BIRZEIT UNIVERSITY

Faculty of Science

Physics Department

Physics 212

Electron Diffraction

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– Abstract:

The aim of this experiment is to measure the lattice spacing of atoms in graphite using electron diffraction. From the slope of graph the diameter of the center fringe versus the potential difference to the power menus half, the lattice spacing of atoms in graphite could be measured. Then, the de Broglie's wavelengths of the electrons can be measured. In this experiment, two lattice spacing of atoms in graphite were measured. The first one is $d_1 = 2.17 \pm 0.11$ Å and the second $d_2 = 1.29 \pm 0.05$ Å.

– Theory:

According to de Broglie's hypothesis, a particle moving with momentum p would have a wavelength λ given by:

$$\lambda = \frac{h}{p}$$

Where h is Planck's constant.

Consider an electron which is accelerated by a potential difference V. Assuming non-relativistic conditions the velocity of this electron can be found from the equation

$$\frac{1}{2}mv^2 = eV$$

$$v = \sqrt{\frac{2eV}{m}}$$

the wavelength is then given by

$$\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{h}{m}\sqrt{\frac{m}{2eV}}$$

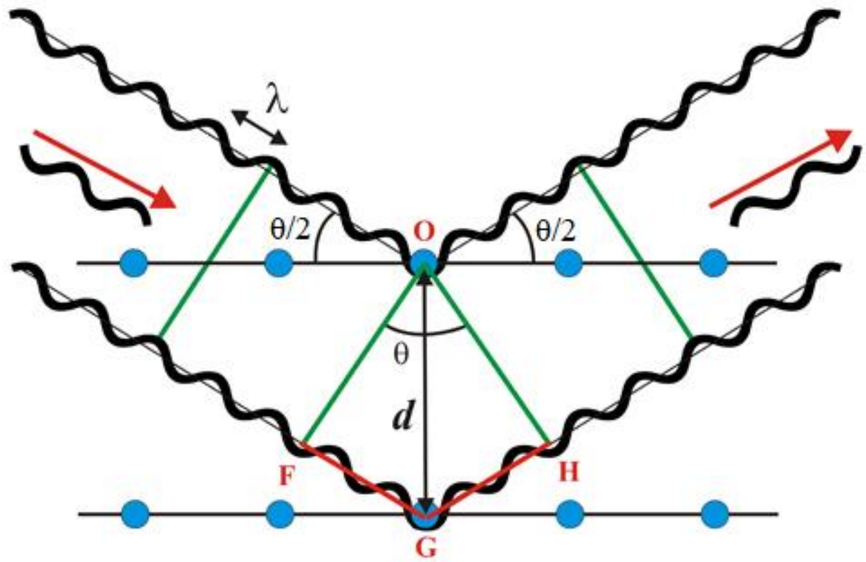
$$\lambda = \sqrt{\frac{h^2}{2emV}}$$

Braggs Diffraction:

In this experiment, a beam of electrons is sent through a thin film of graphite, which acts like a diffraction grating. The resulting ring-shaped interference pattern has maximum intensity at angles specified by Bragg’s law

$$2d\sin\left(\frac{\theta}{2}\right) = n\lambda$$

where d is the separation between lattice planes, n is the order of the diffraction, λ is the wavelength of the electrons, and $\theta/2$ is the angle between the plane of atoms off which the beam of electrons reflects and the reflected beam. In this experiment the diffracted electrons are "seen" when they strike a phosphor screen a distance L from the point of scattering. For $r \ll L$



$$d\theta = n\lambda$$

$$d\frac{r}{L} = n\lambda$$

where r is the distance from the center of the phosphor screen.

$$\lambda = \frac{dD}{2nL}$$

When the value of $n = 1$, then,

$$\lambda = \frac{dD}{2L}$$

Uncertainty:

$$\frac{\Delta\lambda}{\lambda} = \left|\frac{\Delta d}{d}\right| + \left|\frac{\Delta D}{D}\right| + \left|\frac{\Delta L}{L}\right|$$

Graph D vs $1/\sqrt{V}$:

$$\frac{dD}{2L} = \sqrt{\frac{h^2}{2emV}}$$

$$D = k\frac{1}{\sqrt{V}}$$

Hence,

$$k = \frac{Lh}{d}\sqrt{\frac{2}{em}}$$

So,

$$d = \frac{Lh}{k}\sqrt{\frac{2}{em}}$$

Uncertainty:

$$\frac{\Delta d}{d} = \left|\frac{\Delta L}{L}\right| + \left|\frac{\Delta k}{k}\right|$$

– Data:

V(kV)	D_1(cm)	D_2(cm)
2.0	3.010	5.240
2.5	2.710	4.440
3.0	2.515	4.105
3.5	2.250	3.720
4.0	2.095	3.470
4.5	1.910	3.270
5.0	1.750	3.080

$L = 13.50cm$

$\Delta L = 0.05cm$

$V_{source} = 6.3kV$

– Calculations:

V(kV)	D_1(cm)	D_2(cm)	$V^{-0.5}$($V^{-0.5}$)	D_1(m)	D_2(m)
2.0	3.010	5.240	0.0224	0.0301	0.0524
2.5	2.710	4.440	0.0200	0.0271	0.0444
3.0	2.515	4.105	0.0183	0.0252	0.0411
3.5	2.250	3.720	0.0169	0.0225	0.0372
4.0	2.095	3.470	0.0158	0.0210	0.0347
4.5	1.910	3.270	0.0149	0.0191	0.0327
5.0	1.750	3.080	0.0141	0.0175	0.0308

D_1	k	y_{int}
Value	1.524638395	-0.003455433
Error	0.073740357	0.00130468

D_2	k	y_{int}
Value	2.563120396	-0.005775622
Error	0.092897858	0.001643632

Using the formulas:

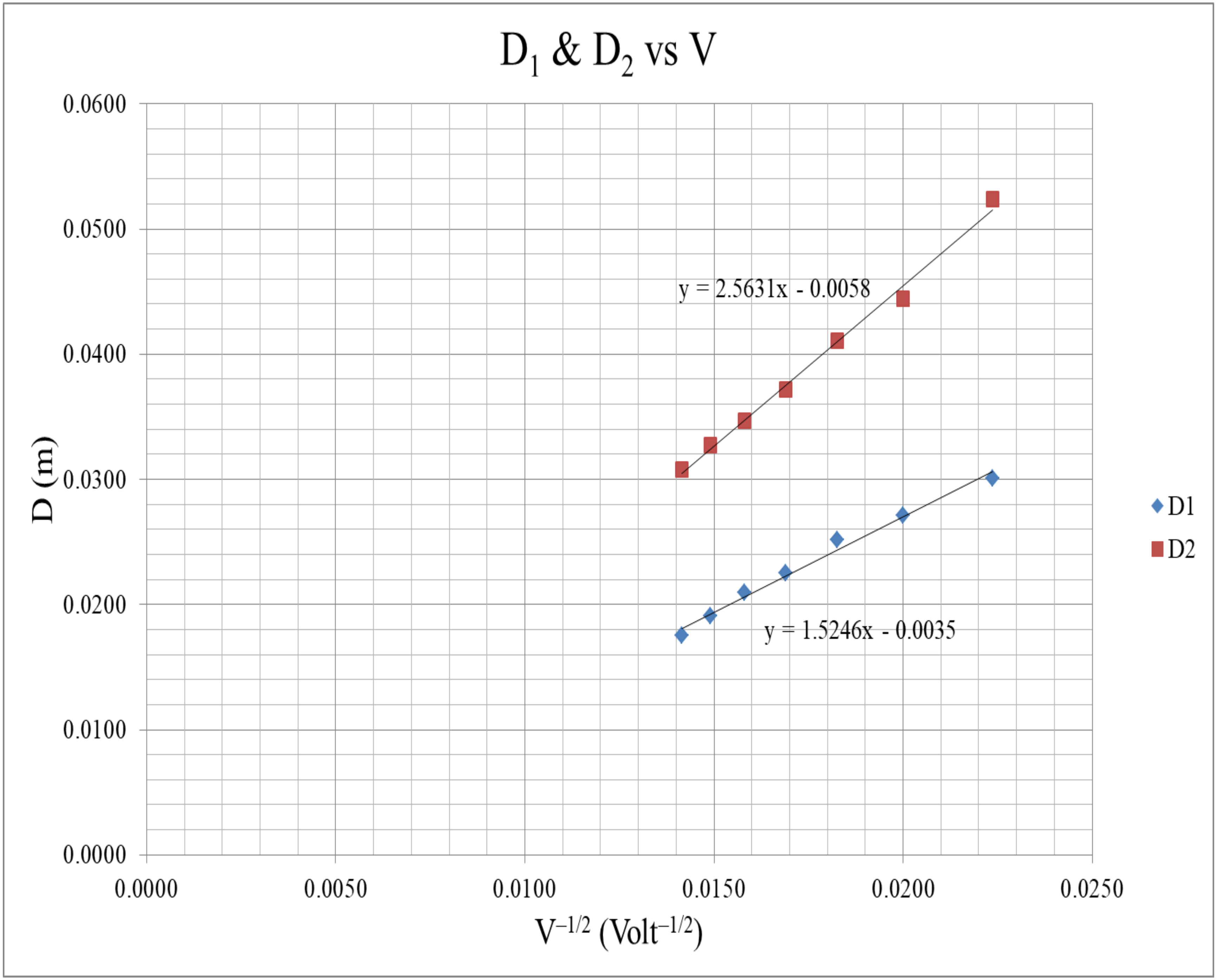
$$d = \frac{Lh}{k}\sqrt{\frac{2}{em}}$$

$$\frac{\Delta d}{d} = \frac{\Delta L}{L} + \frac{\Delta k}{k}$$

	Value	Error
d_1	2.17192E-10	1.13091E-11
d_2	1.29194E-10	5.16099E-12

$$d_1 = 2.17 \pm 0.11\ \text{Å}$$

$$d_2 = 1.29 \pm 0.05\ \text{Å}$$


D1 & D2 vs V
D (m)
0.0600
0.0500
0.0400
0.0300
0.0200
0.0100
0.0000
0.0000
0.0050
0.0100
0.0150
0.0200
0.0250
V−1/2 (Volt−1/2)
y = 2.5631x - 0.0058
y = 1.5246x - 0.0035
D1
D2

Using the formulas:

$$\lambda = \sqrt{\frac{h^2}{2emV}}$$

$$\lambda = \frac{dD}{2L}$$

$$\frac{\Delta\lambda}{\lambda} = \left|\frac{\Delta d}{d}\right| + \left|\frac{\Delta D}{D}\right| + \left|\frac{\Delta L}{L}\right|$$

V(kV)	D_1(cm)	D_2(cm)	λ_{theo}	λ_1(Å)	$\Delta\lambda_1$(Å)	λ_2(Å)	$\Delta\lambda_2$(Å)
2.0	3.010	5.240	0.274	0.242	0.014	0.251	0.011
2.5	2.710	4.440	0.245	0.218	0.013	0.212	0.010
3.0	2.515	4.105	0.224	0.202	0.012	0.196	0.009
