Experiment 6B: Electron Diffraction

PURPOSE: To show that electrons are waves by measuring their wavelength, thus verifying de Broglie's hypothesis. (Thomson's e/m experiment, which you did in PHY 132, shows that electrons are particles by finding the charge to mass ratio of each particle. Between the two experiments, you will have demonstrated the dual wave-particle nature of the electron.)

APPARATUS: Caution! Shock Hazard!   Both the 50 V connections and 2500 - 5000 V connections should be treated with respect. There will be uninsulated connectors at several points.

You have an evacuated glass bulb with an electron gun in one end. Across the gun's exit is a thin layer of carbon (supported by a micro-mesh grid of wires). As the beam goes through this carbon, it is diffracted by two different sets of atomic planes, forming two concentric circular fringes on the luminescent screen. Measuring this interference pattern gives an experimental wavelength, which can be compared to de Broglie's theory.

Since the target is so thin, the beam can burn a hole in it if too intense. You control the beam intensity by adjusting the "bias voltage" applied across two parts of the cathode. In addition to adjusting this correctly, you should also inspect the target from time to time; if it starts to glow dull red, shut down immediately. (The glow from the filament at the other end of the gun is normal.) Make connections to the tube as shown. Be sure that the

negative connections are made to the smaller plug, as shown. Have the instructor approve your wiring before you turn anything on.
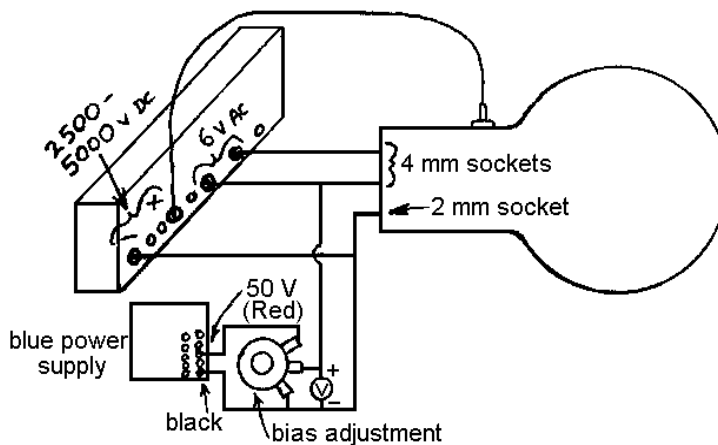
PROCEDURE:

With the high voltage all the way down, turn on the 6 V AC. Wait one minute for the cathode's temperature to stabilize. Then, set the bias voltage to 50 V.

Set the accelerating voltage to about 4000 V. Slowly turn down the bias voltage until rings appear around the central spot. To avoid damaging the target, keep this pattern just bright enough to be seen. (Turn out some of the overhead lights.)

Measure the diameters, D, of both rings for several different voltages between 2500 V and 5000 V. (Measure to the center of the ring, not its inner or outer edge.) You may find using a compass as a pair of dividers more convenient than a ruler against the curved surface. Estimate an uncertainty in D. Readjust the bias each time for minimum brightness. Avoid touching the tube with your fingers while measuring; it distorts the ring pattern by disturbing the static charge on the glass.
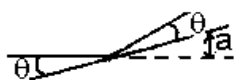
Shut off the high voltage first, then the bias.

CALCULATIONS:

For each ring in each trial, find ϕ, the angle by which the beam was deflected. (The picture is not to scale. ϕ is actually smaller.)

$\frac{D}{2}$

θ a ϕ

approx. 13.7 cm
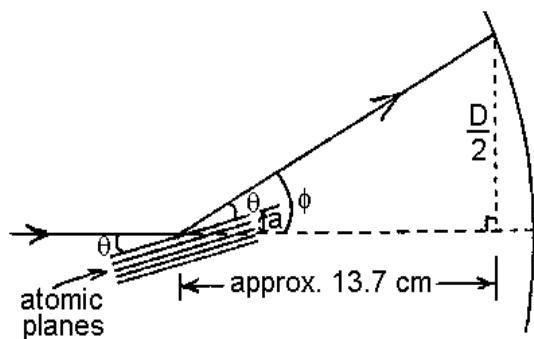
atomic planes

Both rings are due to <u>first order</u> Bragg diffraction. The different diameters are due to different distances between the planes doing the diffracting. The planes responsible for each ring are as shown. (Graphite has a hexagonal atomic arrangement.) Calculate the wavelength which your measurements indicate. Note that ϕ from step 1 is not the same as θ in the Bragg equation. θ is defined as the angle between the beam and the crystal planes. To see the relationship between θ and ϕ, notice that the angle labeled "a" forms vertical angles with θ.

2.13 Å
inner

1.23 Å
outer
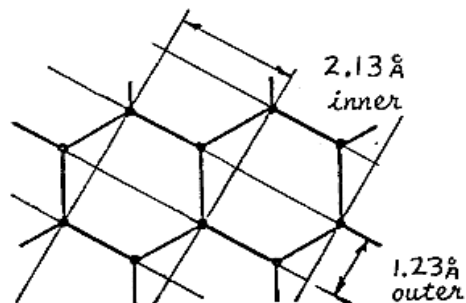
Average the two wavelengths (one from each ring).

For comparison to these wavelengths based on measurement, calculate the wavelengths based on de Broglie's theory. In the homework, you will show that this is $\lambda = (12.26\ \text{Å}) / \sqrt{V}$, where V is the accelerating voltage. (This comes from making some substitutions into $\lambda = h / p$.)

In your conclusion, compare the de Broglie wavelength to what was actually measured. (For the measured λ's uncertainty, average the percent uncertainties in the two diameters used to find it. The uncertainty in the λ from de Broglie's formula is small.)

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V	D inner	D outer	ϕ_i	ϕ_o
	±	±		
	±	±		
	±	±		

λ_i	λ_o	λ_{ave}	de Broglie λ
		±	
		±	
		±	

Sample calculation of ϕ:

Sample calculation of λ:

Sample calculation of λ's uncertainty: