LMC ELECTRONICS

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- ❖ **Read instruction manual carefully.**
- ❖ **The graphical variations shown are exemplary and the numerical values may differ.**
- ❖ **Connect the circuit step by step as written in the procedure.**
- ❖ **Check the circuit again carefully before switching ON the power supply.**

OPERATING INSTRUCTIONS MANUAL FOR THE DETERMINATION OF PLANCK'S UNIVERSAL RADIATION CONSTANT (h) BY USING PHOTOVOLTAIC CELL

MODEL: LMC-106

Connection leads Red-3 & Black-3 (2mm)

OBJECT: - To study inner photoelectric effect in case of photovoltaic cell by using a light source of continuous spectrum and determine the value of Planck's constant (h).

APPARATUS: - Experimental Board, connection leads Red-3 & Black-3 (2mm).

BASIC INFORMATION: - According to quantum radiation theory, a packet of light quantum is known as photon and its energy is exclusively given by $h\nu$, where **h** is **Planck's radiation universal constant** and ν is the frequency of radiation. A part of photonic energy $h\nu$ is used to free electron from atomic binding and the remaining energy imparts kinetic energy to the photo electron. The usual process is expressed by following Einstein's photoelectric equation:

$$\underbrace{h\nu}_{\text{photon energy}} = \underbrace{h\nu_0}_{\text{work function}} + \underbrace{\tfrac{1}{2} mv^2}_{\text{kinetic energy}} \quad \dots (1)$$

In case of photovoltaic cells; let us write the electrical equivalent of Einstein's photoelectric equation as below:

$$eV_1 = eV_0 + eV_{ph} \quad \dots (2)$$

The above equation is applicable in case of optical source capable of converting electrical energy completely into radiant energy. A light emitting diode converts electrical energy completely into radiant energy. However the frequency (ν) emitted by a LED is directly related to the voltage (V) across it. The frequency (ν) and voltage (V) are related to each other by following relation in the light of relation (1 & 2):

$$\nu = (2.424 \times 10^{14}) \times V \quad \dots (3)$$

In relation (2) the $e = 1.6 \times 10^{-19}$ C, the electronic charge and thereby LHS part eV_1 is the electrical equivalent of photonic energy ($h\nu$). The RHS part eV_0 is equivalent to $h\nu_0$ and gives the work function of the optical source; while the electrical part eV_{ph} correspond to kinetic energy ($\frac{1}{2} mv^2$) and represents photovoltaic action i.e. inner photoelectric effect. The V_{ph} is the photo voltage developed in photovoltaic cell by a characteristic radiation from the light source. The photovoltaic action is explained below.

PHOTOVOLTAIC ACTION IN PHOTOVOLTAIC CELLS:

A photovoltaic cell is a silicon p n diode with large junction area since the junction area is to be exposed to radiation to accentuate photovoltaic action.

In order to grasp the photovoltaic action; let us use fig. (1) which shows a photovoltaic cell exposed to radiation from a light source. Firstly consider the creation of depletion region and the knee voltage (V_k) in photovoltaic cell.

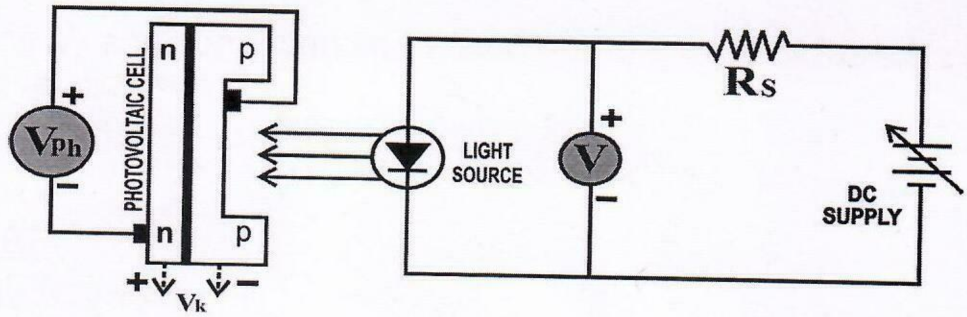


fig. (1)

The holes ρ from **p** semiconductor and electrons σ from **n** semiconductor recombine in the junction area and create a depletion region of say width 'd' and thereby a knee voltage $V_k \approx 0.7$ volt. In this process the **p** semiconductor side becomes –ve while **n** semiconductor side becomes +ve as shown in fig. (1). It is this knee voltage V_k creation which stops the recombination at a definite limit. However the width 'd' depends upon the concentration of **p** and **n** semiconductors. An intense electric field due to V_k and very small value of 'd' is given by following relation:

$$\text{Knee electric field } E_k = \frac{V_k}{d}$$

Next consider the radiation from a light source of continuous spectrum to fall on the photovoltaic cell.

The characteristic radiation at a particular voltage (V) generates electron σ and hole ρ pairs thermally in the depletion region. The knee electric field E_k directs holes ρ to **p** semiconductor and electrons σ to **n** semiconductor. The resulting accumulation of holes ρ on **p** semiconductor and electrons σ on **n** semiconductor results into photo voltage. Thus a photo voltage (V_{ph}) develops due to intrinsic photo electric effect. With increasing voltage (V) across the emitter, the corresponding frequency (ν) increases as per relation (3) and thereby more energetic photons (hν) are created and therefore photo voltage (V_{ph}) increases. However the knee field E_k has a limit to divert holes ρ and electrons σ to the respective **p** & **n** semiconductors. Ultimately the increasing photo voltage (V_{ph}) saturates above a particular voltage. The typical variation of photo voltage (V_{ph}) with the voltage (V) across the light source is shown in fig.(2)

In this way the usual photovoltaic cells are capable of developing a limited photovoltage of about 0.5 volt.

In fig. (2), the graphic extrapolation shows the voltage V_0 at which V_{ph} becomes zero. This gives the value of work function of emitting source in electron volt. Find the sum of V_0 & each value of V_{ph} to give the value of V_1 i.e.

$$V_1 = V_0 + V_{ph} \quad \dots (4)$$

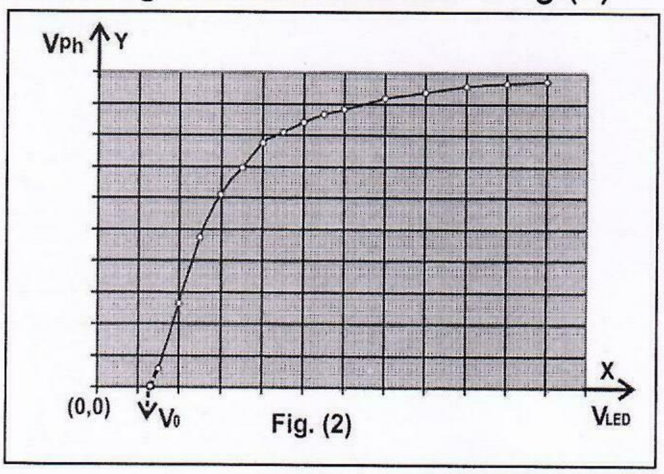


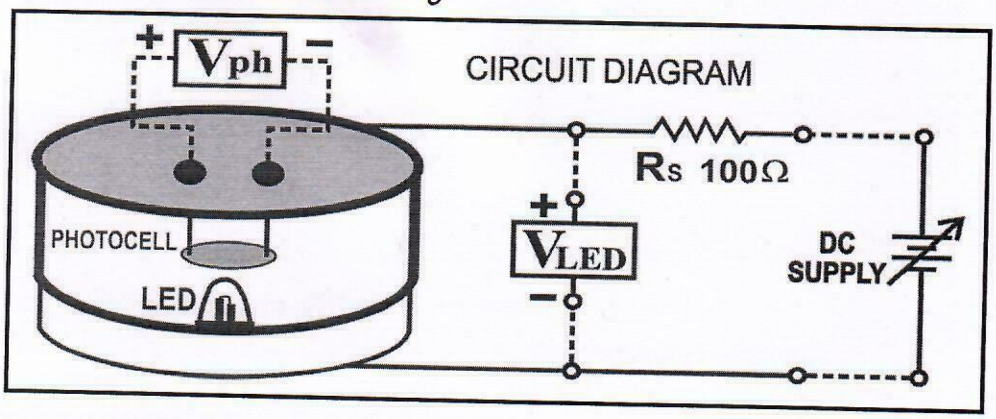
Fig. (2)

Now knowing V_1 and corresponding ν evaluate the value of Planck's constant (h) by following relation:

$$h = \left(\frac{V_1}{\nu}\right) e = \left(\frac{V_1}{\nu}\right) 1.6 \times 10^{-19} = \ldots \text{ j.s}$$

PROCEDURE:-

NOTE:- The variations shown in graphs are exemplary & the numerical values may differ due to physical conditions and individual's working.



- ***Keep power switch in off position.***
- ***Remove all the connections, if any, on the exp. board.***

1. Connect terminals 1 & 2 of DVM (2V) across the photocell terminals given on the top of the chamber in same polarity.
2. Now connect terminals 3-3, 4-4, 5-5 and 6-6.
3. Keep pot-1 at its minimum position. Switch on the power.

PRECAUTION: *Note that the DVM used as very high input impedance and as a result it may record some –ve floating value of V_{ph}. Do not record –ve value, if any.*

4. Set voltage (V_{LED}) across the light source (LED) say at about 2.0 volt & above so that V_{ph} just starts increasing and record the values V_{LED} & V_{ph} in table.
5. Now increase voltage (V_{LED}) in increasing steps of 0.05V upto about 3.30V and record values of V_{ph} for each step.

