Double-Slit Experiment

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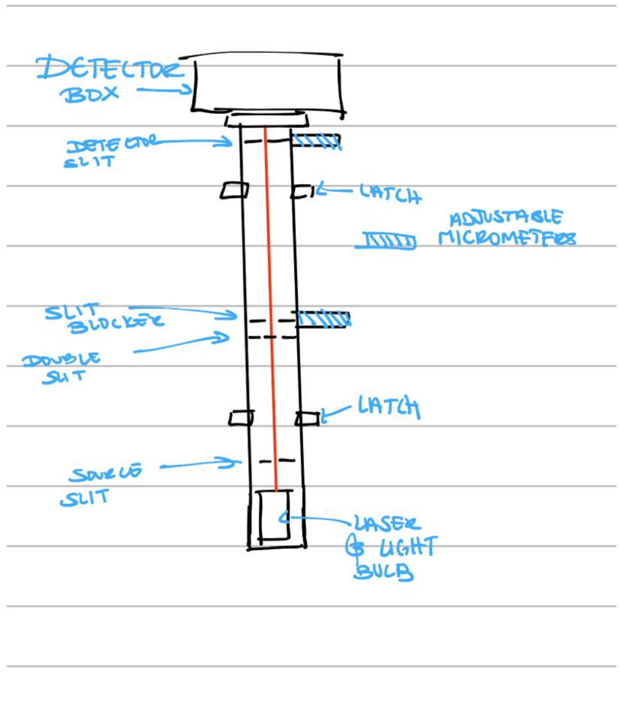
1 Introduction

The purpose of the double-slit experiment is to explore the dual nature of particles, such as electrons or photons. It dives into the interesting behavior of these particles, which appear to have conflicting properties of both waves and particles under different conditions. This experiment tries to unravel the underlying nature of matter and light by observing the patterns generated when particles travel through two neighboring slits, giving insight into the mysterious and elusive behavior of quantum particles. The experiment reveals an astounding wave-like interference pattern formed by individual particles through rigorous observation and analysis, challenging classical intuition. These interference patterns not only highlight quantum physics' uncertain nature but also pose deep questions regarding the fundamental nature of particles and the very existence of reality itself.

2 Procedure

An important first step for this experiment was to make sure the shutter of the single-photon detector was closed, which would protect its extremely sensitive nature, prior to any electrical setup. Thorough safety inspections were done to ensure that the high-voltage section's toggle switch was off and the dial was set to 0.00. The assembly's long two-slit cover was carefully opened to show the interior parts. To do this, the lid was unhooked from the latches holding it in place. The micrometer drives for adjusting the horizontal position of the slit blocker and detector slit were identified since they were going to be used. Then the device was turned on and using a white card, the measurements of where the left, right, and double slit were taken. Once everything was on and running, the measurements were taken in increments of 10 micrometers. After each 10 micrometers, from 0 to 1 centimeter, the voltage was recorded. For the right slit, the increments were done in 20 micrometers from 0 to 1 centimeters. Then for the measurements for the double slit, it was taken in increments of 5. This data was recorded and analyzed in real-time to make sure that the experiment was running smoothly.

2.1 Set-Up



3 Data And Analysis

3.1 Calculations

The following formula was used to determine the angle between the axis of the original laser light and the areas of the diffraction pattern that were most diffracted:

$$tan(\theta) = \frac{x - x_0}{L} \tag{1}$$

Then to find the diffraction patterns for the singular slits, these equations were used, where I is the intensity and I_0 is the peak intensity.

$$\phi = \frac{2\pi}{\lambda} * D * sin(\theta) \tag{2}$$

$$I(\theta) = I_0 * (\frac{sin(\frac{\phi}{2})}{\frac{\phi}{2}})^2 \quad (3)$$

The equations for double slit diffraction patterns are similar, but also include the angle without D, the width of the slit. These equations are shown below:

$$\psi = \frac{2\pi}{\lambda} * sin(\theta) \quad (4)$$

$$\phi = \frac{2\pi}{\lambda} * D * sin(\theta) \quad (5)$$

3.2 Uncertainties

The variables with uncertainty in this experiment included voltage, theta, psi, and intensity.

