INDOSAW
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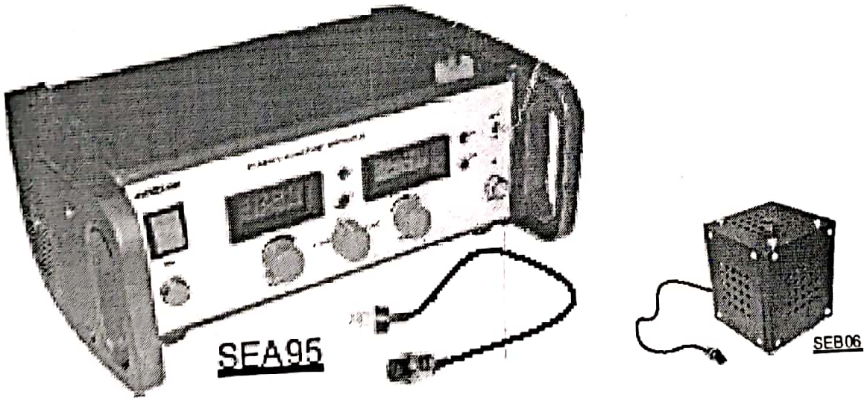
INSTRUCTION MANUAL

PLANCK'S CONSTANT BY LED



OBJECTIVES: **To Study the Plancks Constant**

(i) Determination of material Constant η

(ii) Determination of Temperature Coefficient of Current

THEORY:

The basic idea in this measurement is that the photon energy, which from Einstein's relation is $E\gamma = h\nu$ is equal to the energy gap E_g between the valance and conduction bands of the diode. Energy gap is in turn equal to the height of energy barrier EV_o. Those electrons have to overcome to go from the n-doped side of diode junction to the p-doped side when no external voltage V is applied to the diode. In the p-doped side they recombine with holes releasing the energy E_g as photons with $E_\gamma = E_g = eV_o$ Thus a measurement of V_o Indirectly yields E_γ and Planck's constant. If ν is known or measured. However there are practical and conceptual problems in actual measurement.

Let us consider the LED diode equation:

$$I \propto \exp(-V_o / V_t)[\exp(V / V_t) - 1], \qquad V = V_m - RI \qquad (1)$$

where $V_t = \dfrac{\eta kT}{e}$

k = Boltzmann constant, T = absolute temperature & e =electronic charge.

V_m is voltmeter reading in external diode circuit and R is the contact resistance. The constant η is material constant, which depends on type of diode, location of recombination region etc. The energy barrier eV_o is equal to the gap energy E_g when no external voltage V is applied. The quantities, which are constant in an LED, are impurity atom density, the charge diffusion properties and the effective diode area. The 'one' in the rectifier is negligible if $I \geq 2\ nA$, and the equation becomes,

$$I \propto \exp[(V - V_O / V_t)]$$
$$\propto \exp[e(V - V_o / \eta kT)] \qquad (2)$$

A direct method could be to apply a small voltage on the Led and increasing it till the LED is turn – ON. This turning – ON could be detected by visually observing the light emission. Plotting threshold voltage vs. frequency of peak light output (obtained from LED datasheets) provides the value of h/e .The visual observation of the emission on-set is quite vague. Use of photo-multiplier is sometimes suggested for this purpose but working with it raises maintenance problems and is quit costly, alternately the measurement of threshold current ($<10^{-11}$A). Through the LED may be attempted but it is difficult and not entirely accurate due to in efficiencies of actual LED's.

Another procedure some times used, is to draw a tangent to the I-V characteristics of the diode and obtain its intercept. This procedure may give reasonable good results if the tangents to the I-V characteristics of the diodes are drawn at the same current. The method then really become equivalent to measuring voltage across the LED's at a single current. The intercepts of the tangent are except for an additive constant, identical to diode voltages. The additive constant may be eliminated by considering data from different LED's. However, the bulk of data collected from the original I-V graph becomes irrelevant. A basic drawback of these methods is the assumption that the barrier height V_o is constant, equal to the gap energy E_g divided by the electronic charge E_g/e, which is true only when electric potential V is small or less than E_g/e. Further assume that material constant η is unity which is not correct.

