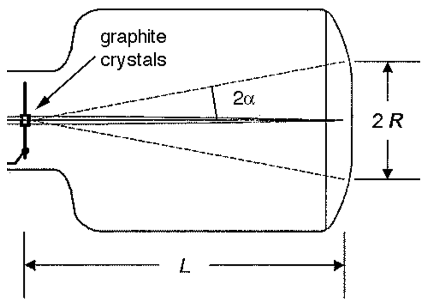
Goals

- To observe the wave nature of matter (electrons in this case).
- To determine the spacing of atomic planes in a graphite crystal.
- To use graphs to calculate quantities by using regression of a linear relationship.
- To practice writing the abstract and the conclusion of a lab report.

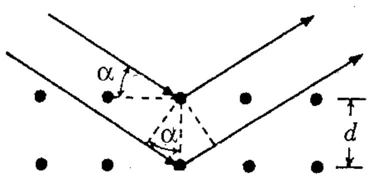
Lab Equipment & Background:

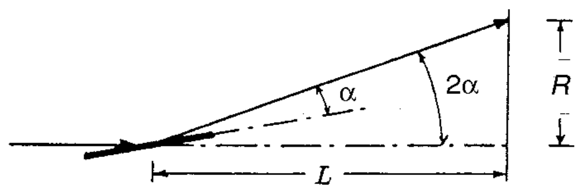
Electron diffraction apparatus, high-voltage supply

The diagram below shows the experimental setup. A beam of electrons strikes the graphite crystal powder and is deflected through an angle 2α. The defected beam strikes a phosphorescent screen so the rings of electrons of radius R can be seen. The distance L between the crystal and the screen is 13.5 ± 0.2 cm

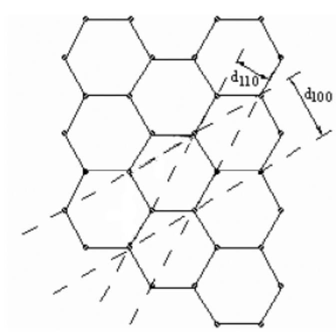


The diagram on the left below shows the geometry at the atomic level. As shown in class, the condition for constructive interference is $2d\sin\alpha = n\lambda$, where d the distance between atomic planes and n is a positive integer. For the patterns that you will see, $n = 1$. In the diagram on the right below, the incoming beam is horizontal and a piece of graphite crystal is tilted at an angle of α with horizontal. (Note that the angle α is different than the angle θ in Figure Q4.3.)





The pattern formed is a circular because the pieces of the graphite are randomly oriented so there is no preferred direction relative to the incoming beam. Graphite has a hexagonal structure as shown in the diagram below. The distances d_{100} and d_{110} are what you will measure.



Reading:

- Chapter 9 (Linearizing a Non-Linear Relationship) and section 3.2 (The Short Sections) of the lab reference manual
- Review chapter Q4

Pre-Lab Problems: Perform 1-5 in WebAssign; also record your answers to 2-5 in your lab notebook (since you'll build on this understanding in the lab.)

1. Exercise 9.1
2. In this lab, electrons will be accelerated through a large electric potential difference $\Delta\phi$. What is the de Broglie wavelength λ of the electron beam as a function of $\Delta\phi$? (Assume that $v \ll c$.)
3. Write an equation relating the angle α, the distance L from the sample to screen, and the radius R of the circular diffraction pattern.
4. During the lab, you will vary the electric potential difference and measure the radius of the diffraction pattern. Find an equation for the radius in terms of the electric potential difference and the spacing d between the atomic planes. The equation should *not* contain the angle α. Assume $n = 1$ and use the small angle approximation.
5. What will you plot in order to make a linear graph? How will you use your graph to find the spacing d? (Note that you should *not* just use a single data point!)
6. For **extra credit**, show that for a crystal with hexagonal structure the ratio between the distances shown in the diagram is $d_{100}/d_{110} = \sqrt{3}$. Make a large, clear diagram and explain your work.

Lab Procedure:

- Note that the equipment cannot tolerate high voltages for a long period of time. Never exceed 5 kV for the accelerating potential and always turn the voltage down to less than 2 kV between measurements.
- Determine the inner radius of the two most visible rings for several different applied voltages, and plot your results in such a way that you get a linear graph. Plot as you go in order to determine the best strategy for getting a good distribution of data points.

Post-Lab Assignment:

1. Treat the data for the inner and outer rings separately. Make linear plots of your data. Use linear regression to find the slope and its uncertainty for each plot.
2. Determine the values of the two different spacings between atomic planes and their uncertainties. It is easier to group the constant e with a unit of volts to get units of eV, rather than plugging in a value for e. You may assume that the uncertainties of the physical constants h, c, m, and e are negligible.
3. Determine the ratio of the spacings and the uncertainty of this ratio. Does your measured ratio agree with the expected value?
4. Write the abstract and the conclusion of a lab report for this experiment. These should be typed.