The equation for the uncertainty of the voltage is:

$$\sigma_V = 4I_0(-2 * \phi^{-3} * sin^2(\frac{\phi}{2})) + (sin(\frac{\phi}{2}) * cos(\frac{\phi}{2}) * \phi^{-2}) * \sigma_\phi \quad (6)$$

The equation for the uncertainty of θ is:

$$\sigma_\theta = \frac{1}{L} * \sigma_x \quad (7)$$

The equation of uncertainty for ψ is:

$$\sigma_\psi = \frac{2\pi}{\lambda} D cos\theta * \sigma_\theta \quad (8)$$

The equation for the uncertainty of the intensity of the single slit is:

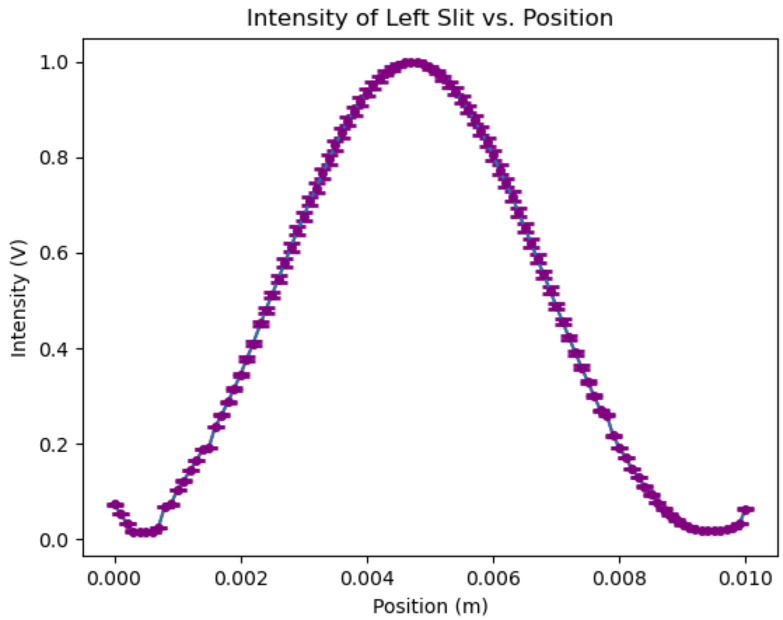
$$\sigma_I = 4{I_\sigma}^2[2\phi^{-3}sin(\frac{\phi}{2}) + \frac{1}{2}cos(\frac{\phi}{2}\phi^{-2})]\sigma_\phi \quad (9)$$

And finally, the equation for the uncertainty in intensity for the double slit is:

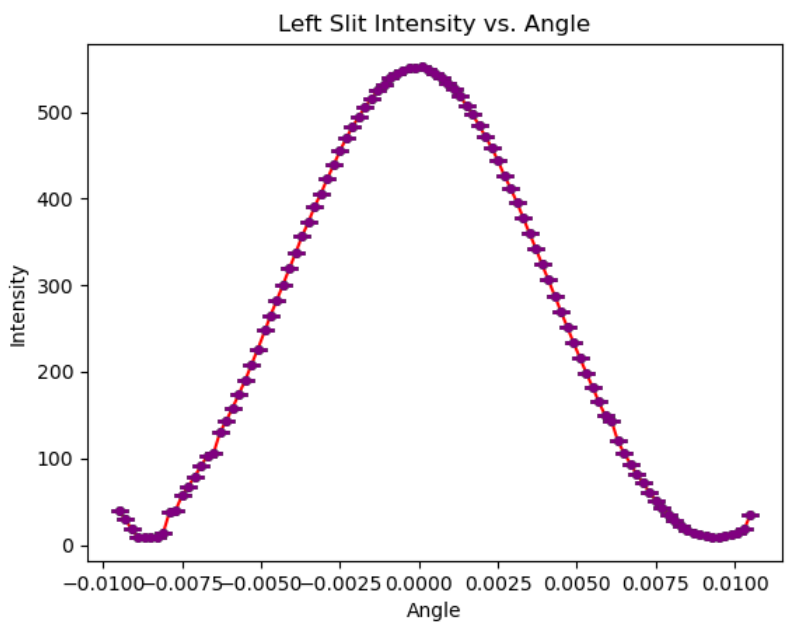
$$\sigma_I = \sqrt{(\frac{\partial I}{\partial \phi})^2{\sigma_\phi}^2 + (\frac{\partial I}{\partial \psi})^2{\sigma_\psi}^2} \quad (10)$$

3.3 Results

Left Slit



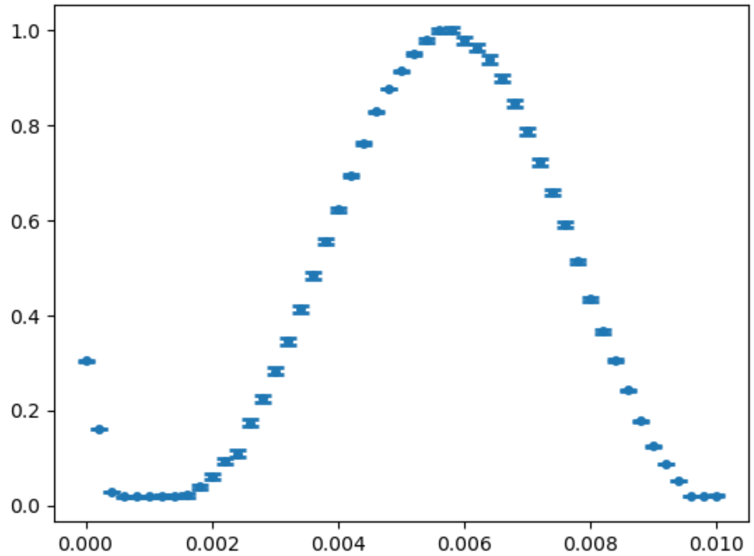
The results from this fitting show:



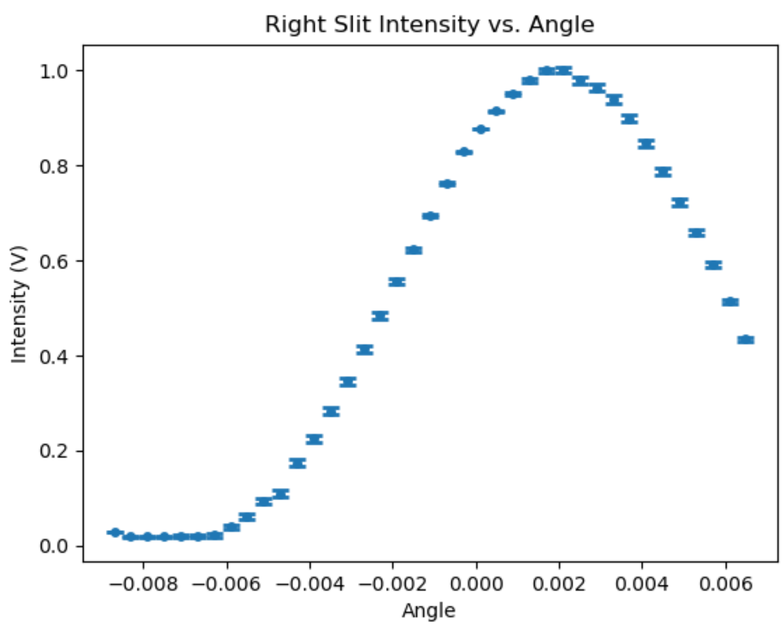
The results from this fitting show: I_0 = 1.00 +/- 48.126, x_0 = 0.0047 +/- 7.577, D = 5.0457e-06 +/- 0.014

Right Slit

Right Slit Intensity versus Position

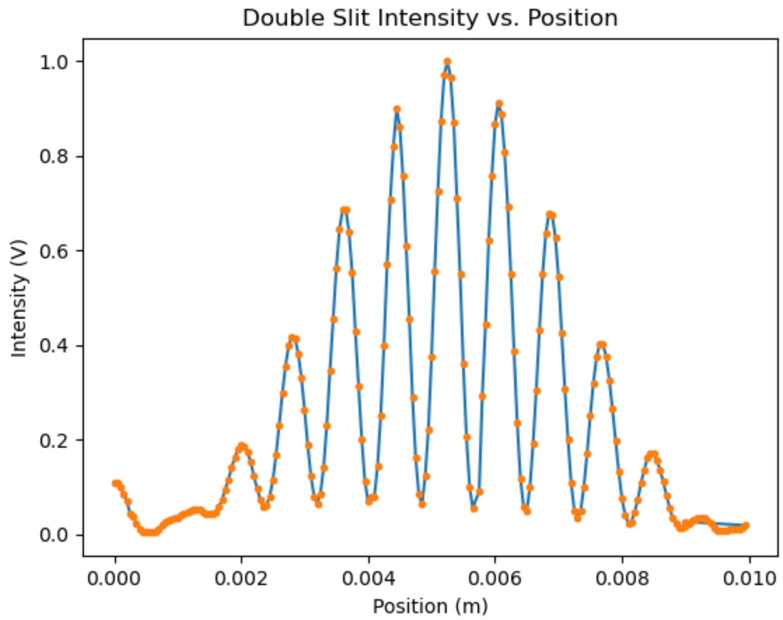


1.0
0.8
0.6
0.4
0.2
0.0
0.000
0.002
0.004
0.006
0.008
0.010



Right Slit Intensity vs. Angle
Intensity (V)
Angle
1.0
0.8
0.6
0.4
0.2
0.0
−0.008
−0.006
−0.004
−0.002
0.000
0.002
0.004
0.006

Double Slit

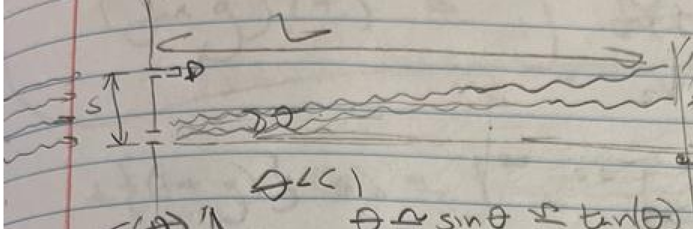


Finding the separation of the slit is possible by subtracting the peak intensity of the left slit from the right slit.

4 Conclusion

The double-slit experiment offered valuable insights into the wave-particle duality of quantum particles. Observations of interference patterns generated by particles passing through two adjacent slits allowed for the calculation of the distances between the slits and the slit width. The experiment demonstrated the simultaneous manifestation of wave-like interference and particle-like characteristics in particles. The results obtained aligned with fundamental principles of quantum physics, challenging classical notions and emphasizing the probabilistic nature of particle behavior. The observed patterns highlighted the relationship between particles and waves, showing the significance of quantum principles in understanding the fundamental nature of matter and light. The findings contribute to the ongoing exploration of quantum particle behavior and serve as a reference for further investigations into the characteristics of light.

DOUBLE-SLIT EXPERIMENT



INTENSITY

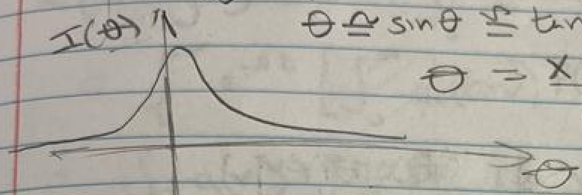
$I \propto$ VOLTAGE

$\theta << 1$

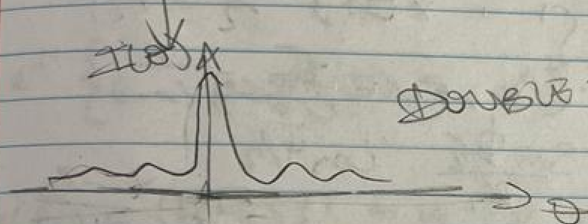
$\theta \cong \sin\theta \cong \tan(\theta)$

θ in RADIANS

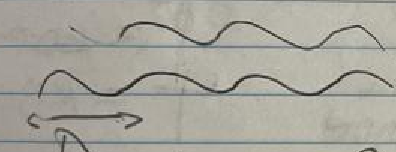
$$\theta = \frac{x - x_0}{L}$$



INTERFERENCE IS



DOUBLE-SLIT



CONSTRUCTIVE INTERFERENCE

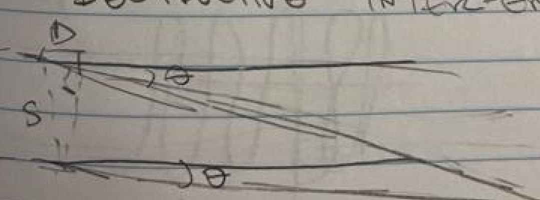
PATH LENGTH DIFFERENCE = $n\lambda$

$$\Delta = n\lambda$$

PATH LENGTH DIFFERENCE IS DIFFERENCE OF TWO PATH LENGTHS

CONSTRUCTIVE INTERFERENCE $- n = 0$

DESTRUCTIVE INTERFERENCE $= \Delta = (n + \frac{1}{2})\lambda$

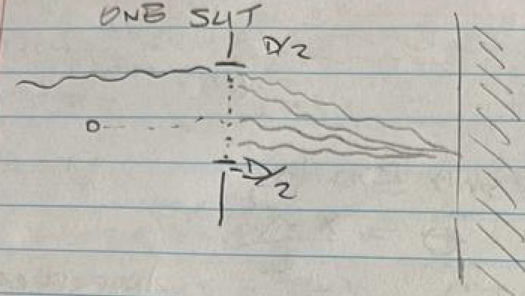


$$\Delta = S \cdot \sin\theta = S\left(\frac{x - x_0}{L}\right)$$

max $\Leftarrow\Rightarrow$ CONSTRUCTIVE INTERFERENCE

INTERFERENCE

ONE SLIT



A: F.T of SLIT GEOMETRY

$$f(x) = \begin{cases} 1, & x \in \left(-\frac{D}{2}, \frac{D}{2}\right) \\ 0, & \text{ELSEWHERE} \end{cases}$$

