Physics 102 Lab 9: Using the spectrometer to measure the spectrum of He

Dr. Timothy C. Black

Spring, 2006

The spectrometer: The spectrometer is shown in figure 1. It consists of a collimator tube, a telescope, a diffraction grating, and a circular measuring platter. The collimator tube holds an aperture at one end that limits the light coming from the source to a narrow rectangular slit. A lens at the other end focuses the image of the slit onto the face of the prism. The telescope magnifies the light exiting the prism and focuses it onto the eyepiece. The diffraction grating allows you to separate the incident light into its constituent wavelengths. Recall from last week's lab that the relationship between the wavelength of the incident light and the angle at which a diffraction maximum appears is given by

$$d \sin\theta = m\lambda \tag{1}$$

where $d = \frac{1\text{mm}}{600\text{ lines}} = 1.67 \times 10^{-6}$ m/line is the grating spacing, and m is the *order* of the maximum. In this lab we will be using the first order diffraction maxima. The measuring platter permits you to read off the angles at which the collimator and the telescope are located.

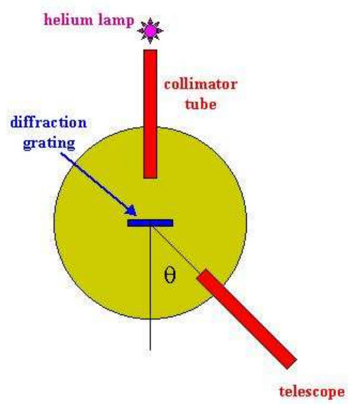


FIG. 1: The spectrometer

The atomic glow-discharge lamp: Your light source for this experiment is a helium atomic glow-discharge plasma lamp. It works by sending a high-voltage through a dilute elemental gas. The high-voltage creates a plasma in which electrons are excited from low energy orbitals to higher energy orbitals. When the electrons drop back down into the low energy orbitals, they emit light. Figure 2 shows both the undiffracted light emitted by the helium lamp (salmon-colored band on the left), and the discrete atomic spectrum emitted by the lamp (series of lines on the right).

There are two important things to bear in mind regarding this light source:

1. The light spectrum emitted from a glow-discharge lamp is discrete, meaning that instead of emitting a continuous band of colors from red to blue, as an ordinary light does, only very narrow bands of color are emitted by the atomic lamps, with large gaps in between the emitted wavelengths.
2. THIS LAMP RUNS ON HIGH VOLTAGE—5000 VOLTS, TO BE EXACT. There is no reason for you to touch it. Don't.

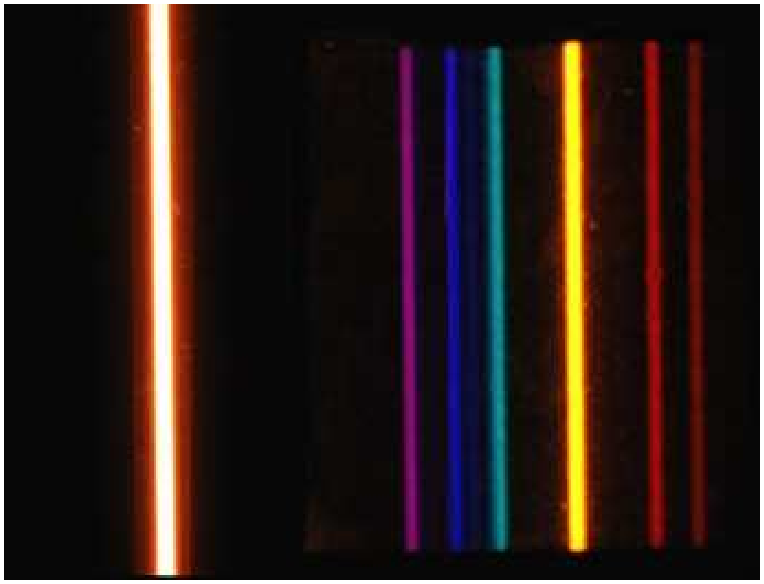


FIG. 2: A helium plasma lamp: The undiffracted light emitted by the tube, visible to the naked eye, is shown on the left of the figure. The atomic lines, as seen through a diffraction grating, are shown on the right.

The spectrometer's vernier scale: The vernier scale on the spectrometer is not the same as the vernier scale that you used with the calipers last semester. Those vernier scales divided the lines into 10^{ths}, essentially giving you one additional decimal of precision. The vernier scale on the spectrometer provides precision up to one arc minute of angular measure. It does this by dividing each half-degree into 30 parts. The procedure for using the spectrometer vernier is as follows:

- First find the angle to the nearest $\frac{1}{2}^circ$; i.e., the half-angle marker which is just less than the first line on the vernier scale. (The first line is actually the 0^{th} line). Call this angle θ_1.
- Find the line on the vernier scale that best lines up with one of the lines on the angle platter, and count off which line this is, taking the first (leftmost) line as zero. There are a total of 30 lines on the vernier scale. Let us say that the n^{th} line on the vernier scale lines up best with one of the lines on the angle platter.
- Each line on the vernier corresponds to $\frac{1}{60^{th}}$ of a degree. Hence, the measured angle ought to be $\theta = \theta_1 + \frac{n}{60}$.
- When recording the measured angle, note that your precision is limited to $\frac{1}{60^{th}}^circ$. The number 60 has two significant figures, so at most, your correction to θ_1 is valid to two significant figures.

