

EE 236: Experiment 5

Temperature Dependence of Solar Cell I/V Characteristics

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1 Aim

To plot dark and lighted forward I-V at various temperatures and observe its effect on power curves, cut-in voltage, V_{oc} , I_{sc} , fill factors and ideality factors.

2 NGSPICE Prelab Simulations

The following code was used to plot the dark and lighted I-V characteristics for a solar cell at 25 °C

2.1 Code for IV Characteristics of Solar Cell

```
.include 'solar_cell.txt'

*Rohan Rajesh Kalbag

v1 0 1 dc
x1 1 2 solar_cell
vsolar 2 3 dc 0
r1 3 0 100

.dc v1 -2 2 0.01
.control

run
let id = i(vsolar)
let vd = {v(1) - v(2)}
plot id vs vd
.endc
.end
```

The subsequent code was used to obtain the I-V characteristics at five different temperatures to study its behaviour

2.2 Code for I-V Characteristics Sweeping Temperature

```
.include ' solar_cell.txt'

v1 0 1 dc
x1 1 2 solar_cell
vsolar 2 3 dc 0
r1 3 0 100

.dc v1 -2 2 0.01 temp 35 75 10
.control

run
let id = i(vsolar)
let vd = {v(1) - v(2)}
plot id vs vd
.endc
.end
```

The following code was used to plot the power curves as a function of temperature and hence obtain the fill factors as a function of temperature

2.3 Code for Power Curves to Measure V_{OC} , I_{SC} , I_{MP} , V_{MP}

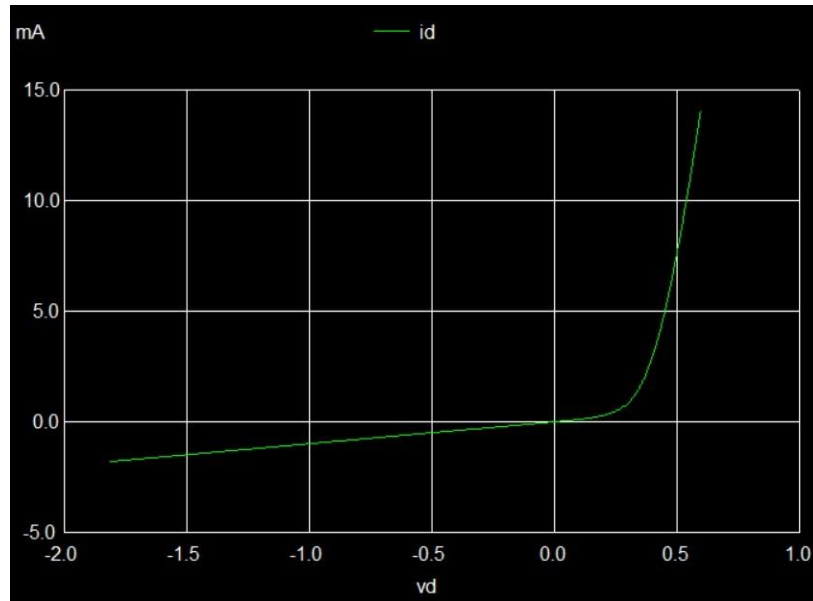
```
.include ' solar_cell.txt'

x1 1 2 solar_cell
vsolar 3 1 dc 0
r1 2 3 100

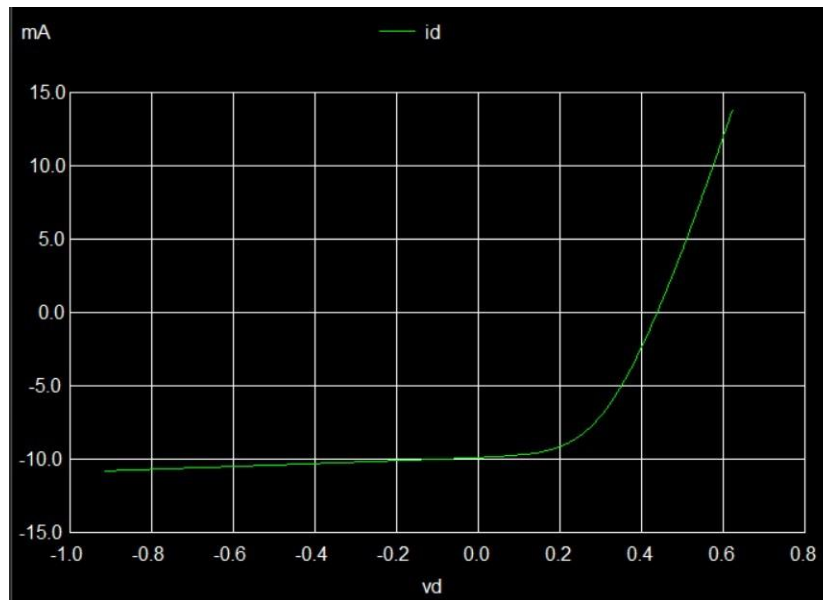
.dc r1 0.001 10k 0.1 temp 35 75 10
.control

run
let power = {i(vsolar)*(v(1) - v(2))}
let id = i(vsolar)
let vd = {v(1) - v(2)}
plot id vs vd power vs vd
.endc
.end
```

