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PLANCK'S CONSTANT - KSCIPLC

PLANCK'S CONSTANT

1. Key Concepts

- Quantum nature of EM radiation
- Band theory of semiconductors

2. Introduction

Planck's constant is one of the fundamental constants of the universe. While studying the properties of the radiation emitted by a black body using the tools of thermodynamics, Max planck coined the term "energy elements" the to divide the total energy E of the radiations emitted by a black body into finite units of energy " ε" via a process known as "quantization". In his seminal paper published in 1900. Planck regarded the energy "as made up of a completely determinate number of finite equal parts, and for this purpose I use the constant of nature h = 6.55 x 10-27 (erg sec)". Thus, Planck laid out the foundation to Quantum mechanics. One of the tenets of quantum theory is energy quantization. The current measured value of planck's constant in the S.I unit is 6.626 069 57 × 10−34 Js.

3. Objective

To determine Planck's constant, "h" using LED.

4. Theory

Light Emitting Diodes (LEDs) are semiconductor devices that have the ability to emit electromagnetic radiation in the visible spectrum when a potential difference is applied across it. LEDs are composed of a p-n junction. The excited electrons transitioning from the conducting band down to the valence band releases a quanta of energy equal to that of the amount of energy required to create the electron hole pair as a photon of energy

(E = h).

An energy band diagram showing the band structure transitions within the semiconductor material (Image 1).

