
Experiment No. 3 **Date:-** 16/03/2021

(Module 3) **Determination of Planck's constant.**

FEC102.3: Interpret the basic knowledge of semiconductor physics in understanding the working of semiconductor devices.

(Module 2)

FEC102.2: Explain the basic concepts of quantum mechanics.

AIM: - To draw the V-I characteristic for Light Emitting Diode (LED) and determine the value of Planck's constant.

Apparatus: - Planck's constant kit, connecting wires.

Theory: - Planck's constant is the fundamental constant in modern physics. It relates the energy of a photon to its frequency. To determine this constant we use Light Emitting Diodes (LED). Diodes today come in a variety of colours. Each colour is achieved by having a slightly different semiconductor material.

The experiment is based on the fact that the energy of the photon relates to its frequency as: $E = h\nu$

Where, E = energy of photon, h = Planck's Constant,

ν= frequency of the emitted photons.

The electric energy needed to switch on a LED is $E = e V_o$ [Joules],

Where, e = electric charge of an electron ($e = -1.6 \times 10^{-19}$ Coulomb)

V_o= Threshold voltage required to overcome the barrier created by p-n junction.

This energy is different for different LED colour (frequency of emitted light, ν).Each electron-hole radiative recombination emits a light photon of energy

$E = h\nu = h(c/\lambda)$

Where, c = speed of light (3×10^8 m/s)

λ = wavelength of light.

This threshold voltage (V_0) is related to the band-gap energy E_g:

$E_g = e V_o + \Delta E$ ..... (1)

Where ΔE is constant which is different from one LED to another.

As the band-gap energy will be the energy carried away by a photon,

Then:

$E_g = E_{photon} = h\nu$,

Eq. (1) becomes

$h\nu = e V_o + \Delta E$ ..... (2)

$hc/\lambda = e V_o + \Delta E$ ..... (3)

