EXPERIMENTAL DETERMINATION OF PLANCK'S CONSTANT USING LIGHT EMITTING DIODES

PROJECT REPORT

Submitted by

RIYA ROY

(AB23PHY018)

Under the guidance of

Dr. PRIYA PARVATHI AMEENA JOSE
Associate Professor,
Department of Physics and Centre for Research,
St. Teresa's College (Autonomous), Ernakulam.

In partial fulfilment of the requirement of award of
Bachelor Degree of science in Physics.

ST. TERESA'S COLLEGE (AUTONOMOUS)
ERNAKULAM
2025-26

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ERNAKULAM

CERTIFICATE

This is to certify that the project report entitled **"EXPERIMENTAL DETERMINATION OF PLANCK'S CONSTANT USING LIGHT EMITTING DIODES"** is an authentic work done by RIYA ROY, St Teresa's College (Autonomous), Ernakulam, under my supervision at Department of Physics and Center for Research, St. Teresa's College (Autonomous), Ernakulam, for the partial requirements for the award of Degree of Bachelor of Science in Physics during the academic year 2025-26. The work presented in this dissertation has not been submitted for any other degree in this or any other university.

Supervising Guide

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Head of the Department

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ERNAKULAM

B.Sc. PHYSICS
PROJECT REPORT

NAME : RIYA ROY

REGISTER NUMBER : AB23PHY018

YEAR OF WORK : 2025-26

This is to certify that this project work entitled, "EXPERIMENTAL DETERMINATION OF PLANCK'S CONSTANT USING LIGHT EMITTING DIODES" is an authentic work done by RIYA ROY.

Staff member in-charge
Dr. PRIYA PARVATHI AMEENA JOST

Head of the Department
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St. Teresa's College (Autonomous) * Department of Physics * Ernakulam

Submitted for the University examination held at St. Teresa's College, Ernakulam.

DATE: 16.04.26

EXAMINER:

1.

2.

DECLARATION

I, RIYA ROY final B.Sc. Physics student, Department of Physics and Center for Research, St. Teresa's College (Autonomous), Ernakulam, do hereby declare that the project work entitled "**EXPERIMENTAL DETERMINATION OF PLANCK'S CONSTANT USING LIGHT EMITTING DIODES**" has been originally carried out under the guidance and supervision of **Smt. Dr. PRIYA PARVATHI AMEENA JOSE**, Associate Professor, Department of Physics and Center for Research, St. Teresa's College (Autonomous), Ernakulam, in partial fulfilment for the award of the Degree of Bachelor of Physics .I further declare that this project is not partially or wholly submitted for any other purpose and the data included in the project is collected from various sources and is true to the best of my knowledge.

PLACE: Ernakulam

DATE:13.04.2026

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I express my sincere gratitude to God Almighty for enriching our minds with knowledge and leading us all along the project. We extend our heartfelt thanks to our project guide, **Dr. PRIYA PARVATHI AMEENA JOSE**, Associate Professor, Department of Physics and Centre for Research, St Teresa's College (Autonomous) Ernakulam, for providing her valuable guidance and encouragement throughout the course work of this project.

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I am grateful to all the faculty members and non-teaching staff for their cooperation and for providing us all the necessary laboratory facilities and equipment needed for carrying out our project work.

- Riya Roy

ABSTRACT

The aim of this experiment is to determine Planck's constant (h) using light emitting diodes (LEDs) of different wavelengths. The experiment is based on the principle that when a LED is forward biased, it emits light when the applied voltage reaches a minimum threshold value known as the knee voltage (V_0). This threshold voltage corresponds to the energy required for electron–hole recombination, and hence the photon energy emitted is approximately equal to the electrical energy supplied.

The V–I characteristics of LEDs of different colours are studied, and the threshold voltage V_0 is determined from the intercept of the linear portion of the forward bias graph. Using the known wavelengths (λ) of the respective LEDs, a graph is plotted between V_0 vs $1/\lambda$, the graph is found to be linear, verifying the relation.

From the slope of the graph of V_0 vs $1/\lambda$ the value of Planck's constant is calculated. The experimentally determined value of Planck's constant is found to be in close agreement with the accepted value.

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1.INTRODUCTION

1.1 PLANCK'S CONSTANT (h)

Max Planck introduced Planck's constant in 1900 while explaining blackbody radiation, marking the birth of quantum theory. Planck's constant, denoted by **h**, is a fundamental physical constant that relates the energy of a photon to the frequency of the electromagnetic radiation through the equation $\mathbf{E = h\nu}$, where E is energy and v is frequency. Its value is $\mathbf{6.626 \times 10^{-34}\ J{\cdot}s}$, and it signifies that energy is emitted or absorbed in discrete packets called quanta rather than continuously. This revolutionary idea resolved the ultraviolet catastrophe predicted by classical physics and laid the foundation for modern quantum mechanics. Planck's constant plays a crucial role in various physical phenomena such as the photoelectric effect, atomic spectra, and wave–particle duality, making it one of the most important constants in physics.

1.2 LIGHT EMITTING DIODES (LED)

A **light-emitting diode** (**LED**) is an electronic component that uses semiconductor to emit light when current flows through it. Electrons in the semiconductor recombine with electron holes, thereby releasing energy in the form of photons. The color of the light (corresponding to the energy of the photons) is determined by the energy required for electrons to cross the band gap of the semiconductor. White light is obtained by using multiple semiconductors or a layer of light-emitting phosphor on the semiconductor device.

