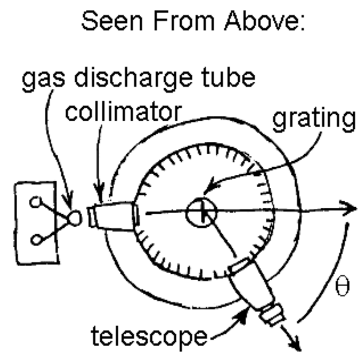
Experiment 7: The Hydrogen Spectrum

PURPOSE. To measure the wavelengths of the first three Balmer lines in hydrogen, and compare to the predictions of the Bohr model.

APPARATUS. Hydrogen in a glass tube is excited by an electric current, making it glow. The light passes through a diffraction grating, which bends different wavelengths through different angles. By measuring these angles, we can compute the wavelengths from the grating equation. The spectrometer used to measure the angles consists of a collimator to define parallel rays falling on the grating, a telescope that swings around to view the spectrum, and a circle divided into degrees and minutes.



CAUTION: The electrodes at the ends of the spectrum tube have 5000 volts between them. These are not in the open but, as they say, nothing is foolproof because fools are so ingenious. Also, the tube gets hot after being on for a while.

CAUTION: Handle the diffraction grating like something expensive and fragile. Do not get it dirty with fingerprints, or scratch it on the clamp that supports it.

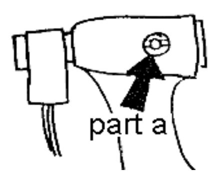
Please turn the tube off when not in use. The more you use it, the sooner it wears out.

Preliminary Adjustment:

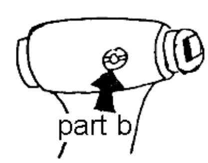
Focus the telescope eyepiece on the cross hairs by pulling it out. Then do not change it.

Illuminate the collimator slit with the spectrum tube. The slit should be at the height of the narrow part of the tube, and very close to it. (You will need to put books under the spectrum tube.) Make the slit reasonably narrow, taking care not to grind its jaws together.
Swing the telescope to where you see light coming through the slit. If the slit's image is not sharp, make the following adjustments. (Ask for a screwdriver.)

a. Focus the telescope on a distant object: Swing the telescope to look at a distant wall (without the grating). If necessary, loosen the screw in the side, and slide the tube which the eyepiece fits over to get a sharp image. Retighten the screw.



b. Focus the collimator. Swing the telescope to look into the collimator. If the image of the slit is not sharp, loosen the screw in the side of the collimator, and slide the slit in the far end of the collimator to get a sharp image of it, as viewed through the telescope. Retighten the screw.

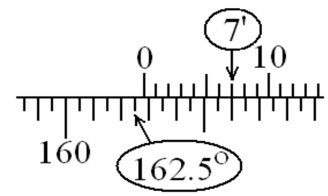


Set the grating perpendicular to the collimator. If you are careful, you might be able to judge this accurately enough by eye. If that doesn't work, a more elaborate procedure is given later.

MEASUREMENTS: Important. Notice that the telescope can be wiggled in the surrounding housing. Moving it once you begin taking measurements will result in inconsistent data. Look (through the eyepiece) but don't touch.

When reading an angle, set the cross hairs on the edge of the slit's image. Use the same side of the slit (right for example) consistently throughout the experiment.

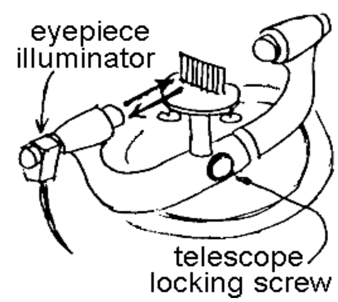
Put the cross hairs on the straight ahead (m = 0) image of the slit and read the angle (which probably isn't 180° 00'). The scale has a magnifying glass and Vernier. It reads in degrees and minutes. Read to half a degree from the last mark left of zero, then add the number of minutes from the vernier scale. This is the mark on the vernier scale that best lines up with a mark across from it on the main scale.



Example: 162°37'

Swing the telescope to the right and read the angle of the violet spectral line, to the nearest minute. Subtract to get the angle from m = 0. Swing the telescope to the left of m = 0 to the other first order violet line, and get another value for θ. If they differ by 10 minutes or more, check more carefully whether the grating is perpendicular to the collimator, like so:

> Point the telescope at the collimator, cross hairs on the slit. Temporarily tighten its locking screw. Darken the room. Plug in the eyepiece illuminator to send light down the telescope. You should see a bright circle in the telescope, which is light reflected from the grating. Adjust the leveling screws under its table, and turn the table so that the circle is centered, meaning light comes straight back up the telescope. After this adjustment, do not disturb the grating again.
> Unplug the eyepiece illuminator, unless you need it to see the cross hairs.



Average the two θs (the angles from m = 0). Estimate an uncertainty based on how closely you can read the scale, and how close you came to getting the same θ for the same line on each side.

Repeat for the bluish green spectral line and the red line. All three angles should have the same uncertainty, since they were found the same way. Turn off the hydrogen lamp.

<u>CALCULATIONS</u>. From d and θ find the wavelength of each spectral line. A tag on the grating gives the number of lines per millimeter. You are looking at the first-order (m = 1) spectrum.

Differentiating the grating equation, (1)λ = (d)(sinθ), gives *dλ* = (d)(cosθ)(*dθ*), where *dθ* is in radians. (Differentials are in italics to avoid confusion between d for distance between lines on the grating and *d* for differential.) Use this to find *dλ*, the uncertainty in λ, from *dθ*, the uncertainty in θ.

As explained in class, the Bohr model predicts that the wavelengths ought to be given by $1/\lambda = R(1/n_f^2 - 1/n_i^2)$. Use this to calculate the wavelengths of the first three lines of the Balmer series. In your conclusion, compare these to your experimental values.

PHY 133 Experiment 7: The Hydrogen Spectrum

Central Max: ________________ ± ________________

	Violet	Blue-green	Red
Reading on right			
θ right			
Reading on left			
θ left			
ave θ	±	±	±
λ	±	±	±

Show how λ comes from θ:

Find uncertainty in each λ:

Calculate predicted λ's: