Escape (The Electron Song)

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Summary

1 What Are We Dealing With?
- A Bit of History
- Experimental Results

2 Concerning an Heuristic Point of View Toward the Emission and Transformation of Light
- Creating a New Theory
- Theoretical Predictions

3 Statistical Analysis
- Measuring V_0

What Are We Dealing With?

A Bit of History

I Can't Believe It's Not History!

Definition (Truth)

We define a story as *true* whenever something can be learned from it. ♠

Hertz & Lenard

Heinrich Hertz Sparks between electrodes occur more easily when ultraviolet light falls on one of them (he was shocked)

Philipp Lenard Experiments with the effect

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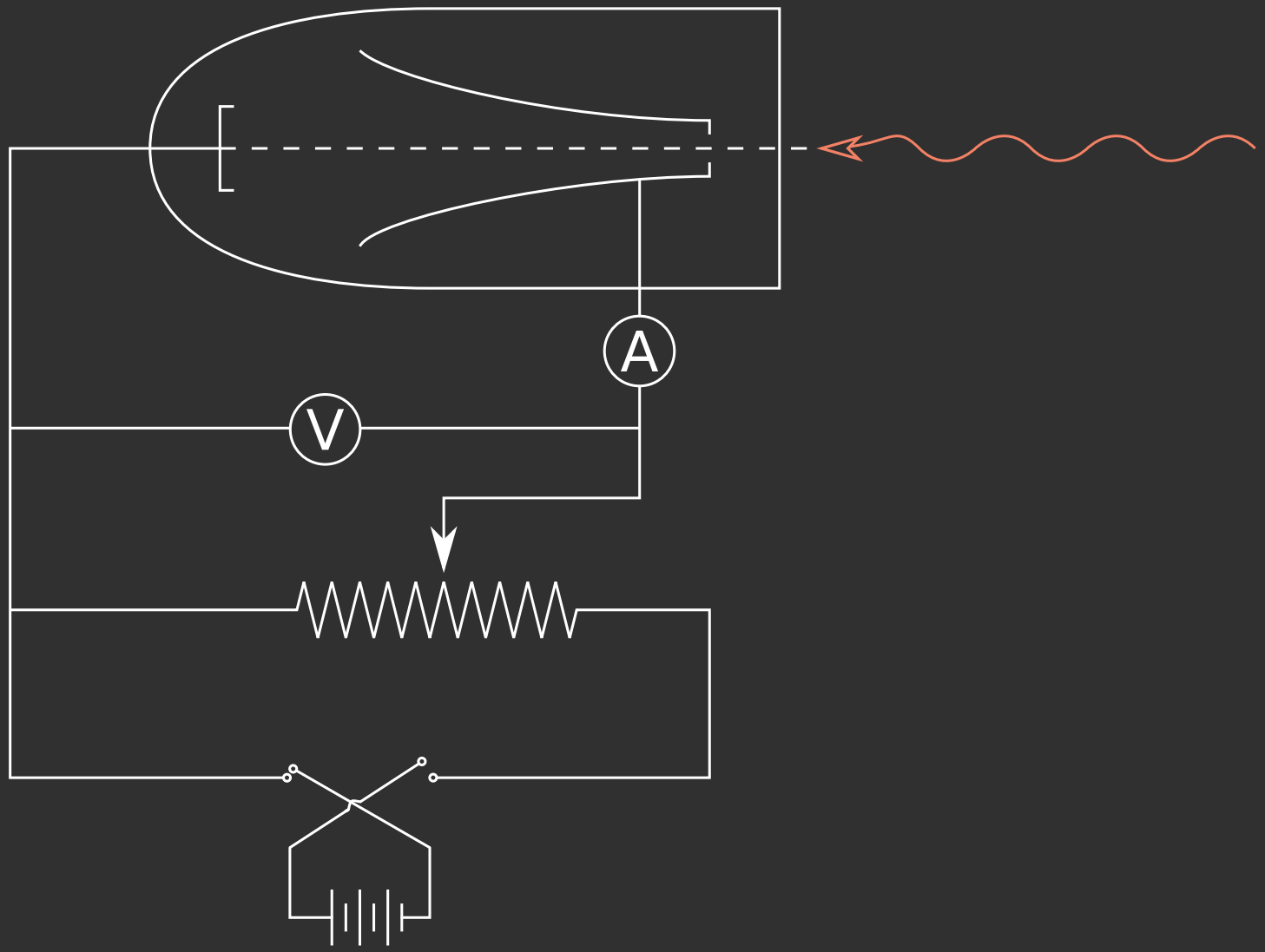
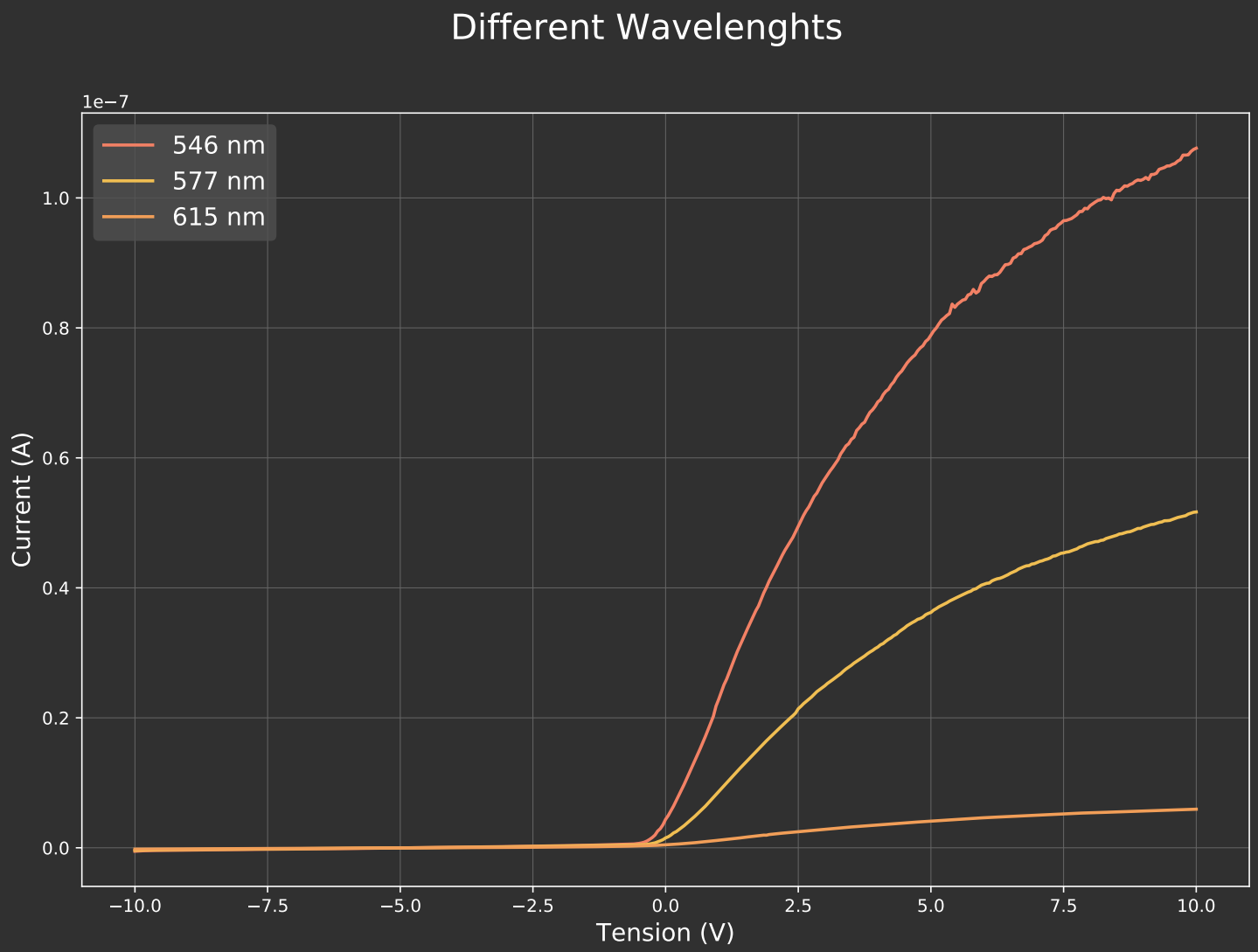
Experimental Results

