Electron Diffraction
De Broglie Wavelength of Electrons

According to de Broglie's hypothesis all matter has wave-like properties. Thus in the same way that light waves passing through a regular pattern of holes interfere to produce a pattern of light and dark areas, electrons passing through a thin crystal should form a diffraction pattern.

The wavelength of a particle is inversely proportional to its momentum, $\lambda = h/p$. The momentum can be varied by accelerating the electron through a potential difference V, giving it a momentum $p = \sqrt{2meV}$. The charge to mass ratio, e/m, can be measured using crossed electric and magnetic fields. The specific charge, e, can be found from the Millikan oil drop experiment. Finally, Planck's constant, h, can be measured by means of the photoelectric effect. Thus de Broglie's hypothesis can be tested directly.

The Teltron Electron Diffraction Tube TEL 555 is an evacuated glass bulb which contains an electron gun that emits a narrow beam of cathode rays. The electrons pass through a thin layer of graphite supported on a fine mesh grid and are diffracted into two rings which are made visible by a luminescent screen on the bulb. The random arrangement of crystals in the layer produces rings rather than distinct spots. One ring corresponds to the 0.123 nm spacing of carbon atoms in the hexagonal graphite crystal, the other ring is due to the 0.215 nm spacing. (Figure 1)

<u>Experiment</u>

The TEL 555 tube requires 6.3VAC heater voltage and 2.5 -5.0 kV anode potential. The anode current <u>must</u> be limited to 0.4 mA to prevent damage to the graphite. A 10 Meg resistor in series with the anode will provide this safety, but has a 2 kV potential drop across it at the 0.2 mA normal operating current. In addition, laboratory digital voltmeters are normally limited to 1.2 kV and so require an external voltage divider to read 5 kV.

Construct the voltage divider of six 1 Meg resistors. (Figure 2) Use a digital meter to measure the values of all resistors. Compute the output voltage across five resistors. Important The high voltage power supply can be very dangerous. Check with instructor before using and be very careful.

At 500 V intervals carefully calibrate the meter on the power supply against the digital meter. Repeat to check these values. When the tube is connected, the current it draws will create an increased voltage drop across one resistor, reducing the voltage read on the digital meter. The reduction will be used to calculate the current drawn by the tube and hence the voltage drop across the protection resistor.

Now, with the power supply off, add the protection resistor and complete the remainder of the circuit. (Figure 3)

Switch on the heater supply and allow about one minute for it to stabilize. Adjust the high voltage to 4kV and switch it on. You should see two rings about a central spot on the luminescent screen. Decrease the high voltage and you should note a change in ring diameter.

In a darkened room, measure the diameter of the two rings with anode voltages between approximately 2.5 and 5 kV. Correct for the voltage drop across the protection resistor as outlined above.

Analysis

Waves diffracted off a crystal with atoms spacing d obey the equation $n\lambda = d\theta$ (for small angles). After the diffracted beam has traveled a distance L, it will be at a radius $R = L\theta$. Thus the crystal spacing can be found from the equation $d = \lambda L/R$. In this tube L = .0.135 m. As outlined above, the electron wavelength, found from the de Broglie equation, is inversely proportional to the square root of the accelerating potential. Thus the diameters of the rings should be plotted versus $1/\sqrt{V}$. The slopes will give the crystal spacings.

Calculate the spacings, including uncertainties. The ratio for an hexagonal crystal should be $\sqrt{3}$:1. Are your results in agreement?