Present method is free from these infirmities. The height of Potential barrier is obtained by directly measuring the dependence of diode current on the temperature keeping the applied voltage and thus the height of barrier fixed. The external voltage is kept fixed at a value lower than the barrier. In our experimental set-up the variation of current I with temperature is measured over about a range of about 30^0C at a fixed voltage V (=1.8volts) kept slightly below Vo. The slope of lnI vs 1/T curve gives $e(Vo - V)/\eta k$. The constant η may be determined separately from I-V characteristic of the diode at room temperature from the relation

$$\eta = (e/kT)(\Delta V / \Delta \ln I) \quad (3)$$

The Planck's constant is then obtained by relation

$$h = eV_o \lambda / c \qquad (4)$$

The contact resistance of LED is usually around 1ohm, while overall internal resistance of LED at applied voltage (1.8V) is few hundred ohms. The factor RI in expression $V = V_m - RI$ may therefore be neglected.

The value of Planck's constant obtained from this method is within 5% of accepted value (6.62×10^{-34} Joules.sec)

EXPERIMENTAL SET-UP

The set-up consists of following units:

1. **Variable Voltage source**
   - Specifications:
     - Range : 0-2 V DC
     - Resolution : 1mv
     - Accuracy : ±0.5%
     - Display: 3*1/2 LED DPM
2. **Current Meter:**
   - Specifications:
     - Ranges: 0-20mA/2000uA.
     - Resolution : 10uA/1uA
     - Display: 3*1/2 LED DPM
3. **Temperature Controlled Oven**
   - Specifications:
     - Range : Ambient to 60°C
     - Resolution : 0.1°C
     - Sensor: PT-100
     - Display: 3*1/2 LED DPM

CONNECTION DIAGRAM OF EXPERIMENTAL SET-UP:

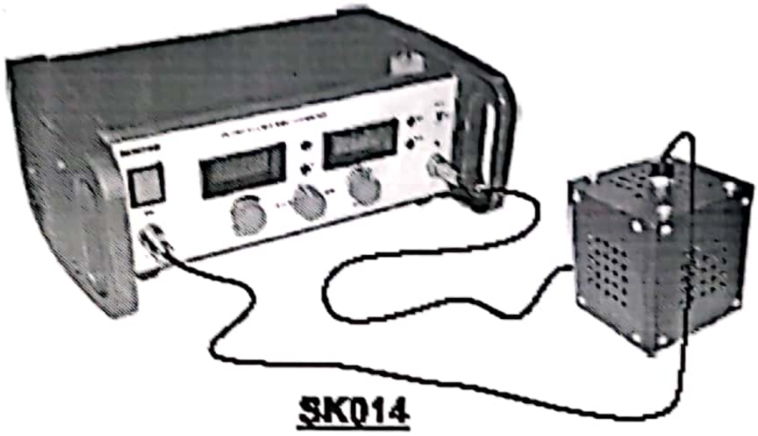


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Figure 1

EXPERIMENTAL SET-UP PROCEDURE:

(a) To draw I-V characteristic of LED

1. Connect LED in socket on set up and switch ON power.
2. Switch the two-way switch to V-I position. In this position the 1st DPM would read voltage across LED and 2nd DPM would read current passing through LED.
3. Increase the voltage gradually and tabulate the V-I reading. Please note there would be no current till about 1.5V. Draw the graph: lnI (I in uA) vs V.

(b) Dependence of current (I) on temperature (T) at constant applied voltage

1. Keep the mode switch to V-I side and adjust the voltage across LED slightly below the band-gap of LED say 1.8V for both yellow and red and 1.95 for green LED.
2. Change the mode of two-way switch to T-I side.

3. Insert LED in the oven and connect the other end of LED in the socket provided on set up. Before connecting the oven check that oven switch is in OFF position and SET Temperature knob is at minimum position. Now 1st DPM would read ambient temperature.
4. Set the different temperatures with the help of Set –Temperature knob. Allow about 5 minutes on each setting for the temperature to stabilize and take the readings of temperature and current.
5. Find the inverse of temperature and draw the graph between ln I & (1/ T).

