Wroclaw University of Science and Technology

GENERAL PHYSICS
LABORATORY REPORT

Theme of class: DETERMINATION OF PLANCK CONSTANT BASED ON CURRENT-VOLTAGE CHARACTERISTICS OF LEDS

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1 Introduction

1.1 Theory

The study of quantum mechanics has revolutionized our understanding of the behavior of particles and electromagnetic radiation at the atomic and subatomic levels. One of the fundamental constants in quantum mechanics is Planck's constant (h), which relates the energy of a photon to its frequency. The determination of Planck's constant is of significant importance in various fields, including physics, electronics, and materials science.

Light-emitting diodes (LEDs) provide a practical and accessible platform for investigating the relationship between energy and frequency through their current-voltage characteristics. When a forward voltage is applied to an LED, it emits light with a characteristic wavelength. By examining the current-voltage behavior of different LEDs, we can obtain valuable insights into the energy levels involved in the photon emission process.

1.2 Equipment

The following tools were used during the laboratory:

- Tunable power supply
- Electroluminescent diode
- Digital multimeters
- Monochromator
- Photoresistor

2 Experiment

In this experiment, a voltage source will be used to provide a range of forward voltages to the LEDs, while a current measurement device will record the corresponding forward currents. By plotting the current-voltage data and analyzing the linear portion of the curve, we can obtain the slope of the line, which is directly related to Planck's constant.

Understanding the value of Planck's constant is crucial for numerous applications, including the development of advanced electronic devices, semiconductor physics research, and the advancement of energy-efficient lighting technologies. By conducting this experiment and determining Planck's constant based on the current-voltage characteristics of LEDs, we can deepen our understanding of quantum mechanics and its practical implications.

2.1 Formulas

- $$\Delta X = \frac{a}{100\%} \cdot X + n \cdot \Delta_{res}$$
- $$U_b = -\frac{b}{a}$$
- $$h = \frac{e}{c} \lambda U_b$$
- $$u_c(U_b) = \sqrt{(b/a^2)^2 \cdot u(a)^2 + (-1/a)^2 \cdot u(b)^2}$$
- $$u_c(h) = \sqrt{(\frac{e}{c} U_b)^2 \cdot u(\lambda)^2 + (\frac{e}{c} \lambda)^2 \cdot u(U_b)^2}$$

e - elementary charge
c - velocity of light in vacuum
λ - wavelength
U_b - potential barrier
h - Planck constant

Data

Initial data

	V [V]	I [mA]
min	2.53	0
max	3.27	16.44
	3.26	16.05
	3.25	15.25
	3.24	14.99
	3.23	14.57
	3.22	14.08
	3.21	13.58
	3.2	13.05
	3.19	12.48
	3.18	12.03
	3.17	11.41
	3.11	8.75
	3.05	6.44
	2.99	4.52
	2.93	2.93
	2.87	1.8
	2.81	0.95
	2.75	0.4
	2.69	0.17
	2.62	0.05
	2.56	0.01

Table 1: Experiment data

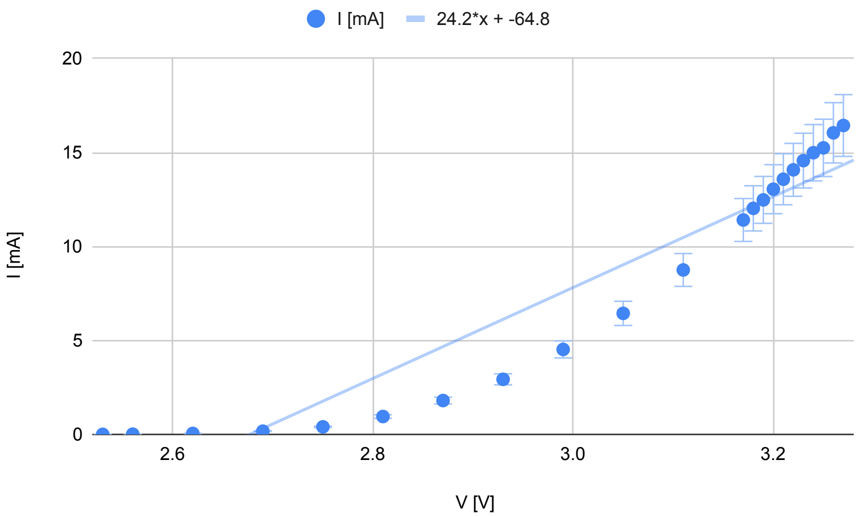

Figure 1: Current-voltage characteristics

a	u(a)	b	u(b)
24.2	1.77	-64.8	5.33

Table 2: Data obtained from linear regression

Meters Uncertainties

Δ_p	λ	I	U
	10mm	1.4% rdg + 3dgt	0.5% rdg + 1 dgt

Table 3: Meters Manual Data

Analysis of results

V [V]	u(V) [V]	I [mA]	u(I) [mA]	$\lambda[nm]$
2.53	0.02265	0	0.03	466
3.27	0.02635	16.44	0.26016	465
3.26	0.0263	16.05	0.2547	464
3.25	0.02625	15.25	0.2435	466
3.24	0.0262	14.99	0.23986	465
3.23	0.02615	14.57	0.23398	
3.22	0.0261	14.08	0.22712	
3.21	0.02605	13.58	0.22012	
3.2	0.026	13.05	0.2127	
3.19	0.02595	12.48	0.20472	
3.18	0.0259	12.03	0.19842	
3.17	0.02585	11.41	0.18974	
3.11	0.02555	8.75	0.1525	
3.05	0.02525	6.44	0.12016	
2.99	0.02495	4.52	0.09328	
2.93	0.02465	2.93	0.07102	
2.87	0.02435	1.8	0.0552	
2.81	0.02405	0.95	0.0433	
2.75	0.02375	0.4	0.0356	
2.69	0.02345	0.17	0.03238	
2.62	0.0231	0.05	0.0307	
2.56	0.0228	0.01	0.03014	.

Table 4: Final data

λ [nm]	u(λ) [nm]	Ub [V]	$u_c(Ub)$ [V]	h [J s]	u_c(h) [J s]
465.2	5.8	2.7	0.3	6.66E-34	≈ 0

Table 5: Final data

Example calculations:

- $$u(U) = \frac{a}{100\%} \cdot X + n \cdot \Delta_{res} = (0.5/100) \cdot 2.53 + 1 \cdot 0.01 = 0.03$$
- $$U_b = -\frac{b}{a} = -\frac{-64.8}{24.2} = 2.68$$
- $$h = \frac{e}{c}\lambda U_b = \frac{1.60E-19}{299792458} \cdot 465.2 \cdot 2.68 = 6.66E-34$$
- $$u_c(h) = \sqrt{(\frac{e}{c}U_b)^2 \cdot u(\lambda)^2 + (\frac{e}{c}\lambda)^2 \cdot u(U_b)^2} \approx 0$$

- values are to small and calculator can't calculate the uncertainty for $u_c(h)$
- $$u_c(U_b) = \sqrt{(b/a^2)^2 \cdot u(a)^2 + (-1/a)^2 \cdot u(b)^2} = 0.3$$

3 Conclusion

The emission wavelength is given at the start and is equal to 465.2[nm] so we do not have to look for its value, as for the Planck constant we calculate it using our measurements and we obtain the value of $6.66 \cdot 10^{-34}$ [J·s] , we can see that our measurements are correct since the actual value of the constant is $6.62607015 \cdot 10^{-34}$ [J·s] and we close enough to assume that our measurements and calculations are correct.