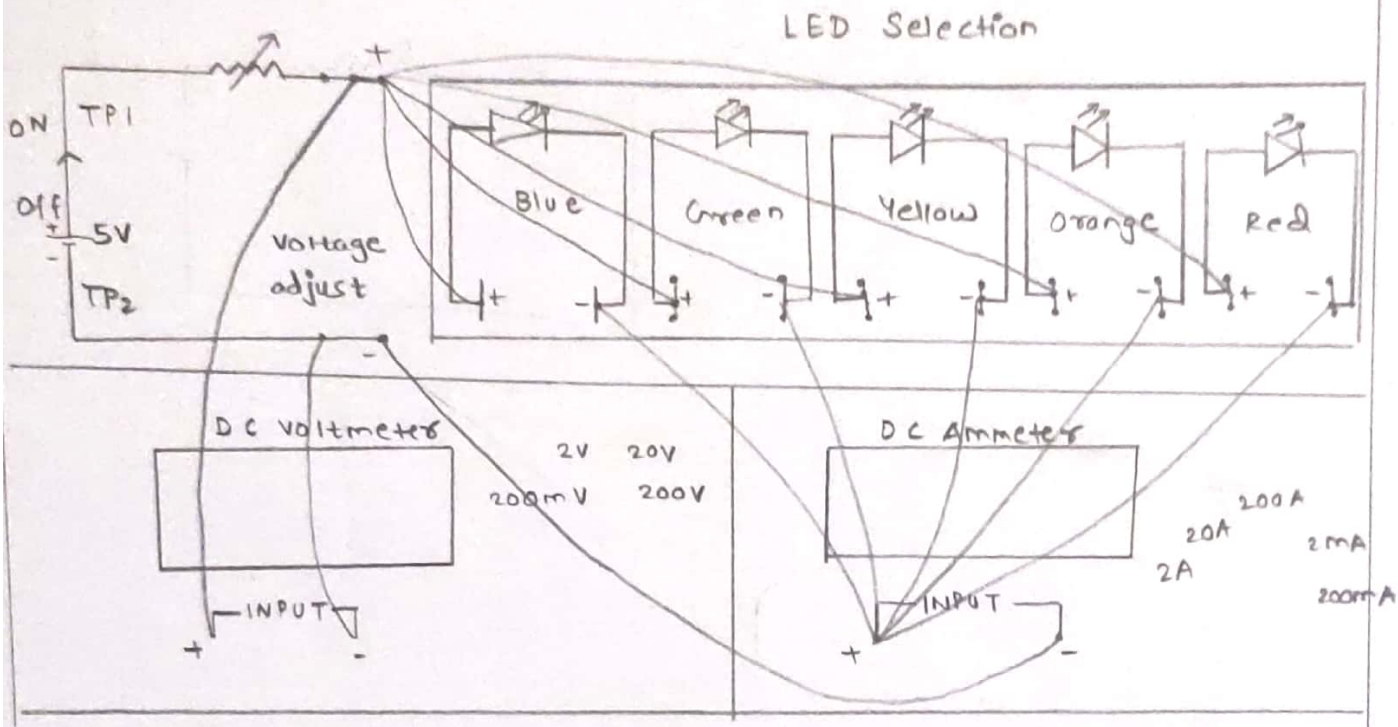
where,

h = Planck's Constant e = electronic charge

λ = wavelength of LED c = velocity of light

In this experiment we use Eq. (3) to determine Planck's constant h. We use several LED's that emit light of different colours (frequencies).

Circuit Diagram:-



Procedure:-

1. Take the Planck's constant Determination Setup. Make the connections as shown in circuit diagram.

2. Connect + ve terminal of power supply to + ve terminal of DC voltmeter and -ve terminal to - ve terminal of DC voltmeter.

3. Now take another patch cord and connect + ve of power supply to + ve of red colour LED.

4. Connect - ve of power supply to - ve of ammeter.

5. Connect +ve of ammeter to - ve of selected LED.

6. Set the voltmeter at the range of 20 V and ammeter at the 200 mA.

7. Connect the mains cord and switch ON the power supply.

8. Now increase the DC voltage at the fix interval as given in the observation table.

9. Note the corresponding current by DC ammeter in observation table.

10. Now take the current on Y-axis and voltage on X-axis and plot a graph between current and voltage

11. Find the knee- voltage or threshold-voltage from the graph.

12. Now switch OFF the DC power supply and break the LED connection.

13. Repeat above experiment for different colours of LEDs.

14. Put this value in given formula and calculate the Planck's constant

$h = eV_0\lambda/c$

Take mean value of h calculated for different LEDs.

Observation

Table I: I-V Characteristics of different colour LEDs

Sr.No.	Voltage (V)	Red Current (mA)	Orange Current (mA)	Yellow Current (mA)	Green Current (mA)	Blue Current (mA)
01	0	0	0	0	0	0
02	0.5	0	0	0	0	0
03	1	0	0	0	0	0
04	1.2	0	0	0	0	0
05	1.3	0	0	0	0	0
06	1.4	0	0	0	0	0
07	1.5	0	0	0	0	0
08	1.6	0	0	0	0	0
09	1.7	0.1	0.1	0	0	0
10	1.8	0.9	0.4	0.3	0	0
11	1.9	5.1	2.4	1.4	0	0
12	2.0	13.6	5.5	3.9	0	0
13	2.1	25.4	10.3	7.1	0	0
14	2.2	40.1	16.6	10.8	0	0
15	2.3	–	–	14.1	0	0
16	2.4	–	–	17.7	0	0
17	2.5	–	–	23.2	0	0
18	2.6	–	–	26.5	0.1	0.1
19	2.7	–	–	30.9	0.5	0.8
20	2.8	–	–	–	1.5	2.6
21	2.9	–	–	–	2.9	4.3
22	3.0	–	–	–	4.6	6.3

Table II: Determination of Planck's constant

Electronic Charge e = 1.6×10^{-19} coulomb

Velocity of Light c = 3×10^{8} m/s

LED	Threshold Voltage V_0 (in V) from graph	Wavelength (Å)	$h = eV_0\lambda/c$ (in J s)	Mean h (in J s)
Blue	2.65	4700	6.643×10^{-34}	6.5606×10^{-34}
Green	2.68	5250	7.504×10^{-34}	
Yellow	1.85	5800	5.723×10^{-34}	
Orange	1.86	6300	6.25×10^{-34}	
Red	1.79	7000	6.683×10^{-34}	

Result:

Standard Value of Planck's constant = 6.626×10^{-34} JS

Calculated Value of Planck's constant = 6.5606×10^{-34} JS

COMMENTS:

1. What is the difference between normal PN Junction diode and LED?

→ LED emits light while PN Junction diode cannot emit light.

→ In LED all energy is converted into light while in PN Junction diode all energy is converted into heat.

