the grating spectroscope

EM Spectrum

1 materials
Scissors, paper punch, paper clip, rubber cement, razor blade, straight edge, transmission grating replica (Edmund Scientific Co.), Geissler tubes of hydrogen, helium, and others, if available.

2 purpose
The exercise will introduce you to the wave nature of light and the phenomenon called interference. You will build your own spectroscope and use it to examine the spectra of various light sources.

3 the grating
The grating you have is very delicate. Do not touch the grating material itself as fingerprints will damage it. Do not look at the Sun with the grating.

The grating plastic contains 5300 grooves per centimeter. These grooves produce the phenomenon called interference in the light passing through it. The result is a spectrum produced by breaking up the light into its various colors. Hold the grating by its cardboard frame near your eye and look at a window or light. Turn the grating until you can see the color fringes easily.

4 interference
Notice that the indigo fringe is closest to the light source and that the red fringe is furthest away. When you look in the direction of the red fringe you see light scattered by a number of the grooves in the grating. Each groove is at a slightly different distance from your eye, as shown in Figure 7–1. Light striking one groove and reaching your eye does not have to travel as far as light striking the next groove and reaching your eye. The result is that the light from these two grooves does not arrive at your eye at the same time but, rather, the light from the nearer groove arrives slightly earlier than the
Figure 7-1. Light scattered from different grooves in the diffraction grating travel different path lengths.

light from the farther groove. If light were tiny particles, this delay would make no difference and we would see both "particles" of light with no trouble. However, light is not a particle; it is something that sometimes behaves as a wave and sometimes as a particle. In this case the wave nature of light produces interference.

If the two waves leave the light source together, then their peaks and their valleys will be lined up. But, as we have seen, when they strike the grooves and then reach our eye, one travels a shorter path and arrives earlier. If the two waves arrive so that the peak of one coincides with the valley of the other, they will cancel each other out and there will be no light at all! This is called destructive interference and is shown in Figure 7-2. If the waves arrive so that the peak of one coincides with any peak of the other they will add together and we will be able to see them. This is called constructive interference.

Whether the interference is constructive or destructive depends not only on the amount of delay but also on the wavelength of the light waves involved. When we look at the red fringe we are looking at a part of the grating where waves of blue, green, and yellow light interfere with themselves destructively but where red light, because of its longer wavelength, interferes with itself constructively. So we see red. If the light source gave off no red waves to start with, we would of course see nothing at all in the red direction.

activity

Look through the grating again and notice that red fringe is farther from the light source than the blue fringe. This is because red light has a longer wavelength than blue light. List the colors you can see in order of increasing wavelength.

<table>
<thead>
<tr>
<th>Short wavelengths</th>
<th>Long wavelengths</th>
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<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Figure 7-2. Destructive interference. When the peaks of one wave coincide with the valleys of another wave, cancellation occurs.

5 wavelength and color

Our eyes can tell one color from another because each color has its own wavelength range. The deep indigo color, for example, has a wavelength range from 410 to 460 nanometers (1 nanometers = 1 nm = 10^{-9} meters), whereas blue light has a range from 460 to 510 nm and so on. Of course the transition from one color to another is gradual so exact wavelengths are not given. When scientists first began to understand optical interference, they realized that light could be a wave and that the wavelengths were very short. In fact, the wavelengths were so short that it was inconvenient to measure them in centimeters, older texts may use the angstrom (Å), (1Å = 10^{-10} m). In angstroms the wavelength of indigo light ranges from 4100 to 4600 Å.

problems

1. Approximately what would the wavelength range of blue light be in angstroms? ____________________________

2. The central wavelength of yellow light is about 5800 Å. How long is that in centimeters? ____________________________

the grating spectroscope
5. **Emission spectra from low pressure gases**

Arrange the discharge tubes in their power supplies, and turn one on. WARNING, these lamps typically use 5000 volts, and so should not be handled when the power is on. If you need to move the lamp, turn it off, move it and then turn it back on. Place the spectrometer on wood blocks so you can conveniently look through the eyepiece and slit and see the glowing discharge tube. Sketch the spectrum observed, record the colors and wavelengths for each prominent line and identify the gas from the glass tube label. Repeat this step for all of the gases provided.

6. **Emission spectra from other sources**

Aim the spectrometer at an overhead fluorescent lamp, sketch the spectrum observed, and record the colors and wavelengths of prominent lines. Repeat for the sodium lamp, and for any other types of lamp you find in the hallway or nearby on campus. Identify each type and/or location of lamp used shown in class.

7. **The continuous spectrum**

Use the spectroscope to look at an incandescent light. In an incandescent light electricity flowing through the filament heats it to a temperature of about 5000 to 6000 K. At this temperature the filament glows, giving off light of all different colors. Our eye sees this light as white, but through the spectroscope our eye can see these colors separately.

Notice that the colors are all present and there are no special bright areas and no dark areas. The spectrum is smooth and continuous. This kind of spectrum is called a continuous spectrum.

<table>
<thead>
<tr>
<th>Color</th>
<th>Approximate Wavelength (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indigo</td>
<td>430</td>
</tr>
<tr>
<td>Blue</td>
<td>480</td>
</tr>
<tr>
<td>Green</td>
<td>540</td>
</tr>
<tr>
<td>Yellow</td>
<td>580</td>
</tr>
<tr>
<td>Red</td>
<td>650</td>
</tr>
<tr>
<td>Deep red</td>
<td>700</td>
</tr>
</tbody>
</table>

Table 7-1  Wavelengths of the Colors