Determining the power and efficiency of a solar cell

Timofei Ryko

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1 Solar cell short circuit current dependence on illuminance.

The solar cell was connected to a multimeter with two wires and the optimal direct current measuring range was chosen (2mA).

Then, the lamp was mounted on a holder in the highest possible position and the solar cell was placed under it. The light source was lowered averagely 30 times and after every lowering the value of illuminance in lx and circuit current in mA were measured. During the experiment measured range of multimeter was changed to 20mA when it became too high.

All the data were entered in Google Sheets, the table is shown on the page 2 (table 1). To find the value of power of light Pv in mW for each value of illuminance the equation $Pv(mW) = E \cdot S \cdot 3.5 \cdot 10^{-4}$ was used, where E is given in lx and the S in cm^2 ($S = 9cm^2$).

To study the correlation between Pv and I a graph was drawn up and the equation of the trend line was calculated (figure 1).

The linear correlation between power of light and short circuit current is observed. This is due to the fact that more photons are sent, more electrons are excited by light travel through the solar cell – light energy is converted into electrical energy.

E (lx)	I (mA)	Pv (mW)
561	0.100	1.767
591	0.106	1.862
611	0.109	1.925
635	0.114	2.000
657	0.118	2.070
729	0.131	2.296
781	0.141	2.460
843	0.152	2.656
890	0.161	2.804
933	0.170	2.939
970	0.177	3.056
1,052	0.193	3.314
1,092	0.199	3.440
1,182	0.216	3.723
1,258	0.231	3.963
1,393	0.255	4.388
1,481	0.270	4.665
1,579	0.290	4.974
1,738	0.320	5.475
2,060	0.380	6.489
2,430	0.448	7.655
2,930	0.546	9.230
3,560	0.669	11.214
4,650	0.877	14.648
5,330	1.014	16.790
6,290	1.237	19.814
7,250	1.410	22.838
8,470	1.605	26.681
10,850	2.160	34.178
13,400	2.820	42.210

Table 1: Data measured for task 1

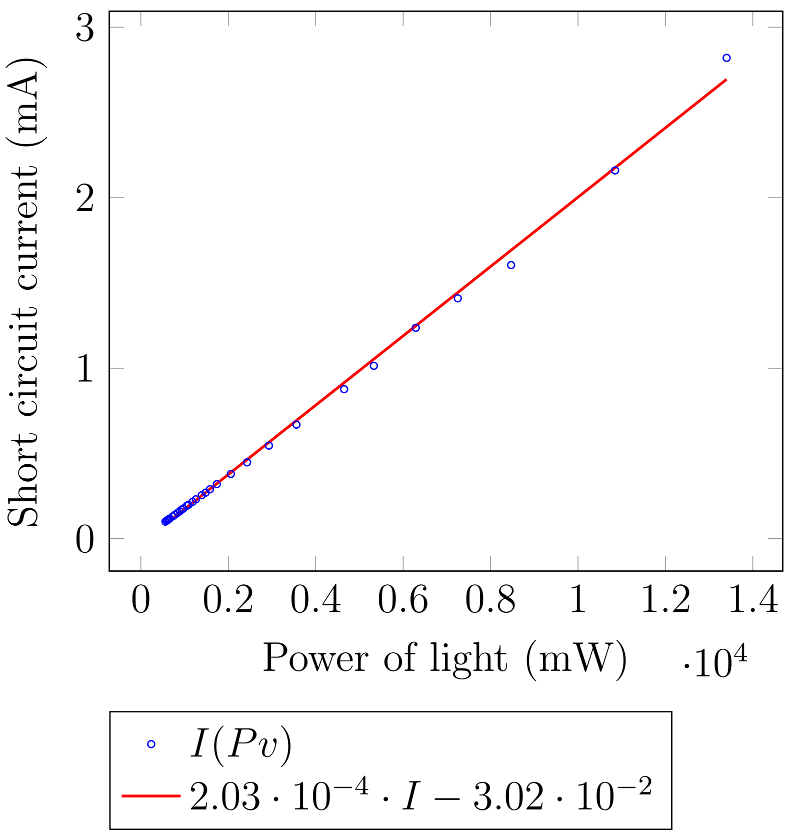


Figure 1: Short circuit current vs power of light

2 The current-voltage characteristic and the energy conversion efficiency of a solar cell

To study the electrical properties of a solar cell the electrical circuit allowing to measure the current-voltage characteristic of the solar cell was built: a voltmeter and a resistor were connected in parallel with the solar cell and an ampermeeter.

