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LAB. QUANTUM: PLANCK'S CONSTANT

AP PHYSICS II

Driving Question | Objective

What is Planck's Constant? How can we determine the theoretical value of this constant with modern items such as LEDs? How do electron energy level drops correspond to the energy of a photon it creates?

You are going to collect data points consisting of the electric potential difference across a Light Emitting Diode (LED) and the wavelength of photons that are produced from each one. You will then extrapolate that data to determine Planck's constant using conservation of energy.

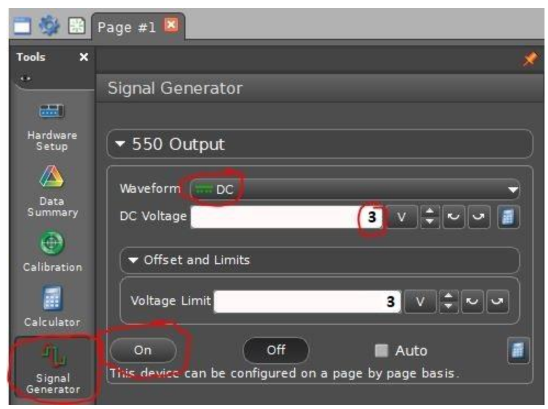
Conduct Your Experiment

It is your group's responsibility to conduct an experiment whose data will support your answer to the driving question above. Use the Law of Conservation of Energy and your knowledge on electron energy levels to drive your understanding of the outcomes of this lab.

Materials and Equipment

- Planck's Constant Determination Box
- Power Supply
- Voltage Meter
- Current Meter

Experimental Design Setup



1. Begin by connecting the Planck's constant determination box to your power supply.
2. Open the PASCO Capstone File found with this lab. In the Signal Generator section, confirm the output Waveform to "DC" at 3V. Afterwards, click "ON".
3. Connect the voltage sensor to Channel A on your interface and the two banana plug holes on the Planck's constant determination box.
4. Connect the Current Sensor to Channel B, but do not connect the Current Sensor to the Planck's Constant Determination Box at this time.

Part 1 – Using Your Vision to Detect Photon Production

1. In this part, we will be using our vision alone to determine when an LED produces as few as 5-10 photons. According to many researchers, the average human can detect the presence of a single photon in complete darkness, but once 5-10 photons strike the retina within 100 milliseconds, a conscious response would be triggered. Read about it here! https://math.ucr.edu/home/baez/physics/Quantum/see_a_photon.html

2. In the section of the Circuit Board that displace the Ammeter symbol, instead place a banana wire connecting the two points. You will ignore readings from the Ammeter in this section.

3. With the room lights and circuit board LEDs turned off, take the small black pipe and place it around the first LED and click "Record" in the Capstone software.

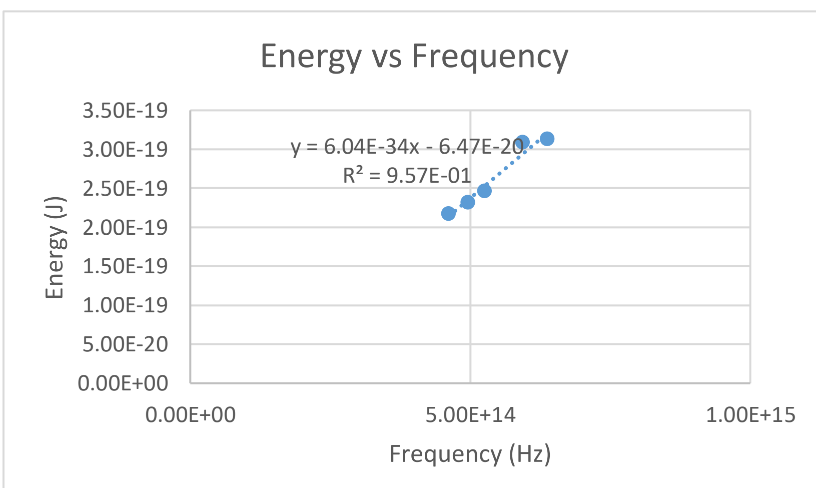
4. Look into the pipe and *slowly* increase the voltage across the LED by turning the knob on the circuit board. Continue to slowly do so until the LED barely turns on.

5. Once the LED turns on, begin *very slowly* reducing the voltage until you can barely detect light coming from the LED. Once you have reached this point, record the Voltage reading from the Capstone software in the table below and the corresponding wavelength of the LED.

