

LED Exciter Box

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The purpose of this experiment is determine the relationship between energy and wavelength.

When a light-emitting diode is switched on, electrons are able to recombine with holes within the device, releasing energy in the form of photons. This effect is called electroluminescence and the color of the light (corresponding to the energy of the photon) is determined by the energy band gap of the semiconductor. An LED is often small in area (less than 1 mm²), and integrated optical components may be used to shape its radiation pattern.[6] LEDs present many advantages over incandescent light sources including lower energy consumption, longer lifetime, improved physical robustness, smaller size, and faster switching.

The LED consists of a chip of semiconducting material doped with impurities to create a p-n junction. As in other diodes, current flows easily from the p-side, or anode, to the n-side, or cathode, but not in the reverse direction. Charge-carriers—electrons and holes—flow into the junction from electrodes with different voltages. When an electron meets a hole, it falls into a lower energy level, and releases energy in the form of a photon.

The wavelength of the light emitted, and thus its color depends on the band gap energy of the materials forming the p-n junction. In silicon or germanium diodes, the electrons and holes recombine by a non-radiative transition, which produces no optical emission, because these are indirect band gap materials. The materials used for the LED have a direct band gap with energies corresponding to near-infrared, visible, or near-ultraviolet light.

While the exact mechanism of an energy level transition in solid state devices such as an LED is slightly different than that learned while studying atomic structure, both the concepts and mathematics are the same. That is, electrons within the LED crystal will be excited to a higher energy state emitting photons as they return to a lower energy state. In our experiment, we will follow this process using an electric current to excite the electrons measuring this energy with a voltmeter. The unit of a volt, a Joule per coulomb, is equivalent to the energy unit, an electron-volt, eV.

Planck's constant is named after Max Planck, a nineteenth century physicist who first described it in the relationship, $E = h\nu$. His work is important in this experiment as it compares the quanta of energy absorbed and with that emitted during electron transitions. Since we know the relationship $c = \lambda\nu$, or the speed of light (3.00×10^8 m/s) = wavelength of the light times its frequency, we can find the wavelength of the light emitted by the diode.

Objectives:

1. In this experiment, you will determine the energy emitted by a selection of light emitting diodes (LED's) by measuring the voltage drop.
2. Measure voltage drop across each light emitting diode, a number related to the energy absorbed by the diodes and using Planck's constant calculate the frequency. Using the frequency calculate the wavelength(m).
3. Convert the wavelength to nm.

Materials:

Voltmeter
voltage sensor

LED exciter box
collection of LED's
labels or masking tape

Procedure:

1. Insert an LED into the exciter box completing the circuit with the longer leg connected to the red wire connected to internal resistor. If the LED doesn't immediately light, reverse the polarity of the device.
2. Record the voltage drop across the LED using a voltmeter.

Guided Conclusion Questions and Calculations:

- Q1. Calculate the energy required to excite each LED in Joules by multiplying the voltage measured by $1.6 \times 10^{-19} \text{J/eV}$.
- Q2..Calculate the frequency, ν , of the light emitted for each LED\
- Q3. Record the color of each LED Tested.
- Q4 . Convert the wavelengths from units of nanometers to meters by multiplying the wavelength by the conversion, $1 \times 10^{-9} \text{ m/nm}$.
- Q5 . According to your data, what is the relationship between the voltage required to excite the electrons in the LED and the wavelength of resulting light produced? How do you explain this trend?.
- Q6. How would you describe the pattern of the various colors of the light produced by the LED's when sorted by wavelength?
- Q7. Plot the energy needed to excite the LED's vs the frequency of the LED light. Determine the slope of the best straight line. What is the significance of the slope?

Data:

Notes for Teachers

1. This experiment is an adaption of one described by Patrick O'Connor and Leah O'Conner in the October 1974 issue of The Physics Teacher, p 435. The major differences being the size of the current limiting resistor and the use of a spectrometer to measure the wavelength of the light emitted.
2. LED Exciter Box Purchased at http://www.pwista.com/Mini_Scale_Concepts.htm
3. This lab addresses the presentation of Essential Knowledge 1.B.1.d and 1.D.3.a of College Board Recent Curriculum.

Sample Experimental Planck's Constant
Data

Wavelength (nm)	Potential (volts)
401	3.06
463	2.92
506	2.89
518	2.81
564	2.00
591	1.92
594	1.96
610	1.87
618	1.88
625	1.84
627	1.83
635	1.83
646	1.66