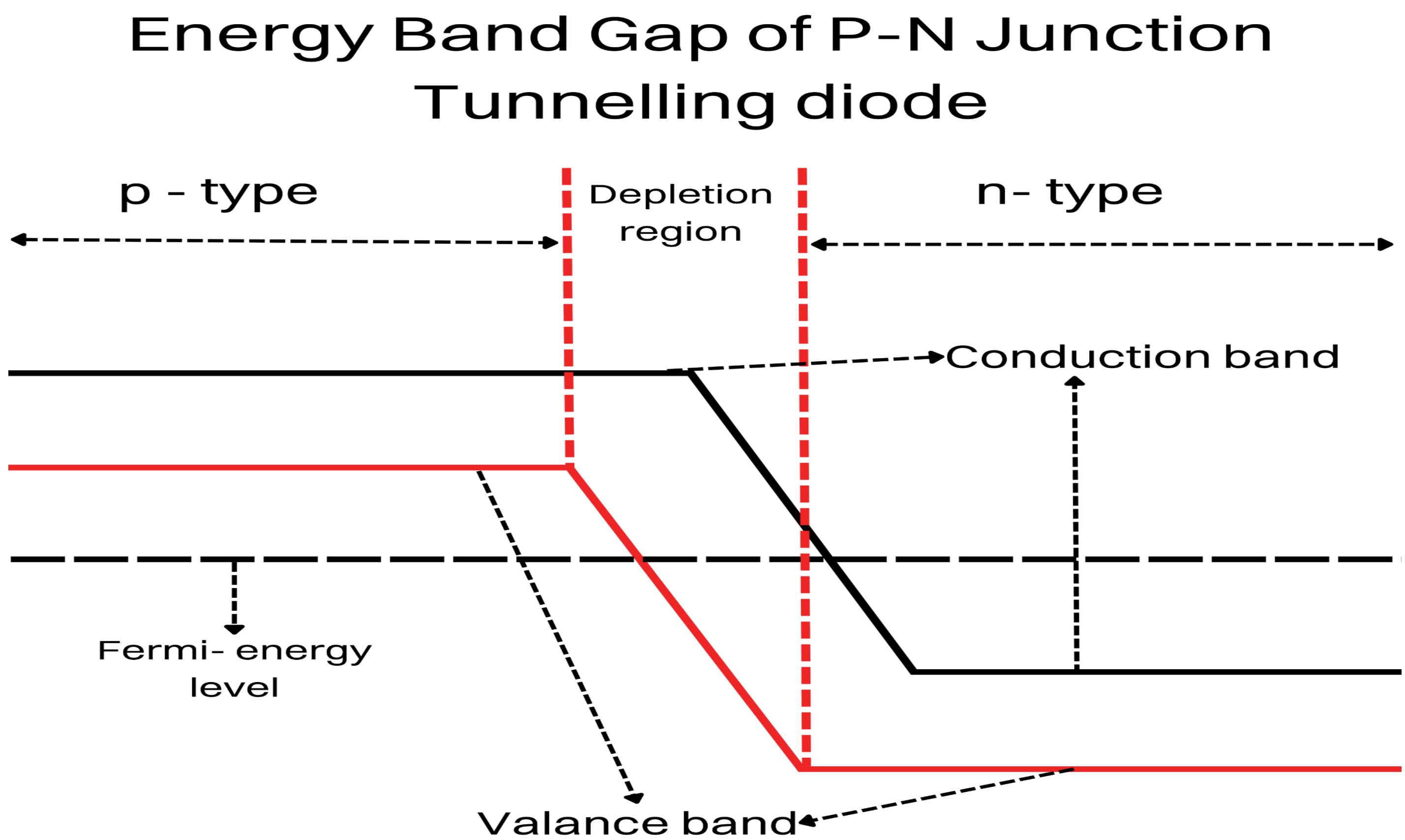


Figure 1: Energy band structure of a PN junction.

The relationship between the wavelength of the emitted photon, the applied potential and discrete quanta of energy *E* is:

$$E = h\nu = \frac{hc}{\lambda} = e\Delta V \qquad (1)$$

Where e = 1.602 × 10^{-19} C is the magnitude of the electron charge and ΔV is the magnitude of the step in applied voltage to the LED.

V-I characteristic for a LED at a constant temperature (room temperature) is obtained and a graph of V vs ln (I) is plotted . Now, keeping the supplied voltage (V) at a fixed value, the
variation in the current through the diode (I) is observed for different temperature (T). A graph of Ln I vs 1/T is plotted and its slope gives

$$\frac{e(V_0 - V))}{\eta k} = \frac{e(\Delta V)}{\eta k}.$$

The constant η is determined by the V-I graph of the LED. From

$$\eta = \left(\frac{e}{KT}\right)\left(\frac{\Delta V}{\Delta ln(I)}\right) \qquad (2)$$

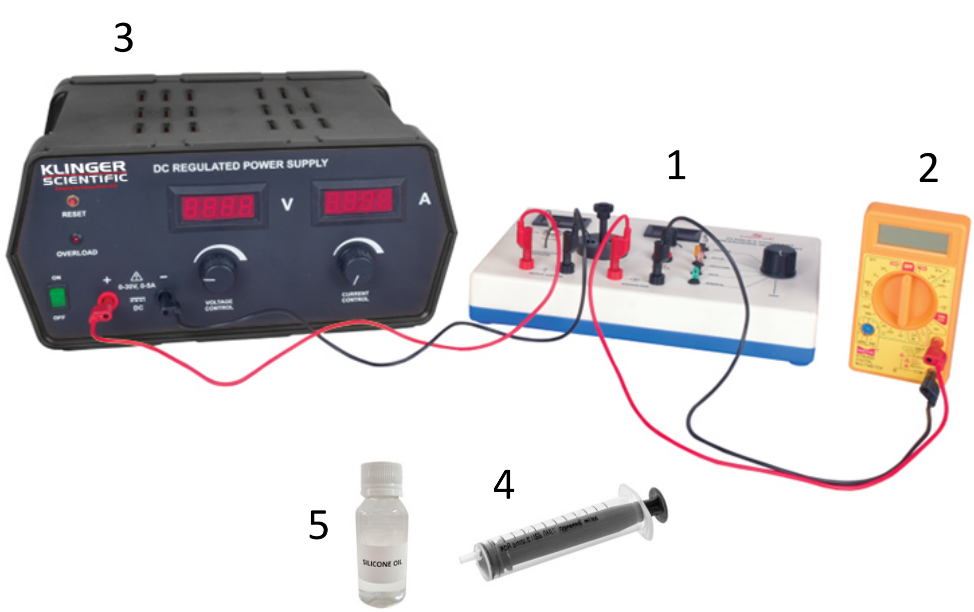
Where, K: Boltzmann constant, e : charge of an electron.

$$V_0 = V - \left[\frac{\Delta ln(I)}{\Delta T^{-1}} \times \frac{K}{e} \times \eta\right] \qquad (3)$$

With the value of V_0 determined. Planck's constant can be determined by equation 4.

$$h = \left(\frac{e \times V_0 \times \lambda}{c}\right) \qquad (4)$$

5. Equipment



*I mages may differ in appearance from the actual product.

