EE236: Lab 5
Temperature Dependence of Solar Cell I/V Characteristics

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1 Aim of the experiment

1. To plot dark forward I-V characteristics at different temperatures.
2. To plot lighted forward I-V characteristics at different temperatures.
3. To observe the effect of temperature on cut-in voltage, V_{OC} , I_{SC} , fill factor and ideality factor.

2 Design & Working

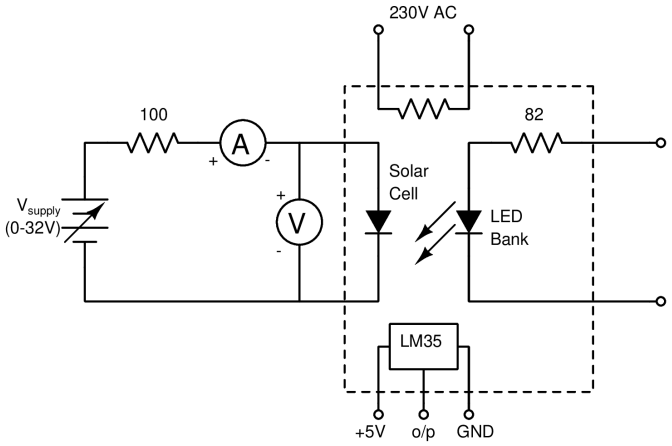

Fig. Circuit diagram for dark I/V characteristics

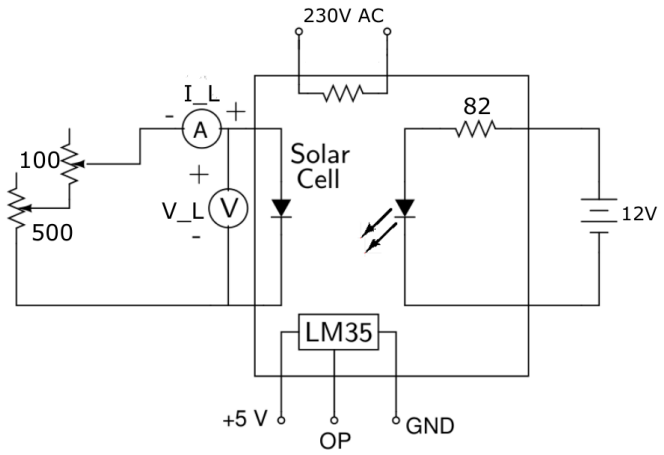

Fig. Circuit diagram for lighted I/V characteristics

3 Simulation

3.1 Code Snippet

```
Solar Cell I-V Characteristics

* Including Solar cell subcircuit
.include Solar_Cell.txt
* Circuit connections
Vs 1 0 dc 20
R1 1 2 100
X1 2 0 solar_cell
.control
* Plot settings
set color0 = white
set color1 = black
set color2 = red
************ T = 35 *************
* Setting the temperature
set temp=35
dc vs -2 2 0.01
* I-V Plot
print -i(Vs) v(2) > IV_light_35.txt
```

```
print i(Vs)*v(2) v(2) > IV_light_power_35.txt
* Measuring cutin voltage (1mA)
meas dc cutin find v(2) when i(Vs) = 1m
* Measuring Isc and Vsc
meas dc Isc find i(Vs) when v(2) = 0
meas dc Voc find v(2) when i(Vs) = 0
* Measuring Im and Vm
let derivout = deriv(v(2)*i(Vs))
meas dc Im find i(Vs) when derivout = 0
meas dc Vm find v(2) when derivout = 0
* Measuring FF
let FF = (Im*Vm)/(Isc*Voc)
print FF
************ T = 45 *************
* Setting the temperature
set temp=45
dc vs -2 2 0.01
* I-V Plot
print -i(Vs) v(2) > IV_light_45.txt
print i(Vs)*v(2) v(2) > IV_light_power_45.txt
* Measuring cutin voltage (1mA)
meas dc cutin find v(2) when i(Vs) = 1m
* Measuring Isc and Vsc
meas dc Isc find i(Vs) when v(2) = 0
meas dc Voc find v(2) when i(Vs) = 0
* Measuring Im and Vm
let derivout = deriv(v(2)*i(Vs))
meas dc Im find i(Vs) when derivout = 0
meas dc Vm find v(2) when derivout = 0
* Measuring FF
let FF = (Im*Vm)/(Isc*Voc)
print FF
************ T = 55 *************
* Setting the temperature
set temp=55