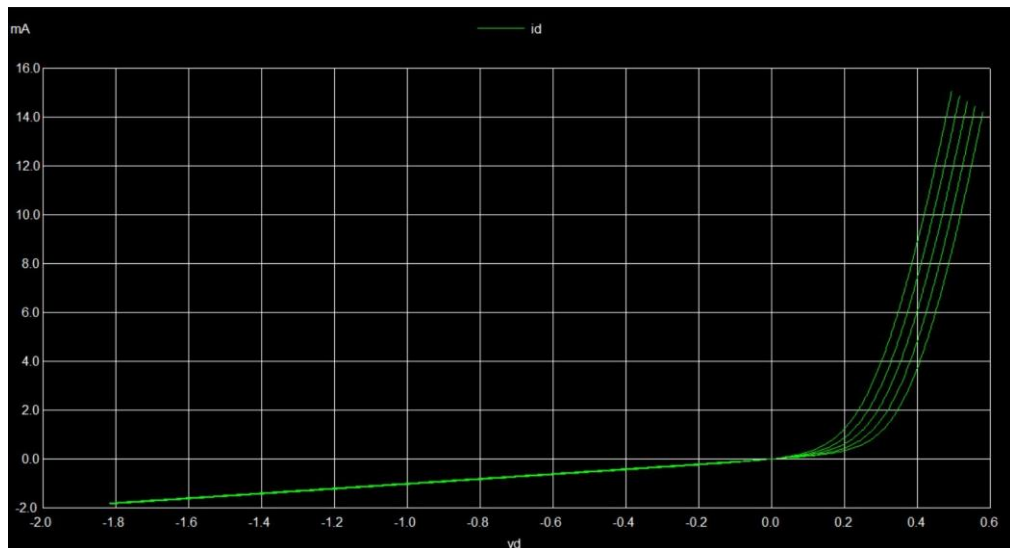
2.4 Simulation Results



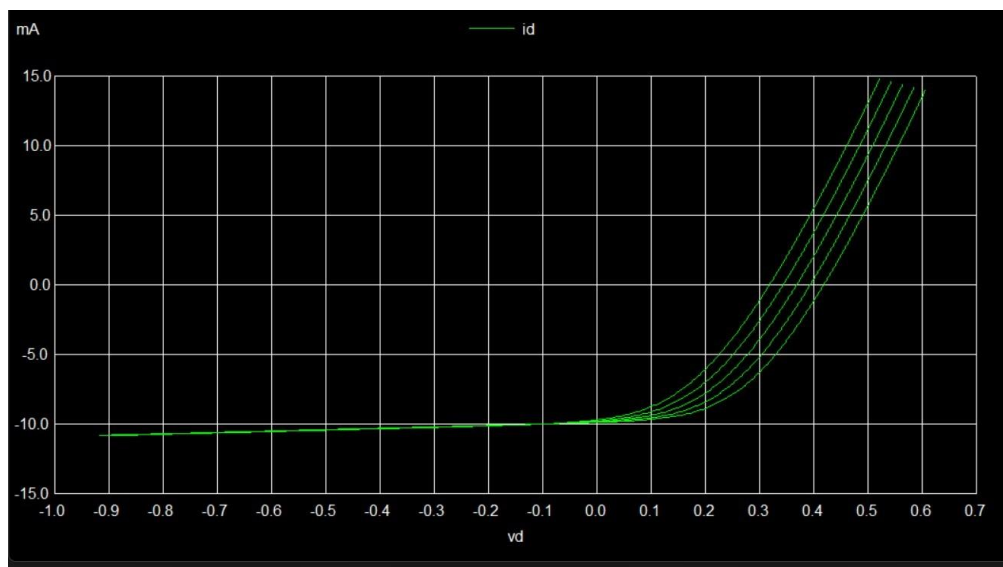
I/V Characteristics for Solar Cell in Dark (Illumination Current of 0 mA)



I/V Characteristics for Illumination Current of 10 mA

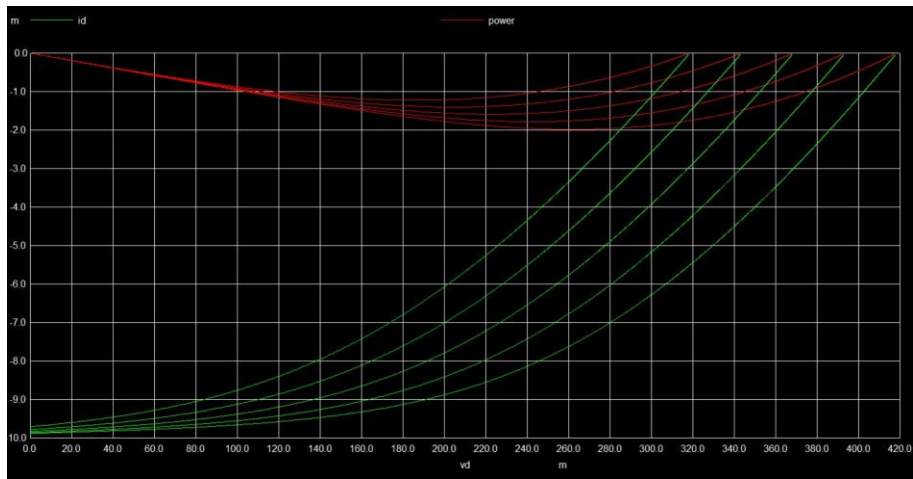


I-V characteristics wrt to Temperature for Dark Condition



I-V characteristics wrt to Temperature for 10mA Illumination

We notice that the I-V characteristics get **translated above** for larger values of voltages in the I-V plane as the **temperature increases**