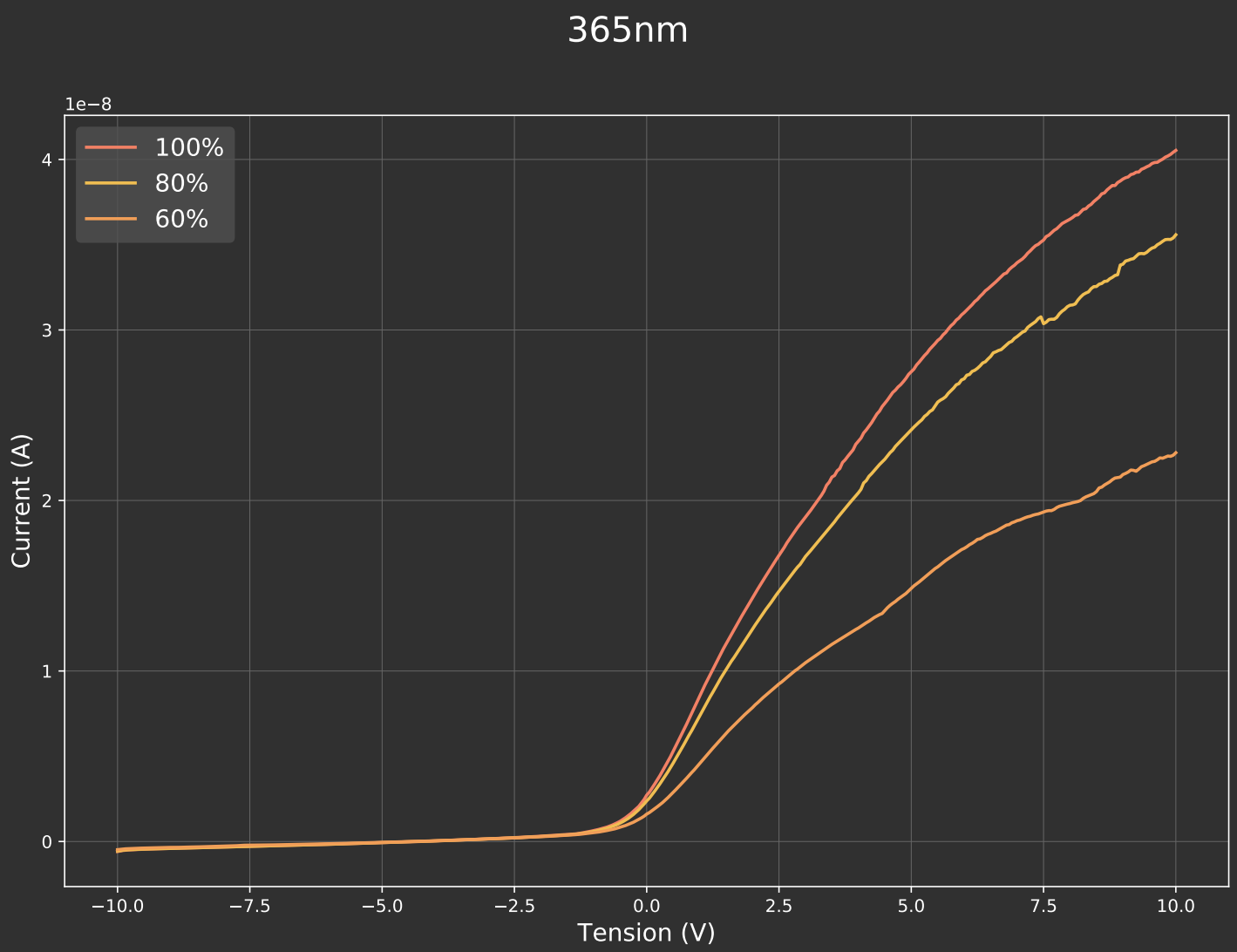
Lab Time



Different Wavelenghts, Same Intensity



UV Light - 365nm



Experimental Observations

- There is a stopping potential V_0 bellow which no current is observed, independent of the intensity of light
- The higher the frequency of light, the higher the current detected
- No time delay (it should take about two minutes for the electron to be emitted, but the process is instantaneous)

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Experimental Observations

How can we explain these weird observations?

Concerning an Heuristic Point of View Toward the Emission and Transformation of Light

Creating a New Theory

Mechanics vs. Electrodynamics

Mechanics

- Positions
- Momenta

Discrete

Electrodynamics

- Charge densities
- Current densities

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Quanta of Light

- Light can be thought of as a particle (photon)
- Energy of photon: $E = h\nu$ (Planck, Einstein)

Collisions Between Photon and Electron

$$K_{e^-} = h\nu$$

After the Collision - Most Energetic Electron

Energy is spent in order to leave the plate

$$K_{e^-} = h\nu - e\phi$$

The tension accelerates the electrons

$$K_{e^-} = h\nu - e\phi + eV$$

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Stopping Potential

There is a potential V_0 at which $K_{e^-} = 0$

$$V_0 = \phi - \frac{h}{e}\nu$$

Theoretical Predictions

Current per Tension

For $V < V_0$, we have

$$\begin{aligned} K_{e^-} &= h\nu - e\phi + eV \\ &< h\nu - e\phi + eV_0 \\ &= 0 \end{aligned}$$

The electrons can't reach the anode and there is no current

Current per Tension

For $0 > V > V_0$, we have

$$\begin{aligned} K_{e^-} &= h\nu - e\phi + eV \\ &> h\nu - e\phi + eV_0 \\ &= 0 \end{aligned}$$

$$\begin{aligned} K_{e^-} &= h\nu - e\phi + eV \\ &< h\nu - e\phi \end{aligned}$$

Some of the removed electrons, but not all of them, can reach the anode and there is a current

