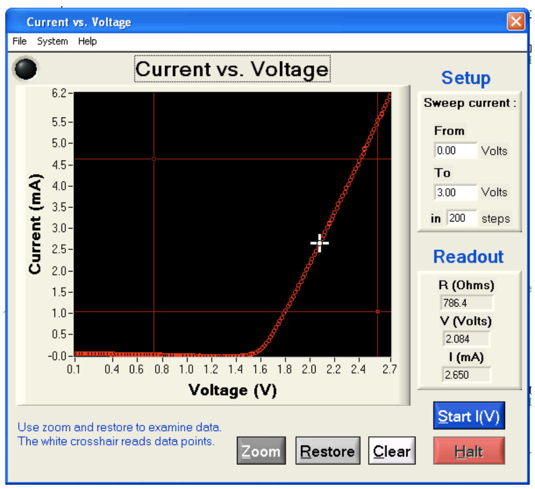
PH102 Lab: Planck's constant

Introduction

At this point you should have connected the lab box to a USB port and started the tutorial software ("Bamalab" on the desktop).

You will need: *Labjack box, two "clippy" banana cables, four regular banana cables, red LED, yellow LED, color-wavelength chart.*

In this experiment we will determine Planck's constant by analyzing the current-voltage characteristics and light output of light-emitting diodes (LEDs). We have already seen in previous labs that diodes are non-Ohmic elements; that is, current and voltage are *not* proportional, as shown below:



When measuring I versus V, as above, the LED will show almost no current until a specific "threshold" voltage is reached, after which the current increases rapidly and the LED begins to glow. Roughly, what should this threshold voltage be?

In a light emitting diode, electrical energy is converted into light energy. How this happens we will learn next week when we discuss quantum physics, but we can already apply conservation of energy. We know that when the LED is glowing, when the voltage is greater than the threshold, only one single color is emitted. This means that *all photons emitted have roughly the same energy*, since we know E=hf, where h is Planck's constant and f is the frequency of the photon. If all of the photons have essentially the same energy, then the increase in brightness of the LED can only come from the LED emitting more and more photons as voltage is increased.

If photons of only a specific frequency and energy are emitted, then we should expect *nothing* to happen until the electrical potential energy supplied to the LED is equal to the energy of the photons emitted. In other words, we imagine that the potential energy of each charge injected into the LED is converted completely to light energy. Right at the threshold voltage, the electrical energy is just equal to the photon energy:

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Above the threshold voltage, the excess electrical energy is just used to create *more* photons - the LED gets brighter.

$$E = hf = hc/\lambda = eV_{th}$$

Given this, by measuring both the threshold voltage V_{th} and the wavelength of the light, we should be able to estimate Planck's constant h:

$$h = eV_{th}\lambda/c$$

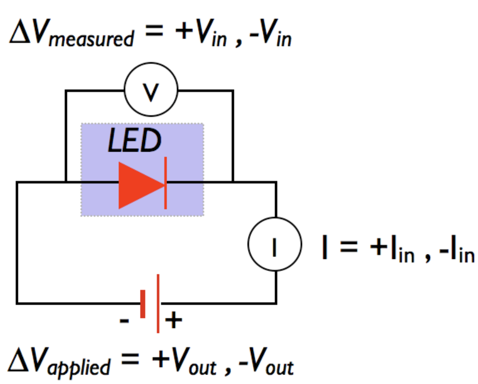
Experiment I: Current-Voltage curve

a) Open the tutorial software, and choose "Current vs. Voltage" from the "dc Circuits" menu.

b) Connect one end of your LEDs to "+Vout." Using a second wire, connect "+Vout" and "+Vin" together.

c) Using a third wire, connect the other side of the LED to "+Iin," and with a fourth wire, connect "+Iin" to "-Vin."

d) Finally, connect "-Iin" to "-Vout." This should give you the following circuit, which ramps the voltage applied to the whole circuit, and measures the current through and voltage across the LED.



e) In the "Current vs. Voltage" panel, sweep the voltage from 0-3 Volts, in 100 or 200 steps. You should see a curve like that on the first page. Do this for both LEDs.

Have an instructor initial that this plot is OK: ____________________ **LED I**

____________________ **LED II**

f) Now, measure the curve again for one LED, but sweep the voltage ***only from slightly above the threshold to ~3V.*** This should give you roughly a straight line. *Save this data.*

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g) In excel, plot this data (I on the y axis and V on the x axis), and make a linear trend-line through your data. The **x-intercept** of your trendline gives the threshold voltage V_{th}.

LED I color = ____________

Slope = _______________ A/V
y intercept = ___________________ A
x intercept = ___________________ V

LED II color = ___________

Slope = _______________ A/V
y intercept = ___________________ A
x intercept = ___________________ V

h) Repeat the steps above for your second LED (which should have a different color).

Experiment II: Estimating the wavelength

Estimate the wavelength of light emitted by your LED with the color charts provided. If there is time, you can measure the wavelength directly using the diffraction gratings as we did before.

LED I: __________ nm

LED II: __________ nm

Analysis

From the equations above, we can derive: $V_{th,1}\lambda_1 = V_{th,1}\lambda_1 = hc$

Calculate both sides of this equation and record your answer below:

Now estimate Planck's constant for each LED, using $c = 3.0 \times 10^8$ m/s and average the two results. Note that your wavelength λ should be in meters, your voltage V_{th} in volts, $e = 1.6 \times 10^{-19}$ J/V, and $c = 3 \times 10^8$ m/s. This gives h in units of J-sec.

$$h = eV_{th}\lambda/c$$

$\boldsymbol{h_I}$ **=** _________________ $\boldsymbol{h_2}$ **=** _________________ $\boldsymbol{h_{avg}}$ **=** _________________

What is the percentage error, compared to the accepted value of Planck's constant? What is a possible source of error? (Hint: where is the energy going?

When you are finished: ***Clean up and turn in a hard copy of your report***