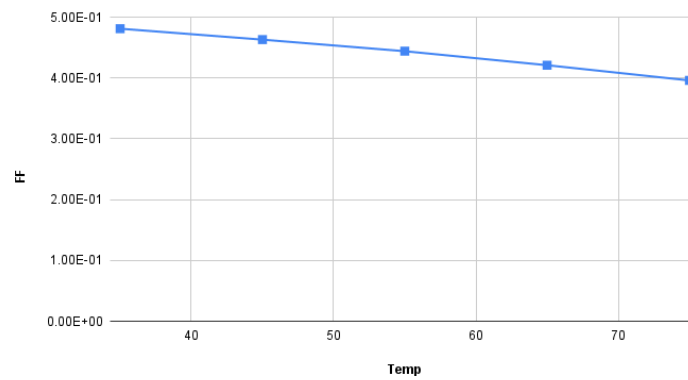


Power Curves varying with Temperature for 10mA Illumination

$$\text{Fill Factor} = \frac{V_{MP} \cdot I_{MP}}{V_{OC} \cdot I_{SC}}$$

Temp	I_{sc} (mA)	V_{oc} (V)	$V_{mp} \cdot I_{mp}$ (mW)	Fill Factor
35	9.88	0.417	1.98	0.481
45	9.82	0.3914	1.78	0.463
55	9.80	0.3657	1.59	0.444
65	9.78	0.3414	1.41	0.421
75	9.67	0.3178	1.22	0.396

Fill Factor Variation with Temperature

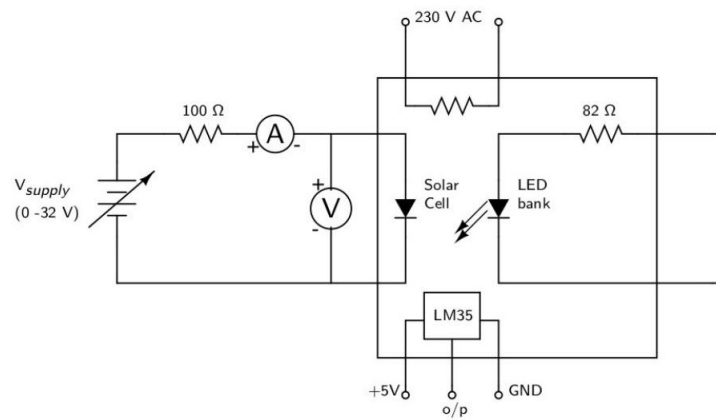


The power curves get **more narrow** as the **temperature increases**. The magnitude of the **peak value** (max) of power **decreases** with temperature.

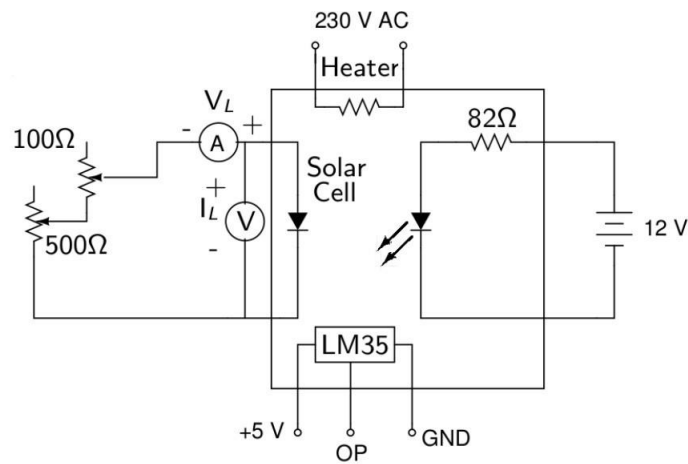
Thus from the value obtained and the plot we notice that fill factor is **decreasing** with **increase in temperature**

