Name: Class:

SOLIDS & LIGHT

Visual Quantum Mechanics

ACTIVITY 12

Using LEDs to Measure Planck's Constant

Goal

In this activity, we will use the electrical and spectral data that we have collected from LEDs and apply the concepts we have learned to determine a fundamental constant.

In the previous activities, we learned that the energy gap of the semiconductor that makes up the LED is related to the threshold voltage of the LED and to the energy of the brightest color of light emitted by the LED. An equation expressing this result is:

$$E_{gap} = E_{light} = eV_{threshold} \qquad (12\text{-}1)$$

where E_{gap} is the energy (in eV) of the energy gap of the semiconductor, E_{light} is the energy (in eV) of the brightest color of light emitted by the LED, e is the charge of an electron (1.6×10^{-19} Coulombs), and $V_{threshold}$ is the threshold voltage (in Volts) of the LED. Although these energies are actually approximately equal to one another, we will assume they are equal.

Recall that visible light consists of photons which are small packets of energy. The energy of these photons is related to the color of light emitted. The energy of a photon (E_{light}) associated with brightest color of light emitted by the LED is related to its frequency by the Planck-Einstein equation:

$$E_{light} = hf_{light} \qquad (12\text{-}2)$$

where h is Planck's constant and f is the frequency (in Hz or 1/s) of the photon of light. We will not go into the details here, but frequency is a property that allows us to understand the nature of light and is also related to visible light's color.

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Another property that is important in understanding the nature of light is its wavelength. The frequency of the light emitted by the LED is related to its wavelength by the equation:

$$f_{light} = \frac{c}{\lambda_{light}} \qquad (12\text{-}3)$$

where c is the speed of light (3.0 x 10 ^{8} m/s), and λ is the wavelength (in meters). When equation (3) is substituted into equation (2), the following equation results:

$$E_{light} = \frac{hc}{\lambda_{light}} \qquad (12\text{-}4)$$

Recall from our earlier investigations in recording spectra that the bottom of the spectral scales that were used had units of nanometers (nm). One nanometer equals 1 x 10^{-9} meters. This unit is frequently used to describe the wavelengths of visible light. The wavelength of light is just another way to indicate the energy (and color) of a photon that is emitted.

In our investigations with LEDs, we also measured the $V_{threshold}$ for each LED in addition to E_{light}. Since equations (12-1) and (12-2) are related by E_{light} , the relationship between the frequency of the brightest color of light emitted by the LED and the threshold voltage is represented by the equation:

$$eV_{threshold} = hf_{light} = \frac{hc}{\lambda_{light}}$$

Solving for Planck's constant (h), the following equation results:

$$h = \frac{eV_{threshold}}{f} \qquad (12\text{-}5)$$

where e is 1.6 x 10^{-19} Coulombs, $V_{threshold}$ is in Volts, and f is in 1/seconds. When these units are used, Planck's constant will be in units of Joules x seconds (Js).

Using the data that we collected in the first two activities and the equations found above, record and determine the values for each LED indicated in the following table provided.

LED	E_{light} (eV)	λ_{light}($\times 10^{-9}$ m)	f_{light} (1/s)	$V_{threshold}$ (Volts)

Now use equation (12-4) and our measurements to determine Planck's constant. Construct a graph of the measured threshold voltage versus the peak emission frequency for each LED. Determine the slope of the resulting graph ($\Delta V/\Delta F$). Planck's constant can be calculated by multiplying the resulting slope times the electronic charge, *e*, (1.6×10^{-19}).

? What is your measured value for Planck's constant?

? The accepted value for the Planck's constant is 6.626 x 10 $^{-34}$ Js. How does your measured value of Planck's constant compare with the accepted value? Use the following equation to compare these values,

$$\%Error = \frac{|h_{accepted} - h_{measured}|}{h_{accepted}} x100\%$$

? What can explain the difference found between the measured and accept values of h?

Planck's constant is a very important number that helps us determine the quantum nature of both light and matter. German physicist Max Planck who used it to develop a model that explained the photons of light (visible and invisible) emitted first introduced the constant in 1900 by a warm (or hot) body like the sun or the filament of an incandescent lamp. Albert Einstein in 1905 used the constant to develop a theory that explained the phenomenon of electrons being ejected from a metal with kinetic energies determine by the energy of photons of light shined on the metal. Today, Planck's constant is fundamental to any equation of quantum science.