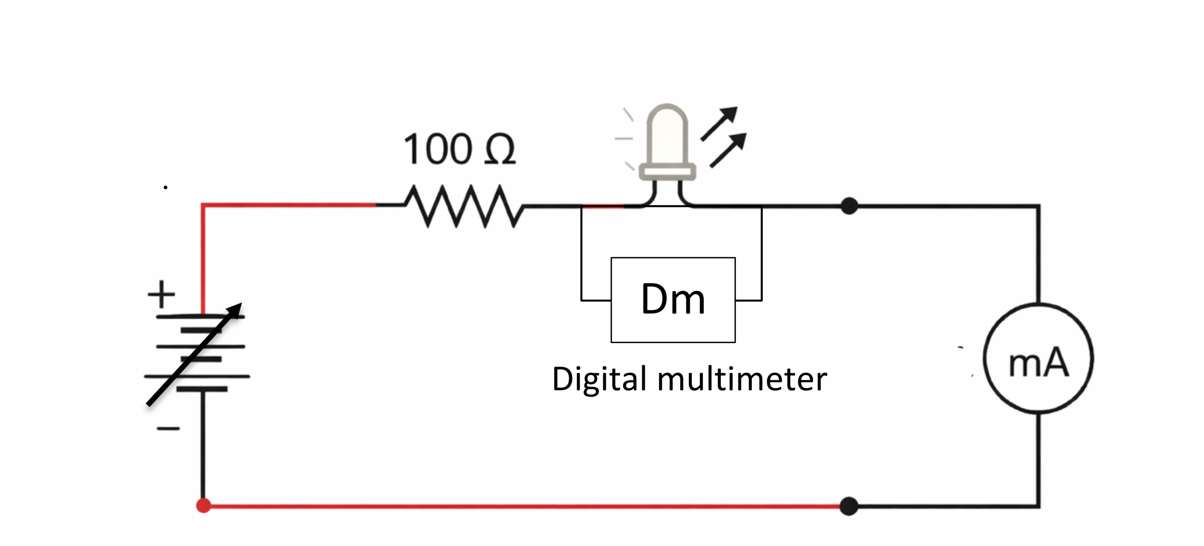
2. EXPERIMENTAL DETAILS

In this experiment, Planck's constant is determined using the working principle of light-emitting diodes (LEDs), which is based on the concept of quantum theory. When a forward bias is applied to an LED, electrons from the conduction band recombine with holes in the valence band, releasing energy in the form of photons. The energy of the emitted photon is directly related to the band gap energy of the semiconductor material and is given by the relation $E = h\nu = hc/\lambda$, where h is Planck's constant, c is the speed of light, and λ is the wavelength of the emitted radiation.

In the first method, LEDs of different colours (and hence different wavelengths) are used. Each LED begins to emit light only after a certain minimum forward voltage, known as the threshold voltage. This threshold voltage corresponds to the minimum energy required for electron-hole recombination, and hence it is approximately equal to the photon energy ($E \approx eV$, where e is the charge of an electron and V is the threshold voltage). By equating the electrical energy (eV) to the photon energy (hc/λ), Planck's constant can be calculated using the relation $h = (eV\lambda)/c$.

In the second method, Planck's constant is determined graphically using the relationship between the threshold (or stopping) voltage and the wavelength of light emitted by LEDs. When an LED just begins to glow, the applied voltage corresponds to the minimum energy required for electron-hole recombination, and hence the emitted photon energy can be expressed as $E = eV_0$, where e is the electronic charge and V_0 is the threshold voltage. According to quantum theory, the photon energy is also given by $E = hc/\lambda$. By equating these two expressions, we obtain $eV_0 = hc/\lambda$.

Rewriting this equation gives $V_0 = (hc/e)(1/\lambda)$, which represents a straight-line equation of the form y = mx. Thus, a graph is plotted between the threshold voltage V_0 and the reciprocal of wavelength (1/λ). The slope of this graph is equal to hc/e. From the experimentally determined slope (m), Planck's constant can be calculated using the relation $h = (me)/c$, where c is the velocity of light.



COMPONENTS USED:

- LED's
- Milli Ammeter (0-100 mA)
- DC Regulated Variable Supply(V)
- 100 Ohm Resistor
- Digital Multimeter

PROCEDURE:

Connect the ammeter in series with the LED to measure the current through it, and connect the digital multimeter in parallel to the LED to measure the voltage across it. A 100 Ω resistor is connected in series with the LED. The applied voltage can be changed by using the variable supply.

Change the voltage in steps of 0.05 V from 0 V to 5 V. and measure the resulting electrical current. Note that when the current flowing through the LED is small, the LED might not light up, but the ammeter can still measure the current.

For each LED, plot a graph of current against voltage. On each graph, find the straight line of "best fit' to join up the points that slope up from the x-axis. If the points lie close to the line, this shows that a linear relationship holds between the applied voltage and the current in this region of the graph

Finally, determine the threshold voltage (V_0) from the collected data. This is the point at which the current begins to increase linearly with voltage. It can be read off the graph by extrapolating the straight line representing the linear response region backwards until it intercepts the x-axis.