OBSERVATIONS:

(a) Determination of Material Constant η

Sample: (RED/ YELLOW) LED

Room Temperature: 340K

Sr.No.	Junction Voltage V (V)	Forward Current I (uA)	ln I

Slope of curve $\frac{\Delta V}{\Delta \ln I}$

Therefore,

$$n = \frac{q\Delta V}{kT\Delta \ln I}$$

(b) Determination of Temperature Coefficient of Current

Sample: (RED/ YELLOW) LED

Voltage =1.803V (constant for whole set of readings)

Sr.No.	Temperature (°C)	Temperature (°K)	Current (mA)	1/Tx10^{-3} (K^{-1})	lnI (I in mA)

From graph $\frac{\Delta \ln I}{\Delta T^{-1}} =$

Therefore,

$$V_o = V - \left[\frac{\Delta \ln I}{\Delta T_1} \times \frac{K}{e} \times \eta\right]$$

now

$$h = \frac{e \times V_o \times \lambda}{c}$$

h = ...Joules.sec

CHECK POINTS:

1. V-I characteristic of LED should be drawn at very low current upto = 1000uA only, so that disturbance to V_o is minimum.
2. In T-I mode, make sure that the oven switch is 'OFF' and SET temp knob is at minimum position before connecting the oven.
3. On each setting of temperature, please allow sufficient time for the temperature to stabilized, between 5-6 minutes

TEST RESULTS

OBSERVATIONS

(a) Determination of Material Constant η

Sample : YELLOW LED

Room Temperature: 290K

Sr.No.	Junction Voltage V (V)	Forward Current I (uA)	In I
1	1.480	1	0.00000000000
2	1.602	23	3.13549421593
3	1.640	56	4.02535169074
4	1.664	99	4.59511985013
5	1.679	136	4.91265488574
6	1.686	160	5.07517381523
7	1.706	253	5.53338948873
8	1.713	296	5.69035945432
9	1.720	342	5.83481073706
10	1.734	460	6.13122648948
11	1.744	560	6.32793678373
12	1.748	612	6.41673228251
13	1.754	699	6.54965074223
14	1.762	804	6.68959926918
15	1.769	911	6.81454289726
16	1.789	1305	7.17395831976
17	1.795	1423	7.26052259809
18	1.807	1753	7.46908388492
19	1.809	1821	7.50714107973
20	1.811	1864	7.53047999525

Determination of Material Constant

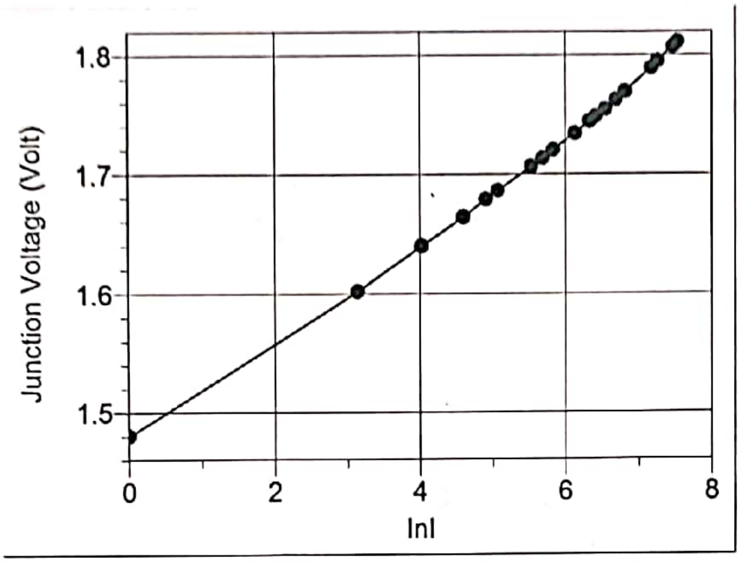


Figure 2

Slope of curve $\frac{\Delta V}{\Delta \ln I}$ = 0.04460

Therefore,

$n = \frac{q\Delta V}{kT\Delta \ln I}$ = $(1.602\times10^{-19}\times0.04460) / (1.381\times10^{-23}\times290)$

