counting our Sun, is about 26,000,000,000,000 miles away. The speed of light is about 300,000,000 meters per second. Mount Everest is about 29,029 feet high. The thickness of a human hair is about 0.0001 meters. An atom of gold has a radius of about 0.000000000135 meters or .135 nanometers.

All of these values are real and accepted by the scientific community. How are these values, both extremely large and extremely small, measured? Obviously, some of these values are approximate, while others are accurate. But *how* accurate are they?

In this lab, you will see firsthand how measurements account for accuracy and how measurements are reported to show this accuracy. You will also see that very small objects (in this case, the wavelength of light, at the nanoscale) can be measured fairly easily with typical science classroom supplies. When measuring on the nanoscale, accuracy is very important due to the extremely small size. Because of the small dimensions at the nanoscale it becomes imperative to be able to accurately measure materials and devices.

Light can be described as a wave, similar to that of ocean waves. In describing it as such, the distance between crests of successive waves (wavelength) can be measured. In fact, different colors of light have different wavelengths (and frequencies). This is what distinguishes between red from blue, or green, or violet, etc. As you will see, these wavelengths are very small on the nanoscale ~400-700nm. In this lab, you will measure the wavelength of three different colors of light and calculate the uncertainty of your measurement.

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Materials
- Lasers of different colors
- Ring stands
- Diffraction grating
- Screen (whiteboard, wall, etc.)
- Meter stick

Question: Which color of light has the greatest wavelength? Using typical high school science lab supplies, within what percentage can you measure the wavelength of light?

Make a Prediction:

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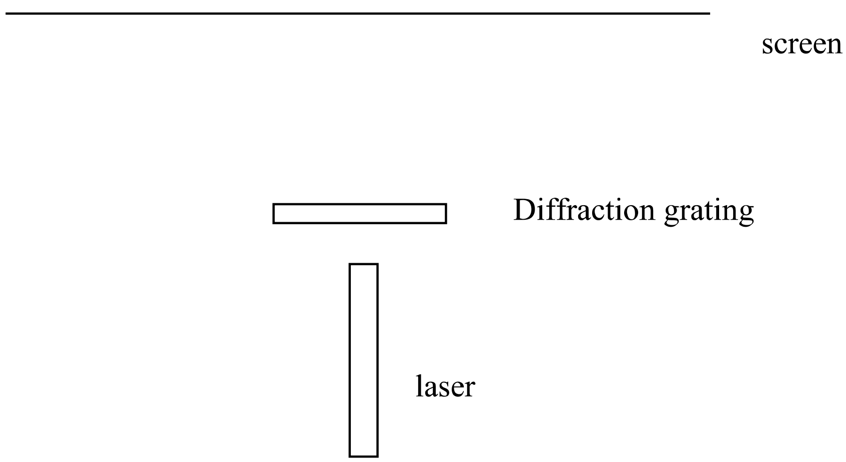
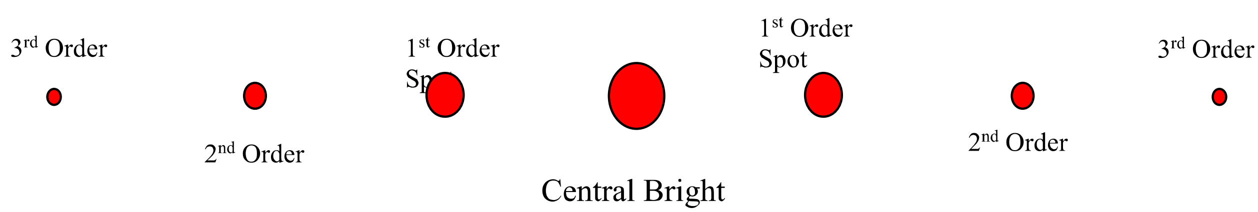
Procedure:

1. Set up your lab bench as shown in the diagram below. Ring stands not shown for clarity.



Overhead view of lab set-up

2. Be sure that laser is securely attached to its support and that the diffraction grating is perpendicular to the beam of the laser.
3. Record the grating spacing, in meters per line, using the information provided on the grating.
4. Turn the laser on and observe the diffraction pattern on the screen. If the pattern is seen vertically, rotate the diffraction grating 90 degrees. You should be able to see the central bright spot along with *at least* the 1st and 2nd order spots, as shown below. (Diagram not to scale.)



