# EXPERIMENT-4,5

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## Problem 1:

### Aim:

To study the forward and reverse bias characteristics of an IN4007 diode and to understand how to pick the value of series resistance for forward and reverse bias.

### Material Required:

Breadboard, Resistor(100Ω,1kΩ,10kΩ), multimeter(potentiometer and ammeter) and DC power supply.

### Procedure:

Forward bias:

- Connect the IN4007 diode in series with a resistor to the power supply.
- Connect the voltmeter in parallel with the diode and the ammeter in series with the circuit.
- Set the power supply to a low voltage (0.1V) and gradually increase the voltage.
- Record the voltage across the diode ($V_{diode}$), the voltage across the resistor ($V_{res}$), and the current through the circuit ($I_{total}$) for each voltage setting.
- Continue until the voltage across the diode is approximately 0.7V.
- Plot the forward bias I-V curve using the recorded data.

Reverse bias:

- Reverse the polarity of the power supply connections to the diode.

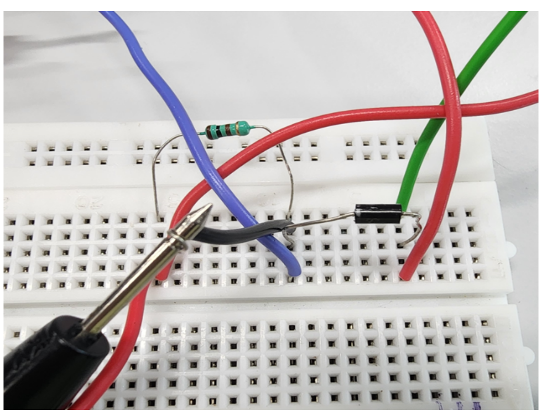
- Set the power supply to a low voltage (0.1V) and gradually increase the voltage.
- Record the voltage across the diode ($V_{diode}$), the voltage across the resistor ($V_{res}$), and the current through the circuit ($I_{total}$) for each voltage setting.
- Plot the reverse bias I-V curve using the recorded data.

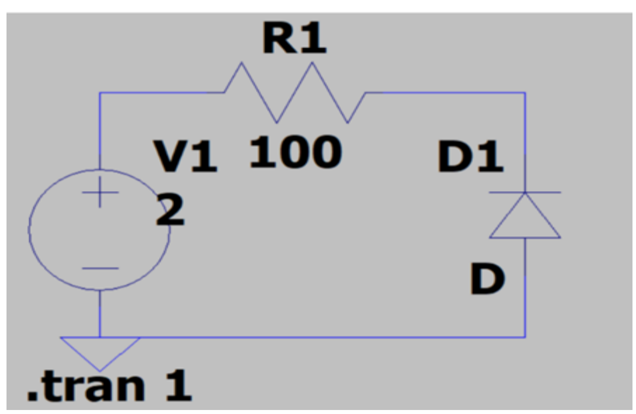
## Observations:

- We noticed that the current through the diode went up exponentially as the voltage went up in the forward biased configuration.
- When we changed the series resistor, we saw that the diode needed a certain voltage drop to start conducting, which was around 0.6-0.7 volts.
- When connected in reverse biased, diode exhibited very low current until a certain reverse breakdown voltage was reached.
- The value of the series resistor is chosen to limit the forward current to a certain value.
- The value of the series resistor should also be chosen such that it allows a sufficient forward and reverse voltage to be applied to the diode.
- we can see that using a higher-value resistor limits the forward current more.
- Also, using a lower-value resistor will allow a higher reverse voltage to be applied to the diode.

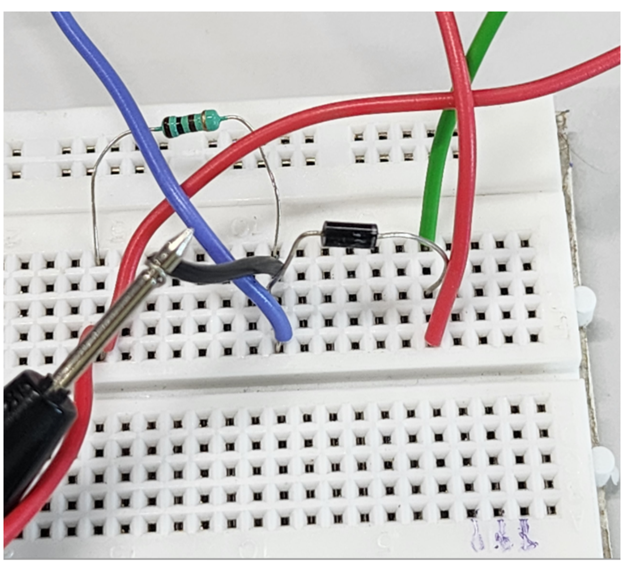
1) **For 100 Ω:**

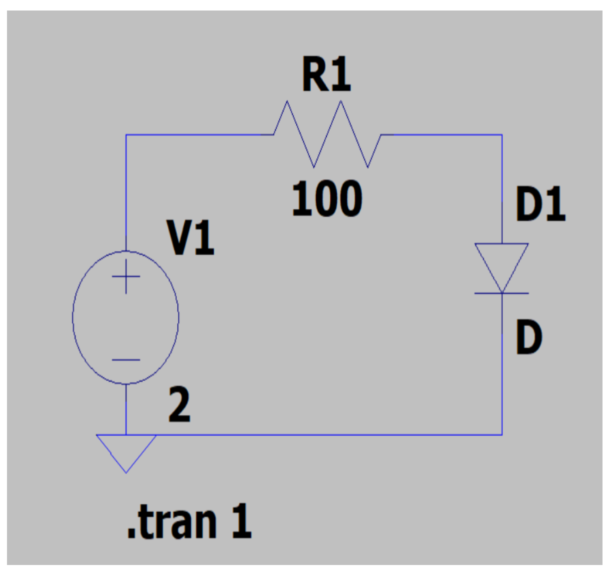
Forward bias:

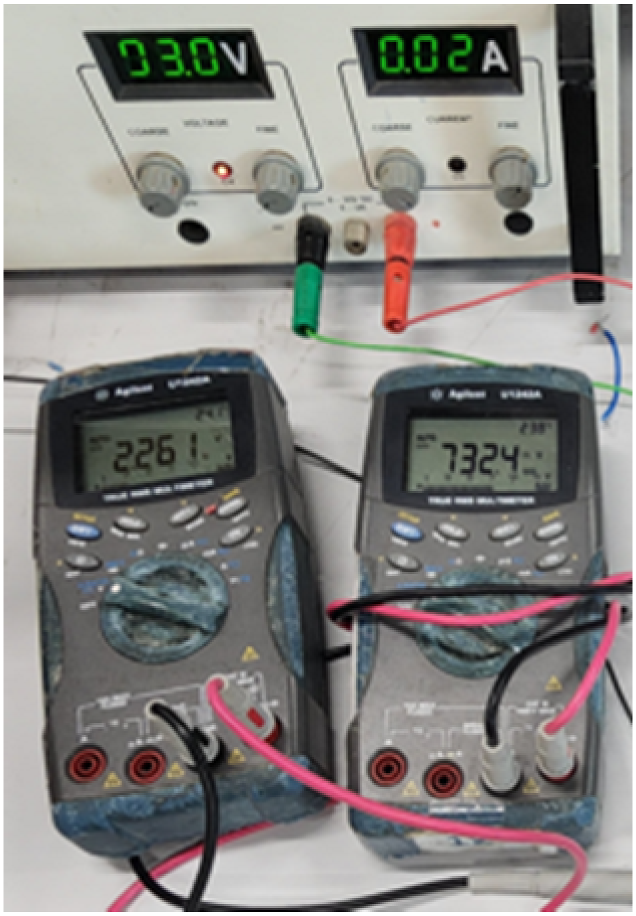





Reverse bias:








For forward bias:

| Vres | Vtot | Vdiode | Ic |
| --- | --- | --- | --- |
| 5.00E-04 | 8.25E-02 | 8.20E-02 | 5.00E-06 |
| 4.00E-04 | 1.95E-01 | 1.95E-01 | 4.00E-06 |
| 6.00E-04 | 3.17E-01 | 3.17E-01 | 6.00E-06 |
| 2.50E-03 | 4.11E-01 | 4.08E-01 | 2.50E-05 |
| 1.45E-02 | 5.05E-01 | 4.90E-01 | 1.45E-04 |
| 5.64E-02 | 6.13E-01 | 5.57E-01 | 5.64E-04 |

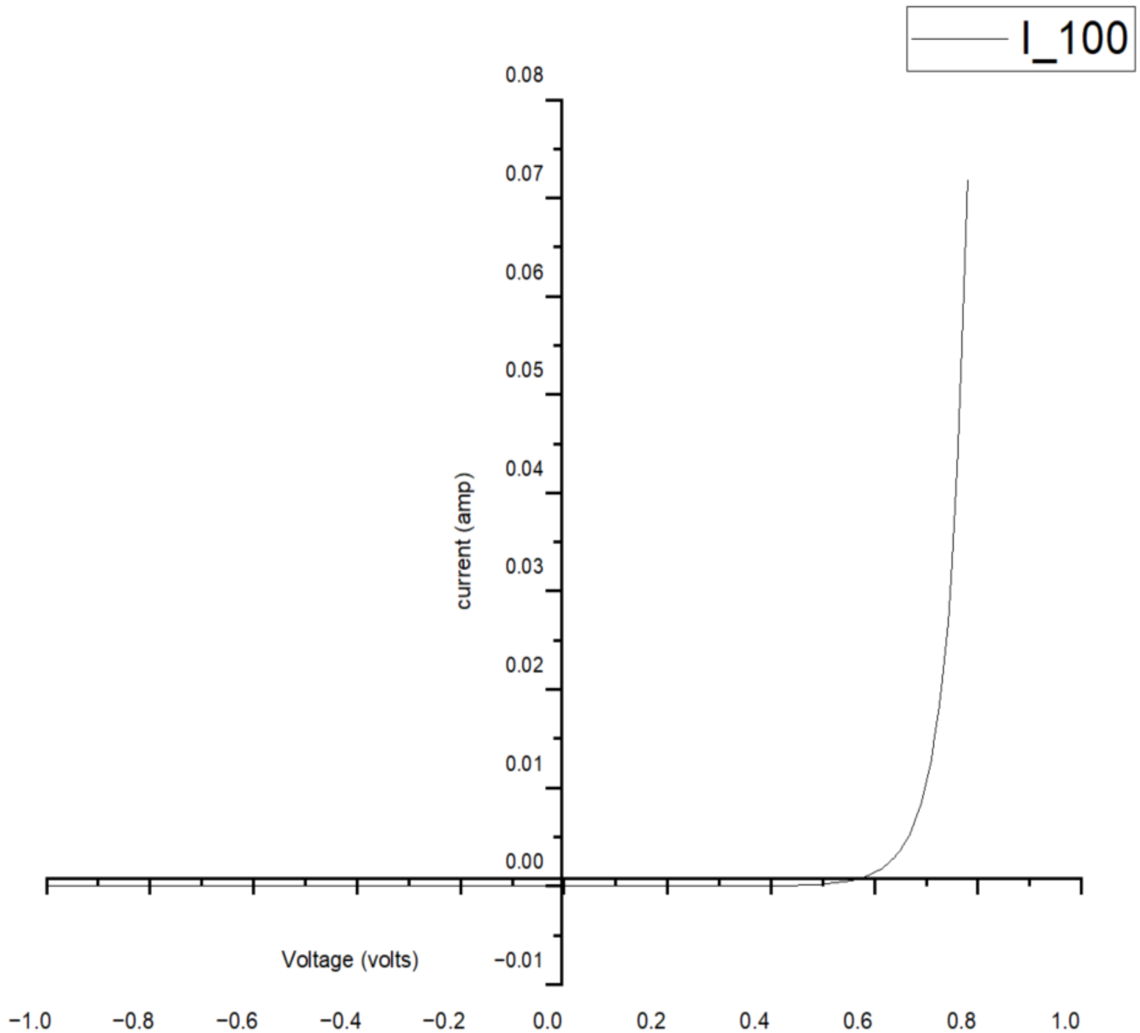
| | | | |
|---|---|---|---|
| 8.29E-02 | 6.59E-01 | 5.77E-01 | 8.29E-04 |
| 1.80E-01 | 7.95E-01 | 6.15E-01 | 1.80E-03 |
| 2.88E-01 | 9.26E-01 | 6.38E-01 | 2.88E-03 |
| 3.66E-01 | 1.02E+00 | 6.50E-01 | 3.66E-03 |
| 5.24E-01 | 1.19E+00 | 6.68E-01 | 5.24E-03 |
| 8.33E-01 | 1.52E+00 | 6.90E-01 | 8.33E-03 |
| 1.28E+00 | 1.99E+00 | 7.10E-01 | 1.28E-02 |
| 1.48E+00 | 2.20E+00 | 7.15E-01 | 1.48E-02 |
| 1.79E+00 | 2.51E+00 | 7.24E-01 | 1.79E-02 |
| 2.05 | 2.78E+00 | 7.30E-01 | 0.0205 |
| 2.3 | 3.03E+00 | 7.35E-01 | 0.023 |
| 2.7 | 3.44E+00 | 7.43E-01 | 0.027 |
| 3.23 | 3.98E+00 | 7.49E-01 | 0.0323 |
| 4.3 | 5.06E+00 | 7.60E-01 | 0.043 |
| 5.35 | 6.12E+00 | 7.68E-01 | 0.0535 |
| 7.19 | 7.97E+00 | 7.80E-01 | 0.0719 |

For reverse bias:

| Vres | Vtot | Vdiode | Ic |
|---|---|---|---|
| -4.00E-04 | -1.14E-01 | -1.14E-01 | -4.00E-06 |
| -2.00E-04 | -2.14E-01 | -2.14E-01 | -2.00E-06 |

