EE 236: Experiment 1
Diode I-V Characterization and Bandgap of Semiconductors

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August 20, 2022

1 Overview

1.1 Aim

To study the I-V characteristics of diodes and estimate the band gap of semiconductors and measure and contrast their values for PN junction diode, Schottky diode, Zener diode and various Light emitting diodes

1.2 Approach

IV plots of various diodes were simulated on NGSPICE. The diodes were also physically connected on a breadboard, and the current corresponding to varying voltage was recorded and tabulated. The plots were compared, and the values of required parameters cut-in Voltage V_γ and ideality factor η were estimated from these data points. A plot was made to see the dependence of V_γ on E_g.

2 Design

The circuit realised on the breadboard is given here.
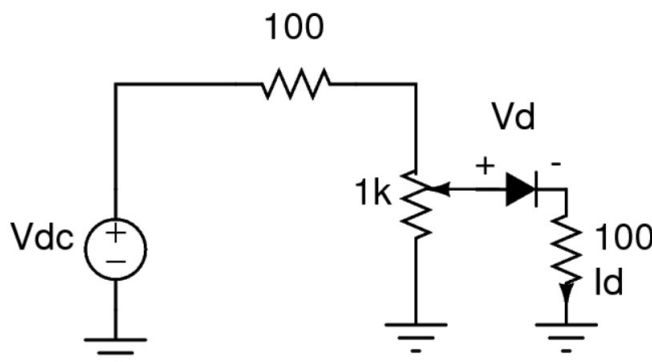
2.1 NGSPICE Code

```
*IV Characteristics

*Rohan Rajesh Kalbag 20D170033
