Estimate of the Planck Constant from the I – V characteristics of LEDs

While conducting this experiment, you will be assessed for CPAC3: Working safely.

Theory

When an LED emits a photon of light of energy E = hf, this energy must come from a corresponding loss of energy of an electron forming part of the current through the diode.

The energy loss of the electron is measured by its drop in p.d., i.e. the p.d. across the LED. Below a certain threshold p.d., V_0, the electron does not have enough energy to cause photon emission, but light emission and current increase rapidly above V_0.

We can equate the photon energy with the loss of electrical energy by the electron at the threshold voltage:

$$eV_0 = hf$$

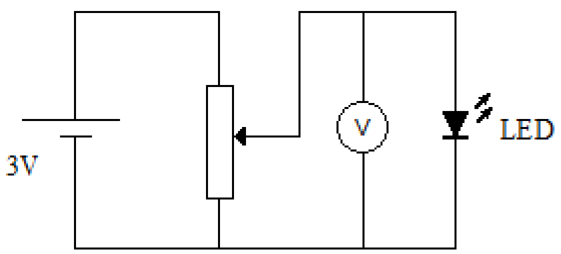
Here e is the charge on the electron, V_0 is the p.d. across the LED, h is the Planck constant, and f is the frequency of the emitted photon.

e is a known constant (1.6×10^{-19} C), V_0 can be measured directly, and we need only an estimate of f to get a value for h.

The frequency can be found from the wavelength of the light emitted by the diode using $c = f\lambda$. The speed of light in a vacuum is 3.00×10^8 m s^{-1}.

Apparatus

Smoothed power supply set to 3 V
Rheostat to be used as a potential divider
Digital multimeter to measure voltage
Various LEDs on "Locktronics" circuit board
Connecting leads
Planck Constant LED "Darkroom"



Method

NOTE : The p.d. across the LEDs must be carefully controlled from zero. There is no resistor in series with the LED and an excessive current may cause it to explode. What safety precaution should be employed when VIEWING the LED? Write the answer below and check with your teacher before proceeding.

Set up the circuit as shown, with each LED in turn. Set the p.d. across the LED to about 1.5 V. If there is no current i.e. it does not light, reverse the LED. The apparatus should now be placed in the LED "Darkroom". This will enable you to carry out the experiment in normal laboratory conditions. Observe the LED inside the box; it is a good idea to allow a few minutes for your eyes to adjust to the light level.

Slowly increase the p.d. across the diode until it just begins to emit visible light. Note the p.d. V_1 at which this happens. Now slowly reduce the p.d. until the emitted light is no longer detectable. Note the p.d. V_2 at which this happens.

Analysis

For each LED, record the values of V_1 and V_2 and calculate an average of these to take as the value for V_0.

For each of the LED colours, calculate the frequency of the light emitted and use the corresponding values of V_0 to find three values for h. Calculate the average value for h and record the range in your results.

Assume the following wavelength values for the LED colours:

Red	670 nm
Yellow	580 nm
Green	550 nm

Discussion

Estimate the uncertainty in your voltage values and discuss whether this contributes significantly to the uncertainty in h based on your range of values.

Look up the accepted value for the Planck constant, remembering to reference the source of your research.

Calculate the percentage difference between this and your average value of h.

Discuss whether experimental uncertainties could account for the above error.

In this experiment we have assumed values for the wavelengths of the emitted light. This is probably the major source of uncertainty. How could you measure the wavelength emitted accurately?

Conclusion

State your average value for the Planck constant.