AMPLITUDE $\propto \dfrac{\sin \phi/2}{\phi/2} \cos \psi/2$

$$\theta = \frac{x - x_0}{L}$$

INTENSITY $= |A|^2$

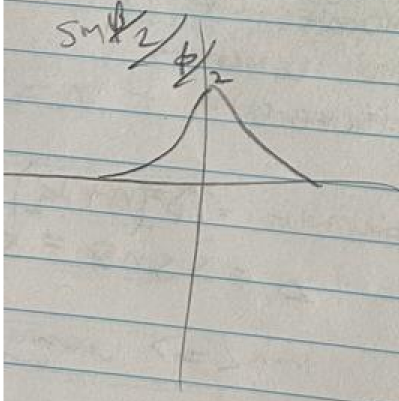
$$\phi = KD \sin\theta$$

$D=$ SLIT WIDTH

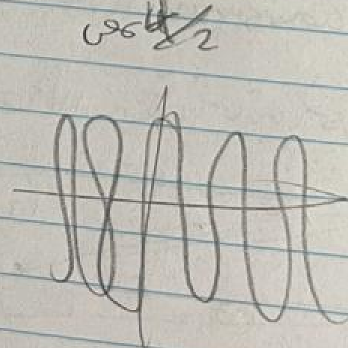
$S=$ SEPARATION

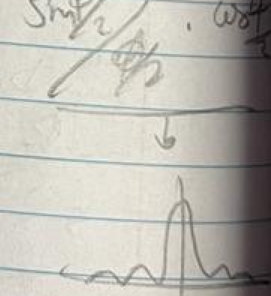
$$\psi = KS \sin\theta$$

$S >> D$

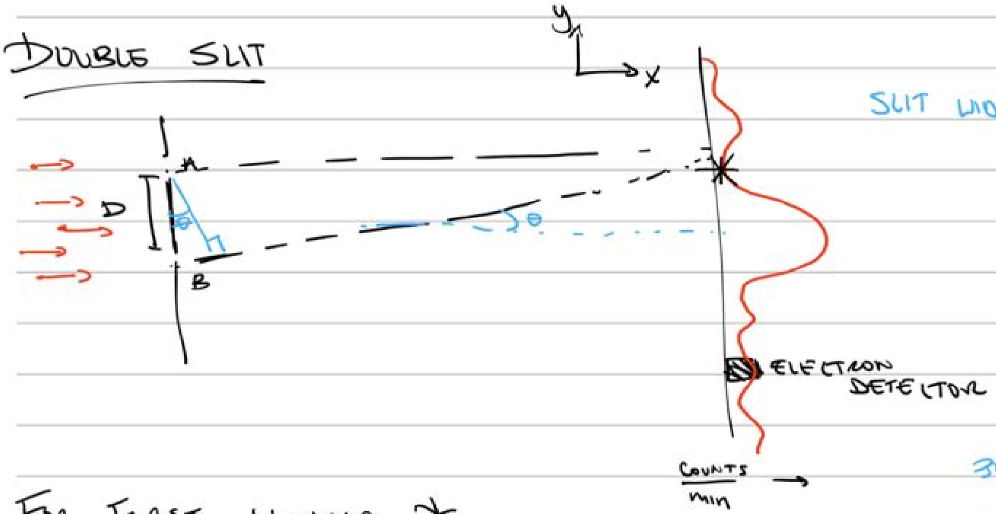


ψ would oscillate faster because S is larger than D





DOUBLE SLIT



SLIT WIDTH DIFFERENCE =

FOR FIRST MINIMA *

PATH DIFFERENCE $= \frac{\lambda}{2}$

$D \sin\theta = \frac{\lambda}{2}$

PATH DIFFERENCE

$D \sin\theta = \frac{\lambda}{2}$

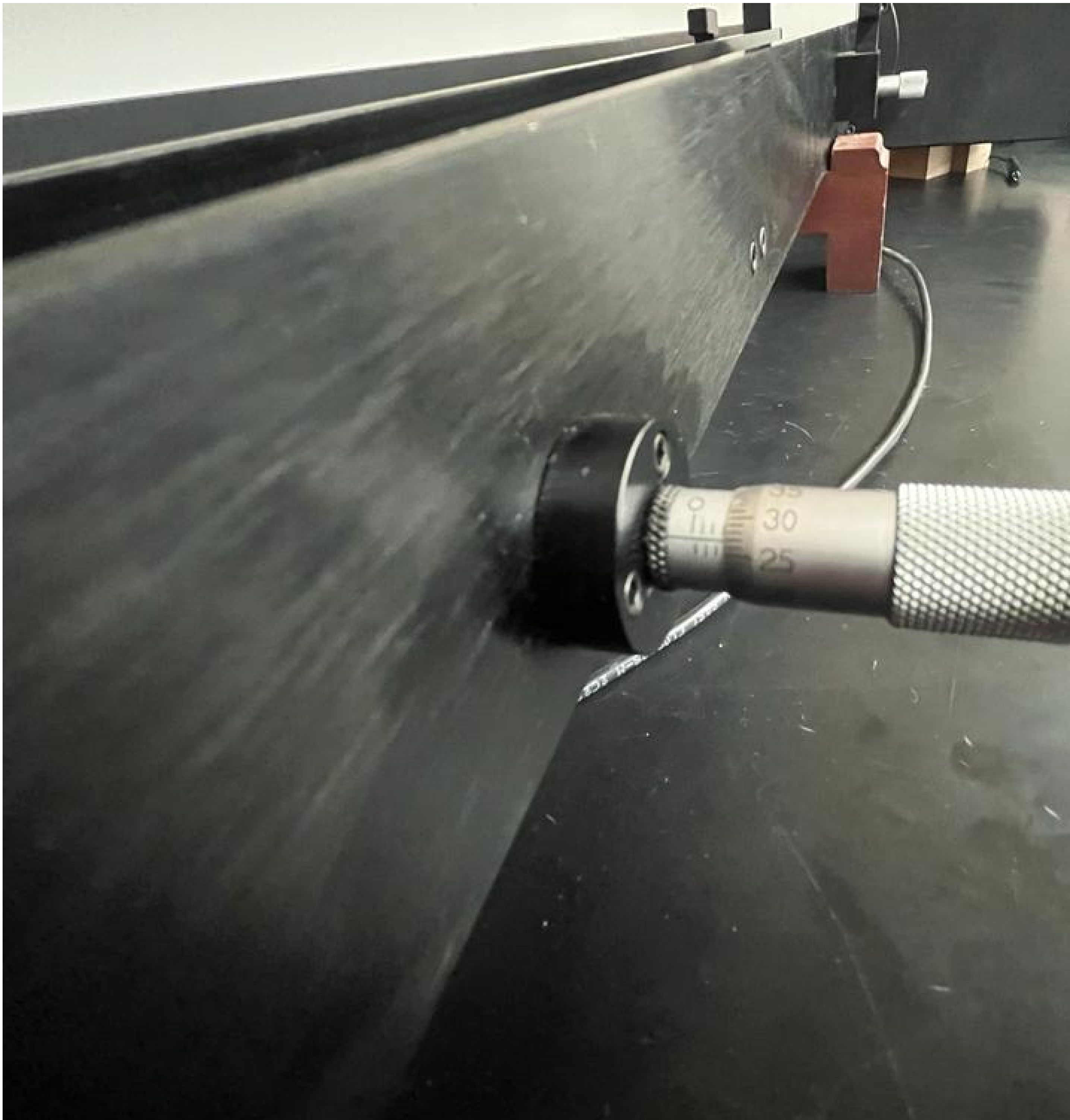
ELECTRON'S WAVELENGTH

$\lambda = h / p_x$

$\sin\theta \approx \theta = \frac{h}{2 p_x D}$

y: DISTANCE OF FIRST MINIMA FROM CENTRAL MAXIMA

$\tan\theta = \frac{y}{R}$ | R: DISTANCE BETWEEN THE SLIT & SCREEN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