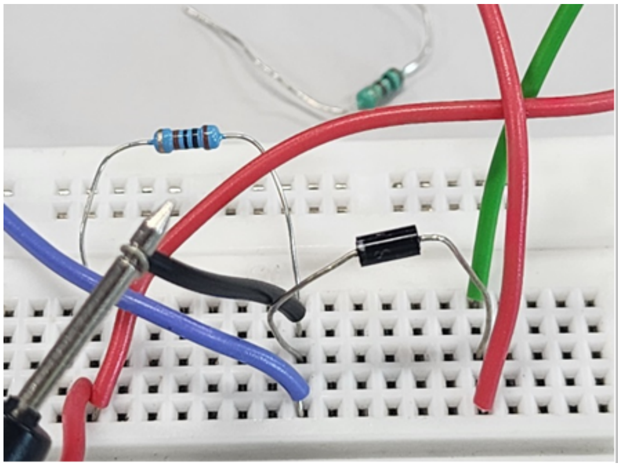
| | | | |
|---|---|---|---|
| -4.00E-04 | -3.16E-01 | -3.16E-01 | -4.00E-06 |
| -4.00E-04 | -3.97E-01 | -3.97E-01 | -4.00E-06 |
| -3.00E-04 | -4.92E-01 | -4.92E-01 | -3.00E-06 |
| -4.00E-04 | -5.99E-01 | -5.99E-01 | -4.00E-06 |
| -4.00E-04 | -6.74E-01 | -6.74E-01 | -4.00E-06 |
| -4.00E-04 | -8.17E-01 | -8.17E-01 | -4.00E-06 |
| -3.00E-04 | -8.99E-01 | -8.99E-01 | -3.00E-06 |
| -4.00E-04 | -1.01E+00 | -1.0089 | -4.00E-06 |
| -4.00E-04 | -1.17E+00 | -1.17 | -4.00E-06 |
| -4.00E-04 | -1.50E+00 | -1.5 | -4.00E-06 |
| -4.00E-04 | -1.67E+00 | -1.67E+00 | -4.00E-06 |
| -4.00E-04 | -2.05E+00 | -2.05E+00 | -4.00E-06 |
| -4.00E-04 | -2.16E+00 | -2.163 | -4.00E-06 |
| -4.00E-04 | -2.54E+00 | -2.54 | -4.00E-06 |
| -3.00E-04 | -2.65E+00 | -2.65 | -3.00E-06 |
| -3.00E-04 | -3.07E+00 | -3.07 | -3.00E-06 |
| -3.00E-04 | -4.03E+00 | -4.03E+00 | -3.00E-06 |
| -4.00E-04 | -5.05E+00 | -5.05E+00 | -4.00E-06 |
| -4.00E-04 | -5.98E+00 | -5.98 | -4.00E-06 |
| -4.00E-04 | -7.93E+00 | -7.93 | -4.00E-06 |

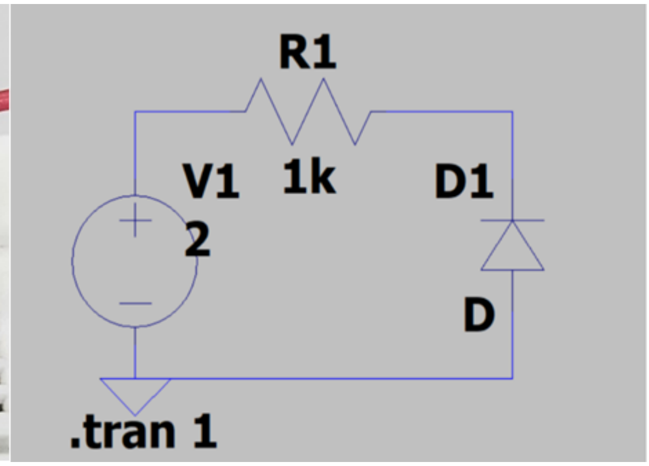
The I-V characteristics of the diode with 100Ω:

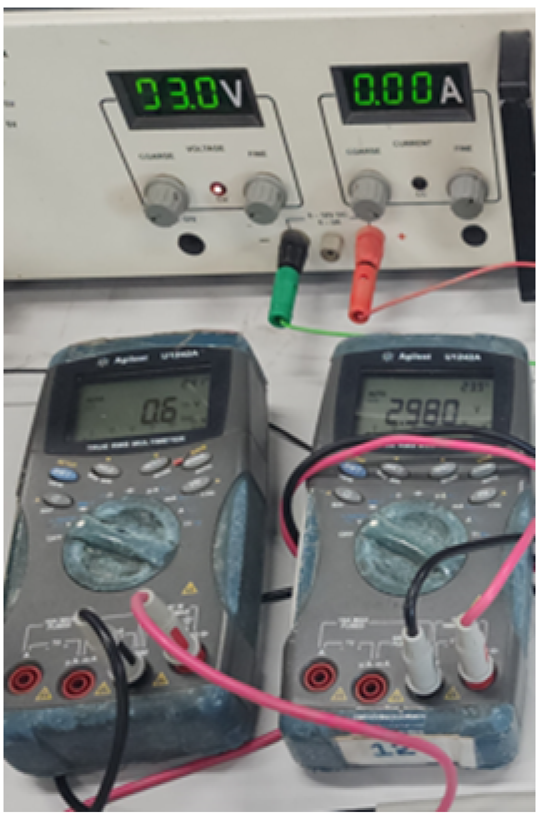


**2) For 1000 Ω:**

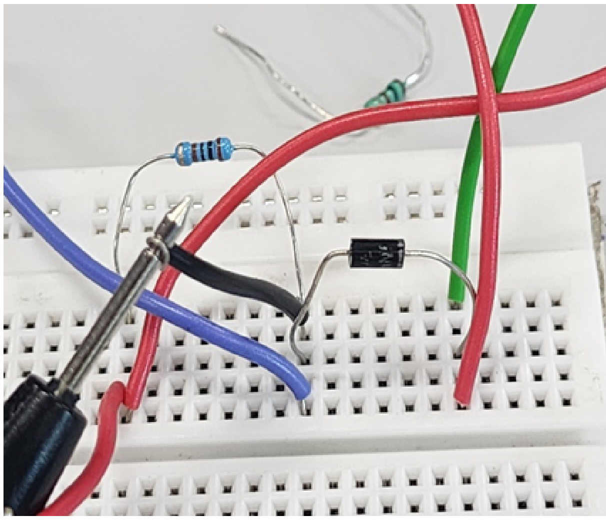
Forward bias:

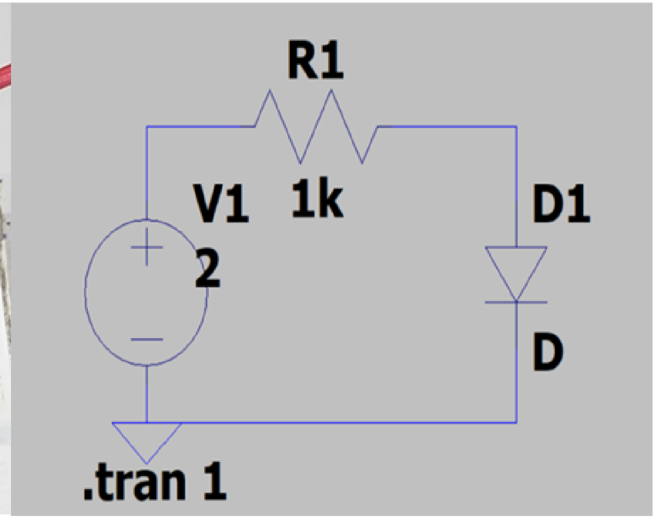


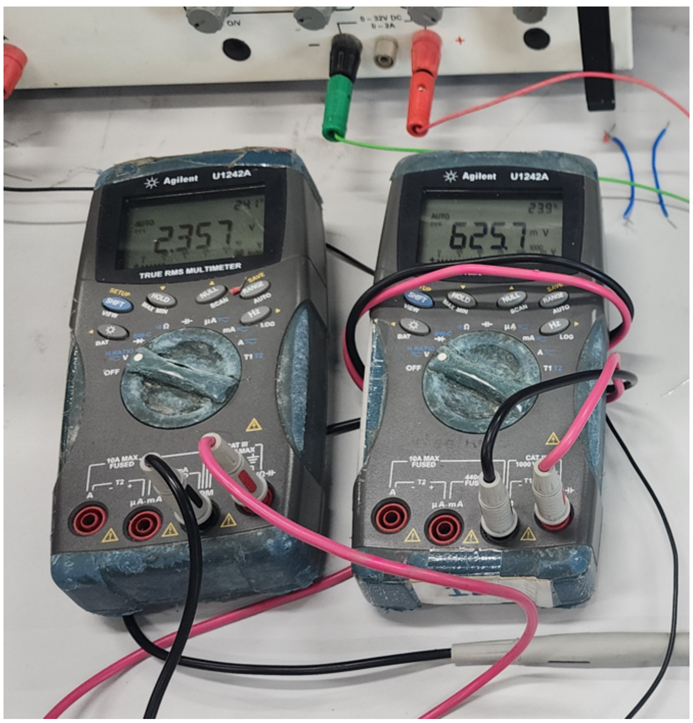



Reverse bias:






For forward bias:

| V_res | V_tot | V_diode | I_c |
|---|---|---|---|

| | | | |
|---|---|---|---|
| 4.00E-04 | 1.04E-01 | 1.04E-01 | 4.00E-07 |
| 4.00E-04 | 1.89E-01 | 1.89E-01 | 4.00E-07 |
| 3.20E-03 | 3.30E-01 | 3.27E-01 | 3.20E-06 |
| 1.06E-02 | 3.89E-01 | 3.78E-01 | 1.06E-05 |
| 3.60E-02 | 4.64E-01 | 4.28E-01 | 3.60E-05 |
| 1.04E-01 | 5.78E-01 | 4.74E-01 | 1.04E-04 |
| 1.86E-01 | 6.93E-01 | 5.07E-01 | 1.86E-04 |
| 2.62E-01 | 7.80E-01 | 5.19E-01 | 2.62E-04 |
| 3.68E-01 | 9.03E-01 | 5.35E-01 | 3.68E-04 |
| 4.52E-01 | 9.97E-01 | 5.45E-01 | 4.52E-04 |
| 6.35E-01 | 1.20E+00 | 5.62E-01 | 6.35E-04 |
| 9.59E-01 | 1.54E+00 | 5.83E-01 | 9.59E-04 |
| 1.158 | 1.75E+00 | 5.92E-01 | 0.001158 |
| 1.36 | 1.96E+00 | 6.01E-01 | 0.00136 |
| 1.63 | 2.24E+00 | 6.10E-01 | 0.00163 |
| 1.88 | 2.50E+00 | 6.17E-01 | 0.00188 |
| 2.11 | 2.73E+00 | 6.22E-01 | 0.00211 |
| 2.4 | 3.03E+00 | 6.29E-01 | 0.0024 |
| 2.85 | 3.49E+00 | 6.38E-01 | 0.00285 |
| 3.36 | 4.01E+00 | 6.46E-01 | 0.00336 |
| 4.32 | 4.98E+00 | 6.57E-01 | 0.00432 |

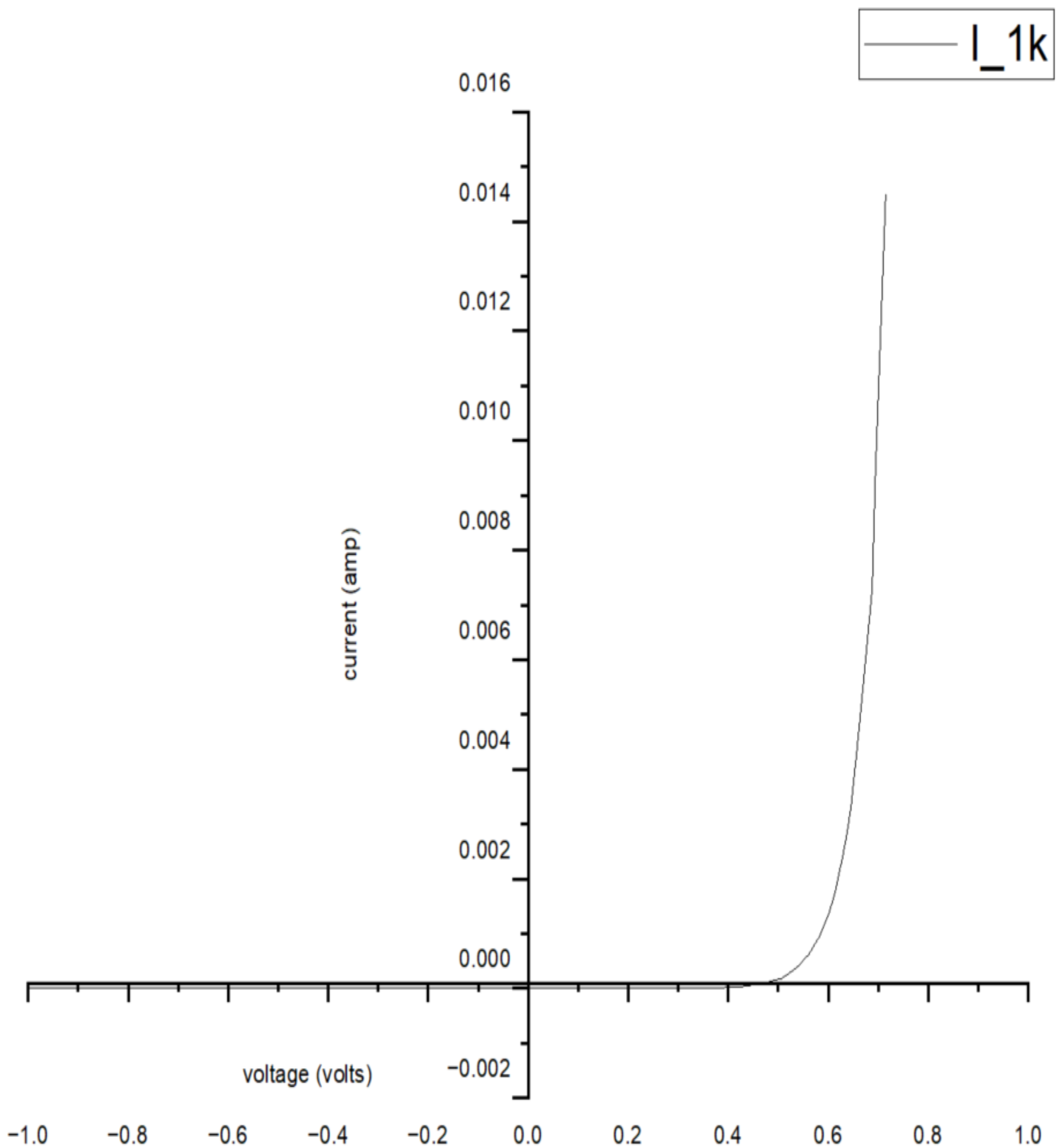
| | | | |
|---|---|---|---|
| 5.35 | 6.02E+00 | 6.68E-01 | 0.00535 |
| 7.29 | 7.98E+00 | 6.88E-01 | 0.00729 |
| 9.3 | 9.99E+00 | 6.94E-01 | 0.0093 |
| 14.5 | 1.52E+01 | 7.15E-01 | 0.0145 |