During the measurement voltage and current were different, but light intensity was constant. The lamp was brought on the height to give the illuminance 3390 lx. Electrical power was calculated according to the Joule's law: $Pe(mW) = I(mA) \cdot U(V)$ and power of light was calculated using the same formula as in the task 1. The effectiveness was evaluated as follows: $\eta = \frac{Pe}{Pv} \cdot 100\%$. All the results are presented in the table 2 on the page 4. The highest efficiency 7.728% was observed at $R = 3000$.

R (Ohm)	**U (V)**	**I (mA)**	**Pe (mW)**	η **(%)**
0	0.000	0.560	0.000	0.000
500	0.288	0.560	0.161	1.510
1,000	0.561	0.560	0.314	2.942
1,500	0.837	0.558	0.467	4.374
2,000	1.102	0.552	0.608	5.697
3,000	1.587	0.520	0.825	7.728
5,000	2.040	0.390	0.796	7.450
8,000	2.110	0.259	0.547	5.118
20,000	2.190	0.111	0.243	2.276
50,000	2.210	$4.5 \cdot 10^{-2}$	$9.95 \cdot 10^{-2}$	0.931

Table 2: Electrical I-V characteristics of the single solar cell for light 3390 lx

3 Connecting solar cells into a solar panel

We studied two cases: solar cells were connected in series and in parallel. The solar cell was placed in the same place in both experiments, the light source was fixed to achieve constant illuminance equal to the illuminance in the previous task.

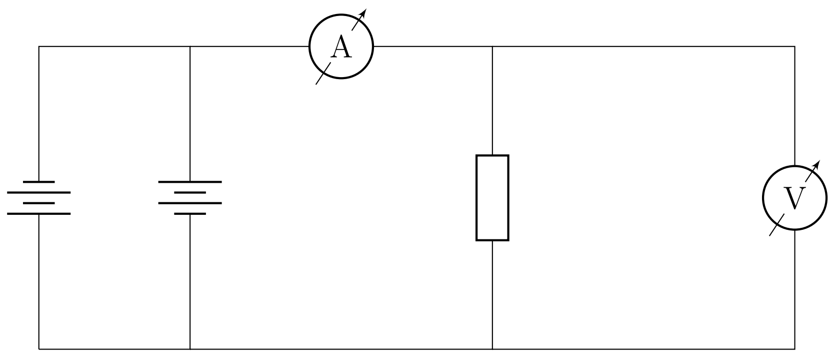


Figure 2: Two solar cells connected to the circuit in parallel

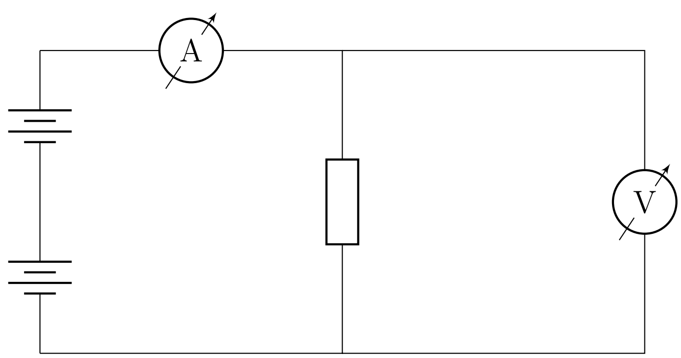


Figure 3: Two solar cells connected to the circuit in series

The illuminance was 3390 lx and P_v was 10.58 mW, based on the formula that is given in the section 1. The obtained I-V characteristics are presented in the tables below.