3 Lab Experiment

3.1 Circuits Used



Circuit to Obtain Dark I-V Characteristics as a Function of Temperature

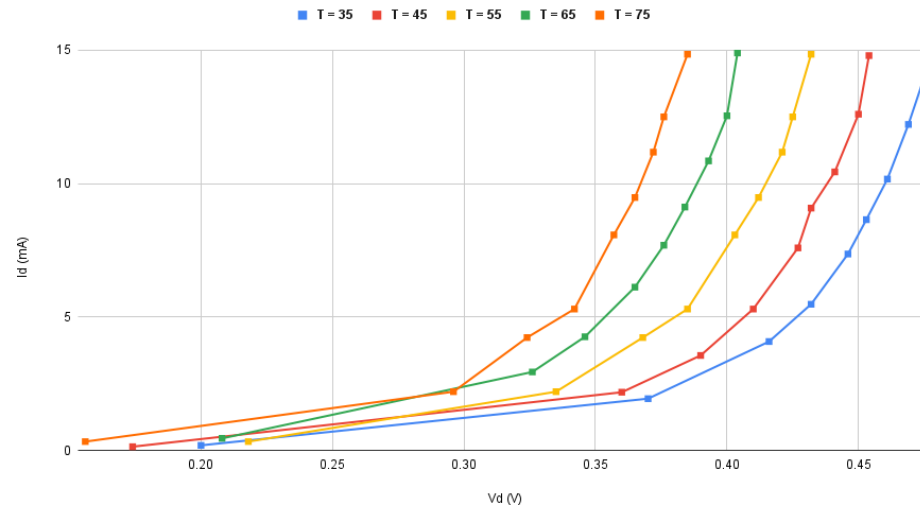


Circuit to Obtain Lighted I-V Characteristics as a Function of Temperature

3.2 Observations and Plots Obtained

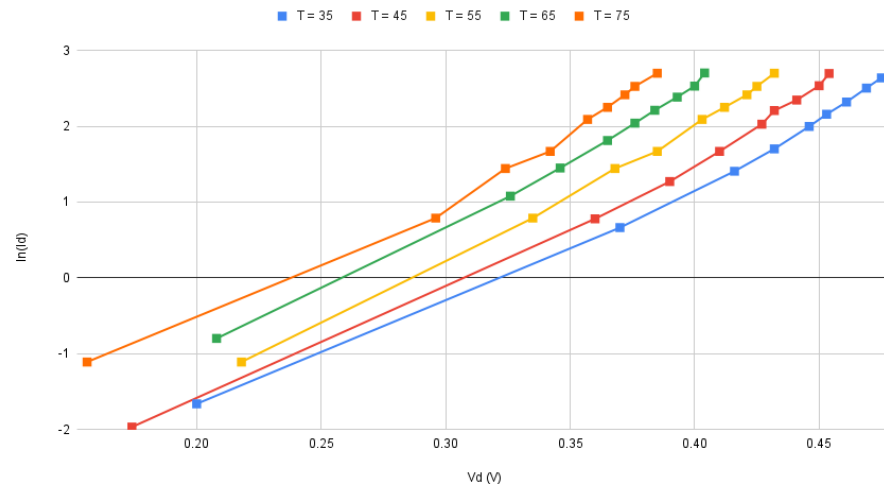
3.2.1 Part 1: Plot Obtained for Dark I-V Characteristics

IV Characteristics for Dark Condition For Different Temp



3.2.2 Part 1: Plot Obtained for Dark $\ln(I)$ -V Characteristics

$\ln(I_d)$ vs V_d Characteristics for Dark Condition



3.2.3 Part 1: Readings Obtained for Dark I-V Characteristics

V_D (V)	I_D (mA)	V_{supply}
0.2	0.19	0.2
0.37	1.94	0.6
0.416	4.08	0.8
0.432	5.48	1
0.446	7.36	1.2
0.453	8.65	1.4
0.461	10.17	1.6
0.469	12.22	1.8
0.475	13.98	2

For $T = 35^\circ\text{C}$

V_D (V)	I_D (mA)	V_{supply}
0.174	0.14	0.2
0.36	2.18	0.6
0.39	3.56	0.8
0.41	5.3	1
0.427	7.59	1.2
0.432	9.08	1.4
0.441	10.44	1.6
0.45	12.6	1.8
0.454	14.8	2

For $T = 45^\circ\text{C}$

V_D (V)	I_D (mA)	V_{supply}
0.218	0.33	0.2
0.335	2.2	0.6
0.368	4.23	0.8
0.385	5.3	1
0.403	8.08	1.2
0.412	9.48	1.4
0.421	11.18	1.6
0.425	12.5	1.8
0.432	14.85	2

