LASER CLASSROOM
Bringing STEM to light®

BIG IDEAS

- Demonstrate the concept of diffraction by calculating the wavelength of red LASER light.

WHAT YOU'LL NEED

- 1 Red LASER
- 1 Diffraction Grating
- Sheet of blank paper
- A ruler
- Diffraction grating holder (optional)

MEASURING WAVELENGTHS

Imagine water waves moving along the shore. What do you think would happen when they suddenly met a harbour wall which contained only a narrow entrance gap for them to move through? How would the waves behave once they passed through the gap?

DIFFRACTION

Diffraction refers to how waves bend when they move through a small opening, or around a narrow obstacle. Consider *Figure 1*. When water shows a wave moving through a small gap in slit in a barrier, you might expect the waves to continue in a uniform fashion, just slightly shorter, but that's not what happens! Instead, the edges of the waves bend towards the barrier as they pass through (*Figure 1*) .

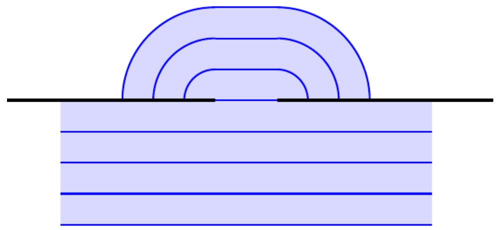

Figure 1: Diffraction through a narrow slit

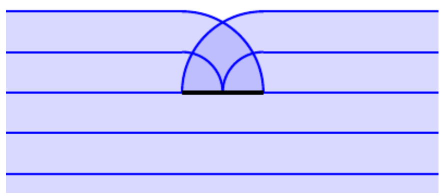

Figure 2: Diffraction around a narrow obstacle

In the same way, water waves bend or diffract as they move past a around a narrow obstacle . This is shown in *Figure 2*. - the waves bend towards the obstacle as they pass.

Light is also a wave, and will also bend (or diffracts) when faced with an obstacle, similar to how water waves behave!

DIFFRACTION GRATING

A diffraction grating is a piece of plastic containing thousands of thin, vertical scratches, running from the top to the bottom. These scratches act as very narrow obstacles, and the light diffracts as it passes through the grating, which is where it gets its name.

As the waves diffract and bend, however, they interfere with each other. When two crests meet, there is constructive interference, and the wave is amplified, or made brighter. When two troughs a crest and a trough meet, destructive interference occurs, and the wave is dampened, or made dimmer. This causes the interference pattern you see emerging from the diffraction grating.

INTERFERENCE PATTERN OF LASER LIGHT

Different wavelengths of light diffract at various angles. If you were to pass white light through the diffraction grating, you would observe all the colors of light which it consists of or the spectrum. As a test, hold the diffraction grating up to one eye and take a look at a source of white light, like the overhead lights. You should observe its spectrum as a rainbow!

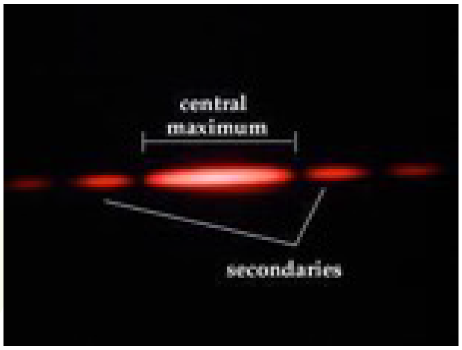

Figure 3: Interference Pattern of LASER Light

But LASER light is monochromatic - it consists of only one wavelength of light. When all the light waves diffract at the same angle, because they are the same wavelength, we observe a series of spots. This series of spots is an interference pattern that consists only of one color light, as shown in *Figure 3*. We can use this pattern to calculate the wavelength of the light!

CALCULATING THE WAVELENGTH OF LIGHT

In order to calculate the wavelength of the LASER light, you need to be able to identify certain parts of its interference pattern. Take a close look at *Figure 3* again. The brightest spot of light, right in the middle, is called the central maximum. The smaller dots on either side of the central maximum are referred to as secondary maxima. In white light, the central maximum of each wavelength overlaps with the next wavelength and so the spectrum looks like a rainbow instead of a series of dots. You can see the rainbow pattern repeat, the same way a monochromatic interference pattern repeats.

The formula for calculating the wavelength λ of light is as follows: $\lambda = \frac{(X)(d)}{L}$

where *X* is the distance between the central maximum and one of the secondary maximaa secondary maximum, *d* is the width of the slits of the diffraction grating, and *L* is the distance from the diffraction grating to the screen showing thewhere interference pattern can be seen .

DIFFRACTION IN REAL LIFE: HOLOGRAMS

Holograms are 3D “photographs” of objects that capture perspective. This means that a hologram has depth, and if you turn the hologram, the picture changes as if you were holding the real object.

To view a transmission hologram, you shine a LASER through a hologram plate. In some cases this hologram plate is actually a glass square with opaque and transparent lines, which acts as a diffraction grating. When you shine a LASER through the hologram plate, the LASER light diffracts and an interference pattern is formed. This pattern becomes the hologram!

ACTIVITY SHEET: MEASURING WAVELENGTHS

We're now going to use what we know about diffraction patterns to measure the wavelength of a red LASER.

1. Stick the blank paper to a wall above a flat surface on which you can rest the red LASER.
2. Place the diffraction grating upright in front of the paper. Measure the distance between the grating and the wall, L, and record it in the table below.
3. Shine the laser pointer through the diffraction grating. If possible, place it on a small box or similar to hold it steady.
4. Mark off the central maximum and one of the first-ordersecondary maxima on the sheet of paper with a pencil.
5. Remove the sheet and measure the distance between maxima. Record the distance X.
6. Repeat twice more with different distances L.

	Diffraction Grating lines/mm	**Slit Width (*d*) cm/line**	**Distance from grating to screen (*L*) in cm**	**Distance from maximum to maximum (*X*)**
1				
2				
3				

7. Substitute the values for measurements 1 to 3 into the equations below to calculate the wavelength of the LASER.

	$\lambda_1 = \frac{(X)(d)}{L}$	$\lambda_2 = \frac{(X)(d)}{L}$	$\lambda_3 = \frac{(X)(d)}{L}$	**Average Wavelength** $\lambda = \frac{\lambda_1+\lambda_2+\lambda_3}{3}$
Subsitutions of Data in Formula				
Final Value (cm)				
Final Value (nm)				

TIP: You need to convert your final value for λ from cm to nm in the table above: 1 cm = 1×10^7 nm = 10,000,000 nm

TIP: Red light usually has a wavelength of 620 nm -– 750 nm. Check that your average wavelength falls in this range!