

Determination of the Planck constant using electroluminescent diodes

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Outline

There are several goals according to this task. The main goal is to obtain Planck constant and related uncertainties. In order to do that we had to determine wavelength of the light emitted by the diodes and measure their current-voltage characteristic.

We were given following equipment:

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

We started by connecting power supply, multimeters and diode. We used Sanwa CD771 for voltage measurements and Kenot KT890 for current measurements. By looking through the monochromator and trying to get diode as brightest as we could and then get the wavelength from monochromator.

The next step we took was to measure current-voltage characteristic. In order to do this we set power to 0 and increased it step by step taking measurements from our multimeters. We took 20 measurements for each diode.

Theory

We start with the equation for light energy for

$$E = h \frac{c}{\lambda}$$

$$E = eV$$

$$eV = h \frac{c}{\lambda}$$

$$eV \frac{\lambda}{c} = h$$

Threshold voltage can be substituted by the slope of current to voltage characteristic.

$$e * U_b = h \frac{c}{\lambda}$$

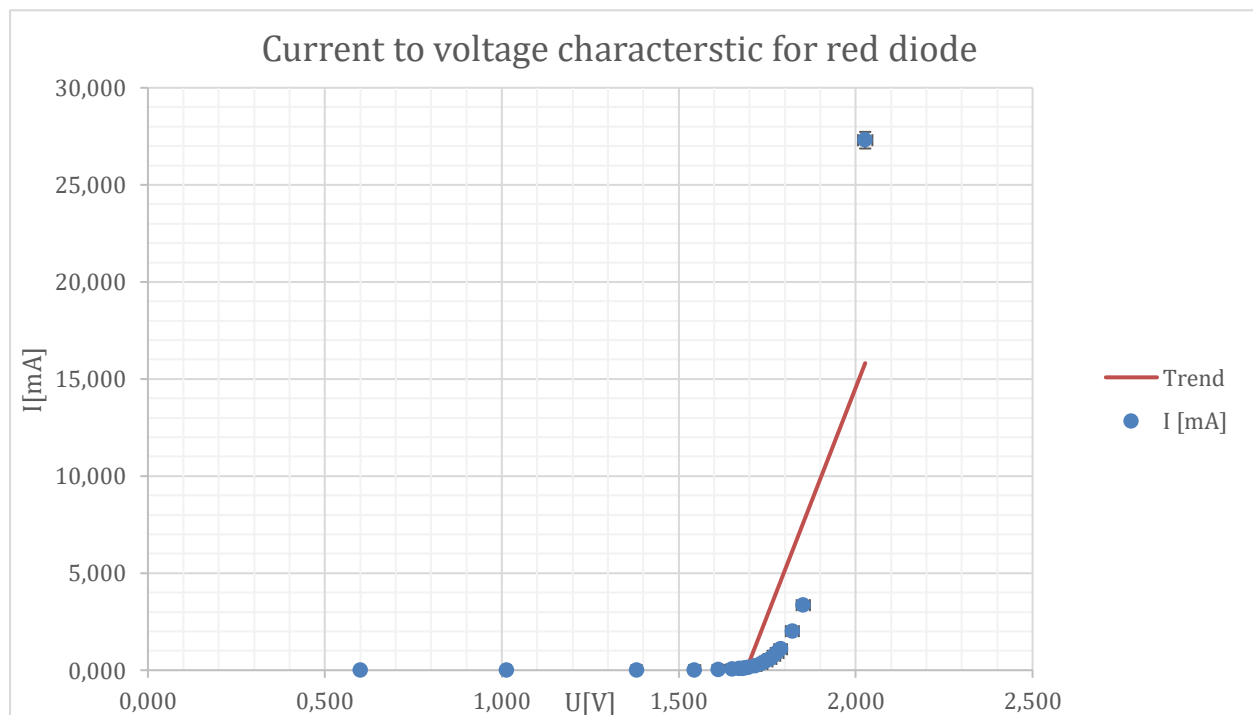
$$y = ax + b$$

$$U_b = -\frac{b}{a}$$

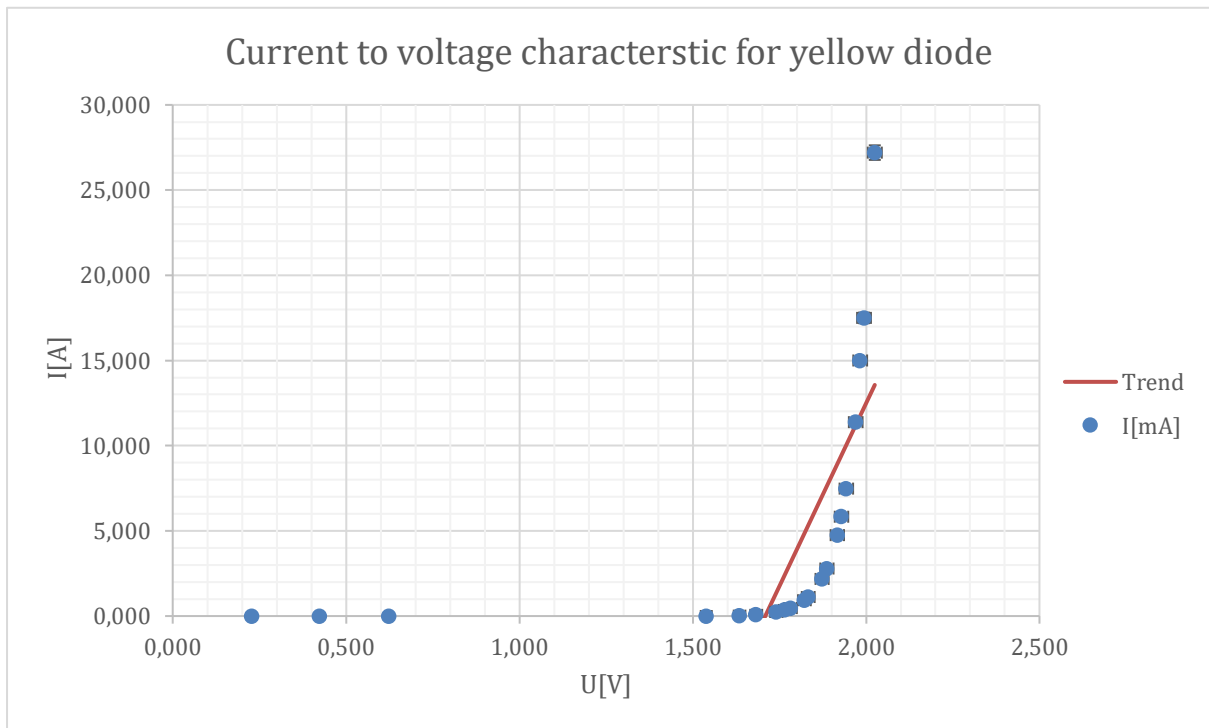
$$h = \frac{e}{c} U_b \lambda$$

Data table presenting measurements and calculations

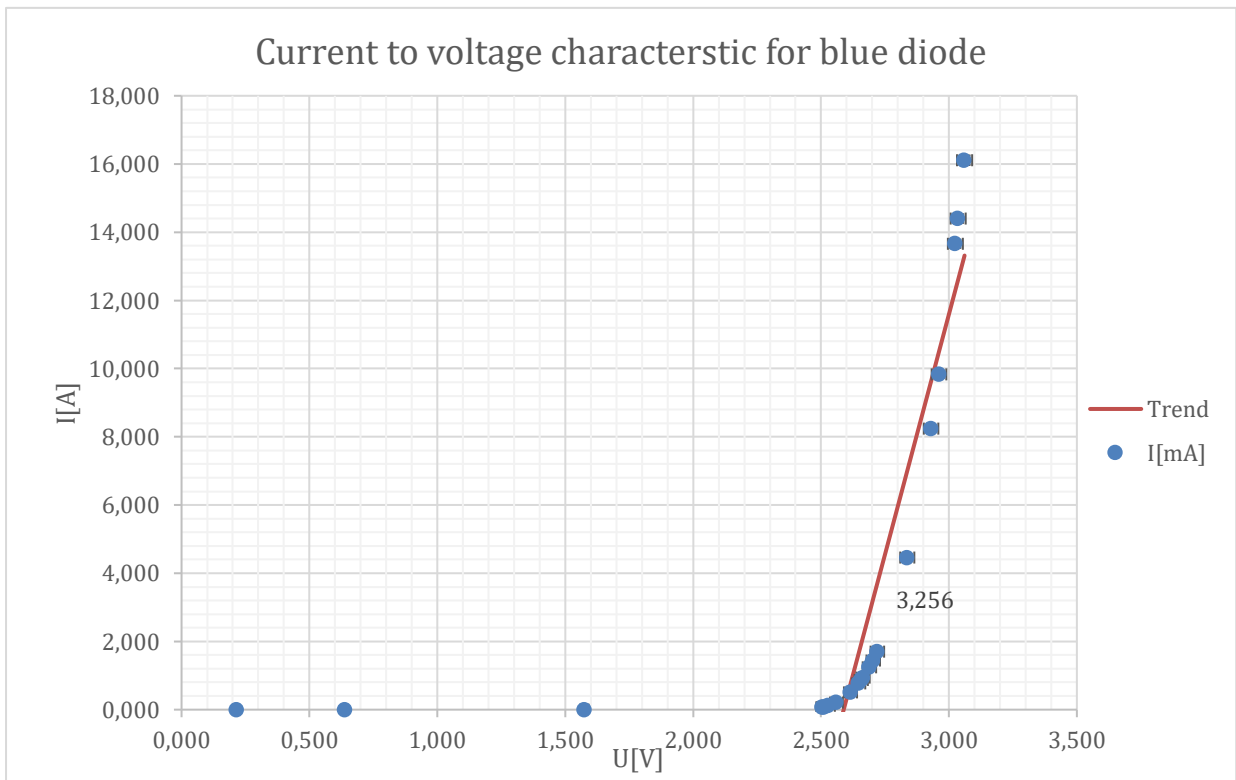
Red	U [V]	u (U)[V]	I [mA]	u(I)[mA]	a	b	γ	U_b	λ [nm]	$u(\lambda)$ [nm]	h [J * s]
	0.600	0.00740	0.000	0.00100	46.99	-79.43	-51.237	1.690397	632	10	5.698E-34
	1.014	0.01113	0.000	0.00100			-31.783				
	1.381	0.01443	0.000	0.00100			-14.538				
	1.545	0.01591	0.003	0.00102			-6.832				
	1.612	0.01651	0.016	0.00113			-3.684				
	1.651	0.01686	0.040	0.00132			-1.851				
	1.671	0.01704	0.067	0.00154			-0.911				
	1.680	0.01712	0.085	0.00168			-0.489				
	1.687	0.01718	0.102	0.00182			-0.160				
	1.697	0.01727	0.130	0.00204			0.310				
	1.716	0.01744	0.213	0.00270			1.203				
	1.733	0.01760	0.318	0.00354			2.002				
	1.747	0.01772	0.448	0.00458			2.660				
	1.758	0.01782	0.580	0.00564			3.177				
	1.769	0.01792	0.741	0.00693			3.693				
	1.778	0.01800	0.885	0.00808			4.116				
	1.788	0.01809	1.080	0.01864			4.586				
	1.821	0.01839	2.010	0.02608			6.137				
	1.852	0.01867	3.350	0.03680			7.594				
	2.027	0.02024	27.300	0.42760			15.817				