.include yellow_5mm.txt
.include red_5mm.txt
.include green_5mm.txt
.include blue_5mm.txt
.include white_5mm.txt
.include Diode_1N914.txt

vs 1 0 dc 0

vyellow 21 31 dc 0
da 1 21 YELLOW
ra 31 0 100

vred 22 32 dc 0
db 1 22 RED
rb 32 0 100

vgreen 23 33 dc 0
dc 1 23 GREEN
rc 33 0 100

vblue 24 34 dc 0
dd 1 24 BLUE
rd 34 0 100

vwhite 25 35 dc 0
de 1 25 WHITE
re 35 0 100

v1n914 26 36 dc 0
df 1 26 1N914
rf 36 0 100

.dc vs 0.001 5 0.01
.control

run
plot i(vyellow) vs v(1) - v(21) i(vred) vs v(1) - v(22) i(vgreen) vs v(1)
    ↪ - v(23) i(vblue) vs v(1) - v(24) i(vwhite) vs v(1) - v(25) i(
    ↪ v1n914) vs v(1) - v(26)
plot ln(i(vyellow)) vs v(1) - v(21) ln(i(vred)) vs v(1) - v(22) ln(i(
    ↪ vgreen)) vs v(1) - v(23) ln(i(vblue)) vs v(1) - v(24) ln(i(vwhite
    ↪ )) vs v(1) - v(25) ln(i(v1n914)) vs v(1) - v(26)
.endc
.end
```
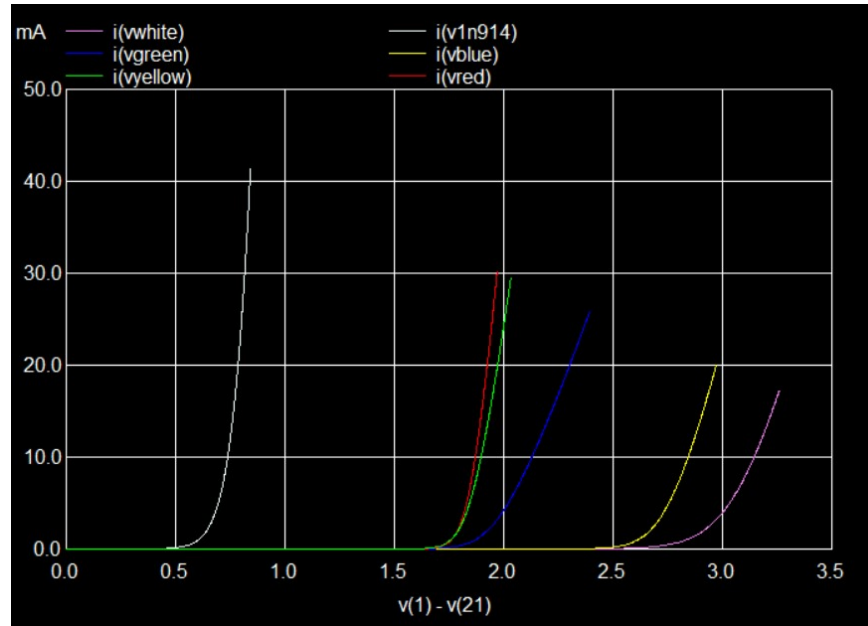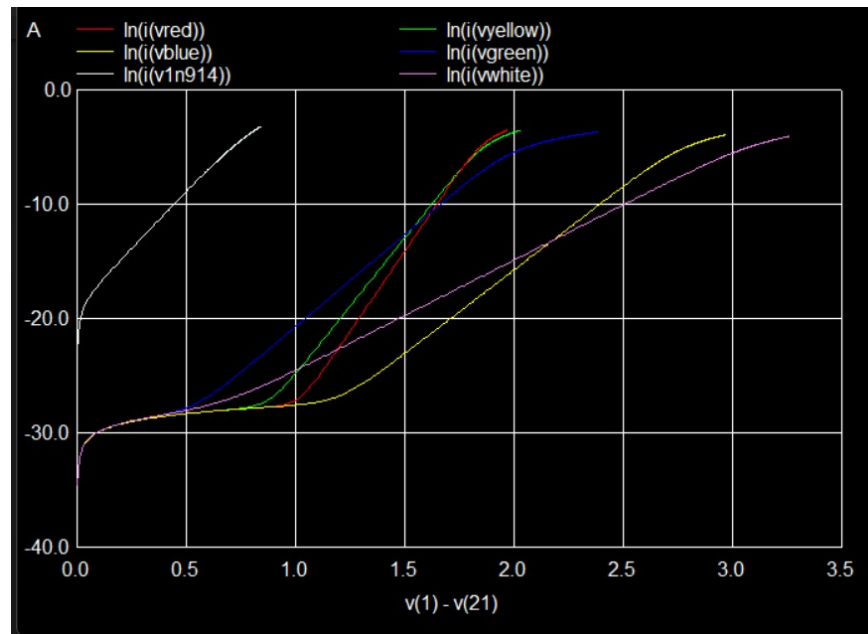
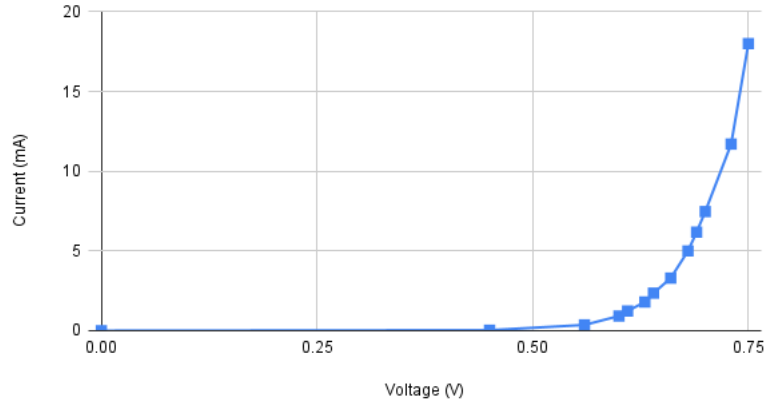## 2.2 Simulation Results