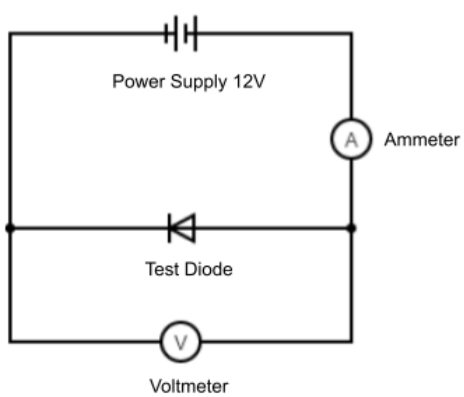
S.No	Equipment	Item Code	Qty
1	Planck Constant Apparatus	KSCIPH94004	1
2	Multimeter	KSCIPH64505	1
3	Power Supply 0-30V, 5 Amp	KSCIPS61035D/5	1
4	Syringe 20ml	KSCIAC012	1
5	Silicone Oil 50ml	AC028	1

6. Safety instructions

- Components like power supply are heavy. Take adequate safety measures while handling them.
- Take precautions while performing experiment as heater will be hot.

7. Experimental Setup

1. Planck constant measuring instrument (PCMI) consist of following
   a) Oil bath with heater
   b) Digital Thermometer with digital display
   c) Rotary knob to select the diodes
   d) A small knob to set voltage across diodes



8.Experiment

8.1 / Part 1: V-I characteristics of LED

•Connect the DC power supply ports to input ports of PCMI. (+ve terminal to +ve terminal and -ve terminal to -ve terminal).

•set 12 V in DC power supply, connect the multimeter (in ammeter) and connect it to the ammeter terminals in PCMI.

•Using the rotary switch, select green LED. And turn on the DC power supply

•Rotate the voltage knob located below the voltage display window in the PMCI.

•Set various voltages across the selected LED and note down the corresponding current values (indicated in the multimeter). record the readings obtained.

•Convert the values of the current to its natural log Ln(I)

•Plot the graph between ln(I) (I in mA) vs V.

•calculate the inverse of the slope obtained from the graph of ln(I) vs V.

•using equation (2) calculate material constant $\boldsymbol{\eta}$ for the LED.

8.2 / Part 2: Current through the LED as function of temperature at a constant bias voltage.

•Fill the oil bath with 15 ml of oil and turn ON the heater.

•Connect the DC power supply ports to input ports of PCMI. (+ve terminal to +ve terminal and -ve terminal to -ve terminal). This is to ensure that the LED is in forward bias mode

•set 12 V in DC power supply, connect the multimeter (in ammeter) and connect it to the ammeter terminals in PCMI.

•Using the rotary switch, select green LED. And turn on the DC power supply.

•Rotate the voltage knob located below the voltage display window in the PMCI until the forward biased led current is 18 mA.

•Switch OFF the heater once the temperature of the oil has reached 90°C.

•Insert the chosen LED into the oil bath.

•observe and record the value of the forward biased LED current (I) for every 5°C drop in temperature.

•convert the temperature to °K.

•convert values of the obtained current (I) to natural logarithm value Ln(I).

•Plot a graph of Ln (I) vs 1/T

•In order to calculate V_o, use the value of slope obtained in equation (3).

•Using the values of the wavelength of light emitted by the LED (see appendix). Calculate Planck’s constant value. Repeat same procedure for other LED's.