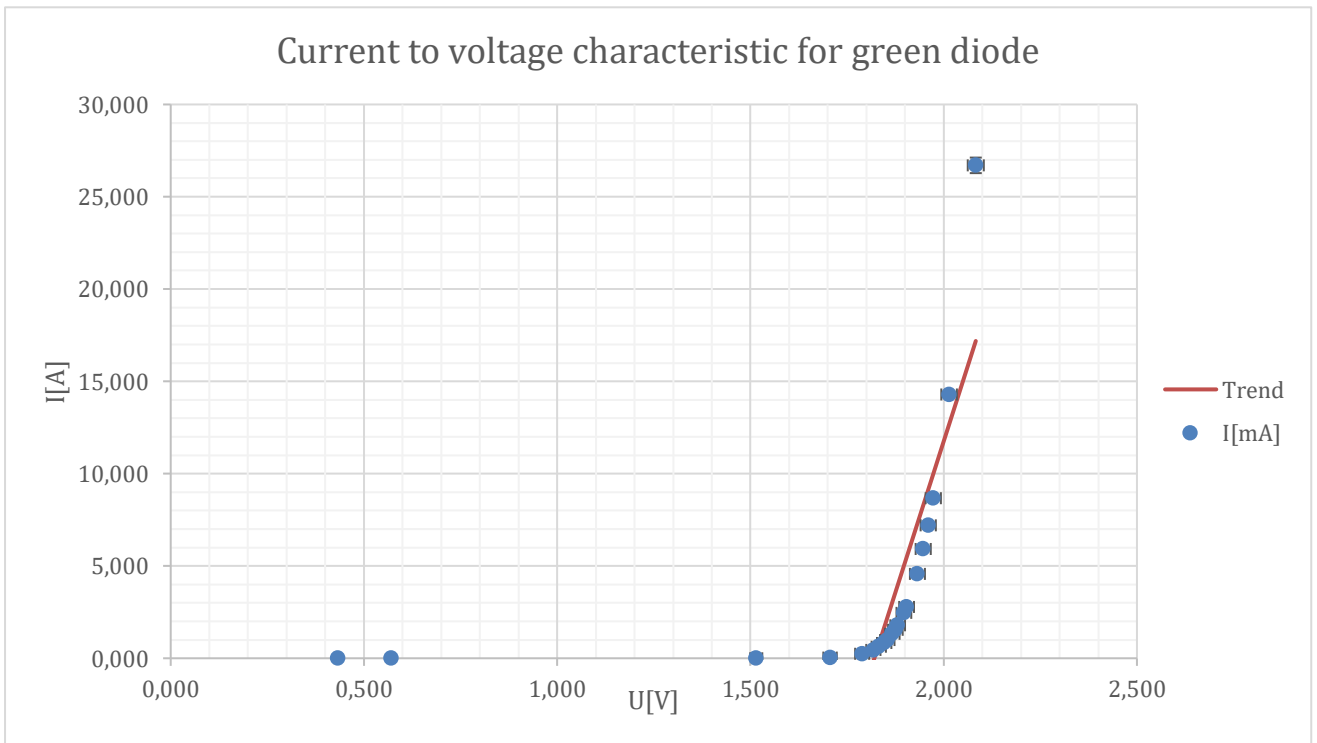
Yellow	U[V]	u (U)[V]	I[mA]	u(I)[mA]	a	b	y	U _b	λ [nm]	u(λ)[nm]	h [J * s]
	0.229	0.00406	0.000	0.00100	42.95	-73.403	-63.585	1.709178	585	10	5.333E-34
	0.423	0.00581	0.000	0.00100			-55.237				
	0.624	0.00762	0.000	0.00100			-46.604				
	1.539	0.01585	0.003	0.00102			-7.309				
	1.635	0.01672	0.026	0.00121			-3.186				
	1.683	0.01715	0.071	0.00157			-1.124				
	1.741	0.01767	0.226	0.00281			1.367				
	1.766	0.01789	0.358	0.00386			2.440				
	1.782	0.01804	0.472	0.00478			3.127				
	1.822	0.01840	0.929	0.00843			4.845				
	1.833	0.01850	1.120	0.01896			5.318				
	1.873	0.01886	2.180	0.02744			7.036				
	1.887	0.01898	2.790	0.03232			7.637				
	1.917	0.01925	4.750	0.04800			8.925				
	1.929	0.01936	5.830	0.05664			9.441				
	1.943	0.01949	7.480	0.06984			10.042				
	1.970	0.01973	11.380	0.10104			11.201				
	1.983	0.01985	15.000	0.13000			11.760				
	1.994	0.01995	17.500	0.31000			12.232				
	2.025	0.02023	27.200	0.42640			13.563				



