H29024 Planck’s Constant Experiment NFU491

Background

Traditionally in schools, Planck’s constant is determined through investigation of the photoelectric effect (e.g. Unilab Planck’s Constant Apparatus H28615). The Planck Experiment is an interesting alternative recommended in “Advanced Physics”, where photon release as a result of recombination in light-emitting diodes (LEDs) is investigated. The voltage across the selected LED is raised until photon threshold is reached, at which point the LED begins to glow. The built-in digital voltmeter displays the voltage across the LED, allowing the electron and photon energy to be calculated. In combination with the wavelength of the LED, Planck’s constant can be established.

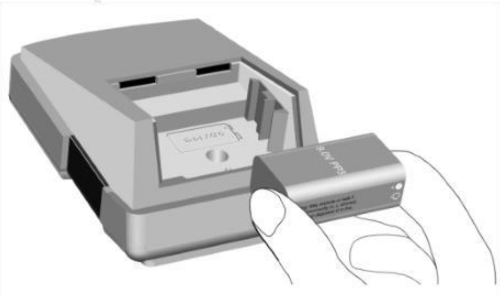
Apparatus Details

Description

The apparatus is self-contained with power provided by an internal PP3 battery. Five LEDs are position on the front panel, selectable by the rotary switch. The potentiometer adjusts the potential difference across the selected LED, measured by the integral digital voltmeter.

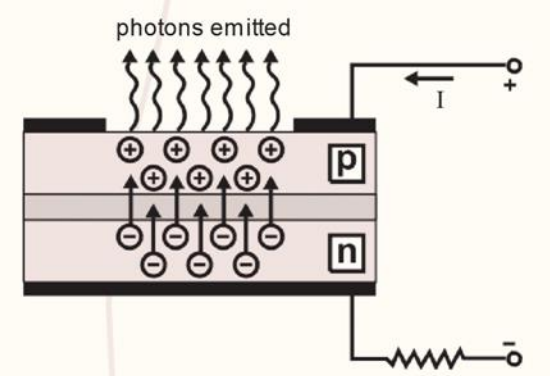
Fitting the battery

All Benchmark units require 9V PP3 type batteries. Open the battery compartment by pressing the battery cover at the top end of the case. This releases the battery cover catch, allowing the cover to be lifted, Check the polarity, press the battery into place and replace the cover.



Auto Switch-off

To help prolong battery life, all Benchmark instruments incorporate automatic switch-off after 50 minutes. The instruments may be reactivated by pressing the ON/OFF keypad. They may also be switched off manually before this time by pressing the same keypad.



Theory

An LED is a p-n junction rectifier, where: n-region semiconductor material contains excess electrons and the p-region semiconductor material contains excess “holes” (essentially missing electrons). When sufficient voltage is applied across the LED (i.e. it is “forward biased”, see left), electrons gain enough energy to move across the junction from the n- to the p-region. Once in the p-region, the electrons are immediately attracted to the holes due to Coulomb forces between the opposite charges, and they recombine as a result.

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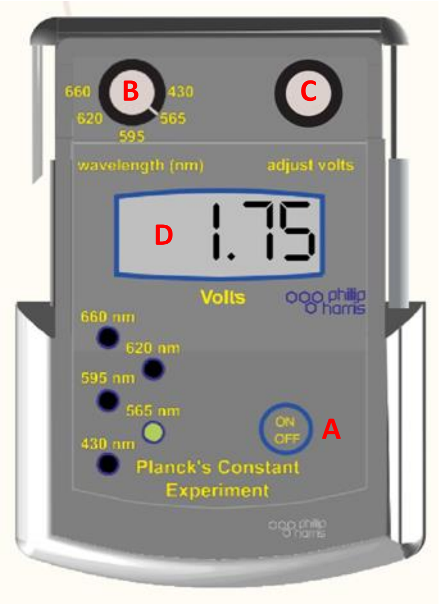
For each recombination the electric potential energy of the electron is released as a *quantum* of electromagnetic energy. This release takes the form of a photon of light in a very narrow frequency range characteristic of the doped semiconductor material.

If the applied excitation voltage exceeds the photon threshold, the excess energy appears mainly as phonons (quanta of lattice vibrational energy). This cannot be taken into account by this experiment, which assumes all energy released is in the form of photon energy.

Experimental procedure

1. Press the ON/OFF switch (A).
2. Turn the rotary switch to select one of the LEDs (B).
3. Adjust voltage until the selected LED just begins to glow (C).
4. Note the threshold voltage on the built-in voltmeter (D) and corresponding characteristic wavelength of the LED (shown on B).
5. Repeat for each LED.
6. Calculate Planck's constant using the equations below.



Calculations

Calculating photon energy

The energy (E) of the light emitted is related to the electrical charge (q) of an electron and the voltage (V) required to light the LED.

Therefore

$$E = qV \text{ joules} \qquad (1)$$

Where

q = 1.6 x 10^{-19} coulomb

The simplification ignores any potential drop across the semiconductor materials of the diode and assumes that the threshold of photon release is accurately determined so that, at recombination, all energy is released as photon energy.

Calculating Planck's constant

Beginning with describing the energy of each photon in terms of its frequency (the Planck-Einstein relation):

$$E = hv \qquad (2)$$

Where

h = Planck's constant
v = photon frequency

But

$$v = \frac{c}{\lambda} \qquad (3)$$

Where

λ = photon wavelength (given on apparatus; note 1nm = 10^{-9}m)
c = speed of light (3 x 10^8 ms^{-1})

Therefore, combining (1) and (2)

$$qV = hv$$

Then substituting in (3)

$$qV = \frac{hc}{\lambda}$$

Gives

$$h = \frac{qV\lambda}{c}$$

Safety advice

For your safety, this product should be used in accordance with these instructions; otherwise, the protection provided may be impaired.
This unit is intended for use in DRY conditions. Avoid spillage of water and other liquids on to the unit.

Disclaimer

If the equipment is used in a way not specified by Philip Harris, then the protection provided may be impaired.

Warranty, repairs and spare parts

The product is guaranteed for a period of one year from the date of delivery to the customer. This warranty does not apply to defects resulting from the action of a user such as misuse, improper wiring, any operations outside of its specification, improper maintenance or repair, or unauthorized modification.

Our liability is limited to repair or replacement of the product. Any failure during the warranty period should be referred to Customer Services.

In the event of a fault, the product should be referred to the Philip Harris recommended repair agent.

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