6. Convert the Photon wavelength to Photon frequency using $c = \lambda f$, assuming the speed of light $c = 3.00 * 10^8 \frac{m}{s}$. Convert the Potential Difference into Electron Energy Level Drop using $\Delta V = \frac{\Delta U_e}{e}$, assuming $e = 1.6 * 10^{-19}\ C$.

7. After you have finished collecting your data, enter it into the chart below. A trend line should automatically appear. You will only be able to do this for this 1st 5 LEDs, as the photons are within the visible spectrum.

Photon Wavelength (nm)	Potential Difference (V)	*x*-variable Photon Frequency (Hz)	*y*-variable Electron Energy Level Drop (J)
470 nm	1.957 V	6.383E+14	3.131E-19
505 nm	1.931 V	5.941E+14	3.090E-19
570 nm	1.541 V	5.263E+14	2.466E-19
605 nm	1.448 V	4.959E+14	2.317E-19
650 nm	1.359 V	4.615E+14	2.174E-19



Note: Right-click on the chart above and click "Edit Data" or "Edit Data in Excel". When entering a number like $6.38 * 10^{14}$ into this chart, it must be entered as 6.38E+14. When entering a number like $3.28 * 10^{-19}$, it must be entered as 3.28E-19 for the spreadsheet to understand it. Do not include units when entering values into this chart.

Part 2 – Using a Current Meter (Ammeter) to Detect When Current Starts Flowing

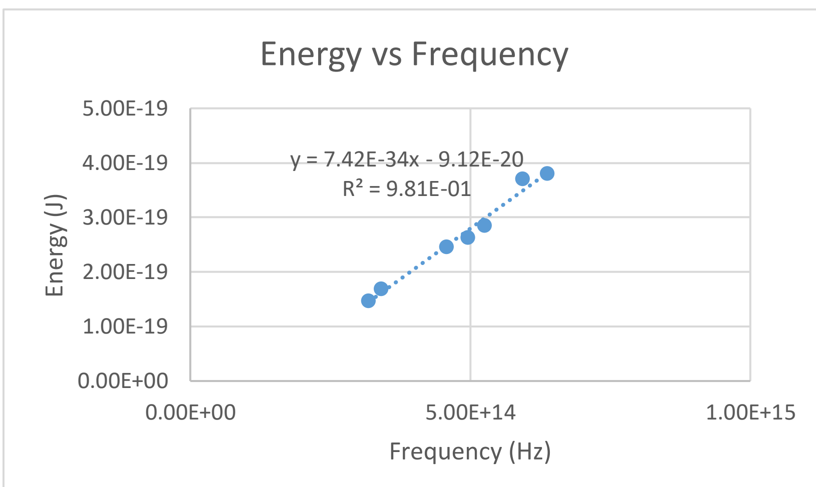
1. In this part, we will be using an Ammeter in place of the shorting wire to determine when current begins flowing through the LEDs. Remove the shorting wire and integrate the ammeter in its place.

2. Begin once again with the first LED and gradually increase the voltage. However, this time, instead of using your vision to determine when the LEDs emit photons, you will determine and what voltage the ammeter reads a value larger than 0.

3. Record the Electric Potential Difference across the LED once the current has registered a non-zero value. You do not need to record this current reading.

4. Record the same values as in Part 1 using this new method but incorporate the data for all 7 LEDs this time.

		x-variable	y-variable
Photon Wavelength (nm)	Potential Difference (V)	Photon Frequency (Hz)	Electron Energy Level Drop (J)
470	2.377	6.38e14	3.8032e-19
505	2.317	5.94e14	3.7072e-19
570	1.780	5.26e14	2.848e-19
605	1.644	4.96e14	2.6304e-19
655	1.539	4.58e14	2.4624e-19
880	1.058	3.41e14	1.6928e-19
940	0.921	3.19e14	1.4736e-19



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Post-Lab Questions

- 1. What type of relationship exists between the frequency and the energy? Between Wavelength and Electric Potential Difference?

Linear for frequency and energy drop while inverse for wavelength and energy drop.

- 2. What does the slope of either graph represent? Why would it represent this?

The slope of both graphs represents Planck's constant

- 3. The theoretical value of Planck's Constant is $h = 6.63 * 10^{-34} \frac{m^2 kg}{s}$. Which method was more accurate to determine Planck's constant?

Using a Current Meter (Ammeter) to Detect When Current Starts Flowing is most likely more accurate as human eye detection could cause results deviations due to human error.

- 4. How many photons does it take for the average human to have a conscious response?

5-10 photos.

Save this file as a PDF (NOT WORD!) document for submission.