For $T = 55^\circ\text{C}$

V_D (V)	I_D (mA)	V_{supply}
0.208	0.45	0.2
0.326	2.94	0.6
0.346	4.26	0.8
0.365	6.12	1
0.376	7.69	1.2
0.384	9.12	1.4
0.393	10.85	1.6
0.4	12.54	1.8
0.404	14.9	2

For $T = 65^\circ\text{C}$

V_D (V)	I_D (mA)	V_{supply}
0.156	0.26	0.2
0.296	2.44	0.6
0.324	4.16	0.8
0.342	6.14	1
0.357	8.23	1.2
0.365	9.96	1.4
0.372	11.52	1.6
0.376	13.1	1.8
0.385	15.72	2

For $T = 75^\circ\text{C}$

3.2.4 Part 1: Observation Table for Dark I-V Characteristics

The slopes (m) of $\ln(I_D)$ vs V_D curves were found for each temp and the Ideality factor was estimated as $\eta = \frac{1}{m \cdot V_T}$

Temp °C	V_D (1mA)	V_D (2mA)	V_D (5mA)	Slope (m)	Ideality Factor (η)
35	0.35	0.39	0.42	15.5	2.481
45	0.32	0.35	0.408	16.4	2.345
55	0.31	0.335	0.38	17.7	2.172
65	0.28	0.31	0.35	17.6	2.185
75	0.27	0.296	0.34	16.6	2.316

3.2.5 Part 2: Readings Obtained for Lighted I-V Characteristics

V_D (V)	I_D (mA)	P (mW)
0.462	0	0
0.459	0.8	0.3672
0.458	1.2	0.5496
0.45	2	0.9
0.445	3	1.335
0.438	4	1.752
0.429	5	2.145
0.418	6	2.508
0.405	7	2.835
0.387	8	3.096
0.342	9.3	3.1806
0.305	9.81	2.99205
0.268	10.1	2.7068
0.17	10.42	1.7714

For $T = 35^\circ\text{C}$

V_D (V)	I_D (mA)	P (mW)
0.441	0.69	0.30429
0.436	1.22	0.53192
0.43	2.06	0.8858
0.424	2.99	1.26776
0.415	4.055	1.682825
0.406	5.06	2.05436
0.396	6.05	2.3958
0.378	7.28	2.75184
0.357	8.25	2.94525
3.4	8.8	29.92
0.301	9.57	2.88057
0.246	10.1	2.4846
0.232	10.17	2.35944

For $T = 45^\circ\text{C}$

V_D (V)	I_D (mA)	P (mW)
0.414	0.65	0.2691
0.41	1.22	0.5002
0.405	2	0.81
0.398	3.1	1.2338
0.393	3.98	1.56414
0.381	5.16	1.96596
0.368	6.23	2.29264
0.357	7	2.499
0.331	8.31	2.75061
0.323	8.6	2.7778
0.277	9.58	2.65366
0.265	9.74	2.5811
0.212	10.14	2.14968

For $T = 55^\circ\text{C}$

V_D (V)	I_D (mA)	P (mW)
0.388	0.72	0.27936
0.386	1.21	0.46706
0.382	2.02	0.77164
0.375	3.04	1.14
0.368	3.96	1.45728
0.356	5.15	1.8334
0.346	6.09	2.10714
0.328	7.32	2.40096
0.303	8.45	2.56035
0.294	8.73	2.56662
0.247	9.63	2.37861
0.212	9.97	2.11364
0.207	10	2.07