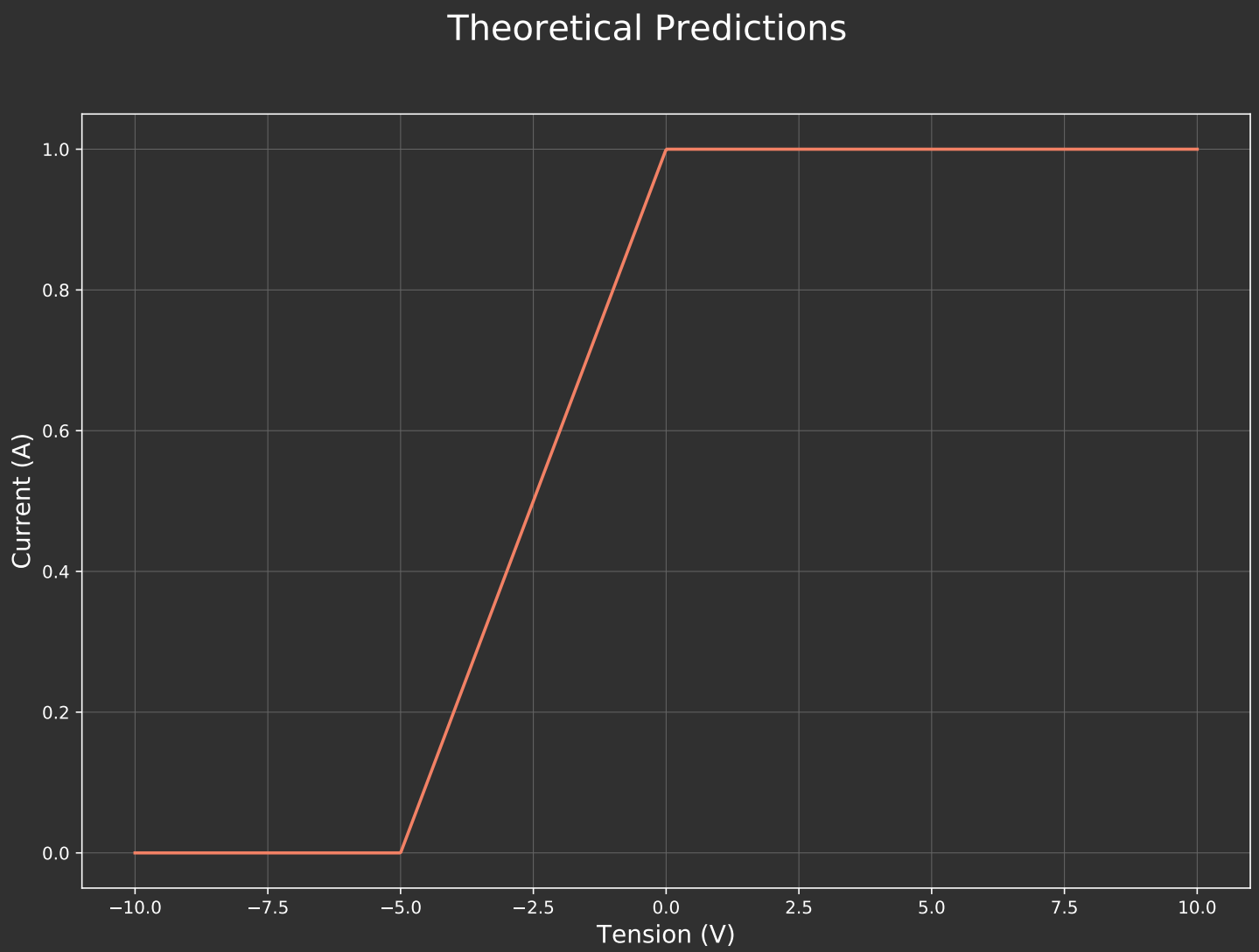
Current per Tension

For $V > 0$, we have

$$\begin{aligned} K_{e^-} &= h\nu - e\phi + eV \\ &> h\nu - e\phi \end{aligned}$$

All removed electrons can reach the anode and there is a maximal current

Current per Tension



Threshold Frequency

Since the electrons leave the plate with kinetic energy $h\nu - e\phi$

$$h\nu - e\phi \geq 0$$
$$\nu \geq \frac{e}{h}\phi$$

If the frequency is lower than a threshold frequency, the Photoelectric Effect won't occur