For reverse bias:

| V_res | V_tot | V_diode | I_c |
|---|---|---|---|
| -4.00E-04 | -1.42E-01 | -1.42E-01 | -4.00E-07 |
| -4.00E-04 | -1.87E-01 | -1.87E-01 | -4.00E-07 |
| -4.00E-04 | -2.63E-01 | -2.63E-01 | -4.00E-07 |
| -4.00E-04 | -4.17E-01 | -4.17E-01 | -4.00E-07 |
| -5.00E-04 | -5.05E-01 | -5.04E-01 | -5.00E-07 |
| -4.00E-04 | -6.04E-01 | -6.04E-01 | -4.00E-07 |
| -4.00E-04 | -6.59E-01 | -6.59E-01 | -4.00E-07 |
| -4.00E-04 | -8.30E-01 | -8.30E-01 | -4.00E-07 |
| -5.00E-04 | -9.08E-01 | -9.07E-01 | -5.00E-07 |
| -4.00E-04 | -1.02E+00 | -1.02 | -4.00E-07 |
| -5.00E-04 | -1.19E+00 | -1.19 | -5.00E-07 |
| -5.00E-04 | -1.53E+00 | -1.53 | -5.00E-07 |
| -5.00E-04 | -1.64E+00 | -1.64 | -5.00E-07 |

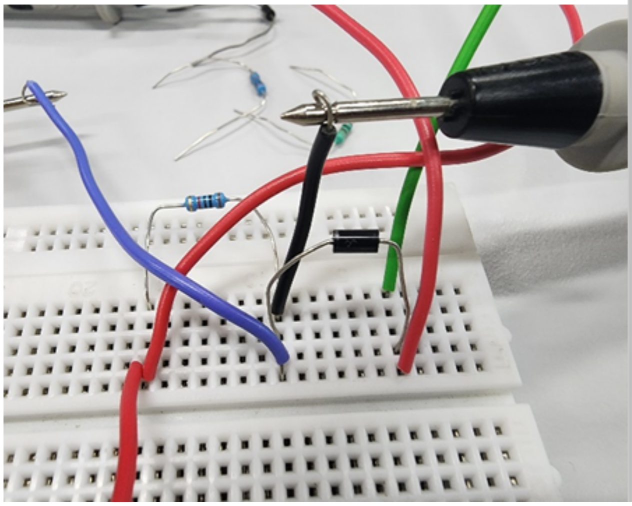
| | | | |
|---|---|---|---|
| -6.00E-04 | -1.98E+00 | -1.98 | -6.00E-07 |
| -6.00E-04 | -2.20E+00 | -2.202 | -6.00E-07 |
| -5.00E-04 | -2.48E+00 | -2.48 | -5.00E-07 |
| -4.00E-04 | -2.74E+00 | -2.74 | -4.00E-07 |
| -4.00E-04 | -3.03E+00 | -3.03 | -4.00E-07 |
| -6.00E-04 | -3.50E+00 | -3.5 | -6.00E-07 |
| -7.00E-04 | -3.95E+00 | -3.95 | -7.00E-07 |
| -7.00E-04 | -4.97E+00 | -4.97 | -7.00E-07 |
| -9.00E-04 | -5.98E+00 | -5.98 | -9.00E-07 |
| -1.10E-03 | -8.03E+00 | -8.03 | -1.10E-06 |
| -1.30E-03 | -1.00E+01 | -10 | -1.30E-06 |

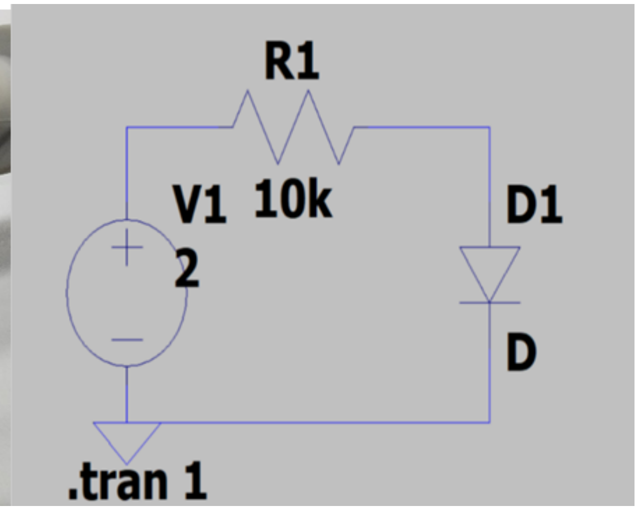
The I-V characteristics of the diode with 1000Ω:

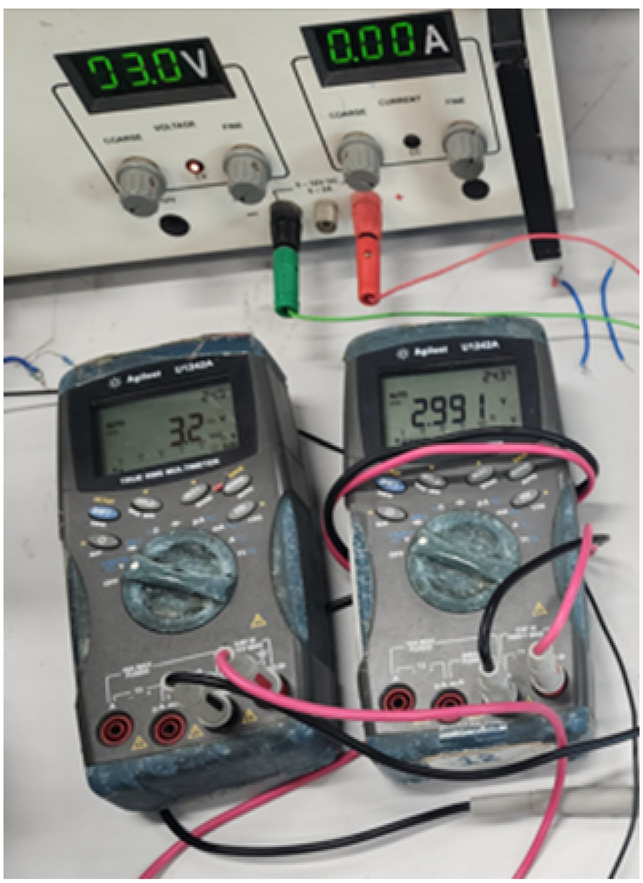


**2) For 10000 Ω:**

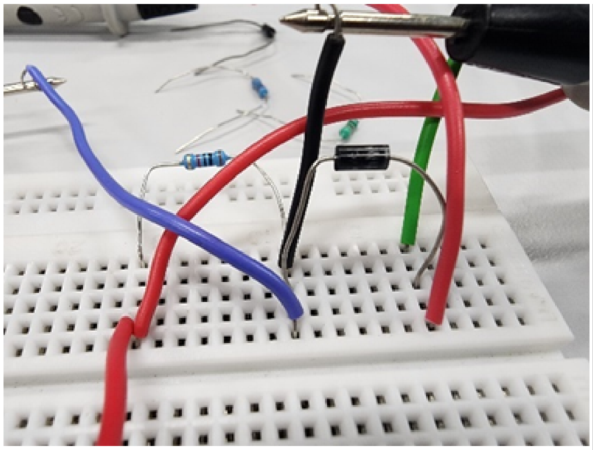
Forward bias:

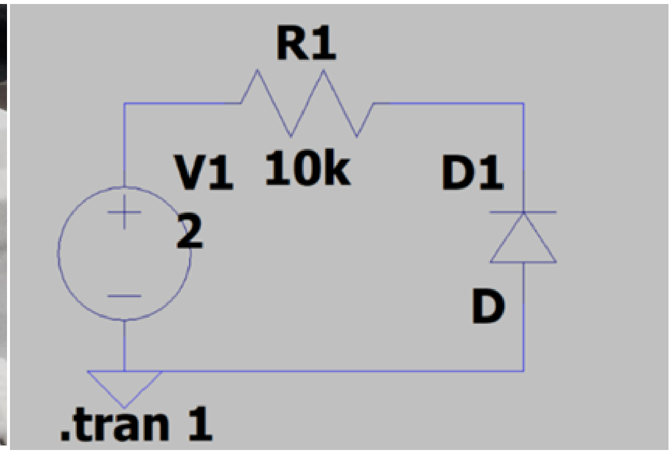


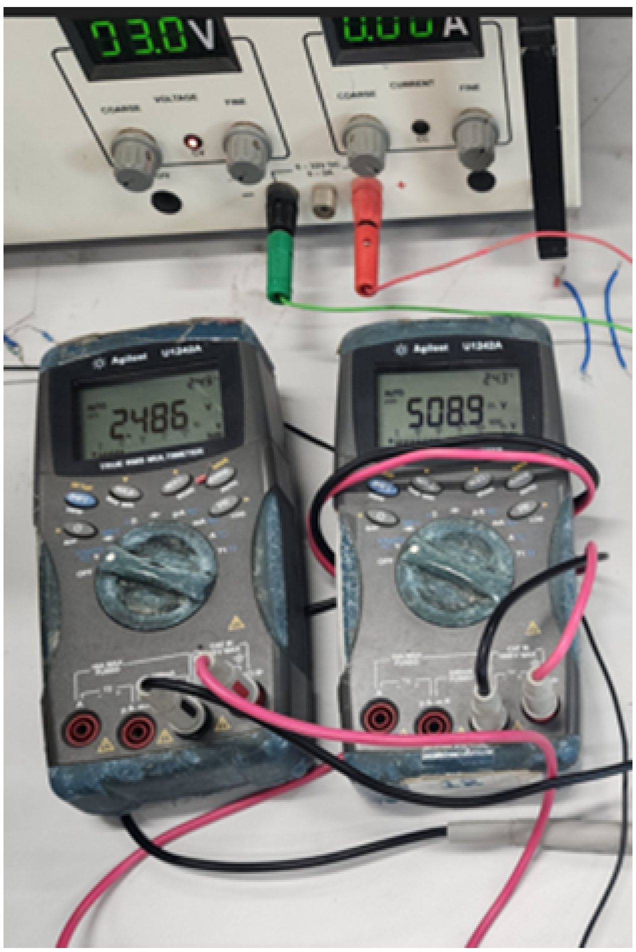


Reverse bias:





For forward bias:

| Vres | Vtot | Vdiode | Ic |
|---|---|---|---|
| 4.00E-04 | 9.57E-02 | 9.53E-02 | 4.00E-08 |
| 1.20E-02 | 2.01E-01 | 1.89E-01 | 1.20E-06 |
| 1.14E-02 | 3.05E-01 | 2.94E-01 | 1.14E-06 |
| 4.02E-02 | 4.02E-01 | 3.62E-01 | 4.02E-06 |
| 1.37E-01 | 5.28E-01 | 3.91E-01 | 1.37E-05 |
| 2.00E-01 | 6.07E-01 | 4.07E-01 | 2.00E-05 |
| 2.62E-01 | 6.92E-01 | 4.30E-01 | 2.62E-05 |
| 3.87E-01 | 8.15E-01 | 4.28E-01 | 3.87E-05 |
| 4.64E-01 | 9.04E-01 | 4.40E-01 | 4.64E-05 |
| 5.74E-01 | 1.02E+00 | 4.49E-01 | 5.74E-05 |
| 7.50E-01 | 1.21E+00 | 4.61E-01 | 7.50E-05 |
| 1.04E+00 | 1.52E+00 | 4.76E-01 | 1.04E-04 |
| 1.21E+00 | 1.69E+00 | 4.83E-01 | 1.21E-04 |
| 1.51 | 2.00E+00 | 4.93E-01 | 0.000151 |
| 1.67 | 2.17E+00 | 4.97E-01 | 0.000167 |
| 1.97 | 2.48E+00 | 5.05E-01 | 0.000197 |
| 2.18 | 2.69E+00 | 5.10E-01 | 0.000218 |
| 2.5 | 3.02E+00 | 5.17E-01 | 0.00025 |