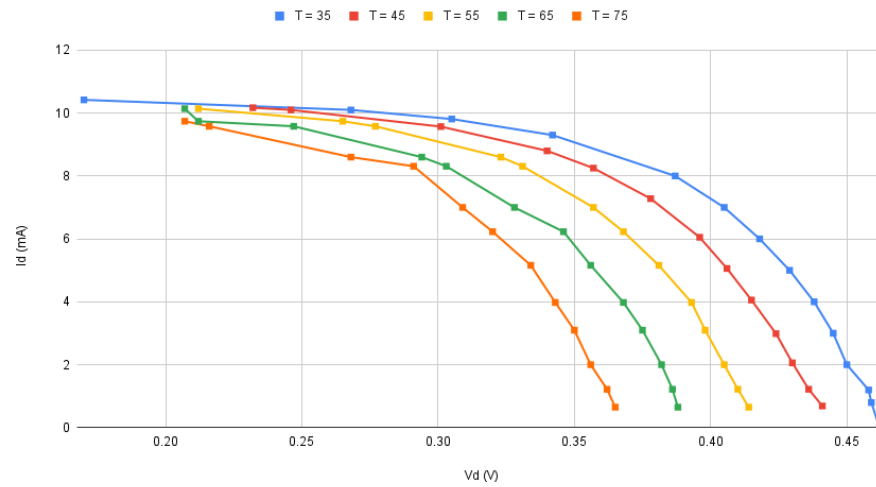
For $T = 65\text{ }^{\circ}\text{C}$

V_D (V)	I_D (mA)	P (mW)
0.365	0.67	0.24455
0.362	1.22	0.44164
0.356	2.02	0.71912
0.35	3.02	1.057
0.343	4.06	1.39258
0.334	5.14	1.71676
0.32	6.3	2.016
0.309	6.99	2.15991
0.291	7.89	2.29599
0.268	8.73	2.33964
0.216	9.68	2.09088
0.207	0.977	0.202239
0.204	9.8	1.9992

For $T = 75\text{ }^{\circ}\text{C}$

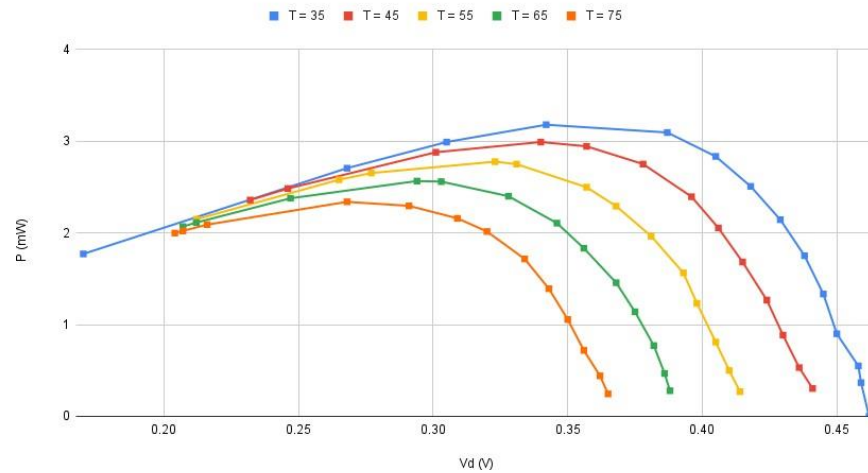
3.2.6 Part 2: Plot Obtained for Lighted I-V Characteristics