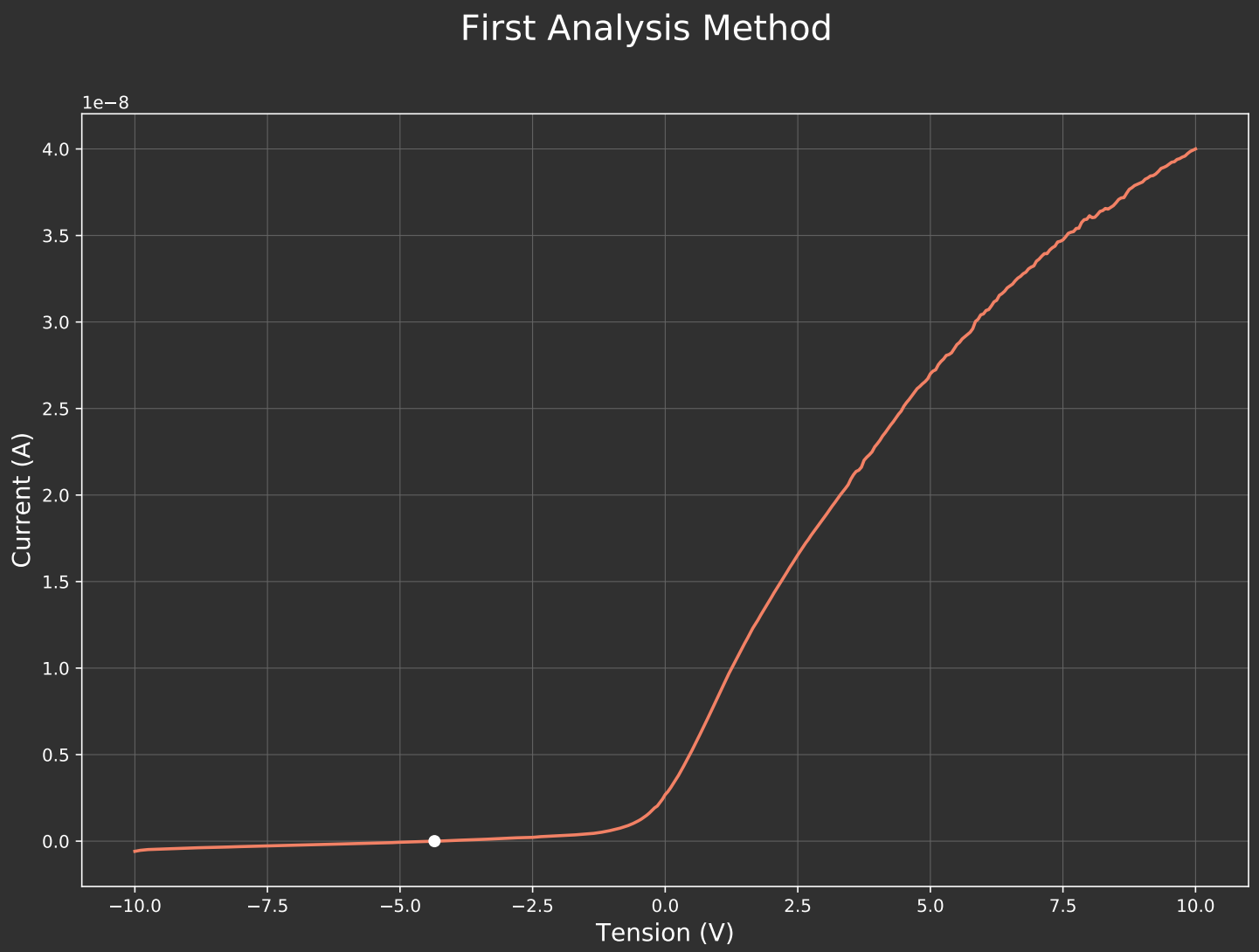
Interaction Delay

Since the electron absorbs all of the energy at once (when colliding with the photon), the interaction is instantaneous.