Simulated IV Characteristics

Simulated log(I) vs V Characteristics

3   Experimental Observations
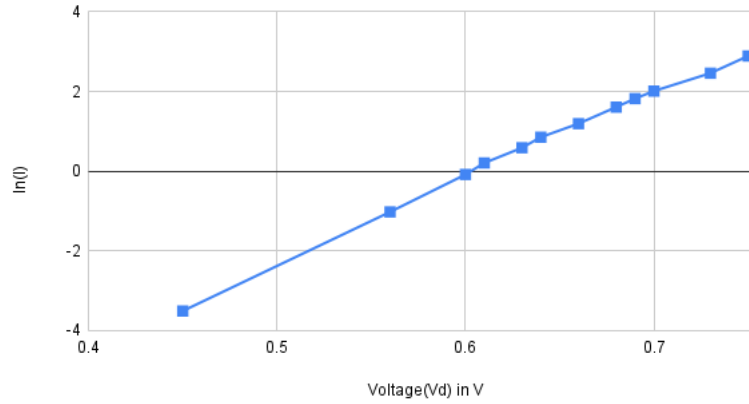
3.0.1   1N914 PN Junction Diode

IV Characteristic for 1N914

Obtained IV Characteristics

ln(I) vs Vd for 1N914

Obtained log(I) vs V Characteristics

E_g for 1N914 $= \frac{hc}{\lambda} = 1.1$eV
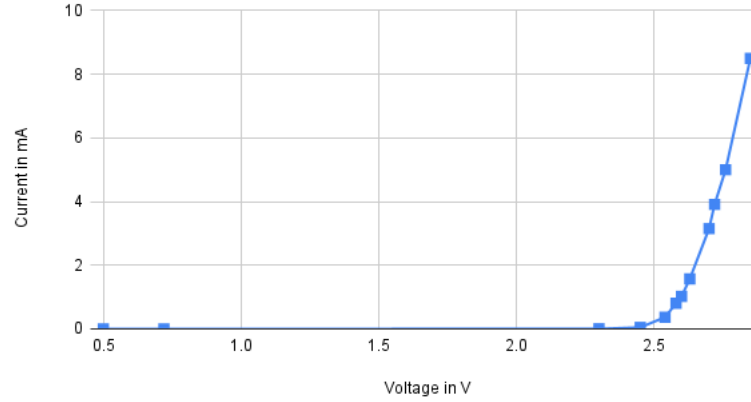From the plots we have V_γ (for $I_D = 5$mA) $= 0.68$V
The value of slope (m) for log plot was estimated as 21.3
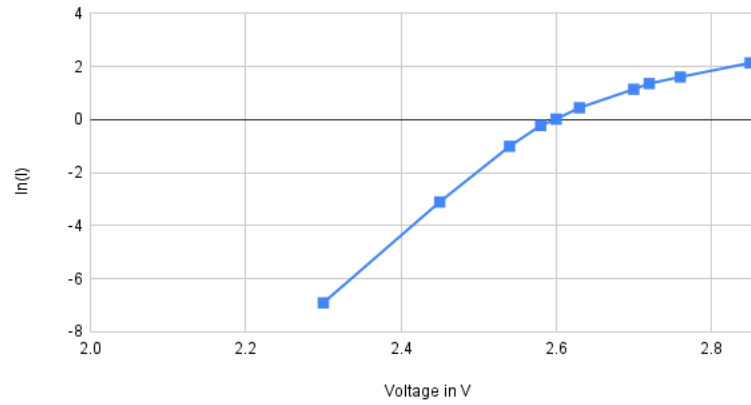Thus, value of $\eta = \frac{1}{mV_T} = 1.805$