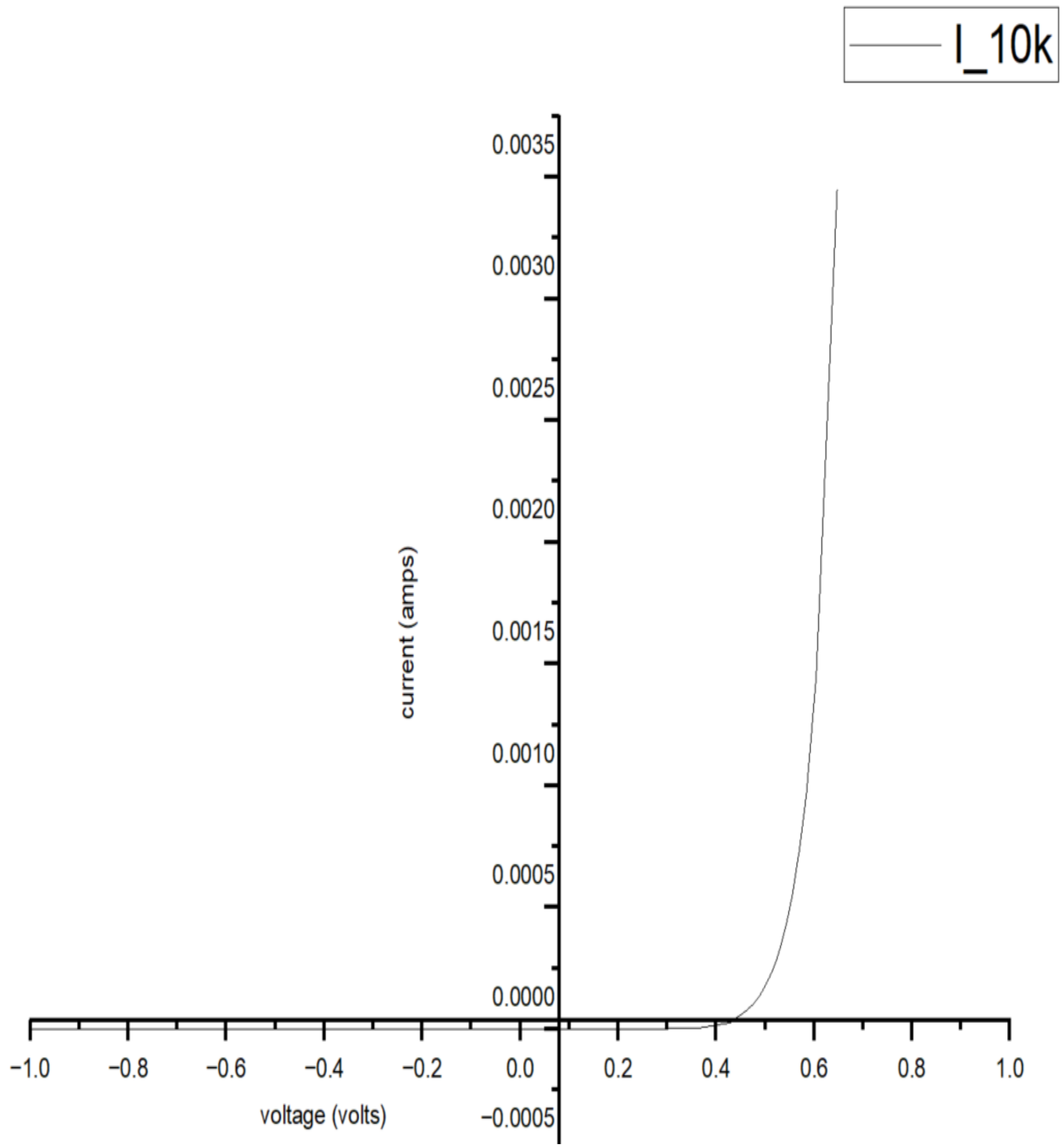
| | | | |
|---|---|---|---|
| 3.02 | 3.55E+00 | 5.26E-01 | 0.000302 |
| 3.5 | 4.03E+00 | 5.33E-01 | 0.00035 |
| 4.46 | 5.01E+00 | 5.45E-01 | 0.000446 |
| 5.54 | 6.10E+00 | 5.56E-01 | 0.000554 |
| 7.38 | 7.95E+00 | 5.70E-01 | 0.000738 |
| 9.63 | 1.02E+01 | 5.84E-01 | 0.000963 |
| 14.48 | 1.51E+01 | 6.04E-01 | 0.001448 |
| 34.49 | 3.51E+01 | 6.47E-01 | 0.003449 |

For reverse bias:

| Vres | Vtot | Vdiode | Ic |
|---|---|---|---|
| -5.00E-04 | -1.18E-01 | -1.17E-01 | -5.00E-08 |
| -5.00E-04 | -2.00E-01 | -1.99E-01 | -5.00E-08 |
| -5.00E-04 | -2.93E-01 | -2.92E-01 | -5.00E-08 |
| -6.00E-04 | -3.67E-01 | -3.66E-01 | -6.00E-08 |
| -6.00E-04 | -4.89E-01 | -4.88E-01 | -6.00E-08 |
| -9.00E-04 | -6.10E-01 | -6.09E-01 | -9.00E-08 |
| -9.00E-04 | -6.85E-01 | -6.84E-01 | -9.00E-08 |
| -1.00E-03 | -8.28E-01 | -8.27E-01 | -1.00E-07 |
| -1.10E-03 | -9.47E-01 | -9.46E-01 | -1.10E-07 |

| | | | |
|---|---|---|---|
| -1.40E-03 | -9.94E-01 | -9.93E-01 | -1.40E-07 |
| -1.40E-03 | -1.19E+00 | -1.19E+00 | -1.40E-07 |
| -1.60E-03 | -1.52E+00 | -1.52 | -1.60E-07 |
| -1.80E-03 | -1.69E+00 | -1.69 | -1.80E-07 |
| -2.30E-03 | -2.01E+00 | -2.006 | -2.30E-07 |
| -2.30E-03 | -2.29E+00 | -2.29 | -2.30E-07 |
| -2.70E-03 | -2.48E+00 | -2.48 | -2.70E-07 |
| -3.00E-03 | -2.72E+00 | -2.72 | -3.00E-07 |
| -3.30E-03 | -2.98E+00 | -2.98 | -3.30E-07 |
| -3.60E-03 | -3.54E+00 | -3.54 | -3.60E-07 |
| -4.20E-03 | -4.03E+00 | -4.03 | -4.20E-07 |
| -5.00E-03 | -5.00E+00 | -4.99 | -5.00E-07 |
| -6.10E-03 | -5.95E+00 | -5.94 | -6.10E-07 |
| -8.00E-03 | -7.98E+00 | -7.97 | -8.00E-07 |
| -9.90E-03 | -9.96E+00 | -9.95 | -9.90E-07 |
| -1.49E-02 | -1.50E+01 | -15.02 | -1.49E-06 |
| -3.48E-02 | -3.51E+01 | -35.05 | -3.48E-06 |

The I-V characteristics of the diode with 10000Ω:



## Problem 2:

### Aim:

To design and simulate a full-wave bridge rectifier and filter circuit to rectify a sinusoidal and triangular wave with $V_{in}$ = 5 V and f = 5kHz.

### Material Required:

Breadboard, Resistor(1MΩ), capacitor(0.18nF and 1nF), 4 x 1N4001 Diodes , multimeter, Oscilloscope and function generator.

### Theory:

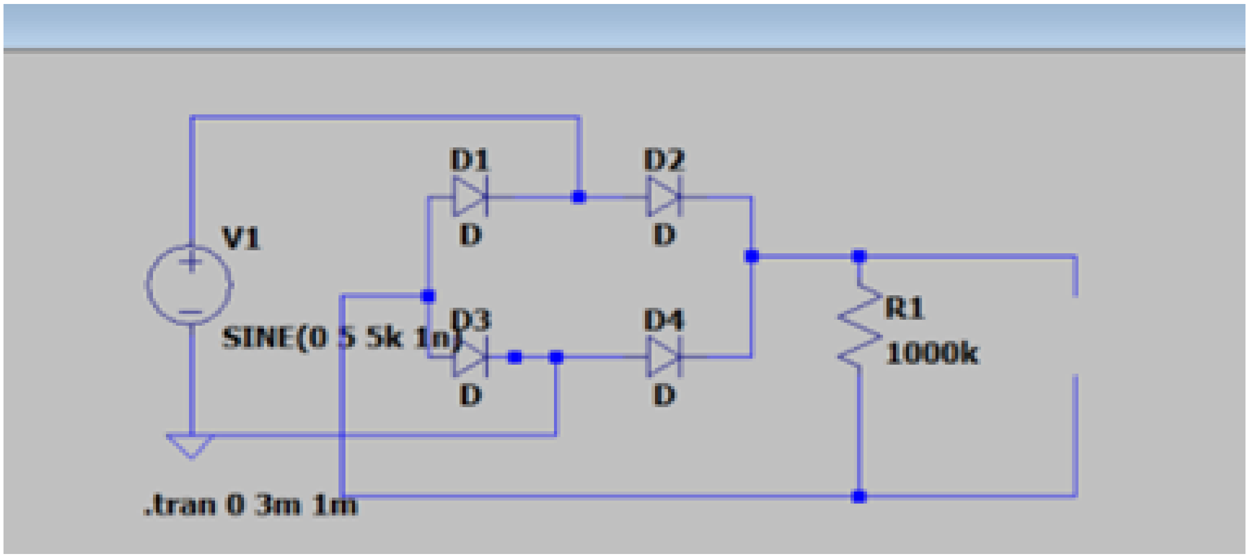
The main objective of this experiment is to convert alternating current (AC) waveforms into direct current (DC) waveforms. We will achieve this by utilizing the unique properties of diodes. Specifically, we will construct a full wave bridge rectifier circuit, which comprises four diodes arranged in a closed-loop bridge configuration.

The full-wave bridge rectifier circuit converts the AC input voltage to a DC output voltage. The filter circuit removes the ripple from the DC output voltage

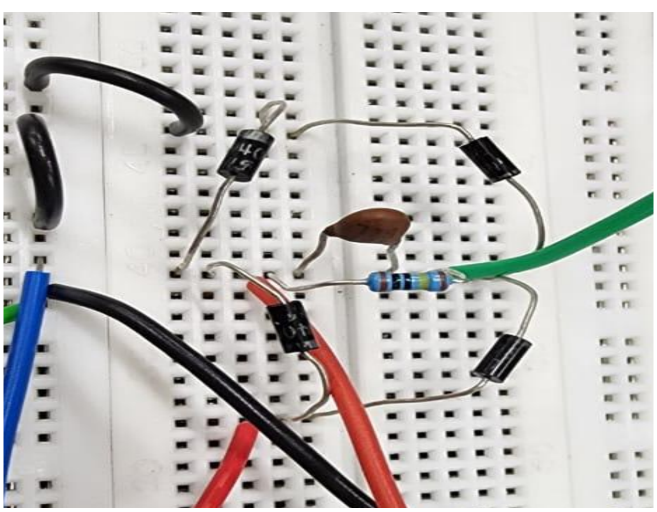
The output voltage waveform of the circuit for a sinusoidal input voltage is a pulsating DC voltage. The output voltage waveform of the circuit for a triangular input voltage is a sawtooth voltage.

The ripple factor of the output voltage waveform is determined by the value of the capacitor in the filter circuit. A larger capacitor value will reduce the ripple factor.Also, a larger resistor deduces the ripple factor.

## Procedure:



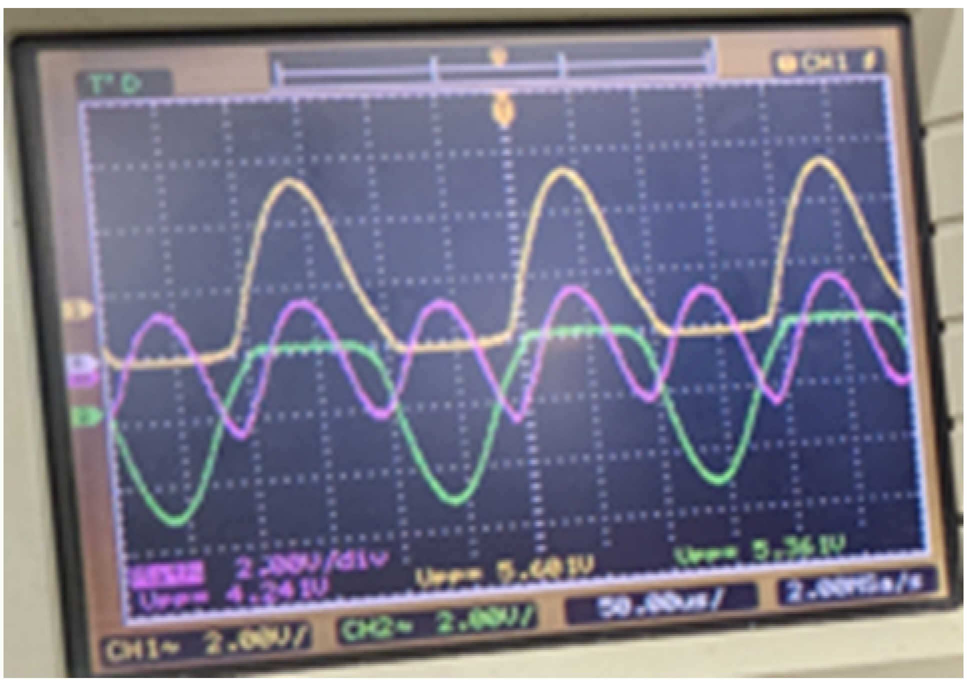

- Assemble the circuit on the breadboard and connect the input voltage source to the circuit according to the above schematic diagram.
- Connect the oscilloscope to the circuit output (we must take half the required output from one node and the other from a different node).
- Using the Math function of the oscilloscope, we have to subtract the two outputs to reconstruct the input signal.
- Adjust the input voltage source to 5 V.
- Adjust the frequency of the input voltage source to 5 kHz.
- Observe the output voltage waveform on the oscilloscope.