IV Characteristics for Lighted Condition



3.2.7 Part 2: Power Curves Obtained for Lighted I-V Characteristics

Power Curves for Light Condition



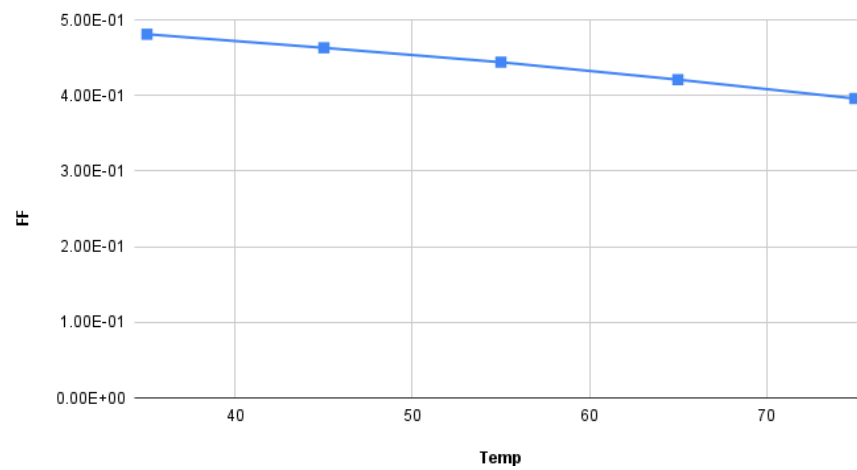
3.2.8 Calculation Tables To Obtain Fill Factors

$$Fill\ Factor = \frac{V_{MP} \cdot I_{MP}}{V_{OC} \cdot I_{SC}}$$

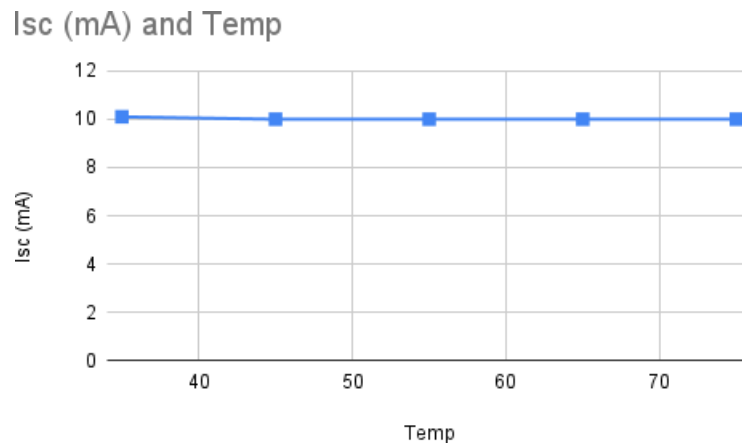
V_{oc}	I_{sc} (mA)	Temp	$V_{mp} \cdot I_{mp}$	Fill Factor
0.46	10.1	35	3.1806	0.684
0.44	10	45	2.992	0.68
0.42	10	55	2.7778	0.661
0.39	10	65	2.56662	0.658
0.37	10	75	2.33964	0.632

3.2.9 Variation of Fill Factors with Temperature

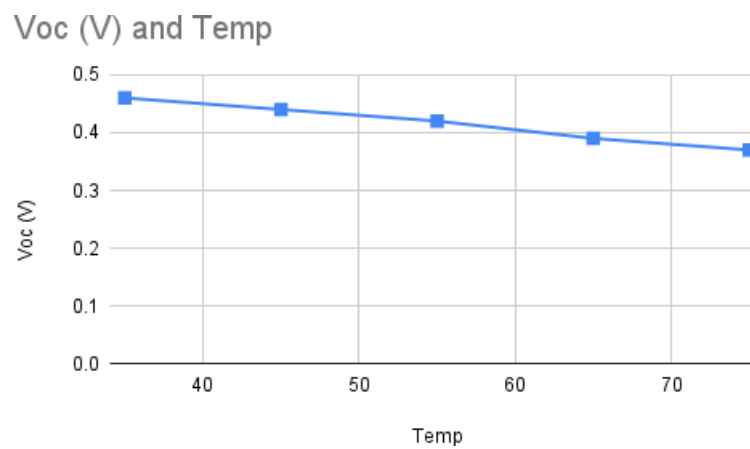
Fill Factor Variation with Temperature



3.2.10 Variation of I_{sc} with Temperature



3.2.11 Variation of V_{oc} with Temperature



I_{sc} almost remains nearly constant whereas V_{oc} and FF decrease with increase in temperature