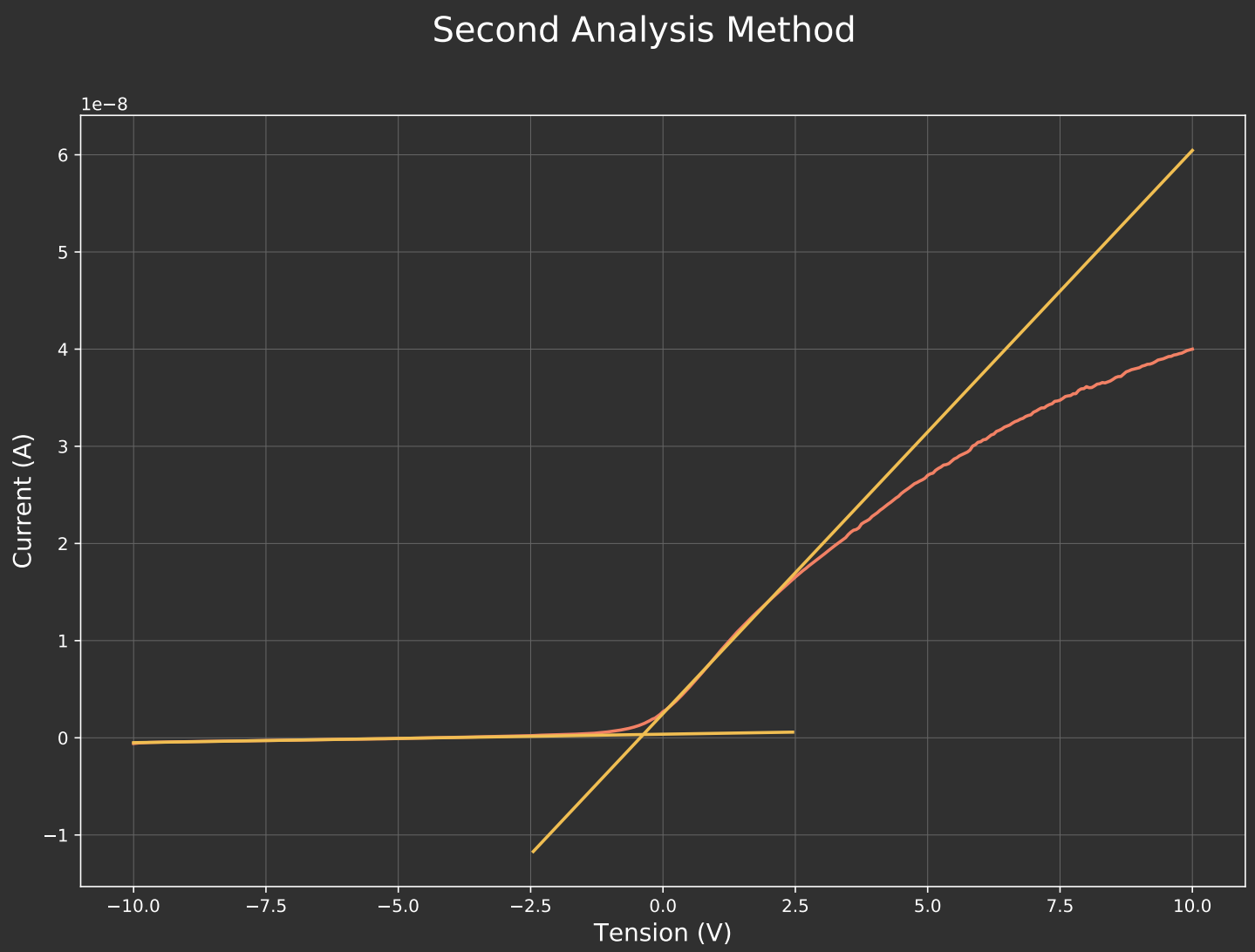
Statistical Analysis

Measuring V_0

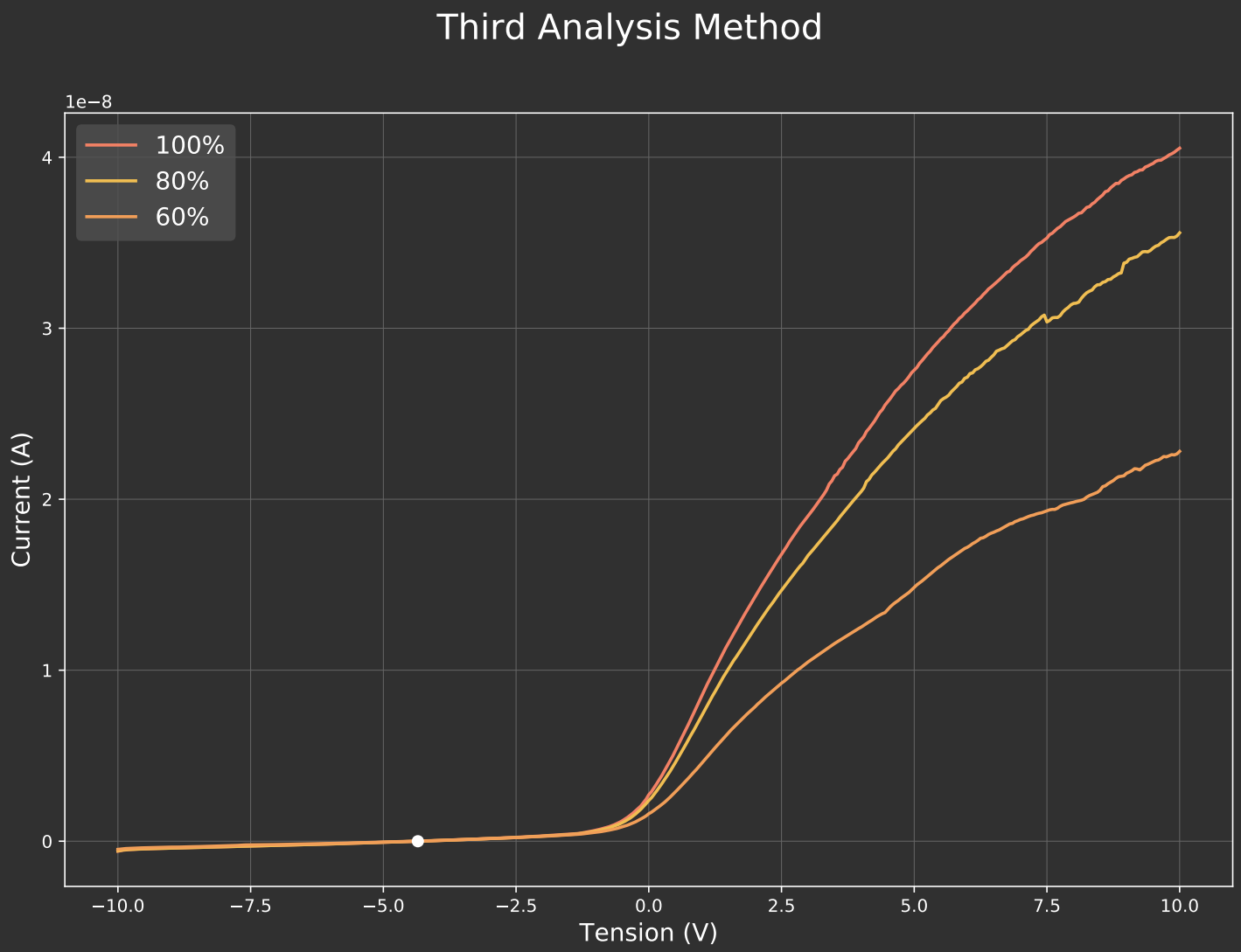
First Analysis Method



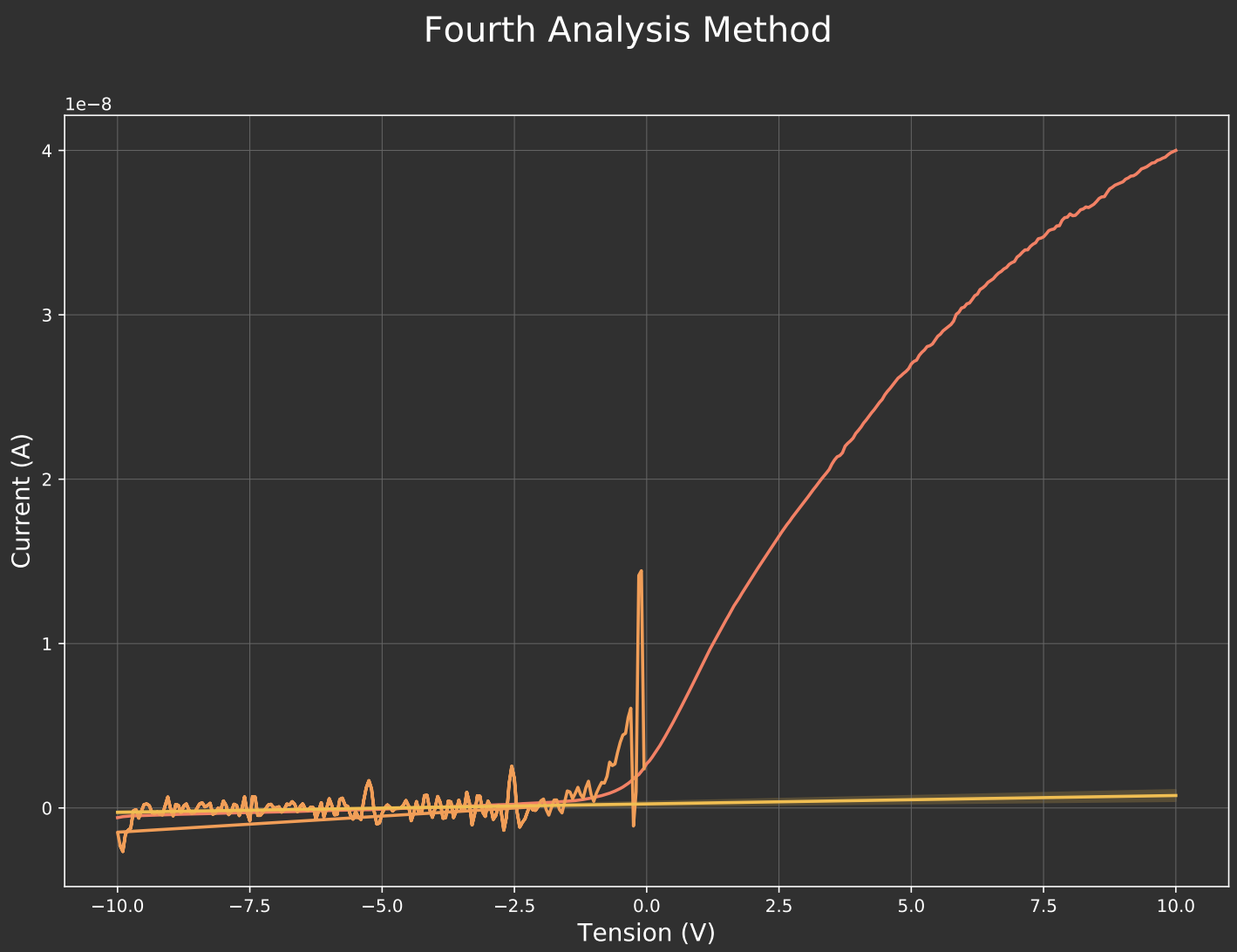
Second Analysis Method



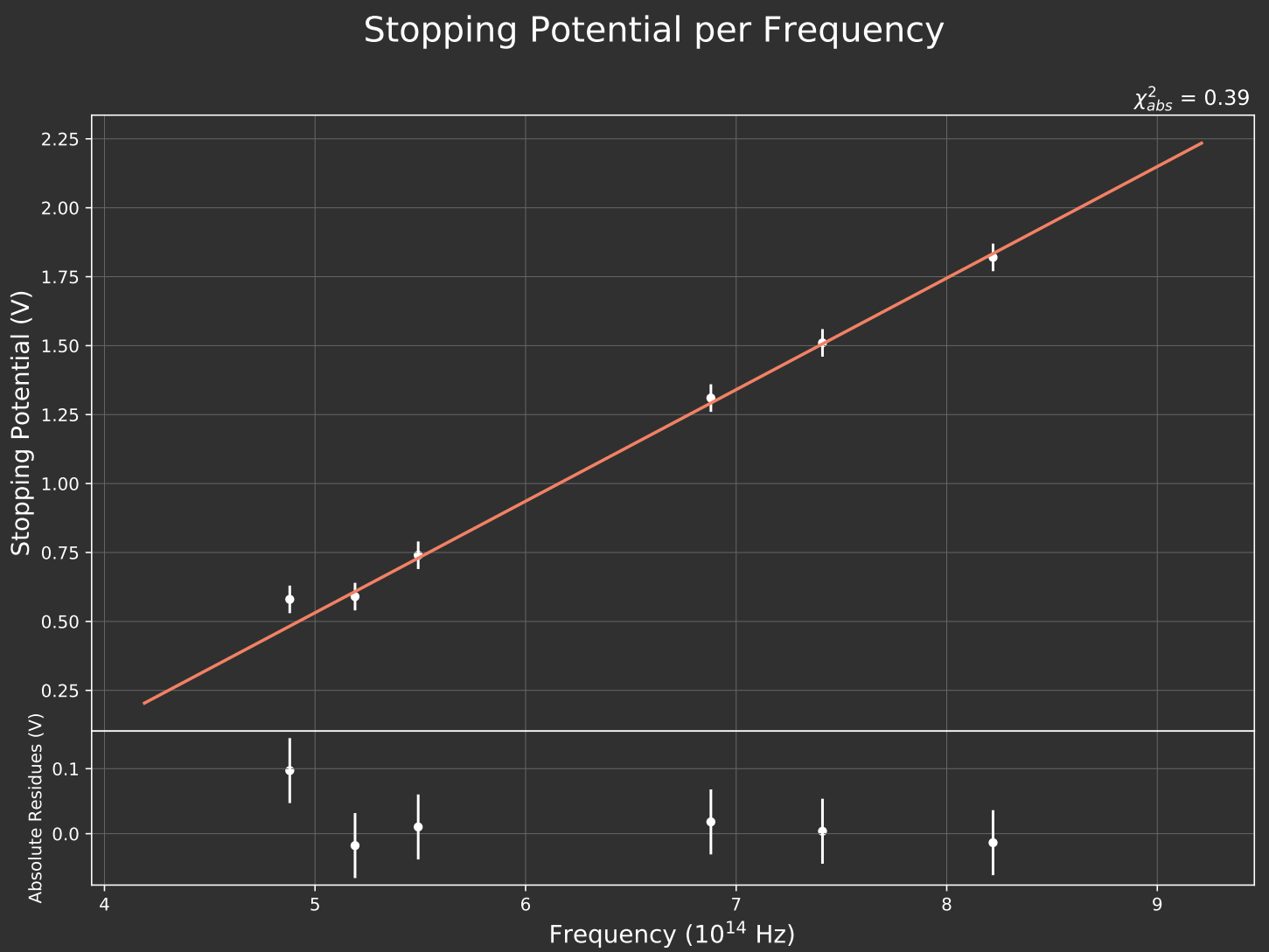
Third Analysis Method



Fourth Analysis Method



Stopping Potential



Least Squares

There is a potential V_0 at which $K_{e^-} = 0$

$$V_0 = \frac{h}{e}\nu - \phi$$

Adjusted Values

$$\frac{h}{e} = 0.404(20) \times 10^{-14}\,\text{V} \quad \phi = 1.49(13)\,\text{V}$$

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Planck's Constant

Value obtained to Planck's Constant

$$h = 6.48(11) \times 10^{-34}\,\mathrm{J\,s}$$

Reference value[5]

$$h = 6.626\,070\,040(81) \times 10^{-34}\,\mathrm{J\,s}$$

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Acknowledgments

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