2.1 EXPERIMENTAL ARRANGEMENT

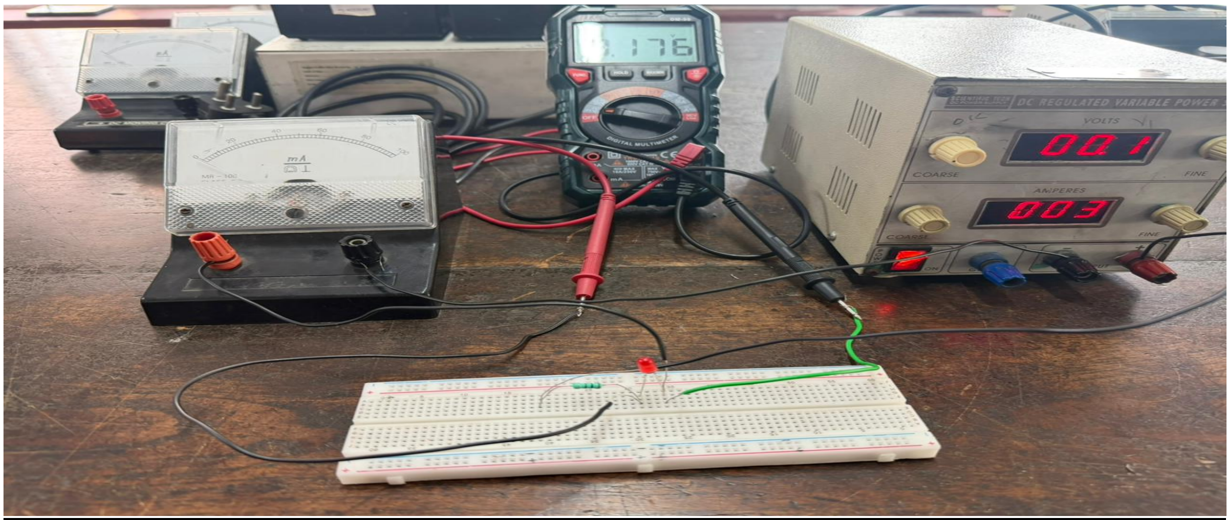


Fig 1

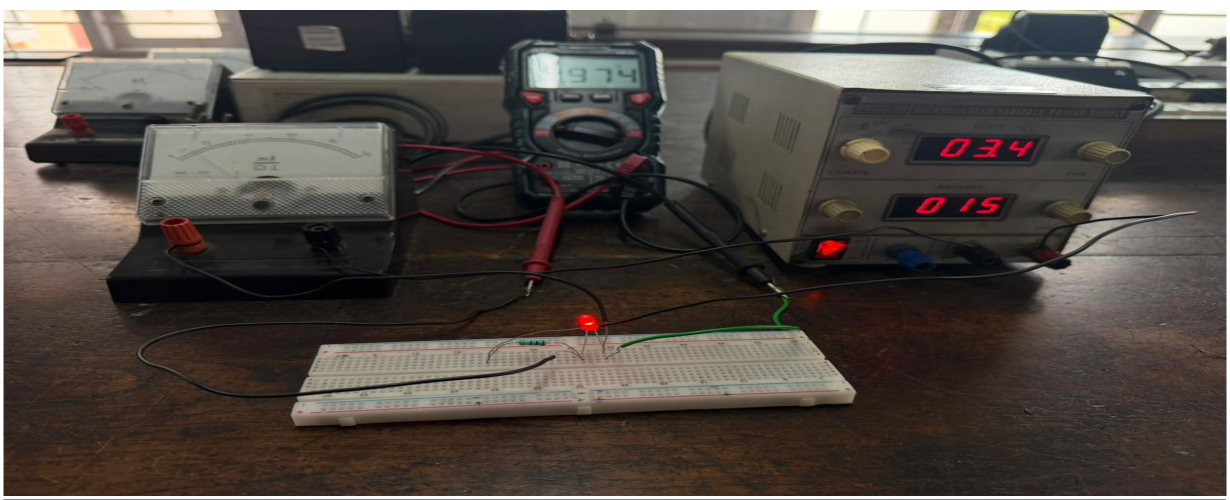
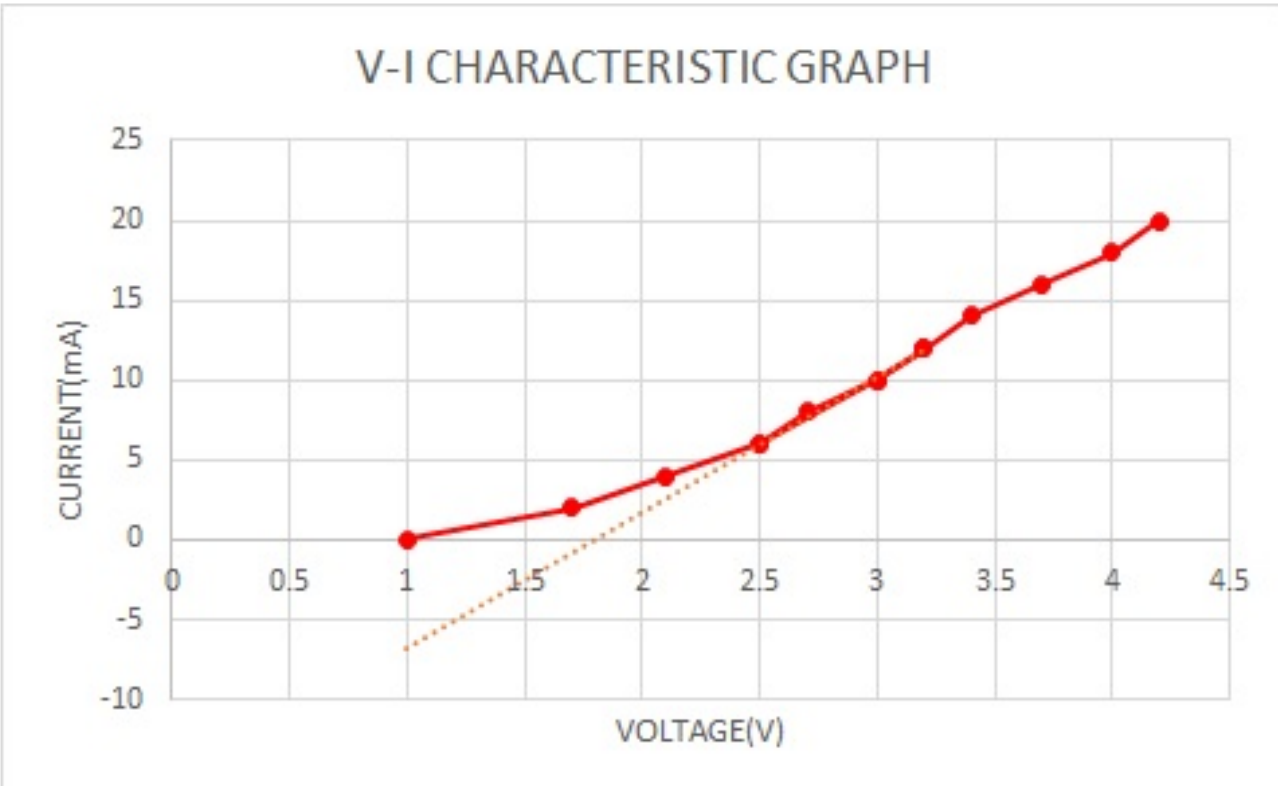


