Table 34.1

Material	Colour of light emitted
Alluminium gallium Arsenide (Al GaAs)	Red and infrared
Gallium Alluminium phosphate (Al GaP)	Green
Gallium Arsenide/Phosphide (GaAsP)	Red, Orange,
Gallium Nitride	Green, Blue
Gallium Phosphide (GaP)	Red, yellow, green
Zinc Selenide	Blue
Indium Gallium Nitride (In GaN)	Bluish green, Blue

Experiment: 34.2 To determine the value of Planck's Constant by using light-emitting-diodes (LED's)

Apparatus: Visible LED's capable of emitting light of different wave-lengths, a battery (5 volts), a rheostat, a voltmeter (0–3V), a millammeter, connecting wires, etc.

Theory: As discussed earlier when an electron is excited by a voltage source of V volts, it gets energy eV which excites it from ground level to excited level. When the excited electron comes back to the ground level (or recombines) this energy appears as radiative energy. Some energy, however, may get wasted in the process of non-radiative recombination and hence we may write,

$$eV = R + h\nu$$

where R is the energy lost in non-radiative recombination But $R << h\nu$ and may be neglected

$\therefore$ $$eV = h\nu$$

or $$eV = \frac{hc}{\lambda}$$

Hence, if a minimum voltage V given to an LED causes it to glow with light of wavelength λ, then a plot of V along y-axis and $\frac{1}{\lambda}$ along x-axis is a straight line with slope equal to $\frac{hc}{e}$ from which the Planck's constant h can be determined.

Procedure

1. Make the circuit as shown in Fig. 34.5. A rheostat is used as a potential-divider to change the voltage across the LED. A voltmeter and millammeter connected in the circuit give respectively the voltage across the LED and the current through it. Different LED's capable of emitting light of different colour are connected as shown in figure and can be incorporated into the circuit one by one by connecting the point O to 1, 2, 3, 4, and 5 turn by turn.
2. Keep the sliding contact of the rheostat towards the P end. Switch on the power supply and connect O with 1. Increase the voltage across the diode by slowly moving the sliding contact towards Q. Note down the voltage V across the diode and current I through it. Plot the I-V curve as shown in Fig. (34.6) and note down the turn on voltage V_0 at which the current just

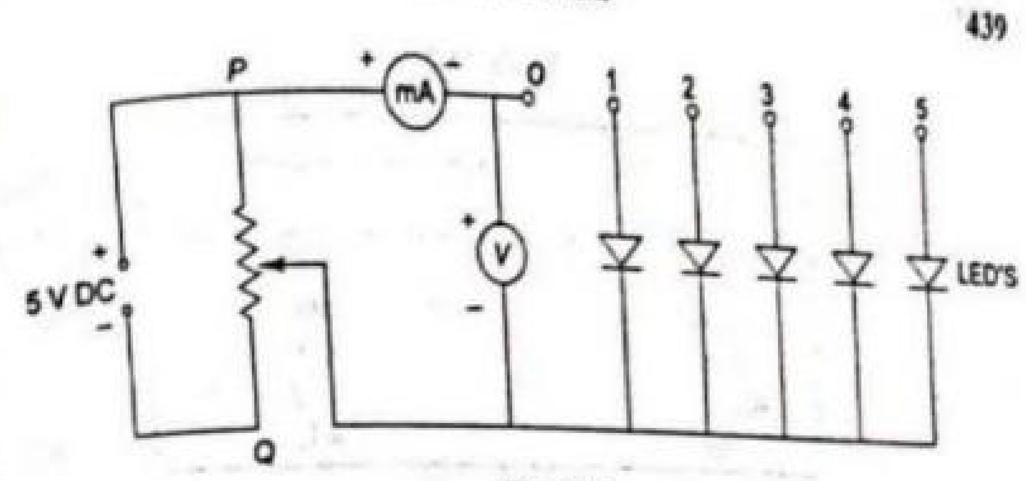

Fig. 34.5

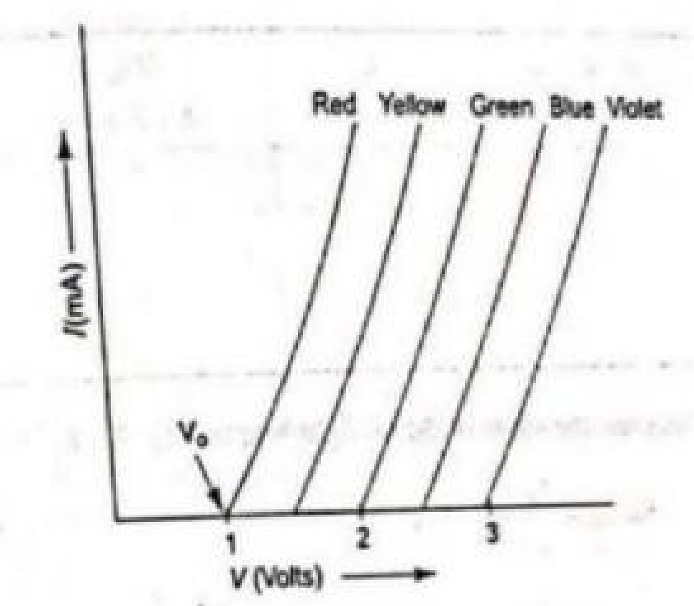

Fig. 34.6

increases from zero. This is the minimum voltage at which the LED just starts to glow. Note also the colour of the light.[1]