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3.0.2 Blue LED

IV characteristics for Blue LED

Obtained IV Characteristics

ln(I) vs Vd for Blue LED

Obtained log(I) vs V Characteristics
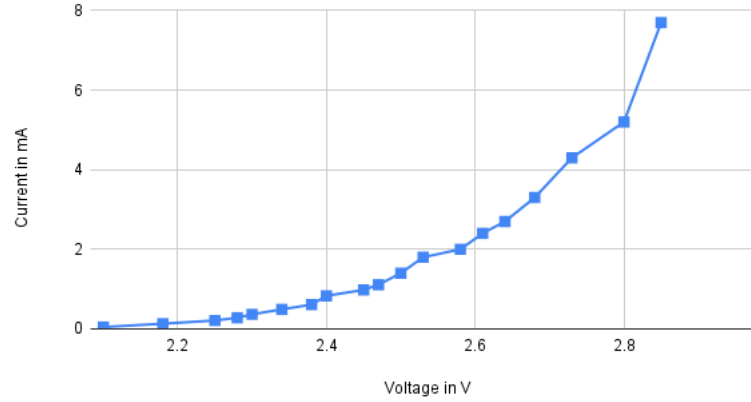
E_g for Blue LED $= \frac{hc}{\lambda} = 2.69$eV
From the plots we have V_γ (for $I_D = 5$mA) $= 2.76$V
The value of slope (m) for log plot was estimated as 14.37
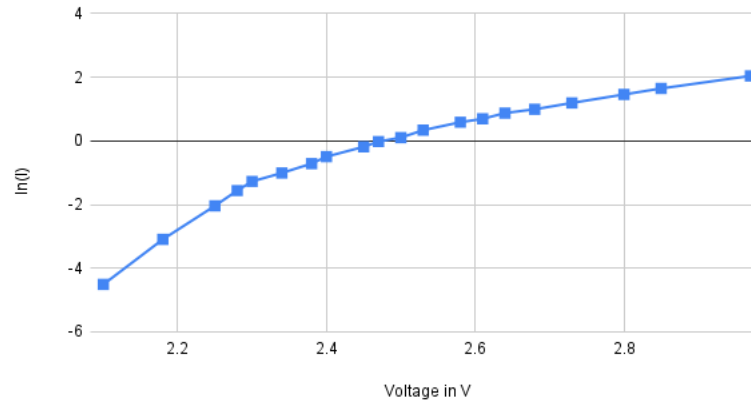Thus, value of $\eta = \frac{1}{mV_T} = 2.675$

3.0.3   Green LED

IV characteristics for Green LED

Obtained IV Characteristics

ln(I) vs Vd for Green LED

Obtained log(I) vs V Characteristics

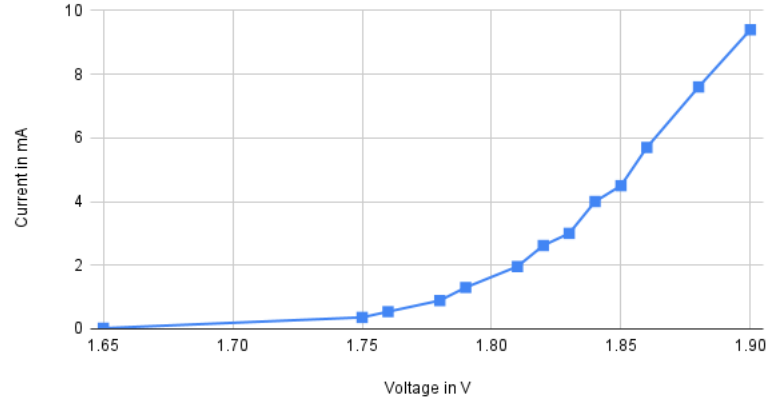E_g for Green LED $= \frac{hc}{\lambda} = 2.39\text{eV}$
From the plots we have V_γ (for $I_D = 5\text{mA}) = 2.82\text{V}$
The value of slope (m) for log plot was estimated as 6.74
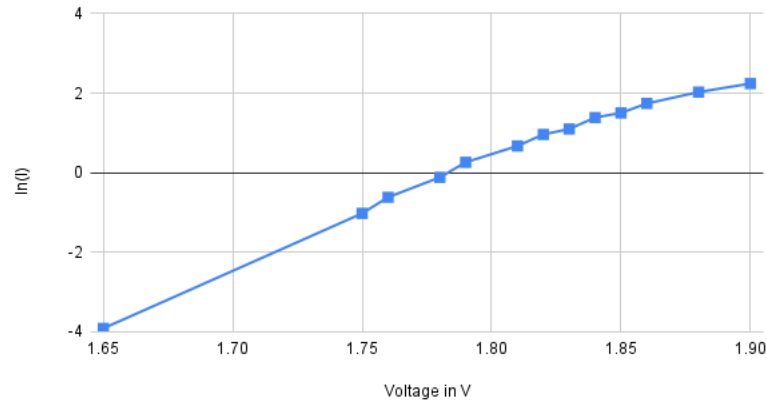Thus, value of $\eta = \frac{1}{mV_T} = 5.706$