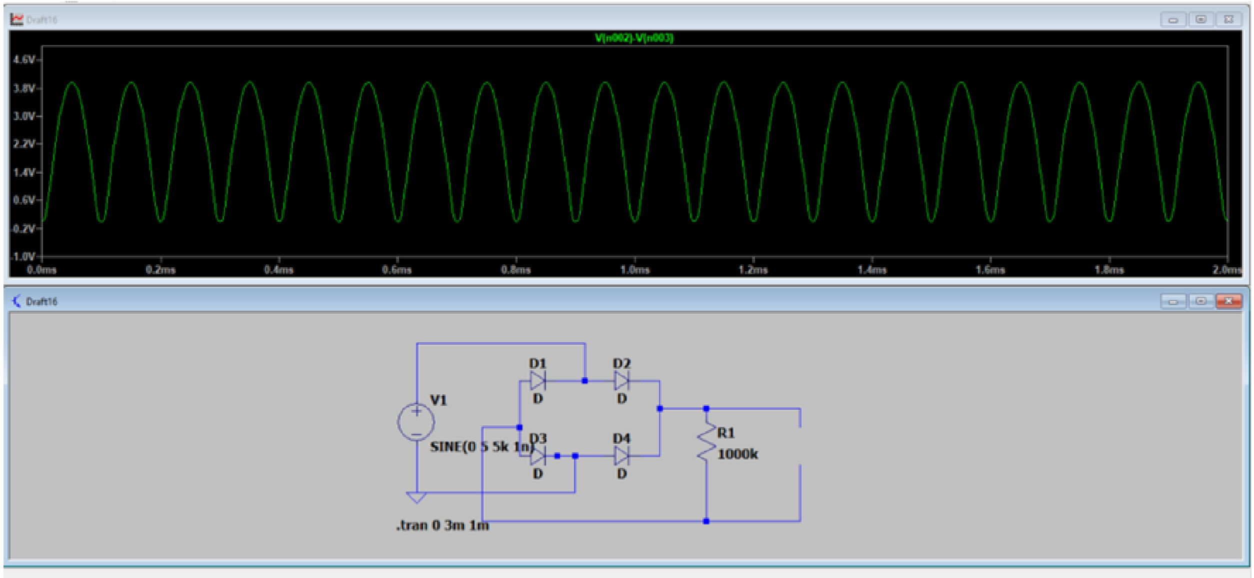


## Observations:

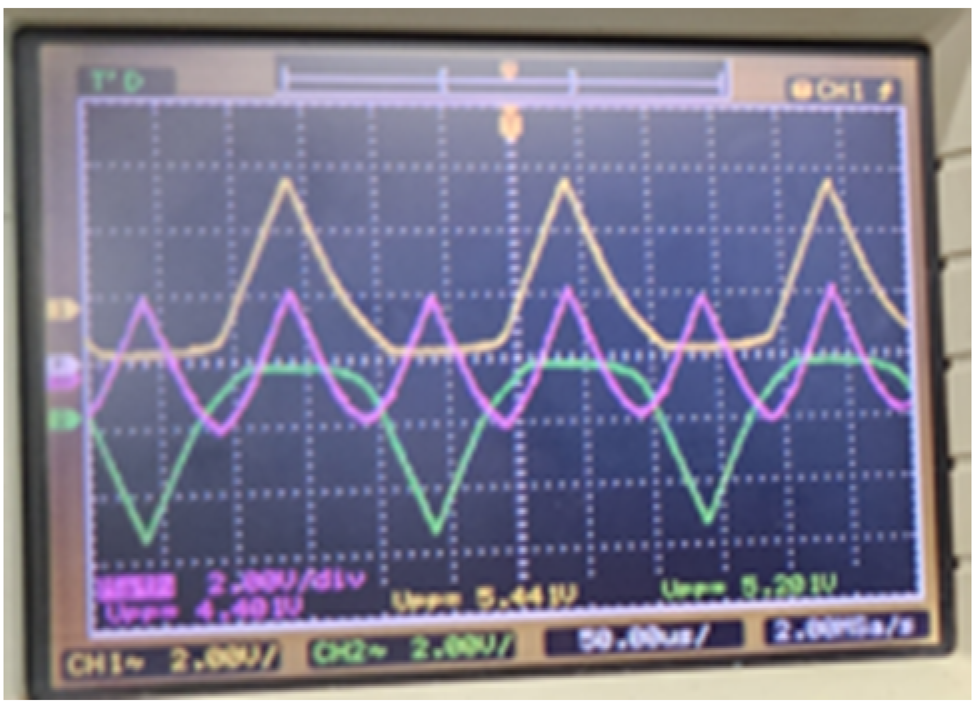
The output of the full wave bridge rectifier, while rectified, may still contain some ripple. To obtain a almost perfect copy of the input, we need higher ripple factor which can be achieved by connecting 0.18nF and 1MΩ as RC. In case of the smoother DC output, we need to decrease the ripple factor. Thus filter consists of a 1MΩ resistor and a 10nF capacitor. The resistor limits the discharge rate of the capacitor, resulting in a more stable DC voltage across the load

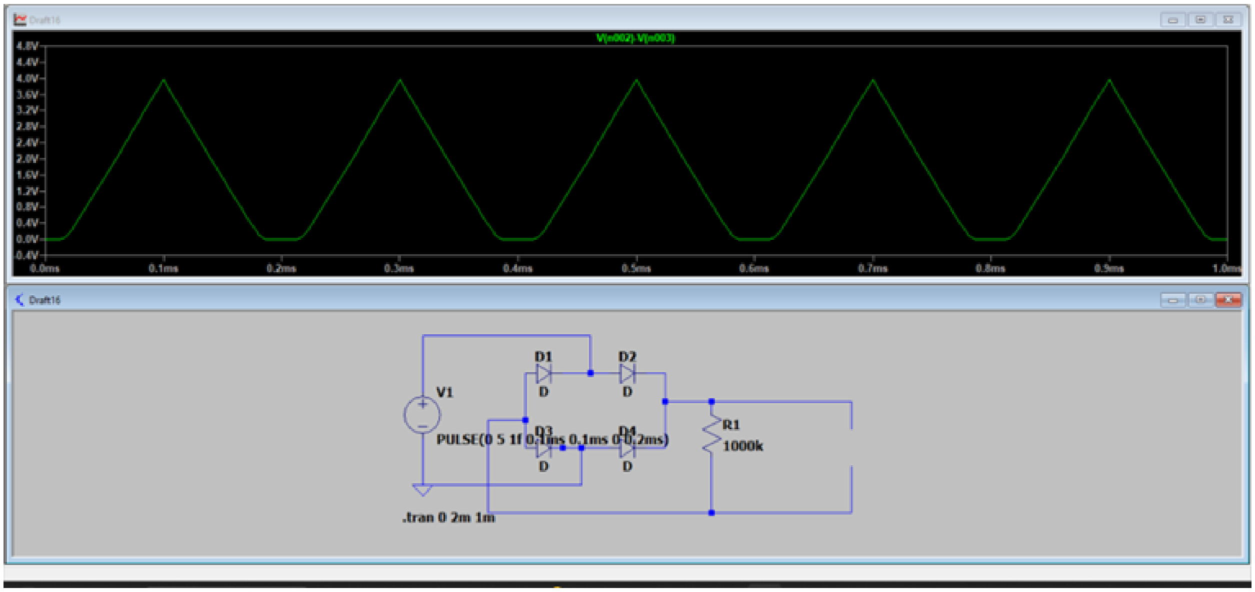
For sinusoidal input(higher ripple factor)



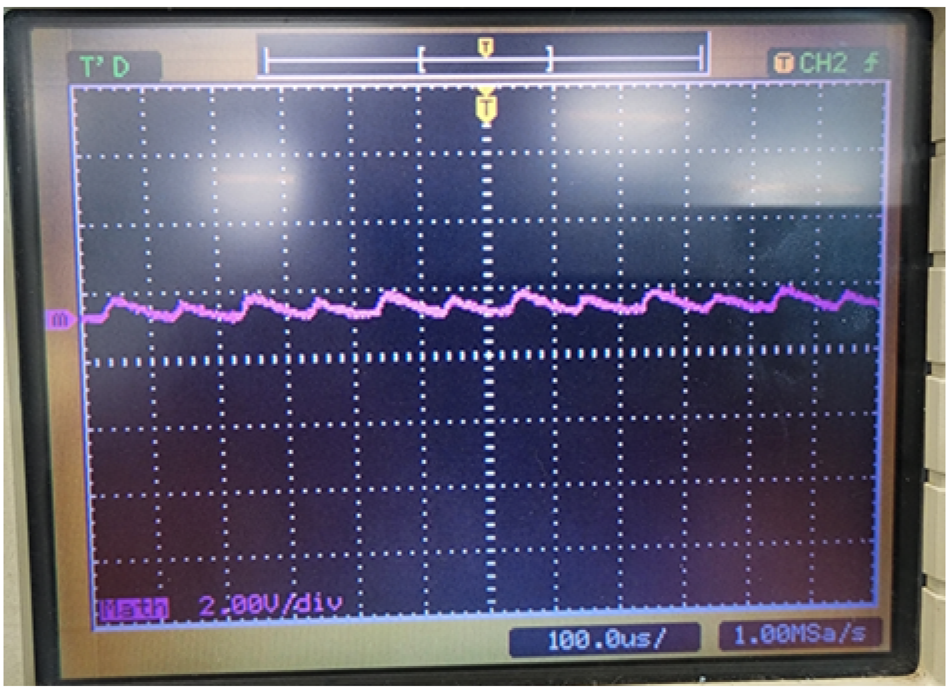


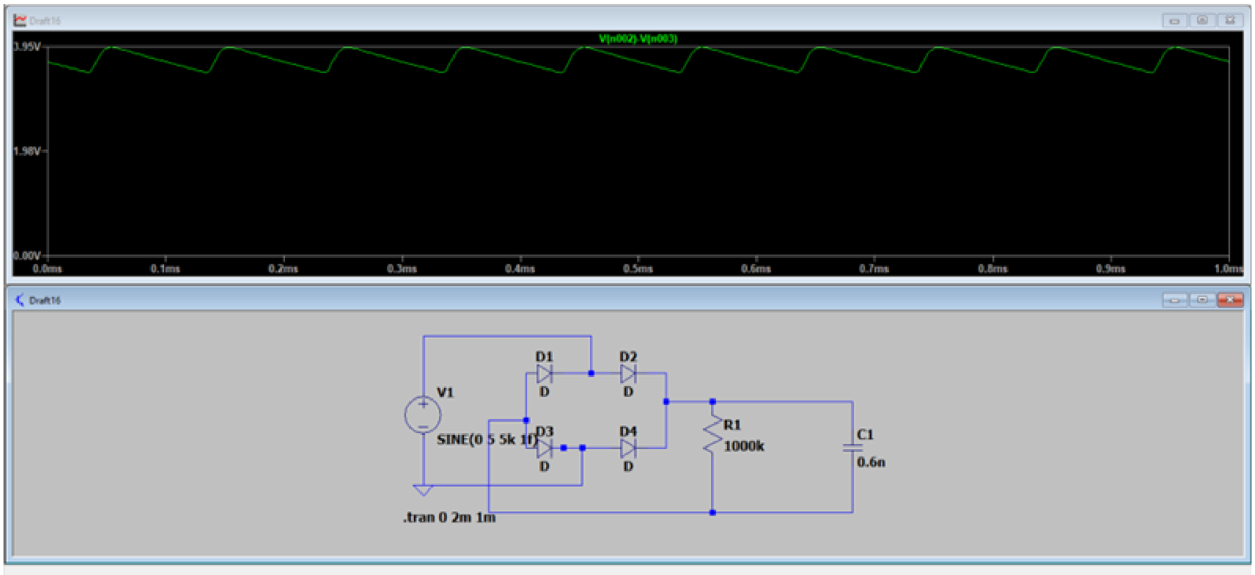

For ramp input(higher ripple factor)



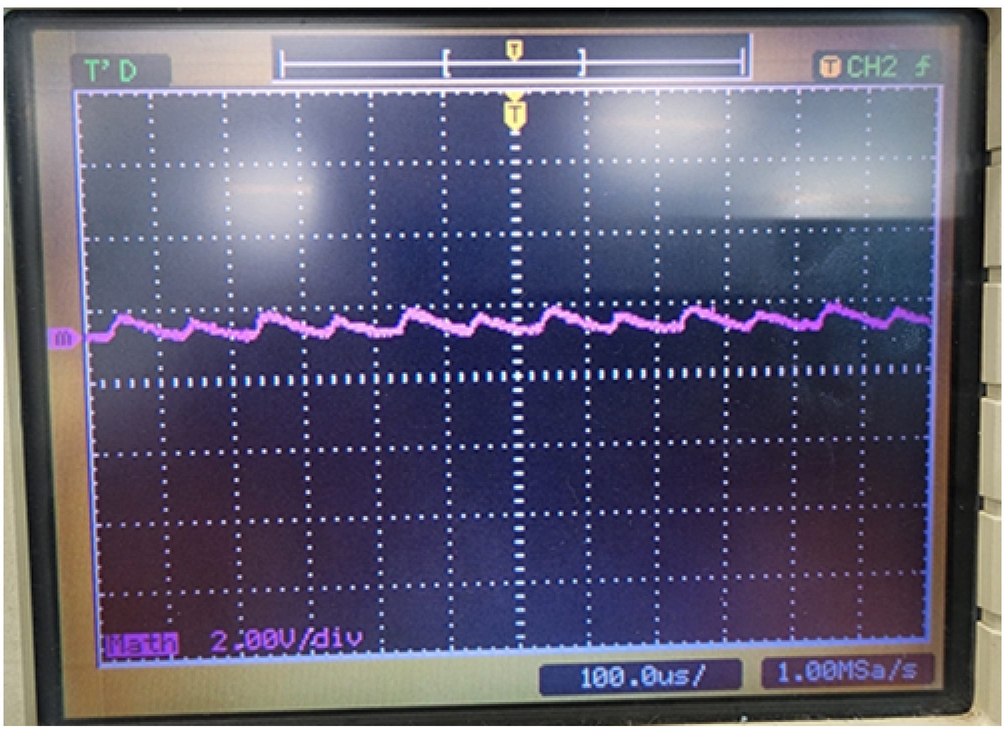


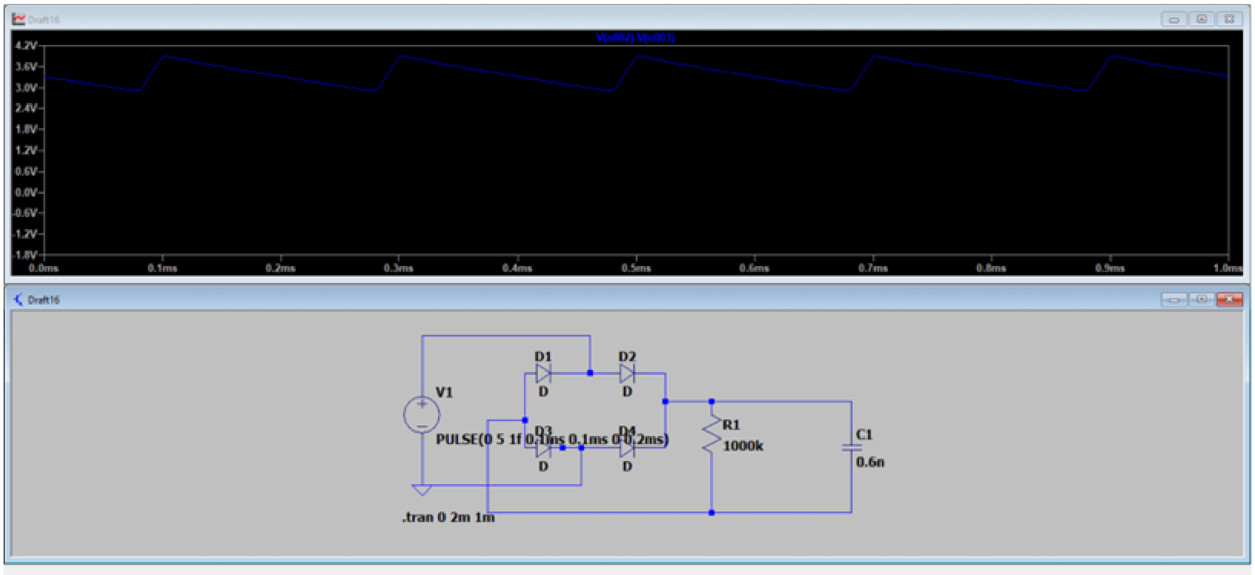

For sinusoidal input(lower ripple factor)






For ramp input(lower ripple factor)






# Problem 3:

## Aim:

To measure the dark and light I-V characteristics of a solar cell with and without a buffer, and to extract the important solar cell characteristics.