Fig 2

OBSERVATIONS

VOLTAGE (V)	CURRENT (mA)
0	0
1	0
1.7	2
2.1	4
2.5	6
2.7	8
3	10
3.2	12
3.4	14
3.7	16
4	18
4.2	20

Table 1



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

$e = 1.602\times 10^{-19}\ C$

$V = 1.85\ V$

$c = 3\times 10^{8}\ m/s$

$$h = \frac{(1.6\times10^{-19})\ (1.85)\ (6.40\times10^{-7})}{3\times 10^{8}}$$ $\boxed{= 6.3146\times10^{-34}\ \text{J s}}$

2.2 EXPERIMENTAL ARRANGEMENT

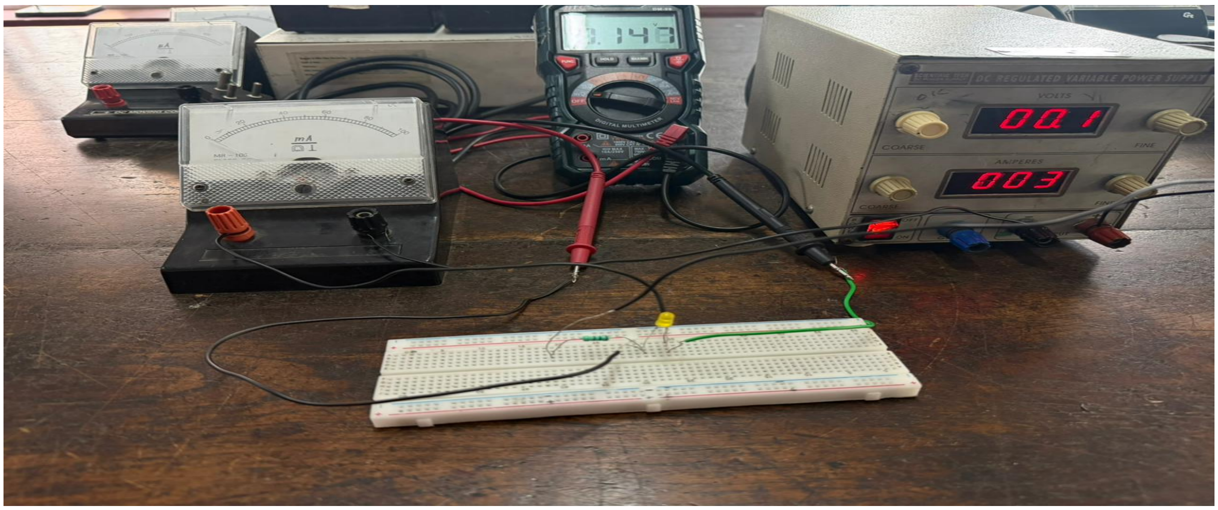


Fig 3

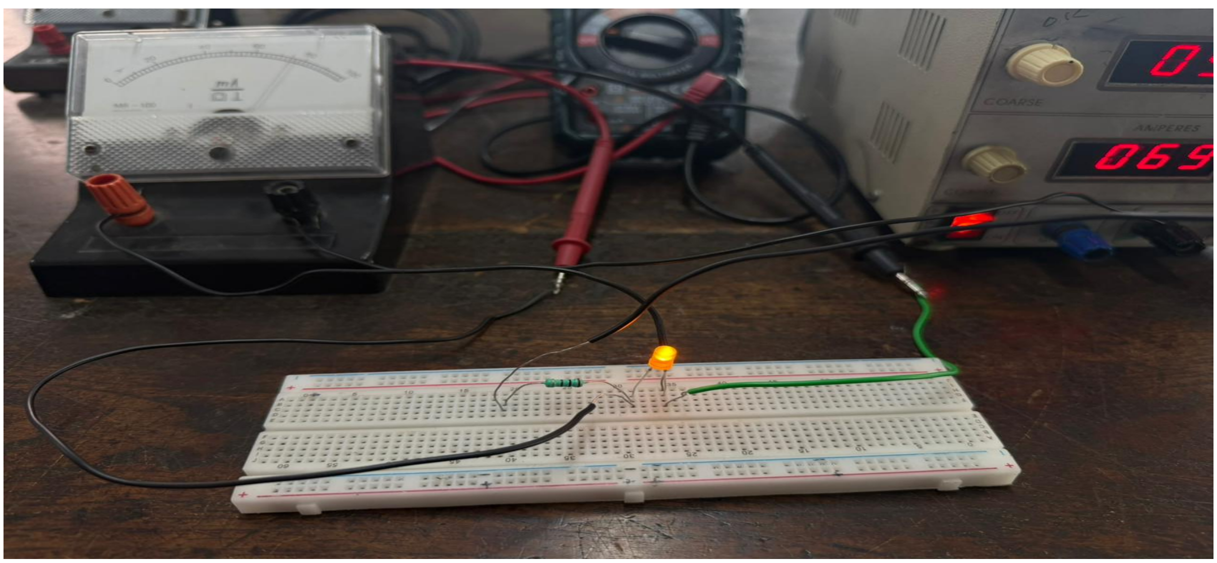
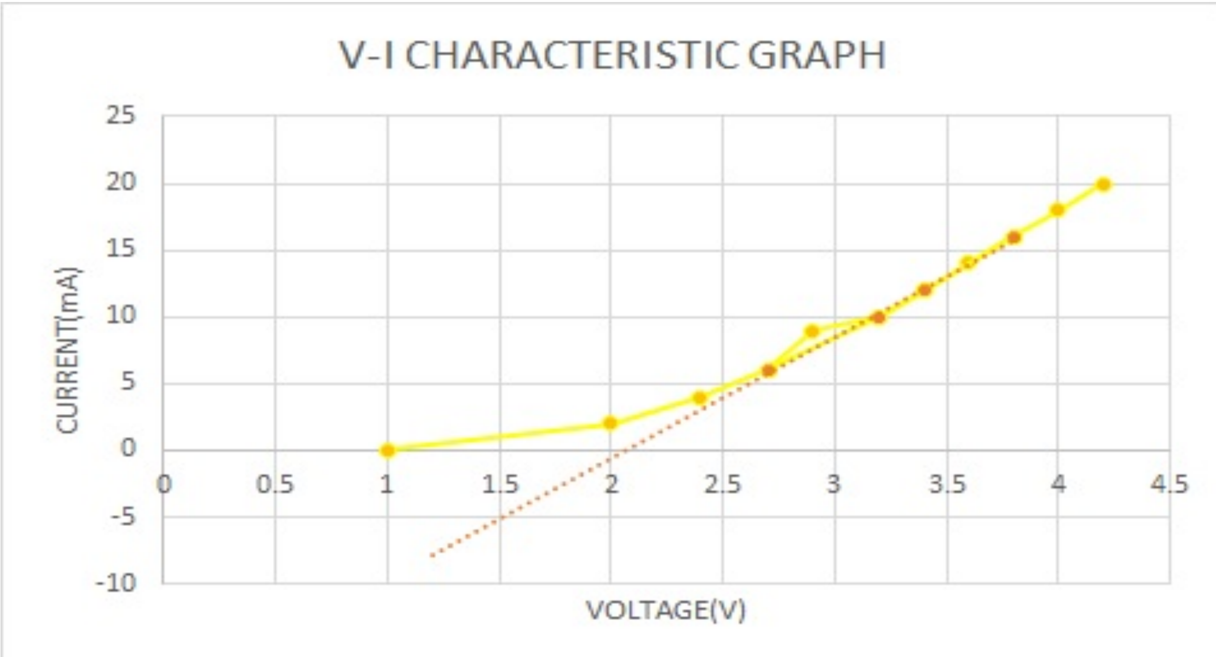