Figures 3A and 3B depict two examples of using the angular vernier scale. In the example shown in figure 3A, the zeroth line is just greater than $\theta_1 = 51.0°$. The 20^{th} line on the vernier lines up best with one of the lines on the angle platter, so the correction is equal to $\Delta\theta = \frac{20}{60}$. The measured angle is therefore

$$\theta = \theta_1 + \Delta\theta = 51.0 + \frac{20}{60} = 51.33°$$

In the example shown in figure 3B, the zeroth line is just greater than $\theta_1 = 56.5°$. The 3^{rd} line on the vernier lines up best with one of the lines on the angle platter, so the correction is equal to $\Delta\theta = \frac{3}{60}$. The measured angle is therefore

$$\theta = \theta_1 + \Delta\theta = 56.5 + \frac{3}{60} = 56.55°$$

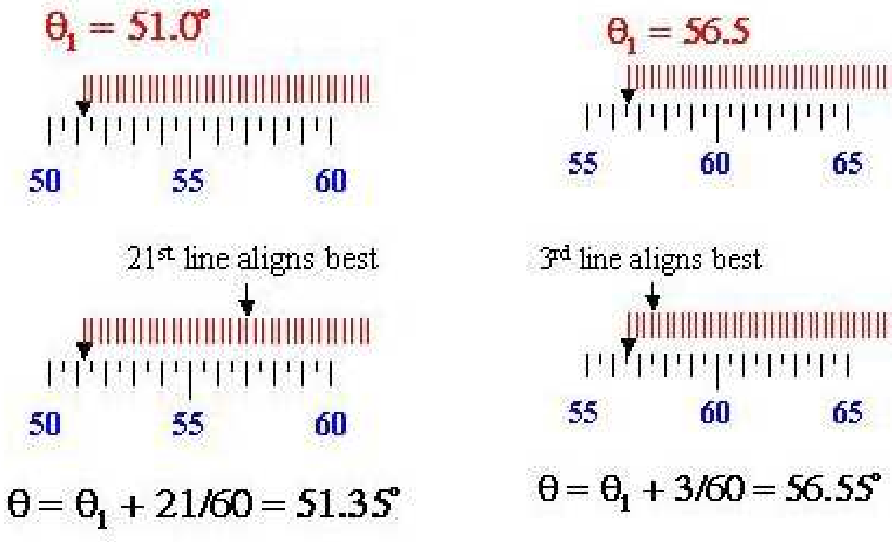


Figure 3A　　Figure 3B

FIG. 3: Two examples of using the angular vernier scale

You will be provided with magnifying glasses, which you will need in order to properly determine which line on the vernier scale best aligns with a line on the angle platter. Take great care to look directly down onto the scale, not from one side or the other, as this will introduce a parallax error.

PROCEDURAL STEPS

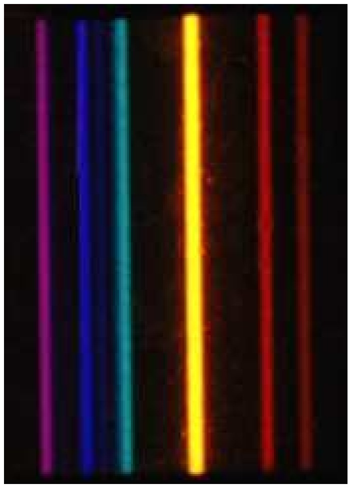
Measuring the wavelengths of the helium spectrum

1. Locate and record the telescope angles $\theta(\lambda)$ for the first order interference maxima for five different colors that you are confident that you can identify in your atomic spectrum. Measure the angles θ_r and θ_l at which the lines appear on both the right and left side of the forward direction and calculate $\bar{\theta} = |\frac{\theta_r - \theta_l}{2}|$. It is this angle that you will use in the grating equation to determine the wavelength.

2. Find the wavelengths of these spectral lines by using the grating equation—Equation1—with $m = 1$, and $\theta = \bar{\theta}$.

3. Using the table of known helium wavelengths given in table I, match your measured wavelengths to their most probable partners in the table. Use the relative intensities and separation of the lines to guide you. Note that not all the tabulated wavelengths may appear in your spectrum. They may be outside your range of vision, or so close that they overlap, or too weak to see.

4. Find the fractional deviations between your measured wavelengths, and the wavelengths given in table I of those lines you designate as their most probable partners.



Color	Wavelength [nm]	Relative Intensity
violet	388.9	1000
violet	396.5	50
violet	402.6	70
blue-violet	438.8	30
dark blue	447.1	100
blue	471.3	40
blue-green	492.2	50
green	501.5	100
yellow	587.6	1000
red	667.8	100
red	706.5	70

TABLE I: The wavelengths of a helium discharge in the visible spectrum