## Material Required:

Breadboard, Resistor(1kΩ), multimeter, Oscilloscope and function generator

## Procedure:

With the insights from Task 1, measure the dark and light I-V characteristics of the given solar cell (2 V). Represent all data graphically (no need to tabulate). Take a clear picture and schematic of the experimental setup for the report. Extract the important solar cell characteristics: Voc, Isc, filling factor, and efficiency.

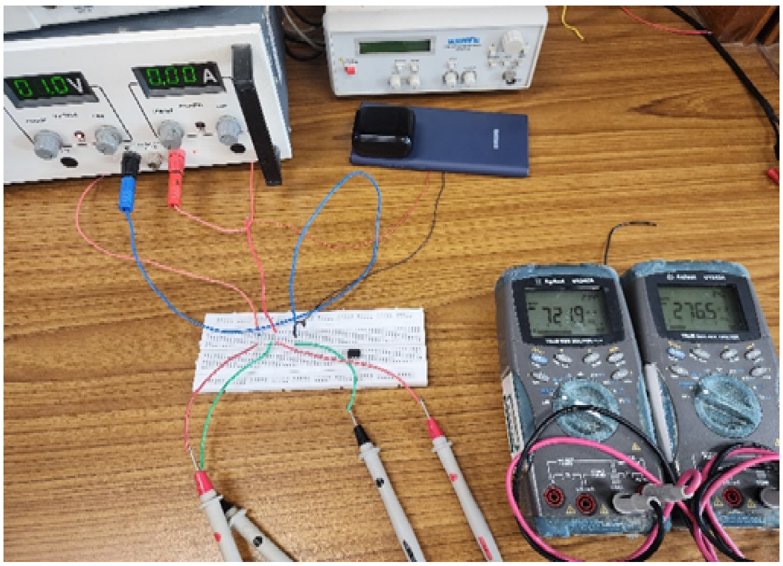
Now repeat the two previous steps with buffer (voltage follower) between the power supply and the series resistor.

## Observations:

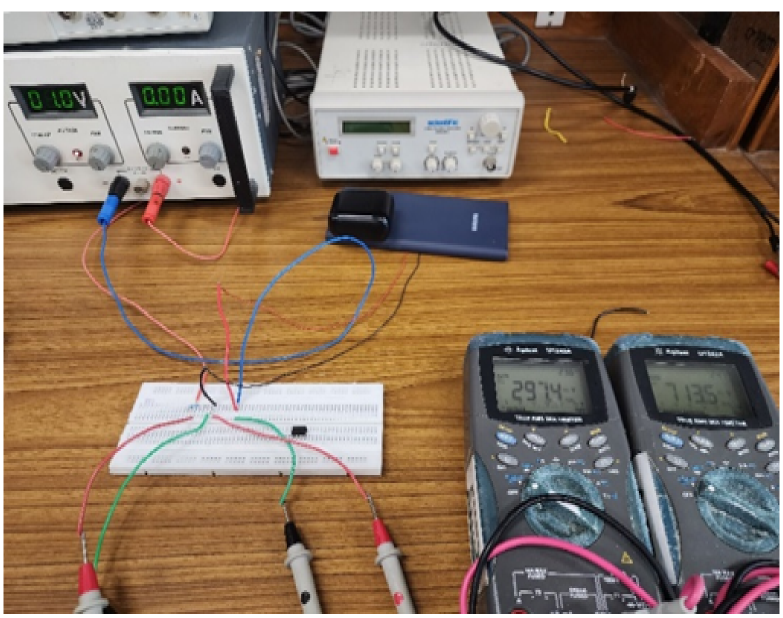
### 1) Solar cell (dark passive mode):

Below are some pictures of the Readings of Vin, Vres, Vcell, and I (Vres/1000)

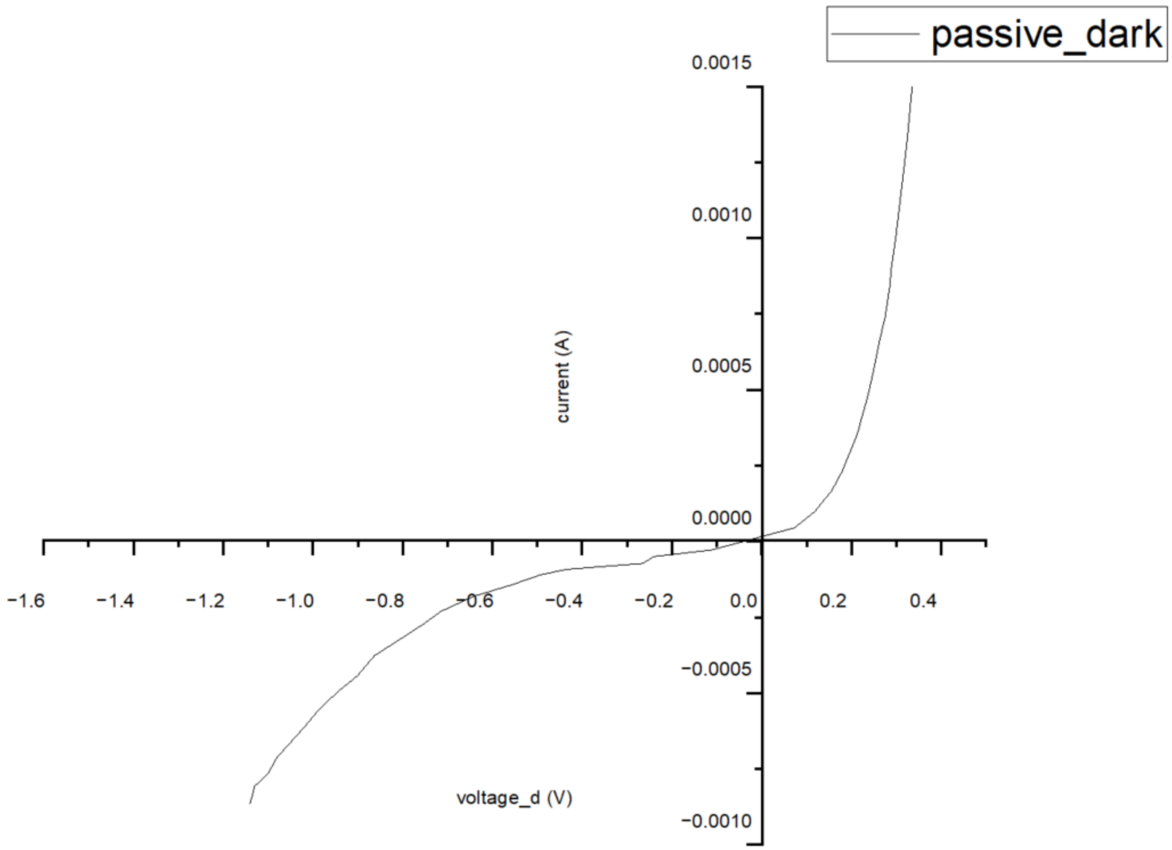
**Forward Bias:**



**Reversed Bias:**



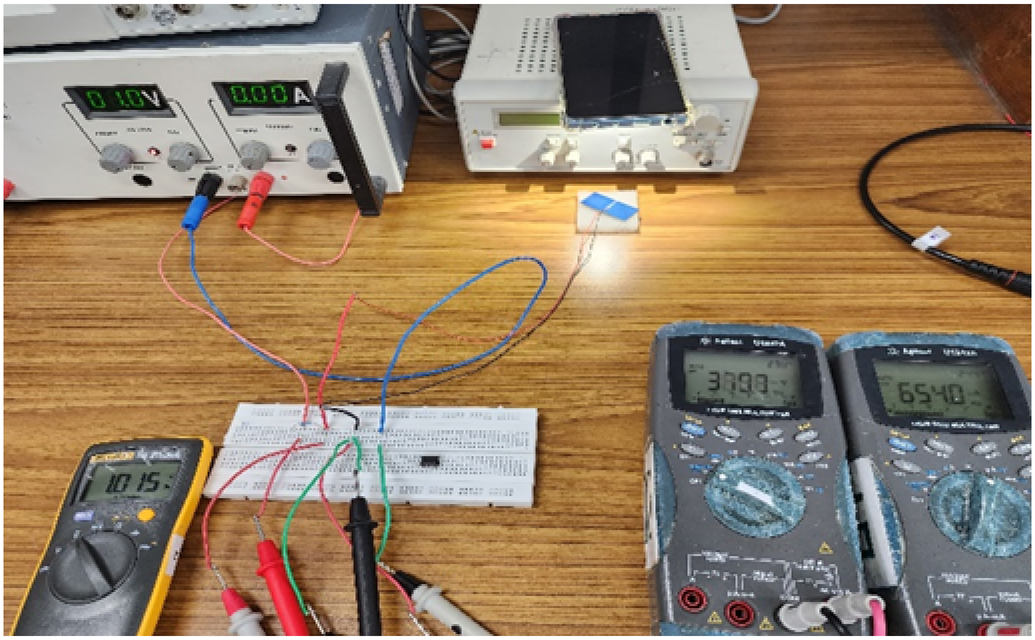
**The I-V characteristics graph:**



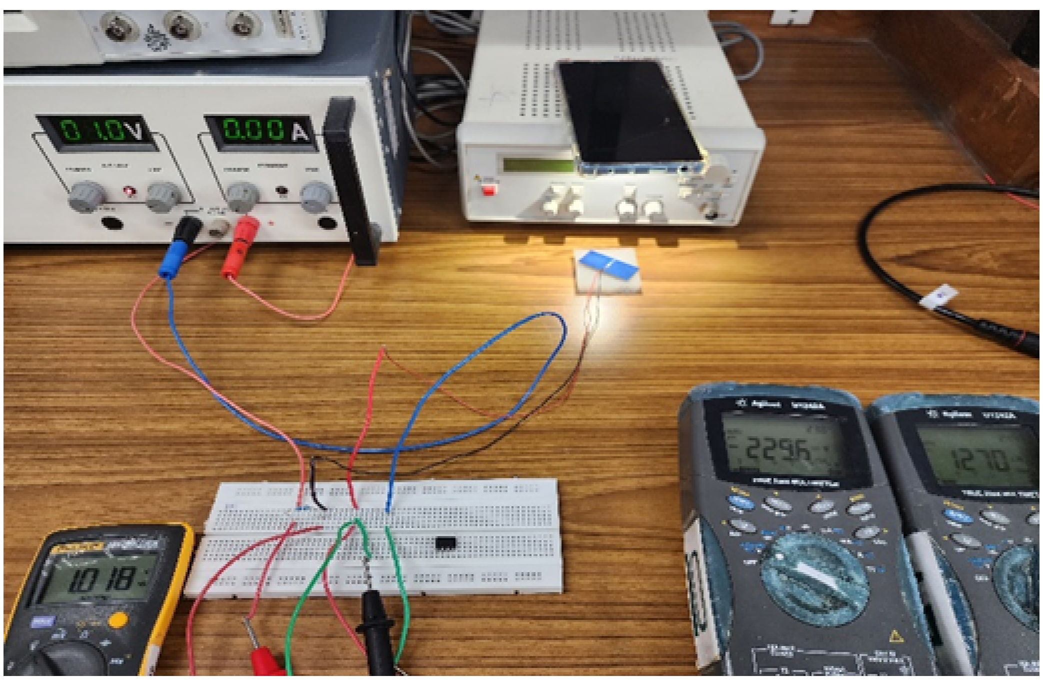
**2) Solar cell (light passive mode):**

Below are some pictures of the Readings of Vin, Vres, Vcell, and I (Vres/1000)

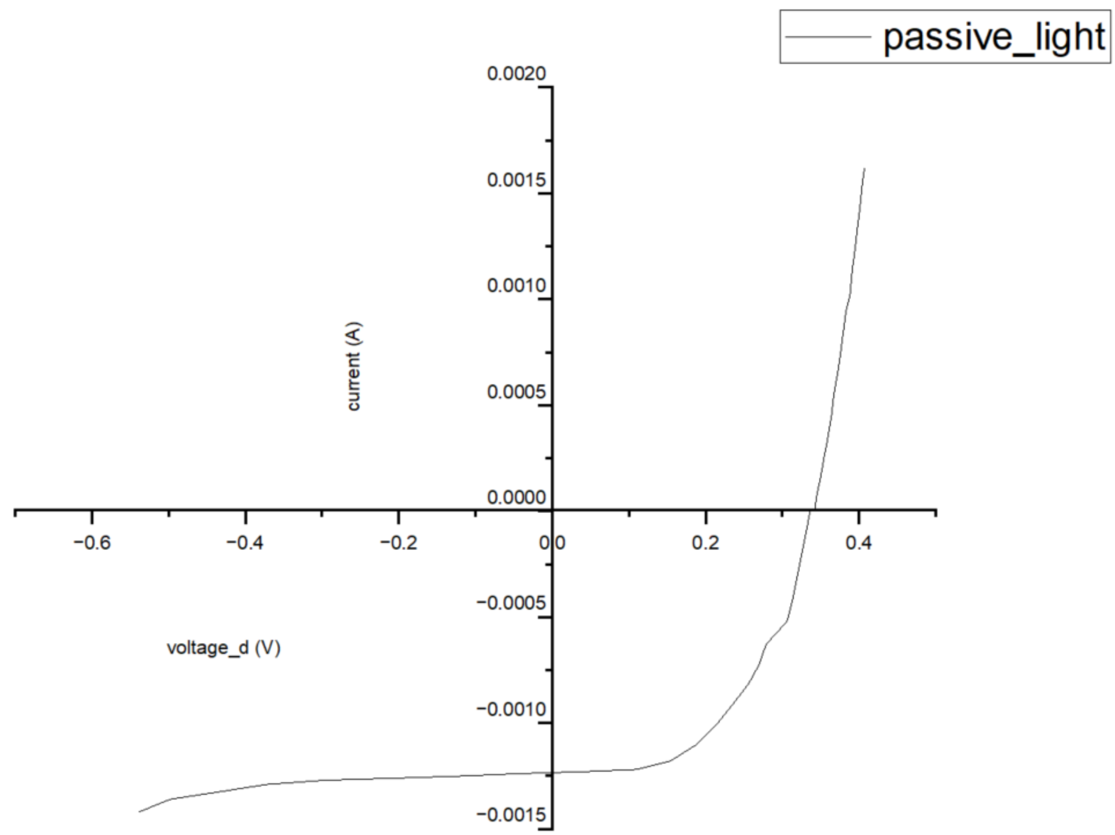
**Forward Bias:**



**Reversed Bias:**



**The I-V characteristics graph:**




The important characteristics of the solar cell are:

- $V_{oc}$ = 0.339V
- $I_{sc}$ = -0.001225A
- $I_{max}$ = -0.000883A
- $V_{max}$ = 0.245V
- Filling factor: $\frac{(Imax \times Vmax)}{Voc \times Isc} = \frac{0.000883 \times 0.245}{0.339 \times 0.001225} = 0.52094$
- $I_{sc}$ is the short circuit voltage when the potential across the diode is 0
- $V_{oc}$ is the open circuit voltage when the potential across the diode is 0.
- $I_{max}$ and $V_{max}$ are the coordinates of the intersection of the I-V curve and the line joining the origin and the point ($V_{oc}$,$I_{sc}$).

