Determining Planck's Constant with LEDs

Goal
You will use the electrical and spectral data that from LEDs to determine Planck's constant.

Prerequisites
Prior to beginning this tutorial you should have studied the relationship between the energy and frequency of light.

Related Materials
Harris: Nonclassical Physics, Chapter 2
Beiser: Concepts of Modern Physics, Chapter 2
Krane: Modern Physics, Chapter 3
Sandia: Essentials of Modern Physics, Chapters 6 & 7
Serway, Moses, Moyer: Modern Physics, Chapter 2
Tipler: Modern Physics, Chapter 3

The energy gap of the semiconductor in an LED is related to the threshold voltage of the LED and to the energy of light emitted by it. The relation is:

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

where E_{gap} is the value of the energy gap and E_{light} is the energy of the brightest light emitted by the LED. (Although these energies are actually approximately equal to one another, we will assume they are equal.)

The energy of a photon (E_{light}) is related to its frequency (f) by the Planck-Einstein equation:

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

where h is Planck's constant.

 Visual Quantum Mechanics is supported by the National Science Foundation under grants ESI 945782 and DUE 965288. Opinions expressed are those of the authors and not necessarily of the Foundation.

The frequency of the light emitted is related to its wavelength (λ) :

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

where c is the speed of light (3.0×10^8 m/s). We can write

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

With LEDs, we can measure the voltage at which the LED first emits lights, $V_{threshold}$. This voltage is related to the energy gap by

$$E_{gap} = eV_{threshold} \qquad (5)$$

where e is the charge on the electron. Thus, the frequency of the brightest light emitted by the LED and the threshold voltage are related by:

$$eV_{threshold} = hf_{light} = \frac{hc}{\lambda_{light}} \qquad (6)$$

Solving for Planck's constant,

$$h = \frac{eV_{threshold}}{f} = \frac{eV_{threshold}\lambda}{c} \qquad (7)$$

If e is considered a constant $V_{threshold}$ is in Volts, and f is in 1/seconds. The units of Planck's constant are electron volts x seconds (eV·s).

Using this result collect sufficient data to determine Planck's constant.

You can find the most recent accepted value for Planck's Constant at the National Institute for Standards and Technology website. (http://physics.nist.gov/cuu/Constants) Compare your results with the accepted value.