9. Measurement & Results

9.1.Determination of emission coefficient η
Test LED: red, yellow, green, blue, amber Temperature (room) T = __K

Voltage Applied , V	Current mA	ln I

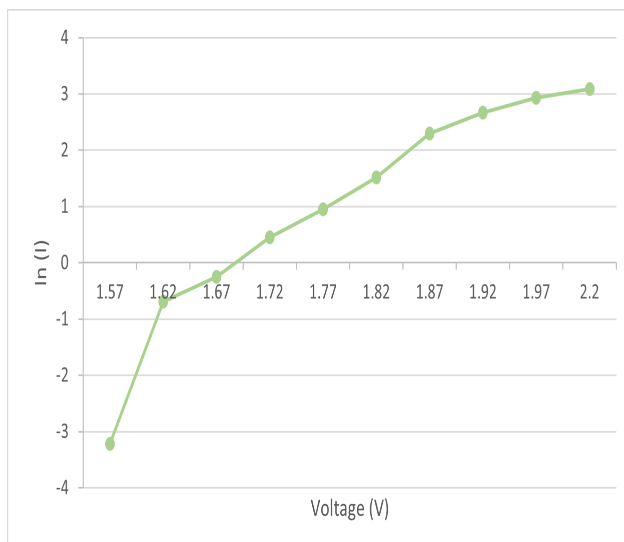
9.2. Dependence of current on temperature at constant bias voltage Test LED: red, yellow, green, blue, amber Voltage V = __ V

TemperatureT, K	Current mA	$\frac{1}{T}$, K^{-1}	ln I

10. Appendix

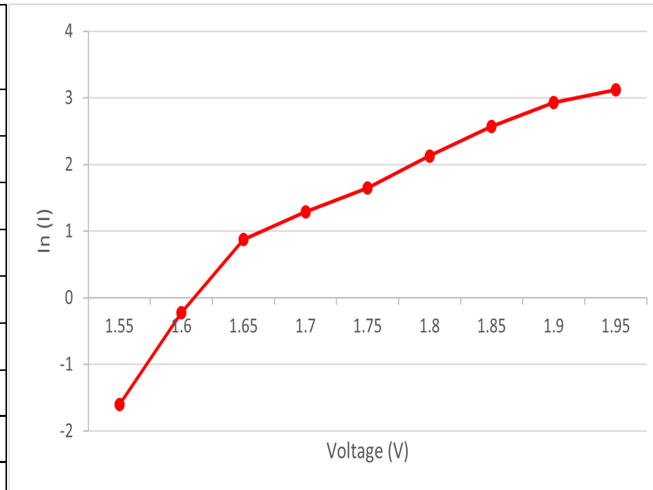
10.1 Determination of emission coefficient η
Test LED: green

Voltage Applied , V	Current mA	ln I
1.57	0.04	-3.218
1.62	0.5	-0.693
1.67	0.78	-0.24
1.72	1.57	0.4510
1.77	2.59	0.95
1.82	4.6	1.52
1.87	10.6	2.3
1.92	14.5	2.67
1.97	18.9	2.93
2.2	22	3.09



10.1 Determination of emission coefficient η
Test LED: red

Voltage Applied , V	Current mA	$\ln I$
1.55	0.2	-1.60
1.60	0.8	-0.223
1.65	2.4	0.875
1.70	3.66	1.29
1.75	5.2	1.648
1.80	8.41	2.129
1.85	13.08	2.571
1.90	18.69	2.927
1.95	22.6	3.117



10.2 Dependence of current on temperature at constant bias voltage
Test LED: green

TemperatureT, K	Current mA	$\frac{1}{T}$, K^{-1}	$\ln I$
373	18,4	0,002680965147	1,264817823
368	18,28	0,002717391304	1,261976191
363	18,01	0,002754820937	1,255513713
358	17,69	0,002793296089	1,247727833
353	17,3	0,00283286119	1,238297068
348	16,89	0,002873563218	1,22762965
343	16,54	0,002915451895	1,218535505
338	16,15	0,002958579882	1,208172527
333	15,74	0,003003003003	1,197004728
328	15,3	0,003048780488	1,184691431