= 0.0001782×10^{4} = **1.782**

V-I Characteristics of LED

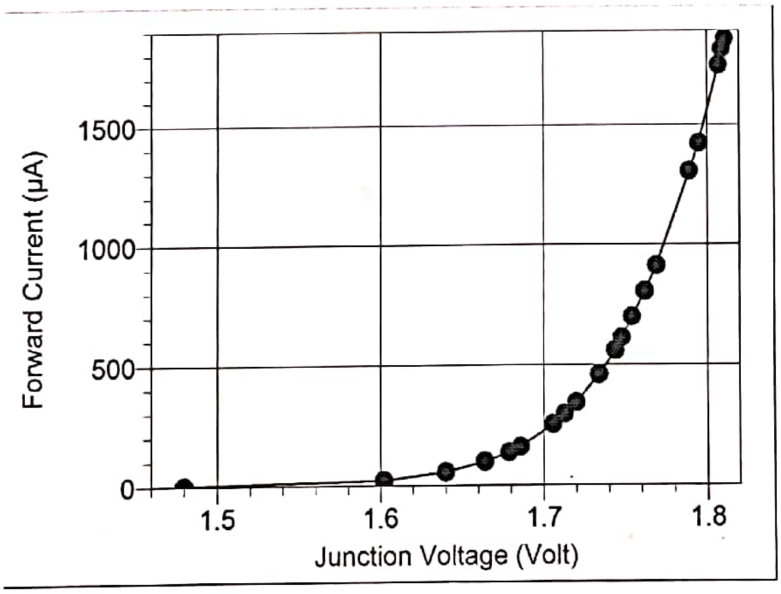


Figure 3

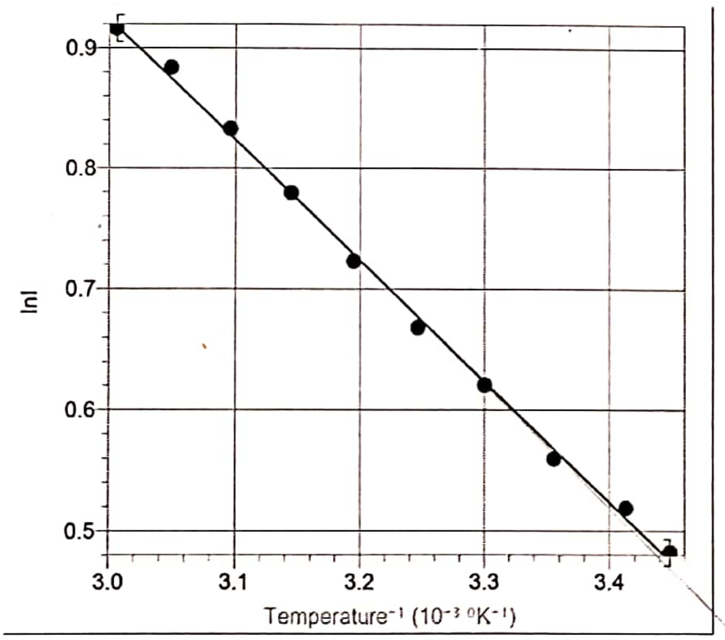
(b) Determination of Temperature Coefficient of Current

Sample: YELLOW LED

Voltage =1.8 V (constant for whole set of readings)

Sr.No.	Temperature (°C)	Temperature (°K)	Current (mA)	1/Tx10^{-3} (K^{-1})	lnI (I in mA)
1	17	290	1.62	3.44	0.482426149244
2	20	293	1.68	3.41	0.518793793415
3	25	298	1.75	3.35	0.559615787935
4	30	303	1.86	3.30	0.620576487725
5	35	308	1.95	3.24	0.667829372576
6	40	313	2.06	3.19	0.722705982801
7	45	318	2.18	3.14	0.779324876801
8	50	323	2.3	3.09	0.832909122935
9	55	328	2.42	3.04	0.883767540169
10	59.7	332.7	2.5	3.00	0.916290731874

Temperature Coefficient of Current



From graph $\frac{\Delta \ln I.}{\Delta T^{-1}}$ = -1.001x10^{3}

Therefore,

$$V_o = V - \left[\frac{\Delta \ln I}{\Delta T_1} \times \frac{K}{e} \times \eta\right]$$

=1.8 - [-1.001x10^{3}x1.381x10^{-23}x1.782 / 1.602x10^{-19}] where η=1.782

=1.954eV

now

$$h = \frac{e \times V_o \times \lambda}{c} = (1.602 \times 10^{-19} \times 1.954 \times 5900 \times 10^{-8}) / (3 \times 10^{10})$$

***h* = 6.148 x10^{-34}Joules.sec**

T-I Characteristics of LED