Fig 4

OBSERVATIONS

VOLTAGE (V)	CURRENT (mA)
0	0
1	0
2	2
2.4	4
2.7	6
2.9	8
3.2	10
3.4	12
3.6	14
3.8	16
4	18
4.2	20

Table 2



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

e= 1.602$\times$ 10^{-19} C

V = 2.10 V

c =3$\times$ 10^8 m/s

$$h = \frac{(1.6\times10^{-19})\,(2.10)\,(5.88\times10^{-7})}{3\times10^{8}}$$

$\boxed{= 6.5856\times10^{-34}\ \text{J s}}$

2.3 EXPERIMENTAL ARRANGEMENT

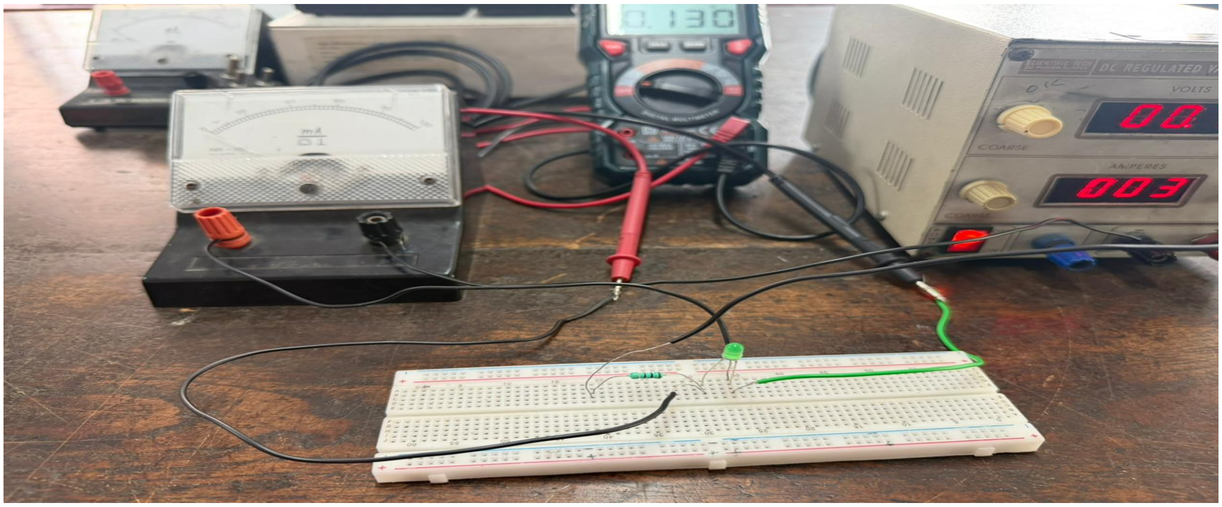


Fig 5