3.5	2.250	3.720	0.207	0.181	0.010	0.178	0.008
4.0	2.095	3.470	0.194	0.169	0.010	0.166	0.007
4.5	1.910	3.270	0.183	0.154	0.009	0.156	0.007
5.0	1.750	3.080	0.173	0.141	0.008	0.147	0.007

– Results:

$d_1 = 2.172 \pm 0.013$ Å

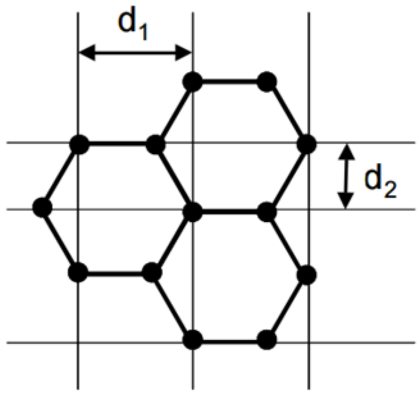
$d_2 = 1.291 \pm 0.008$ Å

$V(kV)$	λ_{theo}	$\lambda_1 \pm \Delta\lambda_1$(Å)	$\lambda_2 \pm \Delta\lambda_2$(Å)
2.0	0.274	0.242 ± 0.014	0.251 ± 0.011
2.5	0.245	0.218 ± 0.013	0.212 ± 0.010
3.0	0.224	0.202 ± 0.012	0.196 ± 0.009
3.5	0.207	0.181 ± 0.010	0.178 ± 0.008
4.0	0.194	0.169 ± 0.010	0.166 ± 0.007
4.5	0.183	0.154 ± 0.009	0.156 ± 0.007
5.0	0.173	0.141 ± 0.008	0.147 ± 0.007

– Discussion:

In diffraction patterns, the small circle came from the big lattice spacing, which was $d_1 = 2.172 \pm 0.013$ Å. The big circle came from the small lattice spacing which was $d_2 = 1.291 \pm 0.008$ Å. Moreover, these values are close to the correct values, which they are 2.13 Å and 1.23 Å.

The shape of patterns is circular due to symmetry. Each crystal in the graphite produces a diffraction pattern and when these patterns combined, they appear as rings



There are systematic errors in the wavelengths about $0.022 \sim 0.032$ Å. This error came from systematic errors in measurements. For example, the approximation of the diameters of the diffraction pattern. Moreover, the value of potential difference isn't precisely. The error estimated in ±50 Volt.

– References:

1. H. Abusara, & A. Shawabkeh (2016, November). *Laboratory Manual: Modern Physics Lab* (Second Edition). *Electron Diffraction* (pp. 119-126). Birzeit University: Faculty of Science.