3.0.4 Red LED

IV characteristics for Red LED

Obtained IV Characteristics

ln(I) vs V for Red LED

Obtained log(I) vs V Characteristics
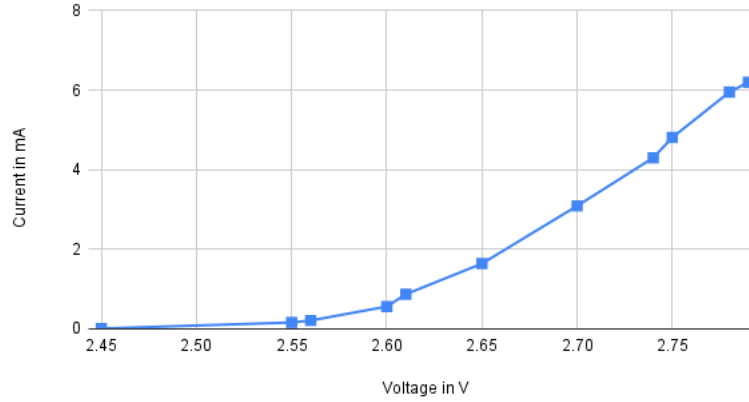
E_g for Red LED $= \frac{hc}{\lambda} = 1.984$eV
From the plots we have V_γ (for $I_D = 5$mA) $= 1.855$V
The value of slope (m) for log plot was estimated as 25
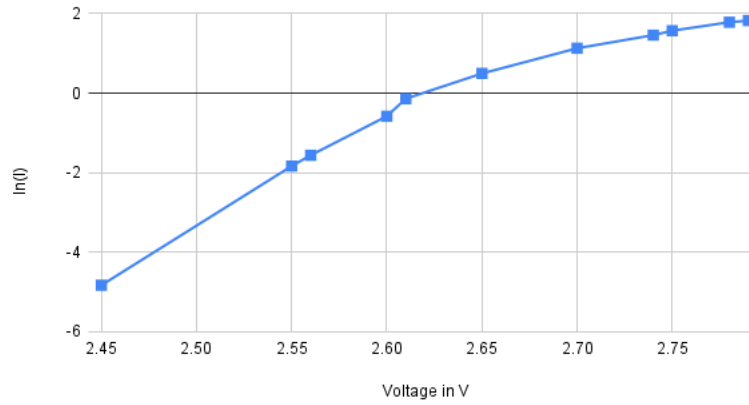Thus, value of $\eta = \frac{1}{mV_T} = 1.538$