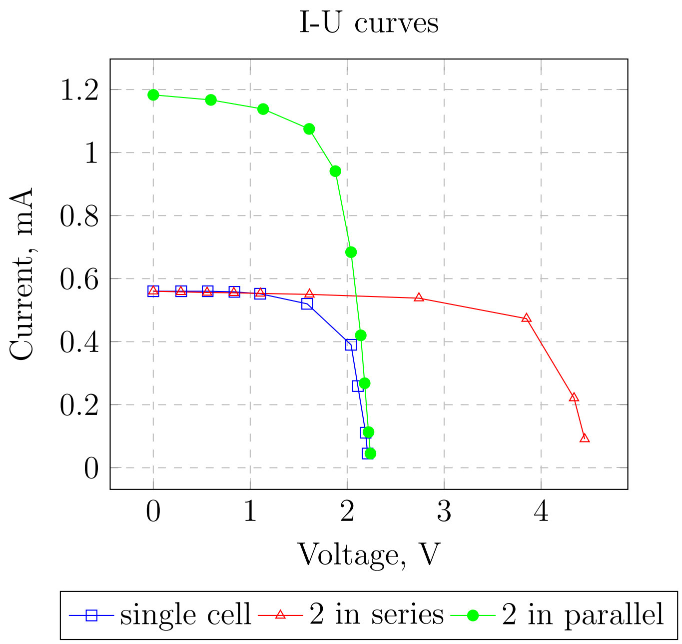
Based on this data, the following curves were plotted: Current-Voltage , Power-Voltage, Efficiency-Voltage, Power-Resistance.

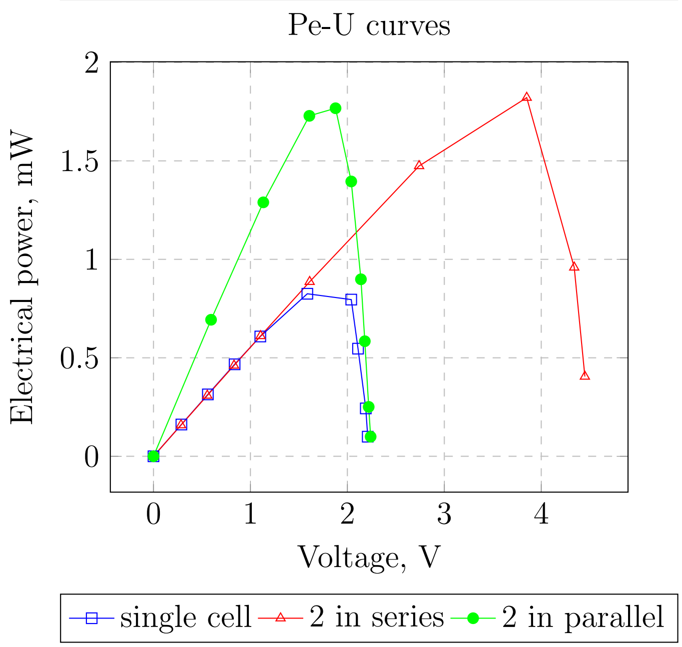
R (Ohm)	**U (V)**	**I (mA)**	**Pe (mW)**	η **(%)**
0	0.000	1.183	0.000	0.000
500	0.594	1.167	0.693	3.246
1,000	1.133	1.138	1.289	6.037
1,500	1.608	1.075	1.729	8.094
2,000	1.878	0.941	1.767	8.275
3,000	2.040	0.684	1.395	6.534
5,000	2.140	0.420	0.899	4.208
8,000	2.180	0.268	0.584	2.736
20,000	2.220	0.113	0.251	1.175
50,000	2.240	$4.5 \cdot 10^{-2}$	$9.95 \cdot 10^{-2}$	$2 \cdot 10^{-3}$