- Efficiency=$\frac{0.000883 \times 0.245}{0.0006} \times 100$=36.06%

The buffer eliminates the voltage drop across the series resistor, which results in an increase in the maximum power output of the solar cell.

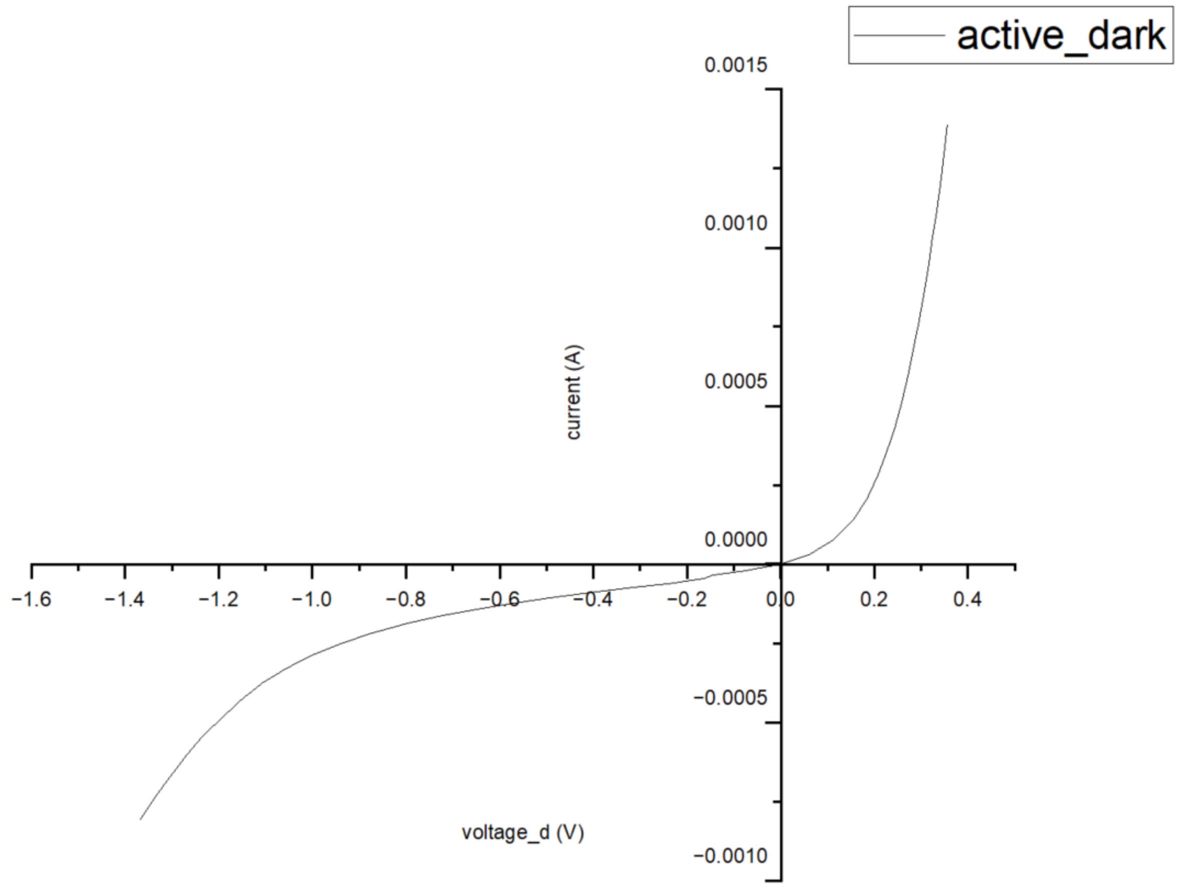
**c) Solar cell (dark active mode):**

Below are some pictures of the Readings of Vin, Vres, Vcell, and I (Vres/1000)

**Forward Bias:**


**Reverse Bias:**


**The I-V characteristics graph**



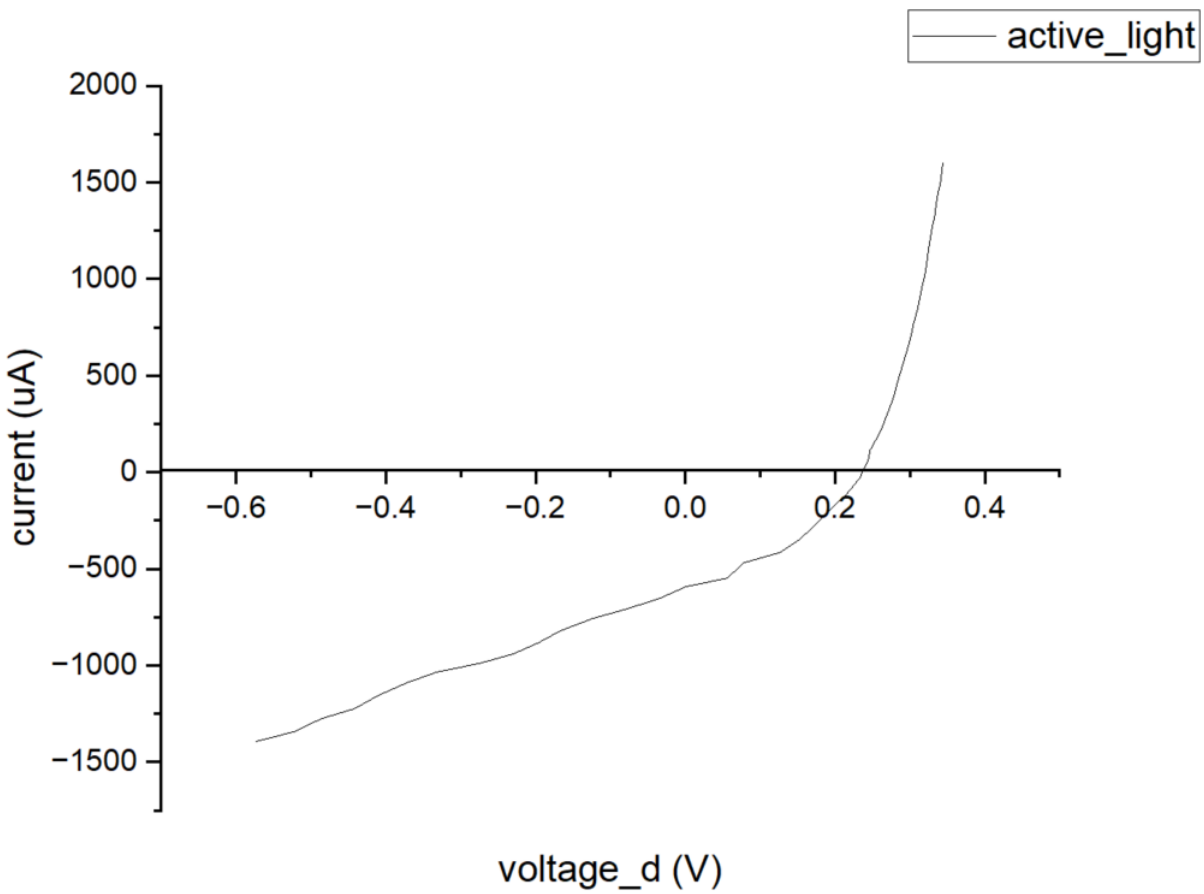

## d) Solar cell (light active mode):

Below are some pictures of the Readings of Vin, Vcell, and I (Vres/1000)

**Forward Bias:**


**Reverse Bias:**

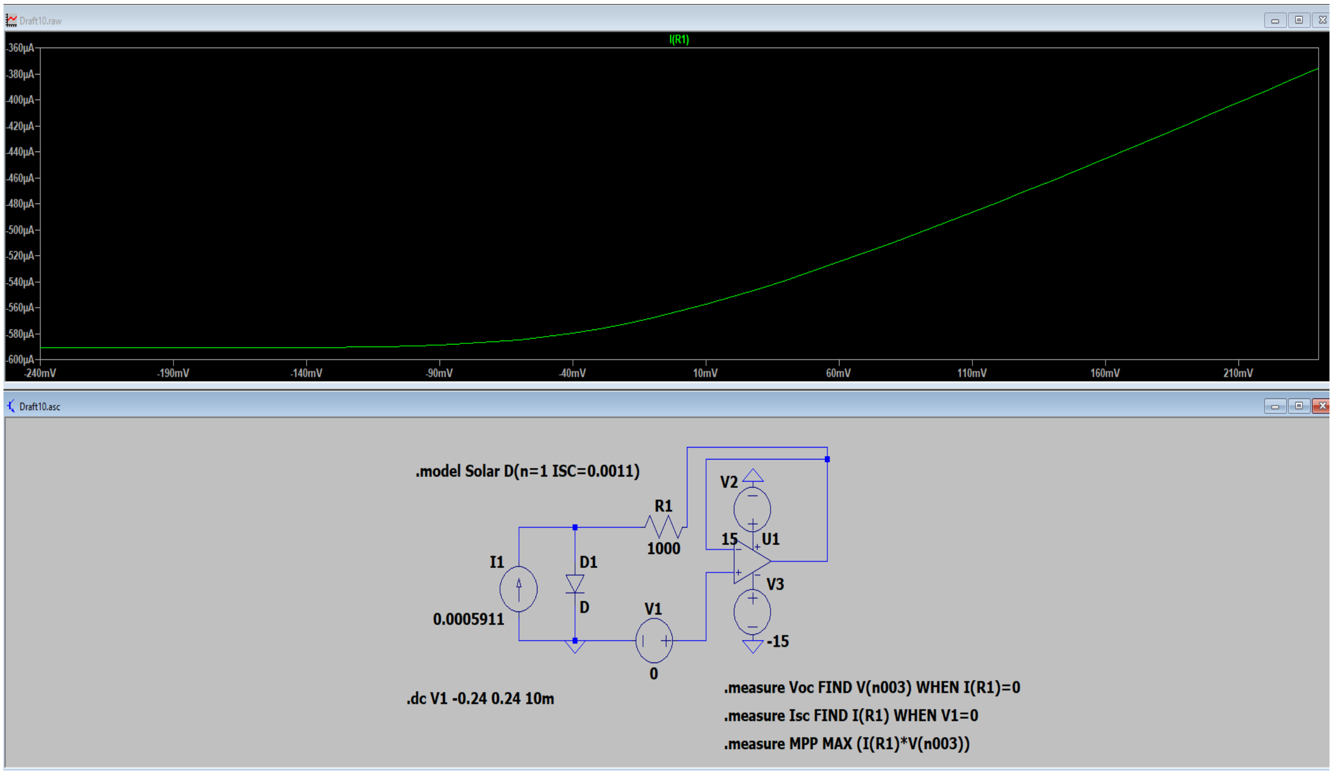

**The I-V characteristics graph:**




The important characteristics of the solar cell are:

- $V_{oc}$ = 0.237V
- $I_{sc}$ = -0.0005911A
- $I_{max}$ = -0.00039433A
- $V_{max}$ = 0.16V
- Filling factor: $\frac{(Imax \times Vmax)}{Voc \times Isc} = \frac{0.000883 \times 0.16}{0.237 \times 0.0005911} = 0.45037$
- $I_{sc}$ is the short circuit voltage when the potential across the diode is 0
- $V_{oc}$ is the open circuit voltage when the potential across the diode is 0.
- $I_{max}$ and $V_{max}$ are the coordinates of the intersection of the I-V curve and the line joining the origin and the point ($V_{oc}$,$I_{sc}$).
- Efficiency=$\frac{0.00039433 \times 0.16}{0.0003} \times 100$=21.515%

# Simulation:




SPICE Error Log: C:\Users\jayvi\OneDrive\Desktop\circuit lab\Draft10.log

```
Circuit: * C:\Users\jayvi\OneDrive\Desktop\circuit lab\Draft10.asc


voc: v(n003)=0.64152 at 0.64152
isc: i(r1)=-0.000562859 at 0
mpp: MAX(i(r1)*v(n003))=0.00984617 FROM 0 TO 3.5


Date: Tue Sep 19 06:23:32 2023
Total elapsed time: 0.302 seconds.

tnom = 27
temp = 27
method = trap
totiter = 7049
traniter = 0
tranpoints = 0
accept = 0
rejected = 0
matrix size = 9
fillins = 0
solver = Normal
Avg thread counts: 1.2/0.0/1.4/1.2
Matrix Compiler1:       19 opcodes  0.1/[0.1]/0.1
Matrix Compiler2: 701 bytes object code size  0.1/0.1/[0.1]
```

## Problem 4:

### Aim:

To study the characteristics of a solar cell and to determine its maximum power output.