dc vs -2 2 0.01
* I-V Plot
print -i(Vs) v(2) > IV_light_55.txt
```

```
print i(Vs)*v(2) v(2) > IV_light_power_55.txt
* Measuring cutin voltage (1mA)
meas dc cutin find v(2) when i(Vs) = 1m
* Measuring Isc and Vsc
meas dc Isc find i(Vs) when v(2) = 0
meas dc Voc find v(2) when i(Vs) = 0
* Measuring Im and Vm
let derivout = deriv(v(2)*i(Vs))
meas dc Im find i(Vs) when derivout = 0
meas dc Vm find v(2) when derivout = 0
* Measuring FF
let FF = (Im*Vm)/(Isc*Voc)
print FF
************ T = 65 *************
* Setting the temperature
set temp=65
dc vs -2 2 0.01
* I-V Plot
print -i(Vs) v(2) > IV_light_65.txt
print i(Vs)*v(2) v(2) > IV_light_power_65.txt
* Measuring cutin voltage (1mA)
meas dc cutin find v(2) when i(Vs) = 1m
* Measuring Isc and Vsc
meas dc Isc find i(Vs) when v(2) = 0
meas dc Voc find v(2) when i(Vs) = 0
* Measuring Im and Vm
let derivout = deriv(v(2)*i(Vs))
meas dc Im find i(Vs) when derivout = 0
meas dc Vm find v(2) when derivout = 0
* Measuring FF
let FF = (Im*Vm)/(Isc*Voc)
print FF
************ T = 75 *************
* Setting the temperature
set temp=75
dc vs -2 2 0.01
* I-V Plot
print -i(Vs) v(2) > IV_light_75.txt
```

```
print i(Vs)*v(2) v(2) > IV_light_power_75.txt
* Measuring cutin voltage (1mA)
meas dc cutin find v(2) when i(Vs) = 1m
* Measuring Isc and Vsc
meas dc Isc find i(Vs) when v(2) = 0
meas dc Voc find v(2) when i(Vs) = 0
* Measuring Im and Vm
let derivout = deriv(v(2)*i(Vs))
meas dc Im find i(Vs) when derivout = 0
meas dc Vm find v(2) when derivout = 0
* Measuring FF
let FF = (Im*Vm)/(Isc*Voc)
print FF
.endc
.end
```

3.2 Simulation Results

Given below is the plot for I_D vs V_D waveform for the Solar Cell obtained from the dc analysis of the circuit at different temperatures under dark conditions:

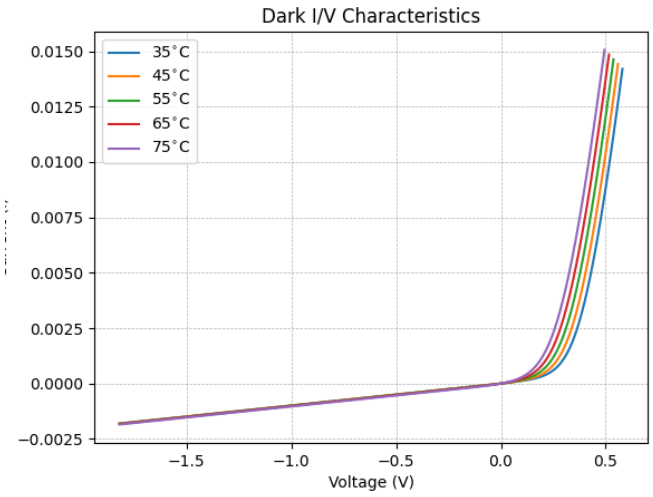

Fig. I-V Characteristics at different temperatures under dark conditions

Given below is the plot for P_D vs V_D waveform for the Solar Cell obtained

from the dc analysis of the circuit at different temperatures under dark conditions:

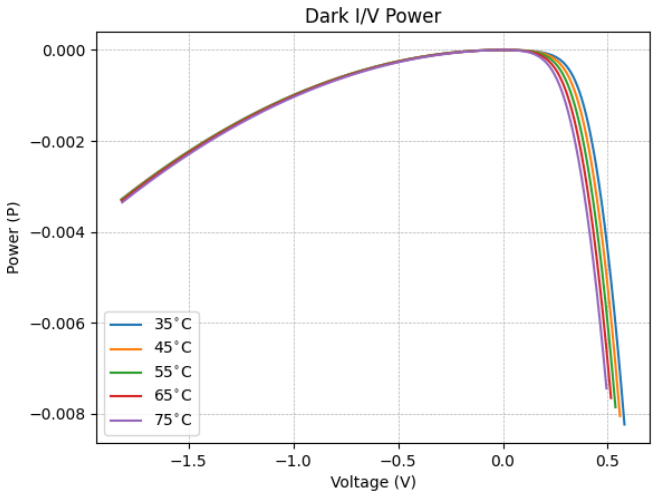

Fig. P-V Characteristics at different temperatures under dark conditions

Given below is the plot for I_D vs V_D waveform for the Solar Cell obtained from the dc analysis of the circuit at different temperatures under lighted conditions:

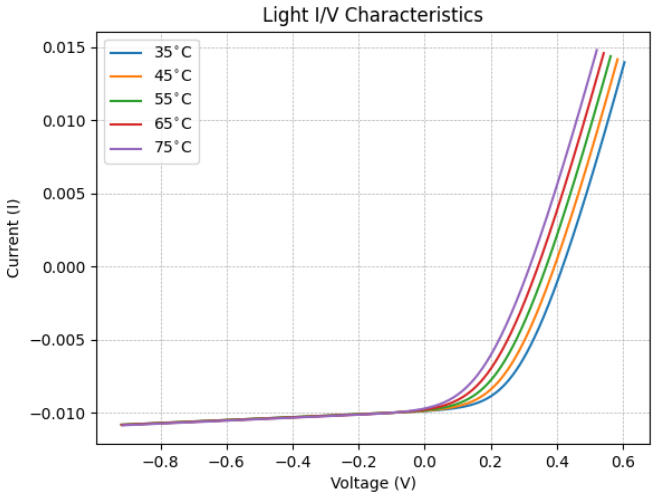

Fig. I-V Characteristics at different temperatures under lighted conditions

Given below is the plot for P_D vs V_D waveform for the Solar Cell obtained from the dc analysis of the circuit at different temperatures under lighted conditions:

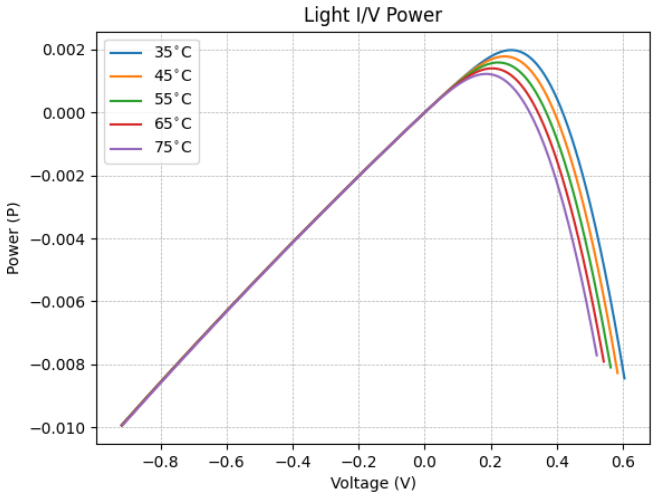

Fig. P-V Characteristics at different temperatures under lighted conditions

Given below are the measured readings using the above simulations for Solar Cell under lighted conditions at varying temperatures:

Temperature	Cutin	I_{SC}	V_{OC}	I_M	V_M	FF
35°C	0.403	9.881	0.418	7.564	0.262	0.479
45°C	0.378	9.864	0.393	7.356	0.242	0.459
55°C	0.352	9.834	0.369	7.123	0.223	0.438
65°C	0.327	9.786	0.344	6.864	0.204	0.417
75°C	0.302	9.708	0.319	6.579	0.186	0.396

4 Experimental Results

Given below are my readings for I_D and V_D for the Solar Cell under dark conditions for varying temperatures:
Given below is the plot for I_D vs V_D waveform for the Solar Cell obtained from the above observations:

Voltage	I (T=35°C)	I (T=45°C)	I (T=55°C)	I (T=65°C)	I (T=75°C)
0.025	0.01	0.029	0.028	0.041	0.045
0.05	0.02	0.058	0.05	0.101	0.095
0.075	0.086	0.1	0.108	0.158	0.157
0.1	0.09	0.143	0.176	0.229	0.285
0.125	0.18	0.214	0.257	0.322	0.366
0.15	0.23	0.31	0.338	0.49	0.529
0.175	0.339	0.418	0.468	0.684	0.758
0.2	0.43	0.593	0.659	0.926	1.011
0.225	0.621	0.767	0.946	1.214	1.49
0.25	0.79	1.01	1.35	1.88	2.13
0.275	1.115	1.364	1.838	2.37	3.08
0.3	1.34	1.838	2.54	3.36	4.28
0.325	1.998	2.7	3.47	4.76	6.4
0.35	2.8	3.73	4.89	7.05	9.63
0.375	3.9	5.27	7.1	10.19	15.19
0.4	5.36	7.4	9.86	14.91	22.9
0.425	6.92	10.97	15.72	25.1	35.3
0.45	11.01	16.27	27	38.6	54.9
0.475	17.08	28.8	39.3	59.4	91.8
0.5	30.1	42.4	64.4	92.6	135.1

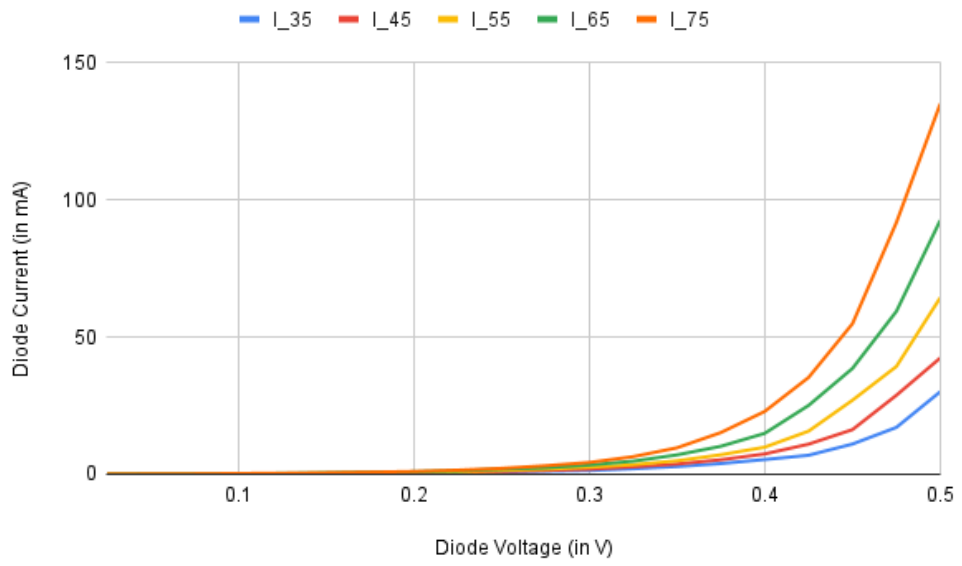

Fig. I-V Characteristics at different temperatures under dark conditions

Given below is the plot for $\log(I_D)$ vs V_D waveform for the Solar Cell obtained from the above observations:

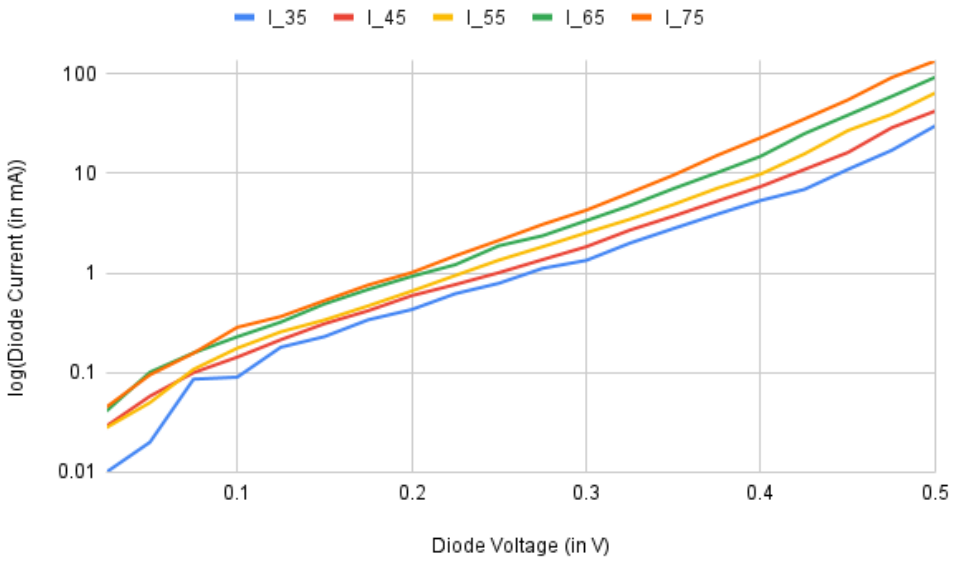

Fig. log(I)-V Characteristics at different temperatures under dark conditions

Given below are the readings observed for the observations given above:

Temperature	V_D ($I_D = 1mA$)	V_D ($I_D = 2mA$)	V_D ($I_D = 5mA$)	η for low bias	η for high bias
35°C	0.275	0.325	0.400	3.061	1.899
45°C	0.250	0.300	0.375	2.531	1.989
55°C	0.225	0.275	0.350	2.682	1.734
65°C	0.200	0.250	0.325	2.541	1.948
75°C	0.200	0.250	0.300	2.431	1.831

Given below are my readings for I_L and V_L for the Solar Cell under lighted conditions for varying temperatures:

Voltage	I (T=35°C)	I (T=45°C)	I (T=55°C)	I (T=65°C)	I (T=75°C)
0.15	9.86	9.78	9.72	9.59	9.47
0.175	9.79	9.71	9.63	9.43	9.29
0.2	9.69	9.61	9.43	9.19	8.99
0.225	9.57	9.46	9.24	8.93	8.64
0.25	9.44	9.16	8.96	8.44	8
0.275	9.21	8.77	8.56	7.92	7.2
0.3	8.85	8.3	7.93	6.99	5.88
0.325	8.49	7.69	7.08	5.75	3.99
0.35	7.8	6.94	5.55	4.02	0.51
0.375	6.88	5.63	3.74	1.41	
0.4	5.63	3.66	0.59		
0.425	3.51	0.75			

Given below is the plot for I_L vs V_L waveform for the Solar Cell obtained from the above observations:

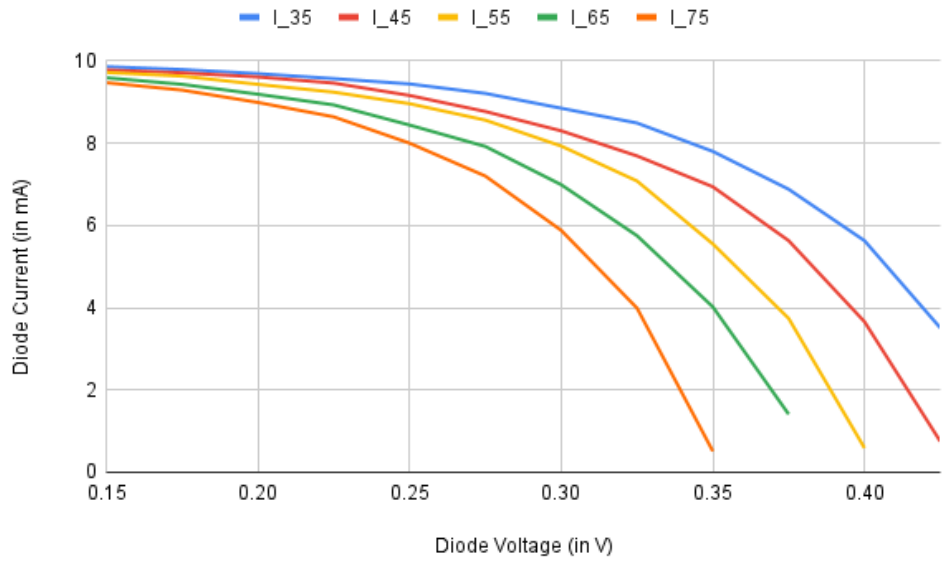

Fig. I-V Characteristics at different temperatures under lighted conditions

Given below is the plot for P_L vs V_L waveform for the Solar Cell obtained from the above observations:

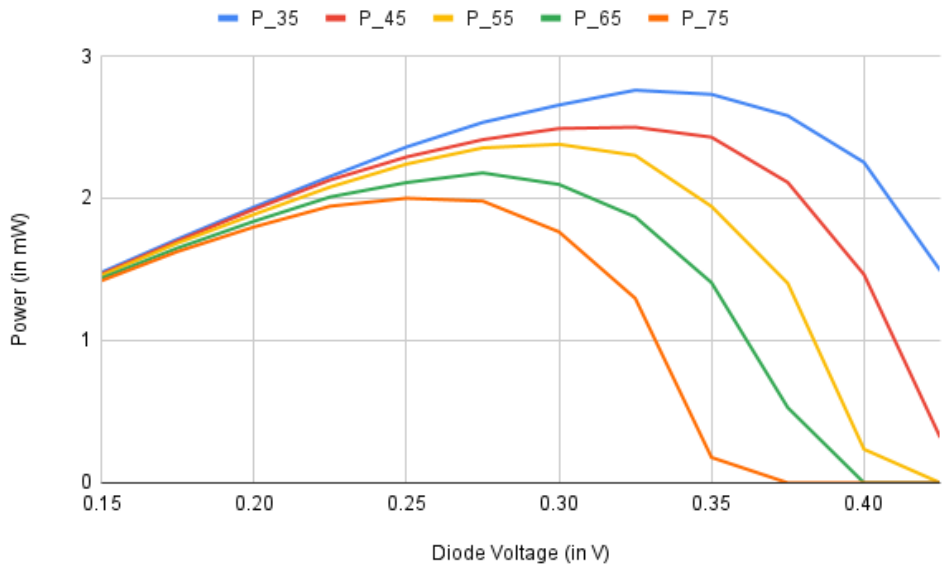

Fig. P-V Characteristics at different temperatures under lighted conditions

Given below are the readings observed for the observations given above:

Temperature	I_{SC}	V_{OC}	I_M	V_M	FF
35°C	9.86	0.4625	8.49	0.325	0.605
45°C	9.78	0.425	7.69	0.325	0.601
55°C	9.72	0.4125	7.93	0.3	0.593
65°C	9.59	0.3875	7.92	0.275	0.586
75°C	9.47	0.0.3625	8	0.25	0.583

Given below is the plot for the Fill Factor (FF) with varying temperature:

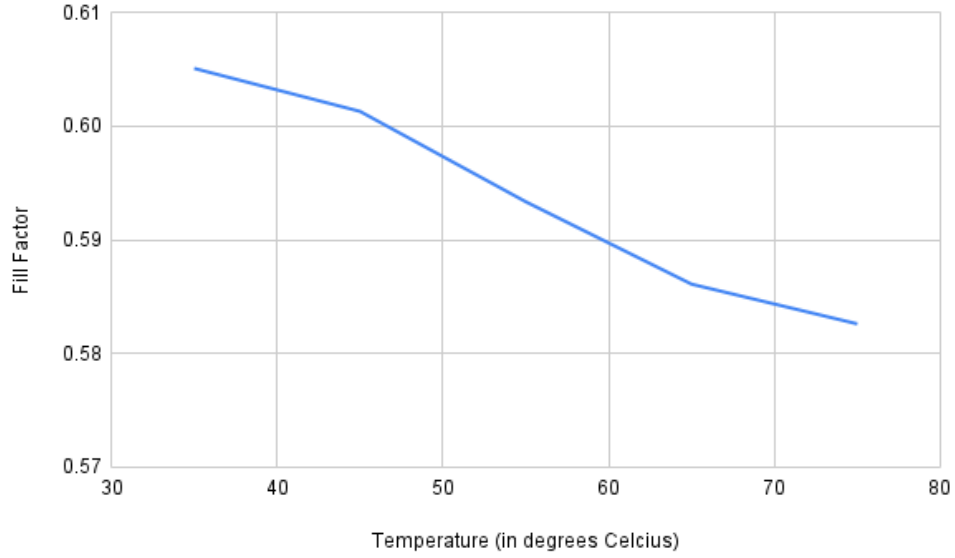

Fig. Fill Factor at different temperatures under lighted conditions

Using the observations taken above, we can conclude that V_{OC}, I_{SC} and Fill Factor decrease with increasing temperature. The decrease in V_{OC} is quite substantial compared to the decrease in I_{SC}