Experiment Name: ELECTRON DIFFRACTION	
Experiment Performed on Date: 30TH JANUARY, 2025	
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Group No. : 1	Viva Marks (5) : 5
	Exp Marks (15):
Examiner Remarks: Penalty (-) : 0 Marks	

Objectives (1):
The main objective of this experiment is to understand wave-particle duality via the de-Broglie hypothesis and the experimental observation of electron waves.

Procedure (2):

The experiment uses a setup with an electron diffraction tube where electrons are accelerated, pass through a graphite sample and then hit a fluorescent screen. We first made the anode voltage knob to zero before turning on the setup. We vary the voltage across the anode and observe that rings of various diameters appear. The resulting diffraction pattern is then analysed. We are calculating the first lattice plane (n=1), i.e., the first diffraction order. The two inner rings correspond to the first-order electron diffraction from two lattice planes. We then plot the graph between the de Broglie wavelength associated with the anode voltage UA (kV) using Bragg's diffraction law and the Radius of the two inner rings separately. As can be seen, the slope of the graph can be calculated, and accordingly, the lattice spacing d can be estimated. We also take slight angle approximations into account for simplifying the calculations.

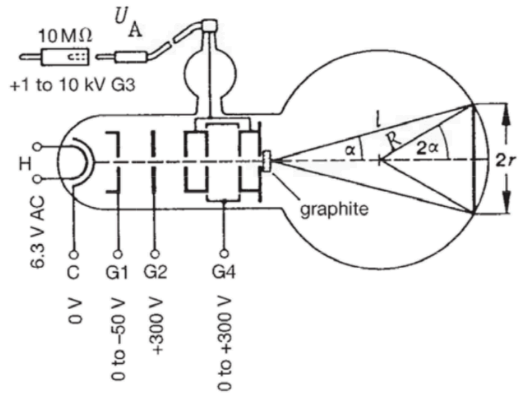


Figure 1.1 Experimental Setup

Observation Tables (2):

D1 and D2 have averaged values in the attached observation table. The calculation for them is ***NOT*** shown. Wavelength is calculated with the help of the following sets of equations.

The wavelength of a photon is given by,

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

Equating the Kinetic Energy with the Potential Energy provided to calculate the electron's momentum.

$$\frac{p^2}{2m_e} = |e|U_A \rightarrow p = \sqrt{2m_e|e|U_A}$$

Equating the momentum back in wavelength to get a relation between the wavelength and Potential Difference.

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2m_e|e|U_A}} = \frac{1.22642596e{-9}}{\sqrt{U_A}}$$

U(kV)	D1(mm)	D2(mm)	R1(mm)	R2(mm)	Wavelength(pm)	d1_wo_app(pm)	d2_wo_app(pm)
1.7	30.99	38.705	15.499	19.35	42.0660634	349.647007	278.5953424
2	28.63	36.54	14.315	18.27	38.78299417	349.4955067	272.4718608
2.4	26.605	33.69	13.303	16.845	35.40386792	343.6823127	270.3014504
2.8	24.855	31.18	12.428	15.59	32.77761253	340.8823835	270.8228925
3.2	22.91	29.435	11.455	14.718	30.66064901	346.2561874	268.6142361
3.6	20.505	27.08	10.253	13.54	28.90713711	365.084465	275.6366547
4	20.395	25.415	10.198	12.708	27.42371817	348.2322269	278.8440356

Table 1.1

Calculations (3):
Bragg's diffraction law relates the lattice spacing (d) with the diffraction angle θ and the wavelength of the incident electron or x-rays and is given as:

$$2d\sin\theta = n\lambda, \qquad n = 1, 2, 3..$$

From Figure 1.1 and using some geometry,

$$\sin 4\theta = \frac{r}{R} \rightarrow \theta = \frac{1}{4}\sin^{-1}\left(\frac{r}{R}\right)$$

Equating everything properly,

$$d = \frac{n\lambda}{2\sin\theta} = \frac{n\lambda}{2\sin\left(\frac{1}{4}\sin^{-1}\left(\frac{r}{R}\right)\right)}$$

We use small angle approximations here to get,

$$d \approx \frac{2R\lambda}{r} \implies r = \frac{2R}{d}\lambda$$

From the graph (slope calculated using Python code attached at the end),
Slope for R1: 0.3747189891415443
Slope for R2: 0.4541878092731705
From here, we can calculate the value of d, given by the expression.

$$d = \frac{2R}{slope}$$

In the given experiment, R = 65 mm

From here,

$$d_1 pm = \frac{130mm}{slope for R1}$$

$$d_2 pm = \frac{130mm}{slope for R2}$$

If we substitute the values we get,
d_1 = 346.9266 pm
d_2 = 286.2252 pm

Percentage Error:-

$$\%\text{Error (d1)} = \frac{346-142}{142}100 = 143.6\%$$
$$\%\text{Error (d2)} = \frac{286-246}{246}100 = 16.2\%$$