### Material Required:

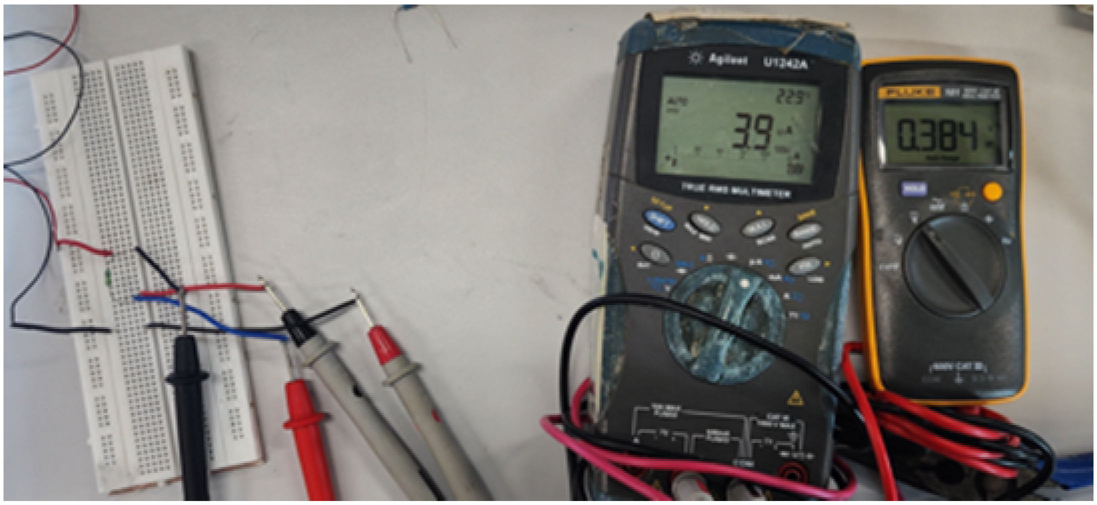
Breadboard, Resistor(10Ω to 10MΩ), solar cell, multimeter, light source

### Procedure:

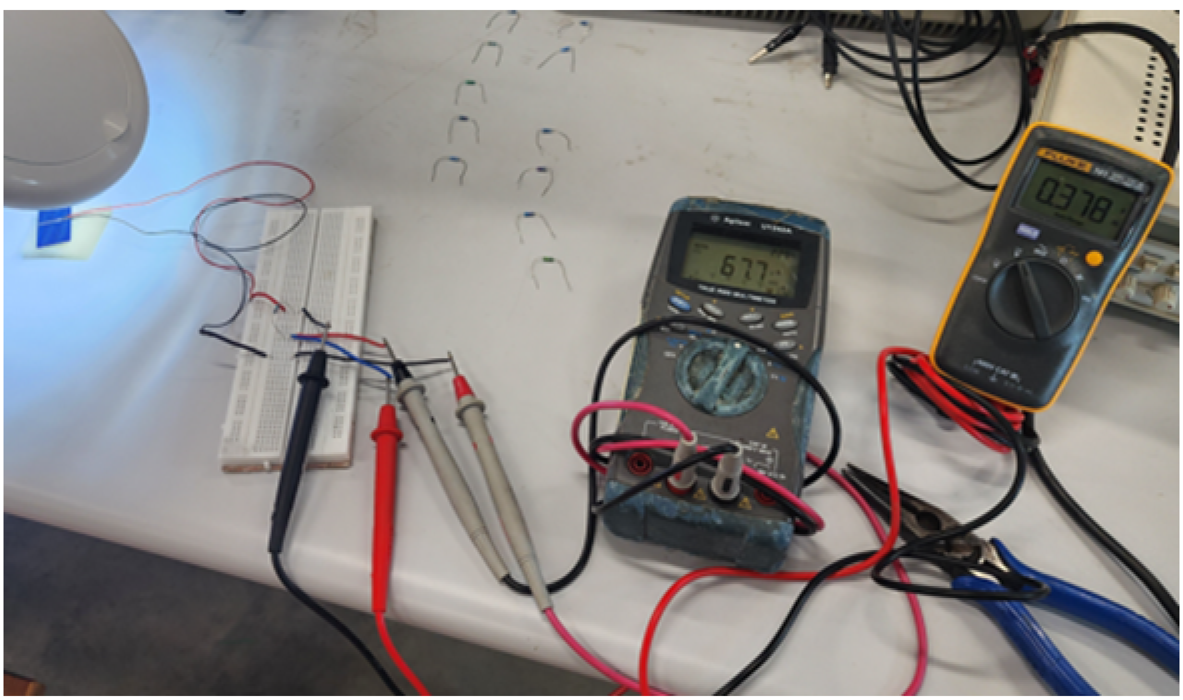
- Connect the solar cell to the potentiometer in series.
- Connect the ammeter and voltmeter in parallel to the load resistance.
- Adjust the potentiometer to vary the load resistance.
- Record the current (I_L) and voltage (V_L) across the load resistance for different values of load resistance.
- Plot I_L, V_L, and P_L (power delivered to the load) against R_L.
- Plot I_L and P_L against V_L.

## Observation:

For 98900Ω,

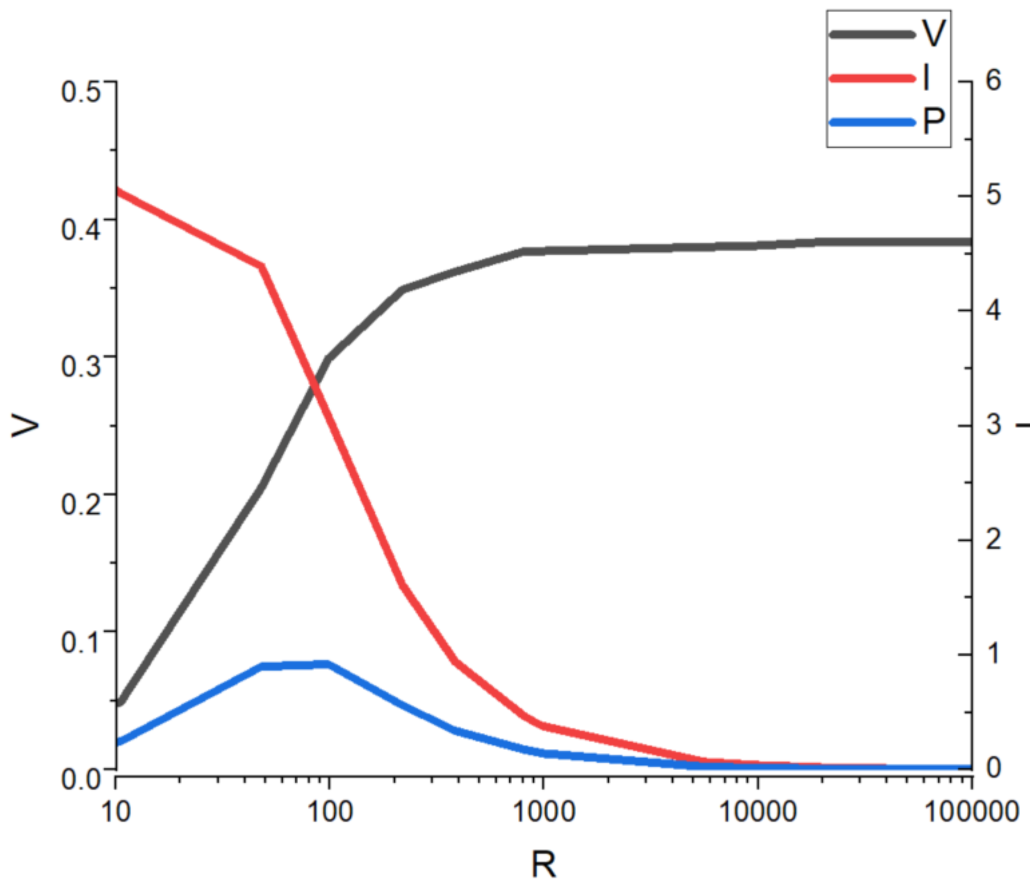



For 5610Ω,

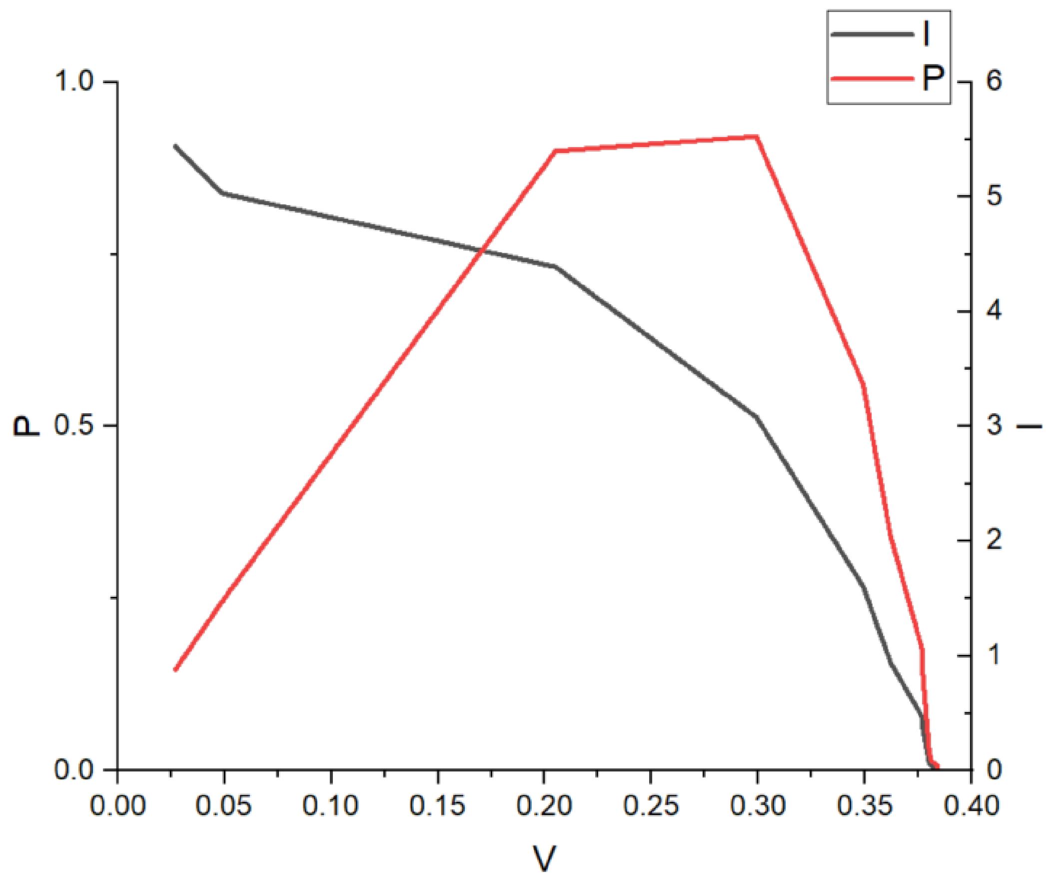


The experimental plots of $I_L$, $V_L$ $P_L$ with $R_L$ and $I_L$, $P_L$ vs $V_L$ respectively are as follows:

## $I_L$, $V_L$, $P_L$ Vs $R_L$



**$I_L$, $P_L$ vs $V_L$**




The following are the readings of the parameters conducted in the experiment

| Resistance | Voltage | Current(m) | Power(m) |
| --- | --- | --- | --- |
| 2 | 0.005 | 1.286 | 0.00643 |
| 5 | 0.027 | 5.44 | 0.14688 |

| | | | |
|---|---|---|---|
| 10.5 | 0.049 | 5.03 | 0.24647 |
| 47.8 | 0.205 | 4.39 | 0.89995 |
| 98.4 | 0.299 | 3.08 | 0.92092 |
| 218.4 | 0.349 | 1.61 | 0.56189 |
| 385.4 | 0.362 | 0.94 | 0.34028 |
| 818 | 0.377 | 0.46 | 0.17342 |
| 989 | 0.377 | 0.38 | 0.14326 |
| 5610 | 0.38 | 0.0678 | 0.025764 |
| 9870 | 0.381 | 0.0387 | 0.0147447 |
| 21760 | 0.384 | 0.0176 | 0.0067584 |
| 55300 | 0.384 | 0.0069 | 0.0026496 |
| 98900 | 0.384 | 0.0039 | 0.0014976 |

The maximum power delivered by the solar cell: Pmax = 0.00093792 W = 937.92 μW.

$P_{max}$ is found via the $V_L$ vs $P_L$, $I_L$. The resistor at which we get the $P_{max}$ is $R_L$ = 92.6Ω This value of resistance signifies that the solar cell's internal resistance is 92.6 Ω

The important characteristics of the solar cell are:

- $V_{oc}$ = 0.384V
- $I_{sc}$ = -0.001286A
- $I_{max}$ = -0.0009978A
- $V_{max}$ = 0.228V
- Filling factor: $\frac{(Imax \times Vmax)}{Voc \times Isc} = \frac{0.0009978 \times 0.228}{0.384 \times 0.0012861} = 0.4606$
- $I_{sc}$ is the short circuit voltage when the potential across the diode is 0

- $V_{oc}$ is the open circuit voltage when the potential across the diode is 0.
- $I_{max}$ and $V_{max}$ are the coordinates of the intersection of the I-V curve and the line joining the origin and the point ($V_{oc}$,$I_{sc}$).
- Efficiency=$\frac{0.0009978 \times 0.228}{0.0006} \times 100$=37.19%
- $P_{max}$ = 0.009978 * 0.228 = 0.0002274984W
- $P_{max}$ = 227.49µW
- Domestic Power consumption = $\frac{225kWh}{24 \times 30} = 0.3125kW$
- Required Number of solar cells = $\frac{312.5}{227.49 \times 10^{-6}} = 1.37 \times 10^{6}$ cells
- The distance between the airport and the campus is approx. 69km, and the average consumption of power by a car is 0.4kWh/km, The energy required is 27.6kWh
- P=23kW
- Number of solar cells required = $\frac{23 \times 1000}{227.49 \times 10^{-6}} = 1.01 \times 10^{6}$

Some of the important challenges in realizing photovoltaics to fulfill day-to-day energy needs include:

- **Cost:** The cost of solar cells has decreased significantly in recent years, but they are still more expensive than traditional energy sources such as coal and natural gas.
- **Efficiency:** The efficiency of solar cells has also improved in recent years, but it is still relatively low. This means that a large number of solar cells are required to produce a significant amount of electricity.
- **Intermittency:** Solar energy is an intermittent energy source, meaning that it is not available all the time. This is because solar cells only produce electricity when they are exposed to sunlight. To address this challenge, energy storage systems can be used to store solar energy when it is available and then discharge it when it is needed.
- **Geographic Variability:**Solar energy is a promising renewable energy source, but its effectiveness can be limited in regions with varying sunlight levels and obstacles like mountains or buildings. To overcome these challenges, engineers are developing innovative solar technologies that can perform optimally despite these constraints.