3.0.5 White LED

IV characteristics for White LED

Obtained IV Characteristics

ln(I) vs Vd for White LED

Obtained log(I) vs V Characteristics

E_g for White LED $= \frac{hc}{\lambda} = 2.74$eV
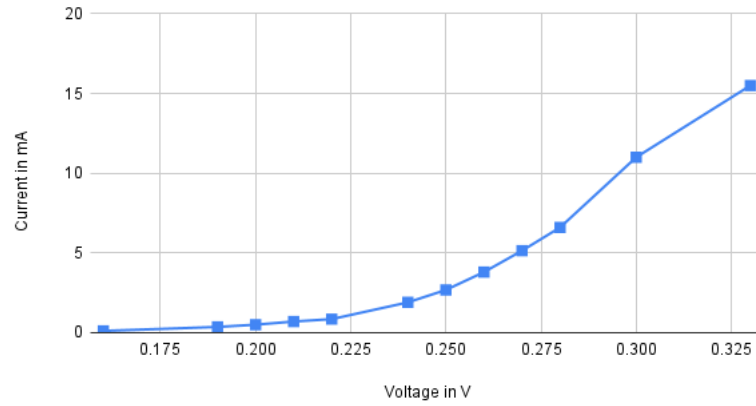From the plots we have V_γ (for $I_D = 5$mA) $= 2.76$V
The value of slope (m) for log plot was estimated as 18.1
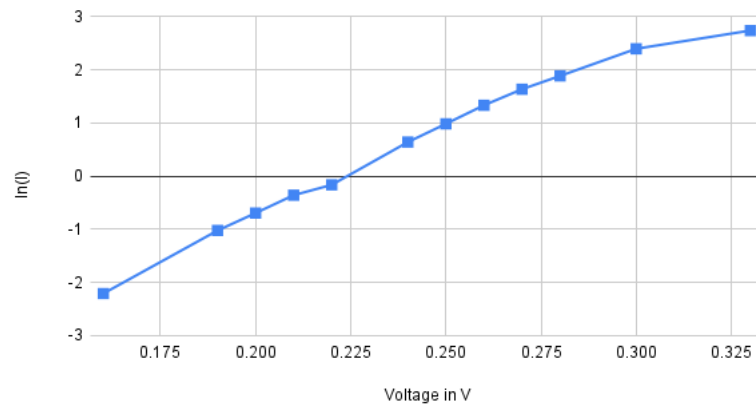Thus, value of $\eta = \frac{1}{mV_T} = 2.124$

3.0.6 Schottky Diode

IV characteristics for Schottky

Obtained IV Characteristics

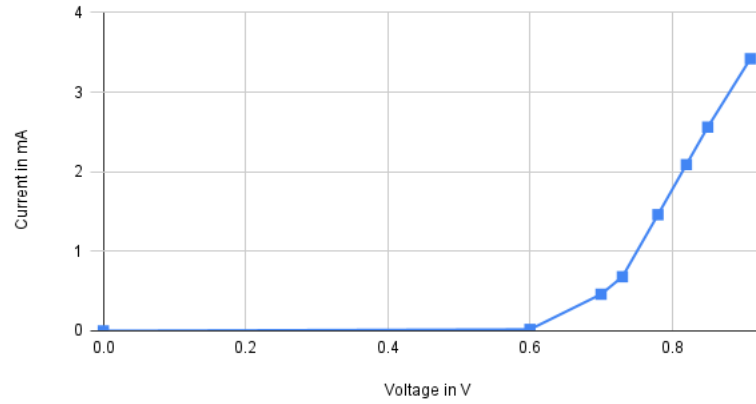**ln(I) vs Vd for Schottky Diode**

Obtained log(I) vs V Characteristics

From the plots we have V_γ (for $I_D = 5\text{mA}$) $= 0.265\text{V}$
The value of slope (m) for log plot was estimated as 30.4
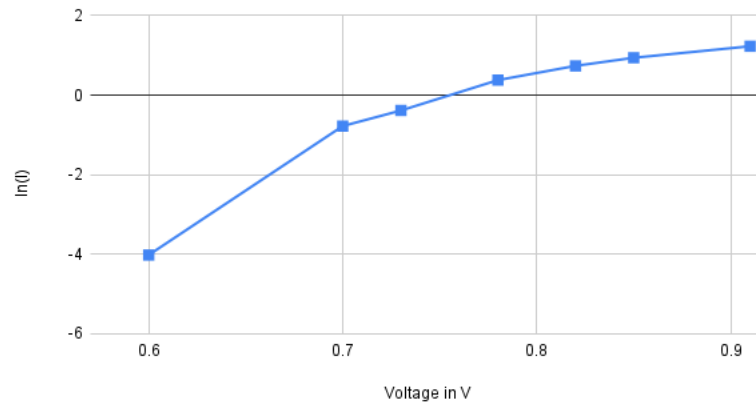Thus, value of $\eta = \frac{1}{mV_T} = 1.265$