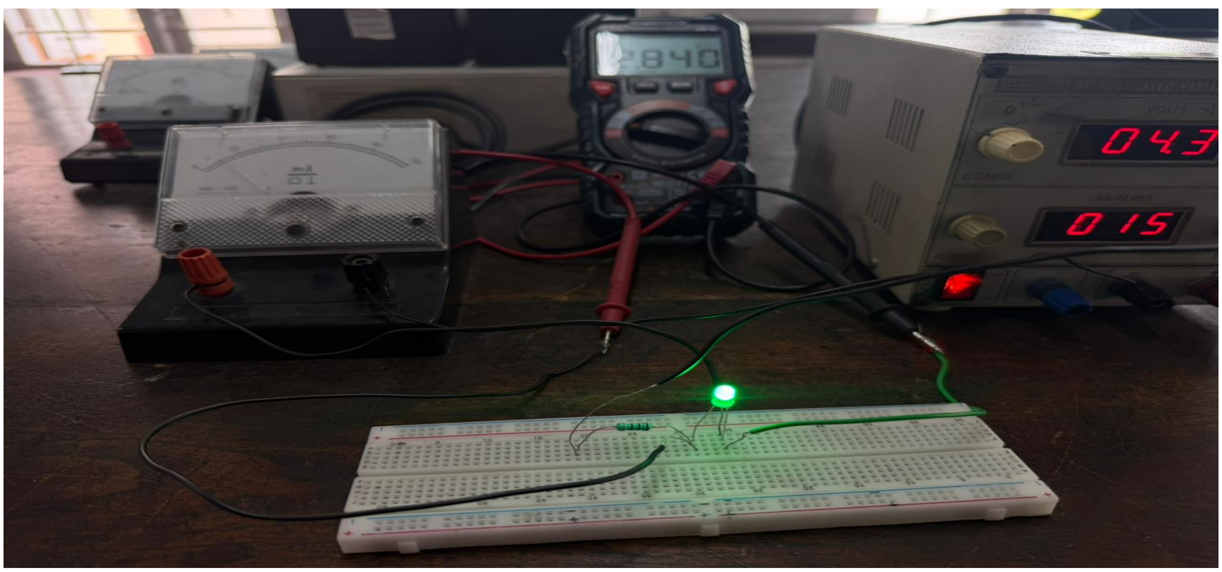
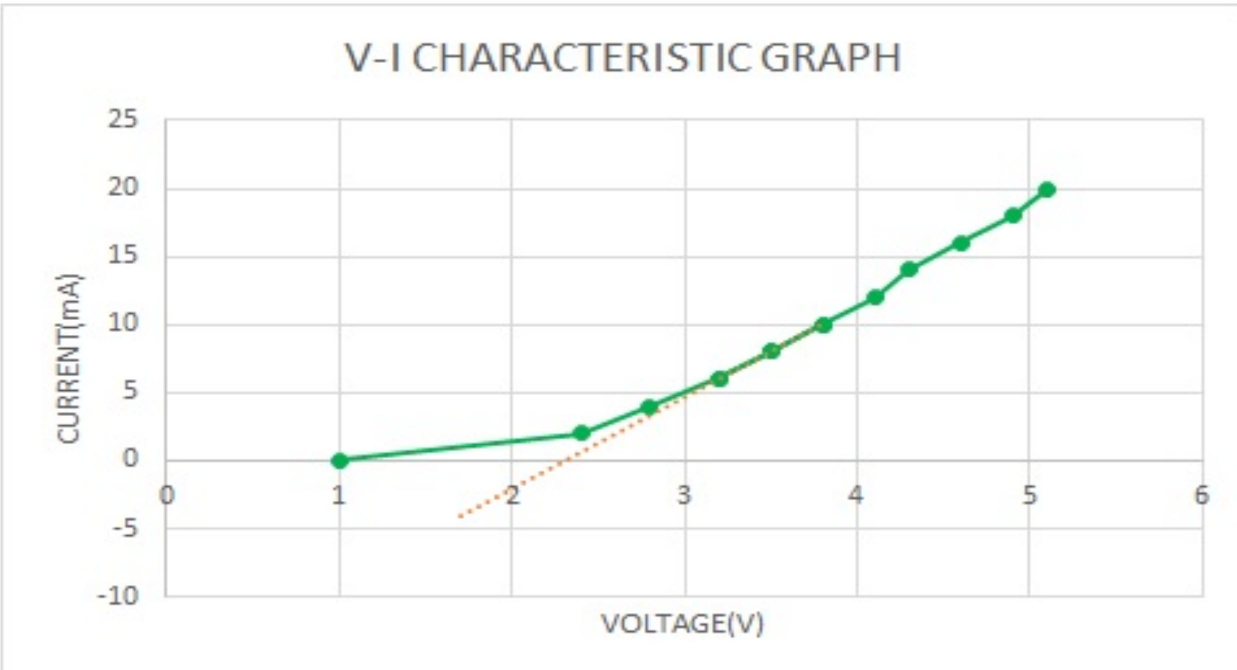


Fig 6

OBSERVATIONS

VOLTAGE (V)	CURRENT (mA)
0	0
1	0
2	0
2.4	2
2.8	4
3.2	6
3.5	8
3.8	10
4.1	12
4.3	14
4.6	16
4.9	18
5.1	20

Table 3



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

e = 1.6× 10^-19^ C

V = 2.35 V

c = 3× 10^8^ m/s

$$h = \frac{(1.6\times10^{-19})\,(2.35)\,(5.20\times10^{-7})}{3\times10^{8}} \qquad \boxed{= 6.5173\times10^{-34}\ \text{J s}}$$

