Planck's constant

- **What is a semiconductor?**
- **What is intrinsic semiconductor?**
- **What is extrinsic semiconductor?**
- **What is an n-type semiconductor?**
- **What is a p-type semiconductor?**
- **What is pn junction diode?**
- **What is forward biasing a diode?**

  When the p type is connected to positive of the battery and n type is connected to negative of the battery, we say the diode is forward biased.
  Current in the circuit when forward biased is called **forward current** I_f.
  Order of I_f is few mA.

- **What is reverse biasing a diode?**

  When the p type is connected to negative of the battery and n type is connected to positive of the battery, we say the diode is reverse biased.
  Current in the circuit when reverse biased is called **reverse current** I_r.
  Order of I_r is few μA.

- **What is light emitting diode (LED)?**

  A pn junction diode which emits light when forward biased is known as LED.

- **Some points about LED**
  - They emit spontaneous radiation in UV, visible or infrared.
  - The amount of light output is directly proportional to the forward current.
  - When the LED is forward biased, electrons cross the pn junction from n type and recombine with holes in the p type.
  - During the process of recombination, the energy is released in the form of light.
  - In ordinary diodes, this energy is radiated in the form of heat.
  - Different compostions of LEDs emit different colours.

Composition	Colour emiited
GaAs	IR
GaAsP	Red
GaN	Blue
GaP	Green

Table 1: Light emitted by different LEDs (No need to memorize this table).

- **What is the aim of the experiment?**

  To determine Planck's constant h.
  $h = 6.626 \times 10^{-34}$ Js.

- **What is Planck's constant?**

  Energy of radiation is proportional to its frequency. It is the constant of proportionality for energy of photon E and corresponding frequency of light ν.

$$E \propto \nu$$
$$E = h\nu.$$

- **What is a photon?**

  Quantum of light is called a photon.
  When light is radiated on a surface like metal for example, the energy of light is not falling continuously on the metal. Rather, the energy comes in discrete units (like particles) called quanta. *(Quantum - singular, Quanta - plural.)* In the case of light they are called photons.

- **What is the rest mass of a photon?**

  Photons have zero rest mass.

- **What is the charge of a photon?**

  The electric charge on a photon is zero.

- **What is the significane of the equation $E = h\nu$?**

  In quantum theory, the energy of light is related to its frequency ($E \propto \nu$).
  Higher the frequency of light, greater is its energy.
  For a single photon we have $E = h\nu$.
  For two photons we have $E = 2h\nu$.
  For n photons we have $E = nh\nu$.
  The intensity of light is proportional to the number of photons n.

- **What is tabulated in the experiment?**

  The voltage across the different LEDs are measured.

- **What is the formula used to determine Planck's constant?**
  $h = \frac{e}{c}(V\lambda)$,
  where
  charge of electron $e = 1.602 \times 10^{-19}$ C,
  speed of light in free space $c = 3 \times 10^{8}\,\mathrm{ms}^{-1}$,
  V is voltage across the LED,
  λ is the corresponding wavelength of light emitted by the LED.

- **Out of blue and red light, which light has more energy?**

- **Why blue LED requires more voltage to glow than red LED?**

Derivation of $h = \frac{e}{c}(V\lambda)$. (For student's reference)

It is the kinetic energy of the electron after recombination which is emiited in the form of light. Energy of a photon

$$E = h\nu \tag{1}$$

Kinetic energy of an electron with voltage V is

$$E = eV \tag{2}$$

charge on an electron $e = 1.602 \times 10^{-19}$ C.
Equating (1) and (2), we get

$$h\nu = eV$$
$$\frac{hc}{\lambda} = eV$$
$$\boxed{h = \frac{e}{c}\lambda V.} \tag{3}$$

- **How is Planck's constant calculated using slope of V versus $1/\lambda$ graph?**

  Rearranging equation (3), we get

$$V = \frac{ch}{e}\left(\frac{1}{\lambda}\right) \tag{4}$$

  which is of the form $y = mx + C$ (equation of straight line with slope=m and y intercept=C).
  So when we plot V along y-axis and $1/\lambda$ along x-axis we get a straight line with slope=ch/e and y intercept=zero.

$$\boxed{\therefore h = \frac{e}{c}(\text{slope}).} \tag{5}$$

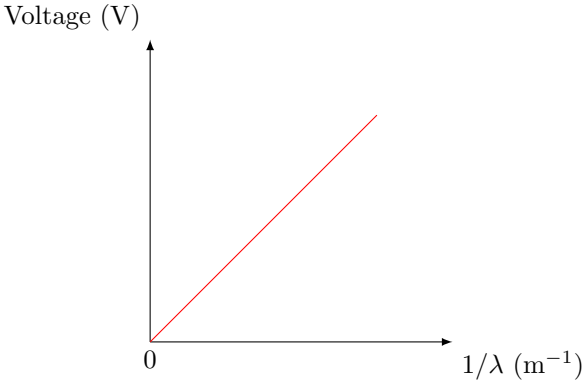

Figure 1: Graph of V versus $1/\lambda$.