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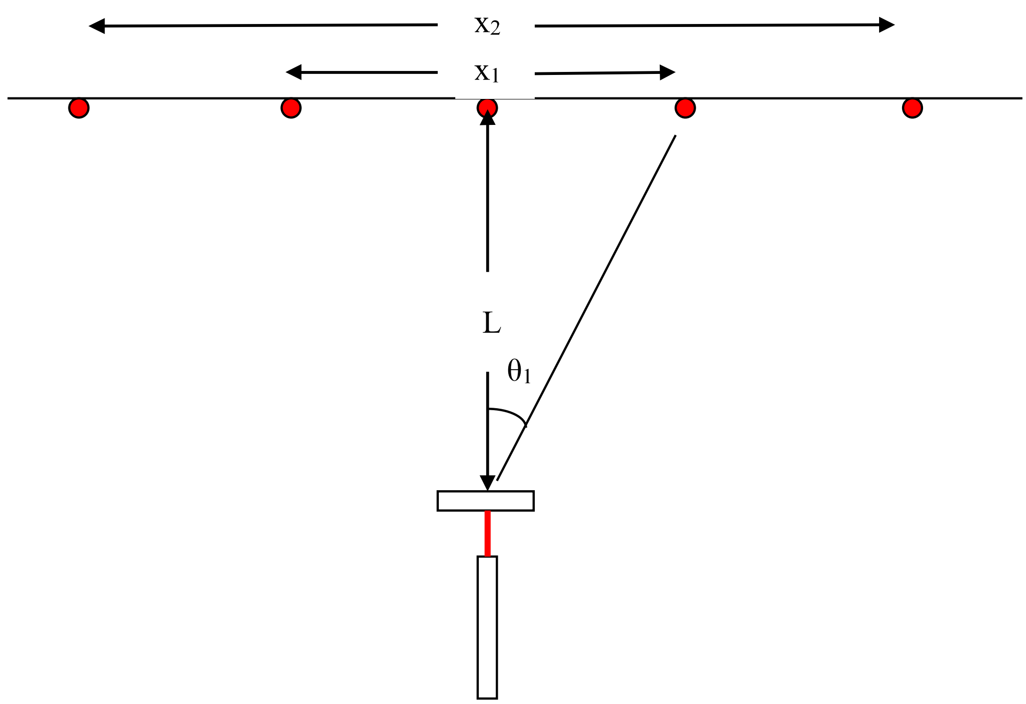
5. Measure the distances between the two 1st order spots, the two 2nd order spots, and the two 3rd order spots, if possible. Record these in the table below. Be certain to include your uncertainty.
6. Measure the distance between the diffraction grating and the screen. Record in the Data Table below. Include your uncertainty.

7. Refer to the diagram below. Notice that θ_1 is the angle between the laser beam and the *1st order* spot.



8. From trigonometry you can calculate the value of θ_1, θ_2, and θ_3 using the relationship

$$\tan\theta_m = \frac{x_m}{2L} \text{ where m = 1, 2, 3, …}$$

Record these values in the Results Table below. Be sure to include your uncertainty.

9. You can now use the relationship from optics to find the wavelength of your laser beam. Use the following relationship to solve for the wavelength, λ, in nanometers. Note that d is the grating spacing.

$$d\sin\theta_m = m\lambda \text{ where m = 1, 2, 3}$$

Record these values in the Results Table below. Be sure to include your uncertainty and express it as an absolute uncertainty.

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10. Repeat for lasers of two different colors, or as instructed.

Cleanup: Return all supplies to their original locations.

Data Table

Color of Laser	d, Grating spacing, m/line	L, Distance from diffraction grating to screen, m		x_1, Distance between 1st order spots, m		x_2, Distance between 2nd order spots, m		x_3, Distance between 3rd order spots, m	
		Value	Uncert	Value	Uncert	Value	Uncert.	Value	Uncert.

Analyze the Results:

Results Table

Color of Laser	θ_1		θ_2		θ_3		λ_1, nm		λ_2, nm		λ_3, nm	
	Value	Uncert	Value	Uncert	Value	Uncert	Value	Uncert	Value	Uncert	Value	Uncert

Clearly show your calculations here or on a separate sheet of paper:

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Draw Conclusions:

1. What are the similarities and differences in the range of uncertainties? Why?

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2. What are the similarities and differences in the values of wavelengths of light, for a given color? Should they be the same?

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3. For a given color of laser, taking into account the range of uncertainties, do any groups' values of wavelength overlap? What does it mean when the overlap? What does it mean when they do not overlap?

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4. Create a graph on a separate sheet of paper of all the results for a given color of laser. Discuss these results.

5. How would the results change if students used a different measuring device other than a meter stick, or one with different gradations on it?

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6. Why do we need precise measurements at the nanoscale? ____________________________

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