3.0.7 Zener Diode

IV forward bias characteristic for Zener Diode

Obtained IV Characteristics
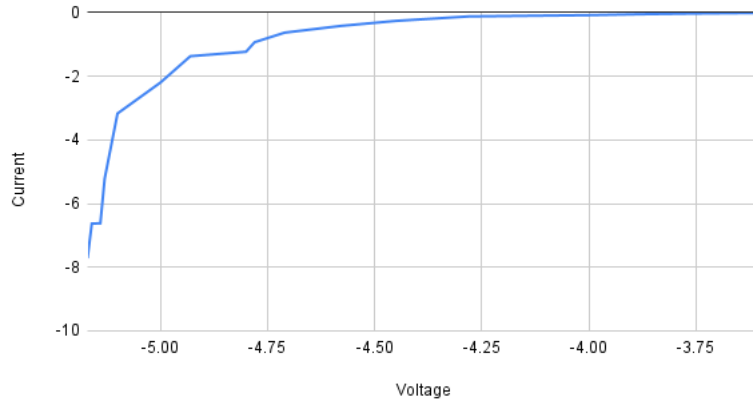
ln(I) vs V forward bias for Zener Diode

Obtained log(I) vs V Characteristics

The value of slope (m) for log plot was estimated as 16.3
Thus, value of $\eta = \frac{1}{mV_T} = 2.359$
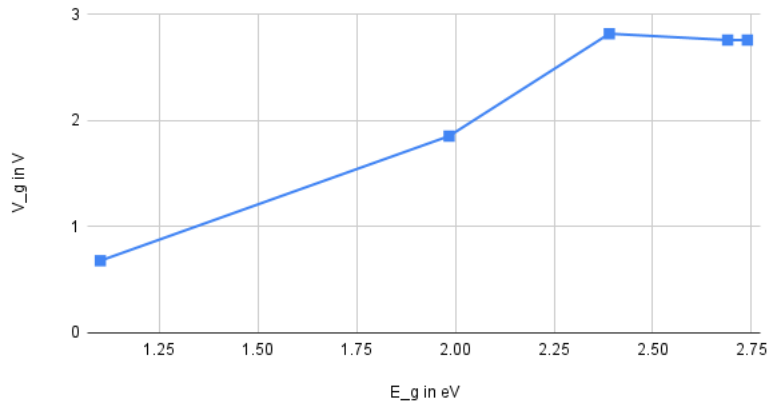
3.0.8 Reverse Biased Zener Diode

Reverse Biased IV Characteristics for Zener Diode

Obtained IV Characteristics

3.0.9 Variation of V_γ with E_g

5mA Cut In Voltage vs Band Gap Energy for Diodes

Thus we see a nearly linear dependence of V_γ on E_g, theoretically, we expect complete linear behaviour, but deviations are seen here, which may have crept in due to experimental error

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3.1 Comparison for Cut-In Voltages

Diode	Calculated	Experimental
1N914	0.68	0.694
Blue LED	2.76	2.761
Green LED	2.82	2.02
Red LED	1.855	1.832
White LED	2.76	3.022

Table for Comparison of 5mA Cut-In Voltage

We notice that 1N914, Blue and Red LED have nearly same calculated and experimental values but it seems to be deviating by a margin for Green and White LEDs.

4 Experiment Completion Status

The experiment was completed in the lab hours and the values and plots obtained for the various diodes, the simulation outputs were shown to the TA and were verified. The `.xlsx` containing all the readings and plots after verification from the TA were uploaded on Moodle during the lab hours