Build Spectroscope

Support for Cornell Center for Materials Research is provided through NSF Grant DMR-0079992

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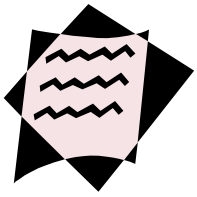
Abstract



Students learn to how to construct, modify, and calibrate a spectrometer. Students also learn the governing equation of diffraction, and ways in which to use the spectrometer.

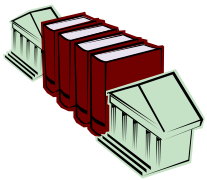
Equipment

1. One Flat Sheet of either Cardboard, Wood or Metal.
2. One Wooden Ruler.
3. Aluminum Foil.
4. Plastic or Glass Diffraction Grating (from Edmund's Scientific, for example)
5. L-bracket for grating.
6. Glue.

Grade Level

This activity is suitable for Middle School or High School Students

State Standards Met



Standard 1 – Analysis, Inquiry, and Design
Standard 4 – Physical Setting and Living Environment

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Standard 7 – Interdisciplinary Problem Solving

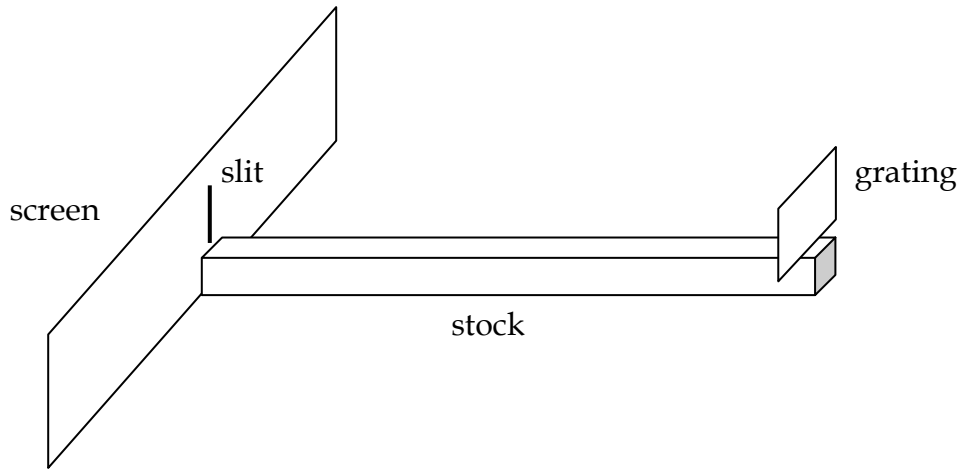
Building a Simple Spectroscope

This spectroscope is used in introductory physics labs here at Cornell. It's portable and doesn't cost a lot to make.

Spectroscope Construction

The grating is the only thing that has to be purchased. The main body of the scope can be constructed from stiff cardboard; however such a scope would naturally be less durable than one constructed from wood and/or metal.

It is a good idea to calculate the spectrum positions (see next section) before starting construction; that way, you can get a rough estimate for the dimensions of the various parts of the scope.



Stock: A rectangular folded cardboard tube, a metal or wooden bar. Wooden rulers also work nicely.

Screen: A flat sheet of either cardboard, wood or metal. Cut a small slit at the middle of the screen. This slit should be as small as possible; however this might not be practical with wood or metal. In this case, cut the smallest slit you can, and then glue a flat sheet of aluminium foil over it. Using a razor blade, slice a straight narrow slit in the aluminium foil. Alternatively, use the edges of two razor blades to form the slit.

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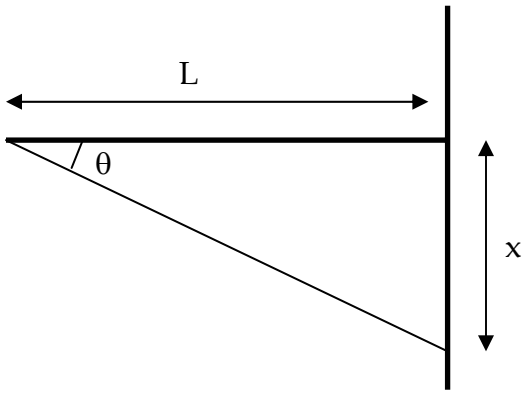
Grating: This can be obtained from Edmund's Scientific, for example. A range of different grating spacing is usually available. Glass gratings give better results than plastic gratings. They are also more expensive and fragile.

When connecting the screen to the stock, ensure that the slit lines up with the centre of the stock. The plane of the grating should be parallel to the plane of the screen. A slot can be made at the end of the stock in which the grating can be inserted; otherwise it might be necessary to fashion some L-brackets to hold the grating in place.

Making the scale

The positions of spectra viewed with the scope will vary depending on the geometry of the scope and the grating spacing.



For a line of given wavelength λ, the angle at which the first maxima appears is given by:

$$d \sin \theta = \lambda$$

where the line spacing of the grating, d, is the inverse of N, the number of lines per unit length of the grating:

$$d = 1/N$$

After calculating $\sin \theta$, the angle θ can be obtained by taking the inverse sine. The position at which the line appear s on the screen is now just a matter of trigonometry:

$$\tan \theta = x/L \quad \Rightarrow \quad x = L \tan \theta$$

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Hence, with these formulae, a wavelength/frequency scale can be drawn up on a sheet of paper. A spreadsheet program is a quick way of generating such a scale. For the visible range, a practical scale would range from 300 to 700 nm, in intervals of 25 nm or 50 nm.

Calibrating the spectroscope

Any gas discharge tube can be used to position the scale on the scope, as long as the wavelengths of the emission lines are known. The most convenient source would be a mercury fluorescent tube (the usual white fluorescent lighting). When viewed through the spectroscope, a few distinct lines should be seen. Their wavelengths and frequencies are given by:

Colour	Wavelength (nm)	Frequency (10^{-14} Hz)
Yellow	577	5.1867
Green	546	5.4897
Teal	492	6.0983
Blue	436	6.8791

Mark off the positions of these lines on the spectroscope screen, and align the scale to these marks. Once the scale is aligned, glue or tape it to the screen.

Modifications

The accuracy of the spectroscope depends on the slit size, the distance between the screen and the grating, and the number of lines on the grating.

Using a grating with a bigger number of lines per unit length will result in the spectral lines becoming sharper.

Reducing the slit size will also result in sharper lines. One quick way of reducing the slit size is to position two razor blades over the slit in the screen until the desired slit size is reached. Small strips of paper can also be used; however the edges of the paper are not as fine as that of a razor blade, and will produce a lower quality image.

Increasing the distance between the grating and the screen will result in the spectrum being spread out more, making it easier to locate the positions of the lines.

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The overall accuracy and resolution of the scope will only be as good as the worst element in the scope; there's not much point in using a grating with a smaller line spacing if the slit size is so large that the spectral lines overlap.

It is also often necessary to recalibrate of the scope if any modifications are made.

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Things to look at

- Lamps, particularly street lamps at night. Sodium and mercury lamps are interesting to look at.
- Glow discharge tubes. These contain neon, argon or xenon.
- Various light producing devices, eg incandescent bulbs, light-emitting diodes, coloured christmas tree lights. Don't look directly into laser pointers! Look at the laser spot on a white sheet of paper instead.
- The sun: usual warning - do not look directly at the sun! However, it is possible to view the spectrum safely by looking at a white sheet of paper in sunlight, or by looking at the moon at night.

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