→ LED has low breakdown voltage while PN junction has high reverse breakdown voltage.

2. Give examples of semiconductor materials which are used as LED.

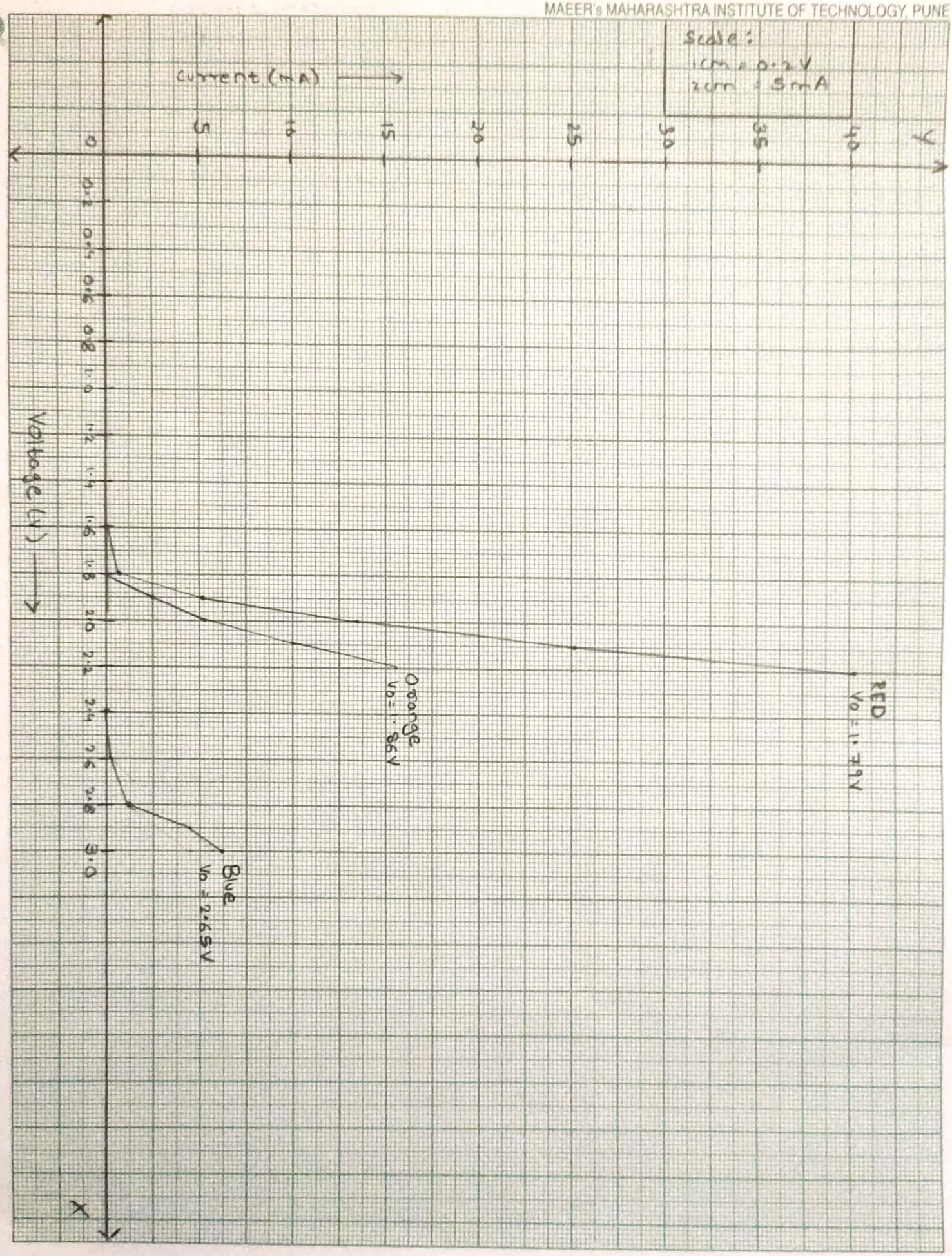
1) GaAs (Gallium arsenide)

2) GaP (Gallium Phosphide)

D.J.S.C.E. (Physics)		
Journal		
Knowledge	3	
Documentation	3	
Punctuality	3	
Virtual Lab (Performance & Documentation)	6	
Total	15	

Date	Signature of the faculty

1) I-V Graph for Red, Orange, Blue



2) I-V graph for yellow and green