If we do not use the small angle approximation, we have to use

$$d = \frac{n\lambda}{2\sin\theta} = \frac{n\lambda}{2\sin\left(\frac{1}{4}\sin^{-1}\left(\frac{r}{R}\right)\right)}$$

from here, n =1, and using values from the table,

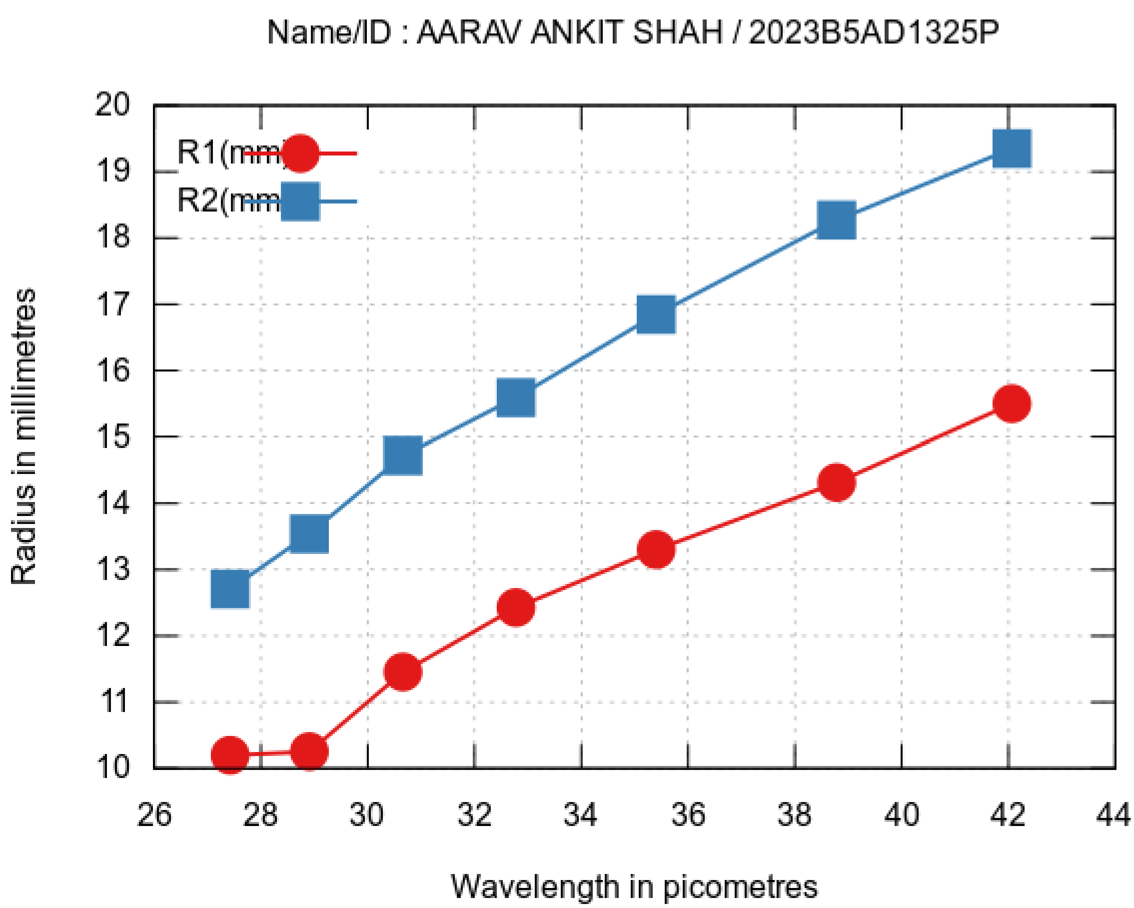
d_1 (average) = 349.0400127435817 pm

d_2 (average) = 273.6123531983382 pm

<u>NOTE: An image of calculations is not attached to the file as all calculations were computerised or shown in the Gdoc file.</u>

<u>Note: This experiment's calculations, codes and graphs can be found at Github-Repo.</u>

Graphs (4):



Concluding Remarks and Learning Outcome (3):
The electron diffraction experiment is conducted with a polycrystalline graphite sample to study the wave-particle duality properties of electrons and measure the interplanar spacing of graphite crystals.
The essential conclusions based on the experiment are given below:

- Wave-particle duality of electrons: The experiment shows that the electrons have wave-like behaviour. This is the core idea in quantum mechanics, as diffraction patterns were seen when electrons were passed through the graphite sample.
- Diffraction patterns: When the graphite diffracts the electrons, they produce concentric rings on a fluorescent screen. These rings are due to constructive interference of electron waves from different atomic planes in the graphite.
- Measurement of interplanar spacing: By analysing the radii of the diffraction rings and knowing the wavelength of electrons, the experiment calculates the spacing between interplanar graphite crystals. This is applied using Bragg's law of diffraction.
- Relationship between accelerating voltage and wavelength: The de Broglie wavelength of the electrons is directly proportional to their momentum, which is set by the accelerating voltage. It can be observed that changing the accelerating voltage causes changes in the diffraction pattern.