2.4 EXPERIMENTAL ARRANGEMENT

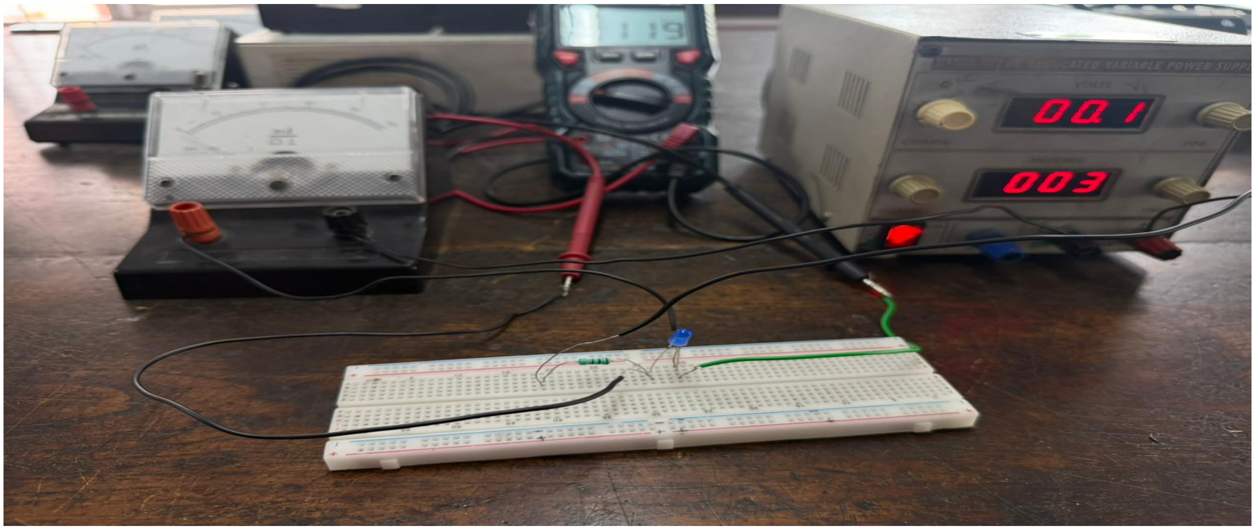


Fig 7

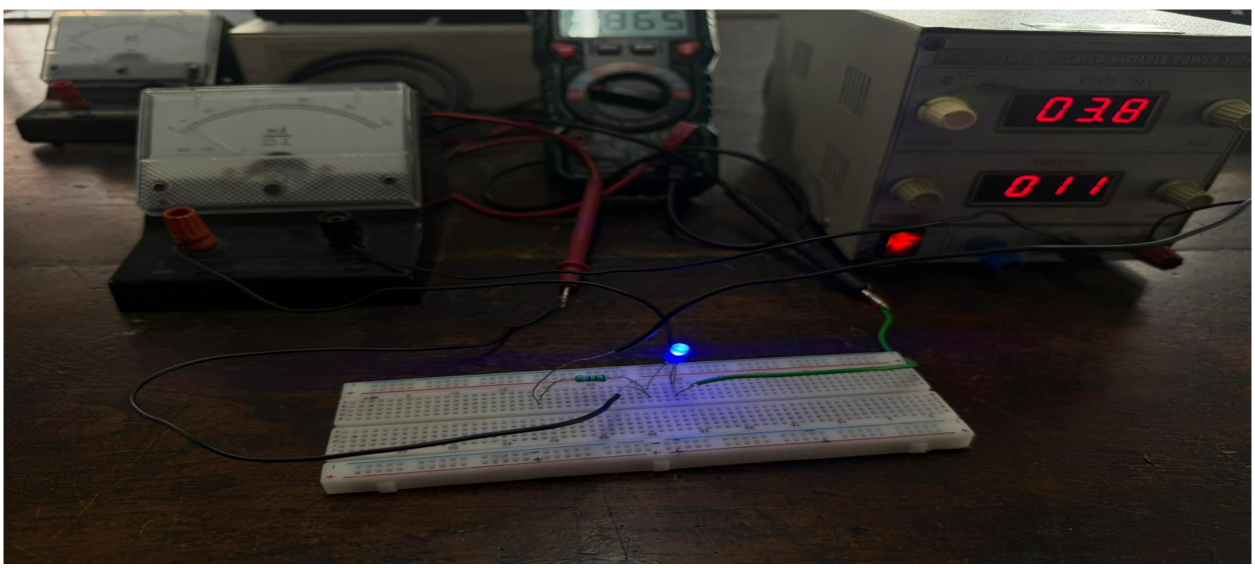
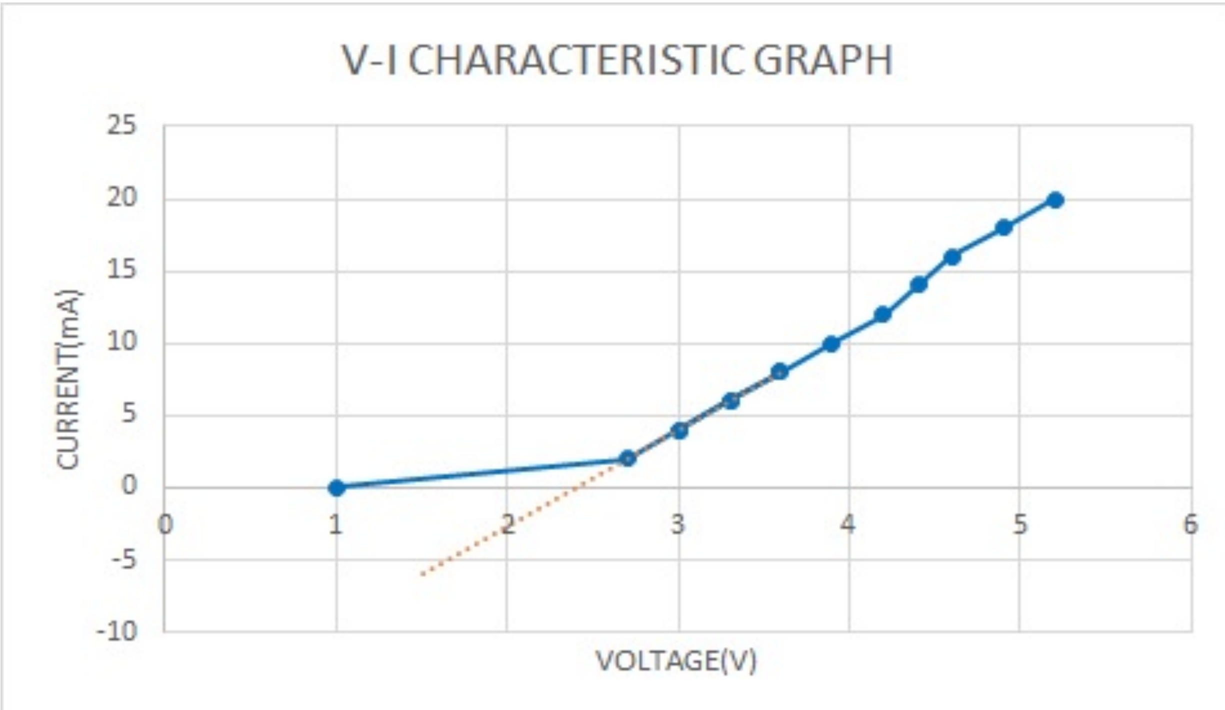