Blue	U[V]	u(U)[V]	I[mA]	u(I)[mA]	a	b	y	U_b	λ [nm]	$u(\lambda)$ [nm]	h [J * s]
	0.215	0.00393	0.000	0.00100	28.17	-72.928	-66.873	2.588421	405	10	5.591E-34
	0.639	0.00775	0.000	0.00100			-54.924				
	1.575	0.01618	0.000	0.00100			-28.553				
	2.506	0.02455	0.068	0.00154			-2.322				
	2.511	0.02460	0.077	0.00162			-2.181				
	2.529	0.02476	0.113	0.00190			-1.674				
	2.560	0.02504	0.208	0.00266			-0.801				
	2.615	0.02554	0.506	0.00505			0.749				
	2.647	0.02582	0.769	0.00715			1.650				
	2.657	0.02591	0.870	0.00796			1.932				
	2.664	0.02598	0.939	0.00851			2.129				
	2.689	0.02620	1.240	0.01992			2.834				
	2.704	0.02634	1.440	0.02152			3.256				
	2.720	0.02648	1.700	0.02360			3.707				
	2.837	0.02753	4.460	0.04568			7.004				
	2.930	0.02837	8.240	0.07592			9.624				
	2.961	0.02865	9.830	0.08864			10.497				
	3.025	0.02923	13.660	0.11928			12.300				
	3.036	0.02932	14.400	0.12520			12.610				
	3.061	0.02955	16.110	0.13888			13.315				



Green	U[V]	u(U)[V]	I[mA]	u(I)[mA]	a	b	y	U _b	λ [nm]	u(λ)[nm]	h [J * s]
	0.433	0.00590	0.000	0.00100	65.49	-119.23	-90.870	1.82059	560	10	5.437E-34
	0.571	0.00714	0.000	0.00100			-81.832				
	1.515	0.01564	0.000	0.00100			-20.012				
	1.706	0.01735	0.038	0.00130			-7.504				
	1.789	0.01810	0.244	0.00295			-2.069				
	1.818	0.01836	0.451	0.00461			-0.170				
	1.832	0.01849	0.626	0.00601			0.747				
	1.846	0.01861	0.828	0.00762			1.664				
	1.854	0.01869	0.987	0.00890			2.188				
	1.867	0.01880	1.325	0.01160			3.039				
	1.875	0.01888	1.542	0.01334			3.563				
	1.881	0.01893	1.786	0.01529			3.956				
	1.897	0.01907	2.460	0.02968			5.004				
	1.904	0.01914	2.780	0.03224			5.462				
	1.932	0.01939	4.570	0.04656			7.296				
	1.947	0.01952	5.920	0.05736			8.278				
	1.960	0.01964	7.200	0.06760			9.130				
	1.973	0.01976	8.670	0.07936			9.981				
	2.014	0.02013	14.290	0.12432			12.666				
	2.083	0.02075	26.700	0.42040			17.185				



Calculations

$$h = \frac{e}{c} U_b \lambda$$

$$h = \frac{1.6 * 10^{-19} \text{ C}}{3 * 10^8 \text{ m}} \lambda U_b$$

Example calculation for blue diode:

$$\begin{aligned}h &= \frac{1.6 * 10^{-19} \text{ C}}{3 * 10^8 \text{ m}} 405\text{nm} * 2.588421 \text{ V} \\ &\approx 5.591 * 10^{-27} * 10^{-7} \text{ C} * \text{V} = \\ &= 5.591 * 10^{-34} \text{ J} * \text{s}\end{aligned}$$

Conclusions

As we can see our Planck constant is far off from the real one. We assume that the cause of it is the congestion in our measurements around 1.7V to 1.9V which results in small amount of points after 1.9V. (except blue LED). If we take only higher voltages in the calculation of trend we would easily get values around 6.4, which is much better result.