3. Disconnect 1 and connect O with 2, 3, 4, 5, one by one and repeat the step 2 and note down the turn-on voltage V_0 and the colour of light.
4. Find the maximum wavelength (minimum frequency) λ_m of the light emitted by the different LED's by spectrometer[2], or simply take the values from the table (34.2).
5. Plot a graph with $1/\lambda_m$ along x-axis and the turn-on voltage V_0 along y-axis. It will be a straight line.
6. The slope of the above graph is equal to $\frac{hc}{e}$ where c is the speed of light and e is the electronic charge. Calculate h from the slope.

1. The turn on voltage V can be found without plotting the I-V curve just by looking at the diode carefully. But this would cause error as it would be difficult to find the voltage V at which LED just begins to glow.
2. Perform the experiment in a dark room to determine the wavelength with the help of spectrometer. A band will be observed whose maximum gives λ_{max}.

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Table 34.2

Light emitted by diode	λ_m *(nm)*
Red	695
Yellow	660
Green	630
Blue	472
Violet	432

Observations

S. No	*Colour of Light emitted*	λ_m *(nm)*	$1/\lambda_m$ *(X* $10^9\ m^{-1}$*)*	V_0 *(Volts)*
1				
2				
3				
4				
5				

Calculations: Calculate the slope of the straight line in Fig. 34.7.

$$\text{Slope} = \frac{hc}{e} = \ldots\ Vm$$

$$\therefore \quad h = \frac{e}{c} \times \text{slope}$$

$$= \ldots\ \text{J.sec}$$

where $e = 1.6022 \times 10^{-19}$ C

and $c = 2.998 \times 10^{8}$ m/s.

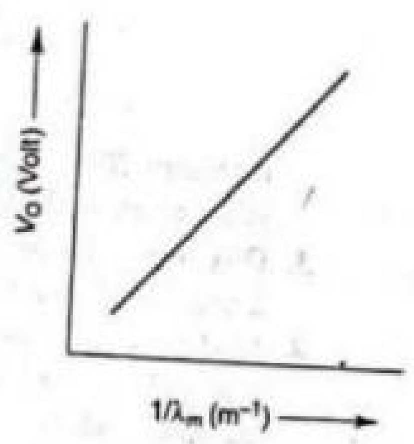

Fig. 34.7

Result: The experimentally determined value of the Planck's constant = ... J sec

Actual value = 6.626×10^{-34} J sec

% Error = ...

Precautions and sources of error

1. The current through the LED should not increase the prescribed limit.
2. The turn on voltage V_0 should be noted very carefully.
3. The voltmeter and the millimeter should be free from any errors.

Weak Points

It is difficult to obtain the exact value of the turn-on voltage. Also the energy lost due to non-radiation recombinations is different for different LED's. An error can also be introduced in the determination of λ_m. Because of these reasons, the value of the Planck's constant as determined by this method is not expected to be very accurate one.

QUESTIONS FOR VIVA

Q. Define Planck's constant. What is its value?

Ans. The fundamental constant equal to the ratio of the energy of a quantum of energy to its frequency, is called Planck's constrant i.e., $h = \frac{E}{\nu}$.

Its value is 6.626×10^{-34} Js.

Q. Are these methods accurate for the determination of *h*?

Ans. No, there are several inaccuracies in both the methods. But they are reasonably correct to give an approximate value of *h*.

Q. Define photoelectric effect.

Ans. The liberation of electrons from a metal surface exposed to electromagnetic radiation is called photoelectric effect.

Q. On what factors do these depend?

(*i*) number of electrons emitted per unit area, and

(*ii*) the kinetic energy of the emitted electrons.

Ans. The number of electrons emitted per unit area depends on the intensity of incident radiation and the kinetic energy of the emitted electrons depends on the frequency of incident radiation.

Q. What are LED's? How are they different from normal *pn*-diodes?

Q. What are the common materials for LED's.

Q. Why don't Si and Ge diodes emit light?

Ans. Because Si and Ge have an indirect band gap i.e., the minimum of the conduction band and the maximum of the valence band are not at the same value of the wave vector *k*. This is why radiative transitions are very rare in these.

Q. What are the operating voltages for LED's?

Ans. 0–3 V

Q. Give the construction and working of a light emitting diode.

Q. Why do we measure the maximum value of the wavelength i.e., λ_{max} for LED's?

Ans. Because λ_{max} corresponds to ν_{min} or minimum energy which corresponds to the turn-on voltage V_0.

thus $h\nu_{min} = eV_0$

or $\frac{hc}{\lambda_{max}} = eV_0$

Q. What are radiative and non radiative recombinations?

Ans. When an electron and a hole recombine, energy is released. When this energy is emitted as radiation, the recombination is called *radiative recombination*. In some cases known as *non-radiative recombinations*, this energy is given to the lattice and no radiation is emitted.

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