Fig 8

OBSERVATIONS

VOLTAGE (V)	CURRENT (mA)
0	0
1	0
2	0
2.7	2
3	4
3.3	6
3.6	8
3.9	10
4.2	12
4.4	14
4.6	16
4.9	18
5.2	20

Table 4



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

e= 1.6× 10⁻¹⁹ C

V = 2.60 V

c =3× 10⁸ m/s

$$h = \frac{(1.6\times10^{-19})\,(2.60)\,(4.70\times10^{-7})}{3\times10^{8}}$$

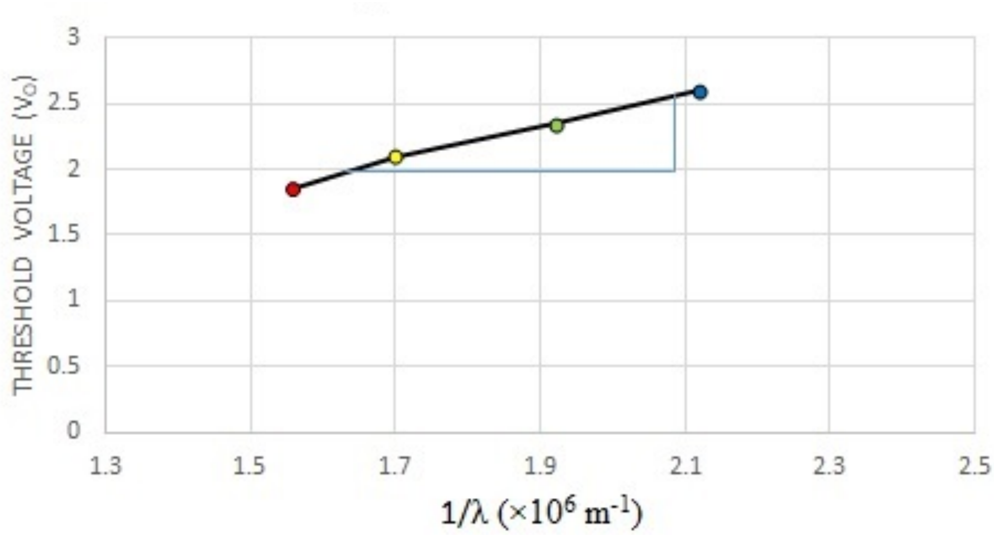
$\boxed{= 6.5173\times10^{-34}\text{ J s}}$

PROCEDURE

The connections are made as shown in the circuit diagram. The LED is forward biased and the threshold voltage (knee voltage) for each corresponding LED's is obtained from its V-I characteristics. A graph of threshold voltage (V_0) vs reciprocal wavelength $1/\lambda$ is plotted for different LED's

COLOUR	THRESHOLD VOLTAGE (V_0)	WAVELENGTH λ (nm)	$1/\lambda$ (nm^{-1})
RED	1.85	640	1.5625×10^{-3}
YELLOW	2.10	588	1.7006×10^{-3}
GREEN	2.35	520	1.9230×10^{-3}
BLUE	2.60	470	2.1276×10^{-3}

THRESHOLD VOLTAGE VS RECIPROCAL OF WAVELENGTH



$$h = \frac{me}{c}$$

$$m = slope = \frac{\Delta Vo}{\Delta\left(\frac{1}{\lambda}\right)}$$

$$m = \frac{2.56-2}{2.06-1.62} = 1.2727\times10^{6.}\ \mathrm{V.\ m^{-1.}}$$

$$h = \frac{(1.2727\times10^{-6})\ (1.6\times10^{-19})}{3\times10^{8}}$$

$$\boxed{= 6.7877\times10^{-34}\ \mathrm{J\ s}}$$

CONCLUSION

The experiment was carried out to determine Planck's constant using LEDs of different colours by measuring their threshold voltages and corresponding wavelengths. The stopping potential was found to increase with the increase in inverse wavelength, and the graph between stopping potential and inverse wavelength was observed to be a straight line, confirming the linear relationship predicted by quantum theory. Using the slope of the graph, the value of Planck's constant was evaluated.

$h = 6.7877 \times 10^{-34}$ J s

which closely agrees with the standard accepted value $h = 6.626 \times 10^{-34}$J.s. The small difference between the experimental and theoretical values may be due to experimental limitations such as inaccuracies in voltage measurement, variation in LED characteristics, and approximation of dominant wavelength.

Hence, the experiment verifies the quantum behaviour of light and establishes that LEDs can be effectively used for the determination of fundamental constants like Planck's constant.

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