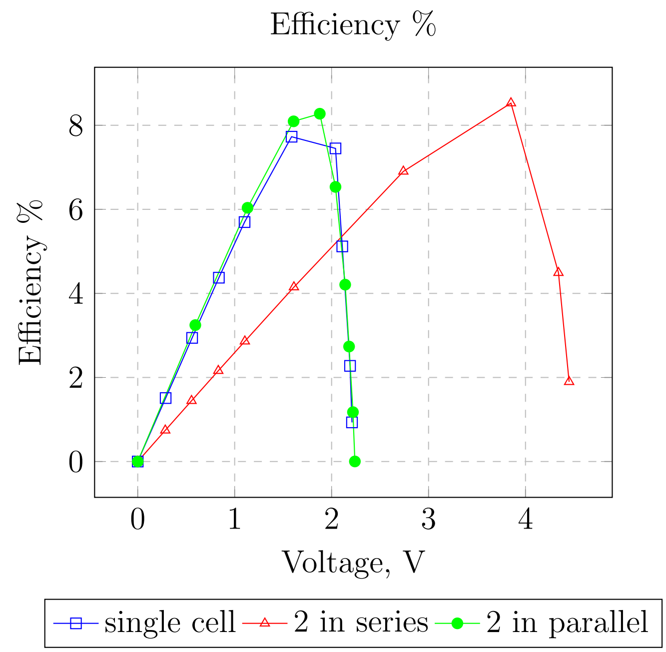
Table 3: Electrical I-V characteristics of the two solar cells connected in parallel for light 3390 lx

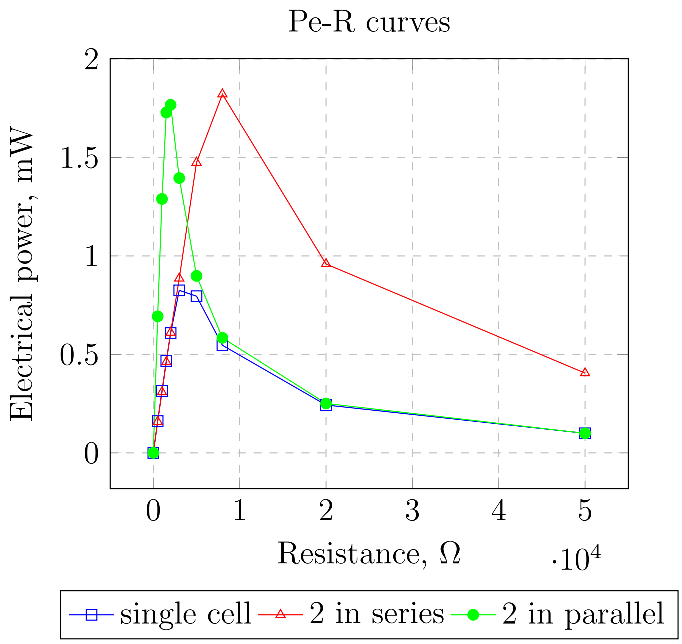
R (Ohm)	**U (V)**	**I (mA)**	**Pe (mW)**	η **(%)**
0	0.000	0.560	0.000	0.000
500	0.284	0.558	0.159	0.742
1,000	0.555	0.556	0.309	1.445
1,500	0.831	0.555	0.461	2.160
2,000	1.105	0.553	0.611	2.861
3,000	1.611	0.550	0.886	4.149
5,000	2.740	0.538	1.474	6.902
8,000	3.850	0.473	1.821	8.527
20,000	4.340	0.221	0.959	4.491
50,000	4.450	$9.1 \cdot 10^{-2}$	0.405	1.896

Table 4: Electrical I-V characteristics of the two solar cells connected in series for light 3390 lx


I-U curves
Current, mA
Voltage, V
1.2
1
0.8
0.6
0.4
0.2
0
0
1
2
3
4
single cell
2 in series
2 in parallel


Pe-U curves
Electrical power, mW
Voltage, V
2
1.5
1
0.5
0
0
1
2
3
4
single cell
2 in series
2 in parallel


Efficiency %
Efficiency %
Voltage, V
0
2
4
6
8
0
1
2
3
4
single cell
2 in series
2 in parallel


Pe-R curves
Electrical power, mW
Resistance, Ω
$\cdot 10^4$
0
0.5
1
1.5
2
0
1
2
3
4
5
single cell
2 in series
2 in parallel

Conclusion

Based on theese curves, we can say that:

- For in parallel configuration higher current is observed in compare with single cell and in series configurations
- For multiple sollar cells connected in parallel or in series higher electrical power is observed (it is simply becuase there are more cells)
- Hovewer, maximum efficiency is the same in all cases
- Maximum value of efficiency is hited when voltage isn't very law and isn't very high
- Maximum efficiency in the case of a series connection is achieved at higher voltage values than in other cases