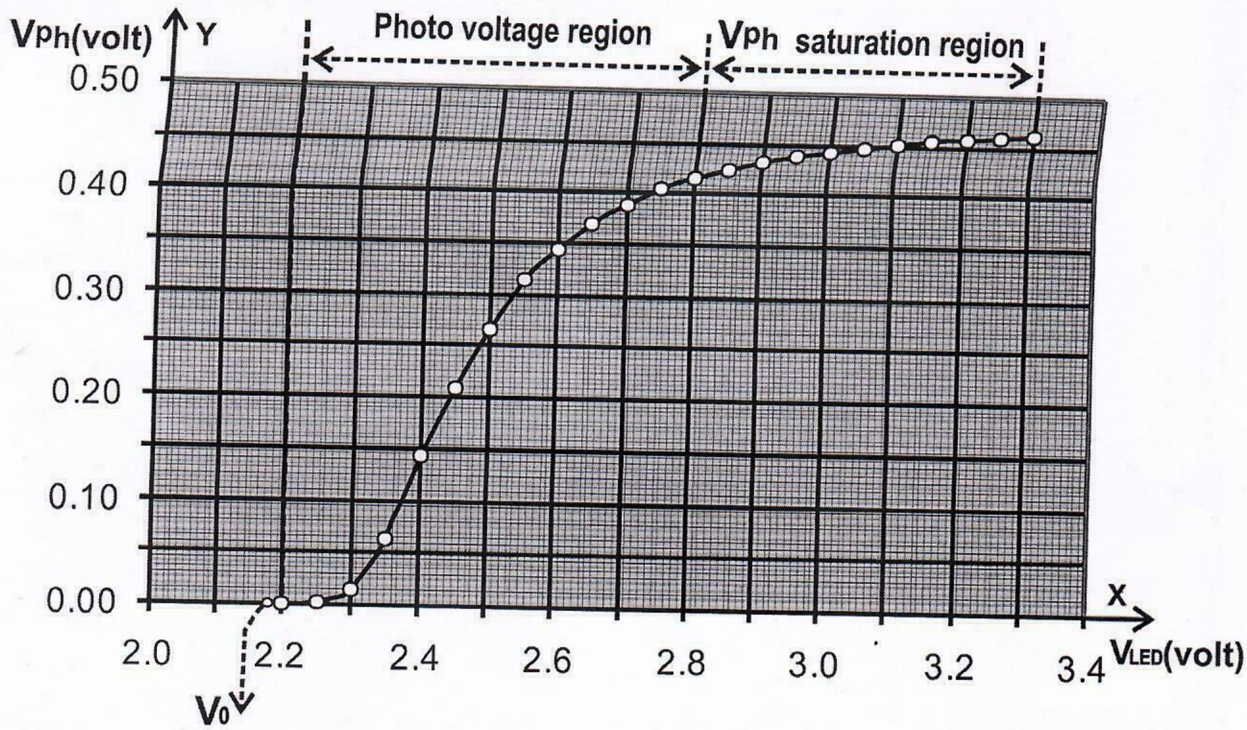
Record the experimental values of V_{LED} & V_{ph} in volt in following table:

Sl no.	Experimental values		Evaluated values				
	V_{LED} volt	V_{ph} volt	ν Hz	V_0 Volt	$V_1 = V_0 + V_{ph}$ volts	h J .sec	Average **h** J .sec
				...			...

6. Calculate the value of frequency ν in Hz for each value of V_{LED} by following relation and record in table:

$$\nu = (2.424 \times 10^{14}) \times V_{LED} = \ldots \text{ Hz}$$

7. Take voltage (V_{LED}) on X-axis and V_{ph} on Y-axis to plot a graph of type shown below:



8. Record the value of V_0 in table for which V_{ph} = 0 from the graph.
9. Knowing constant value of V_0; calculate V_1 for each value of V_{ph} by using following relation and record in table:

$$V_1 = V_0 + V_{ph} = \ldots \text{ volt}$$

10. With recorded values of V_1 and corresponding ν; calculate the value of Planck's constant (h) by following relation for each value:

$$h = \left(\frac{V_1}{\nu}\right) e = \left(\frac{V_1}{\nu}\right) 1.6 \times 10^{-19} = \ldots \text{ j.s}$$

11. Calculate the average value of h within saturation limits of V_{ph} beyond which the photovoltaic action ceases.

<u>RESULTS AND FINDINGS</u>:-

(i) The work function of the LED V_0 = ... eV.

(ii) The average value of Planck's radiation constant h = ... j.s.

<u>COMMENTS</u>:-

(1) This experiments gives an insight of inner photoelectric effect.

(2) The equivalence between the photonic & electrical energy is satisfied by a LED which converts electrical energy (eV) into radiant energy ($h\nu$).

(3) The Einstein equation is proved in its electrical analogue form in case of inner photoelectric effect.