Photovoltaic

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1 Introduction

The main goal of this experience is to find the efficiency and the fill factor of the Photovoltaic cell. The efficiency: $\epsilon = \frac{P_{cell}}{P_{sun}}$, is calculated through measurements of the current and voltage of the photovoltaic cell to find the power of the cell and measurements of the tension of a Peltier cell and a pyranometer to find the solar intensity.
The Fill factor is an index that regards the deviation between an ideal cell: $FF = \frac{I_{max}V_{max}}{I_{sc}V_{oc}}$. To find it we took some curves I-V of the cell with different light intensities; the curves are fitted and translated at negative currents using the diode formula:

$$I = I_{photo} + I_0 \left(e^{qV/k_b T} - 1 \right) \tag{1}$$

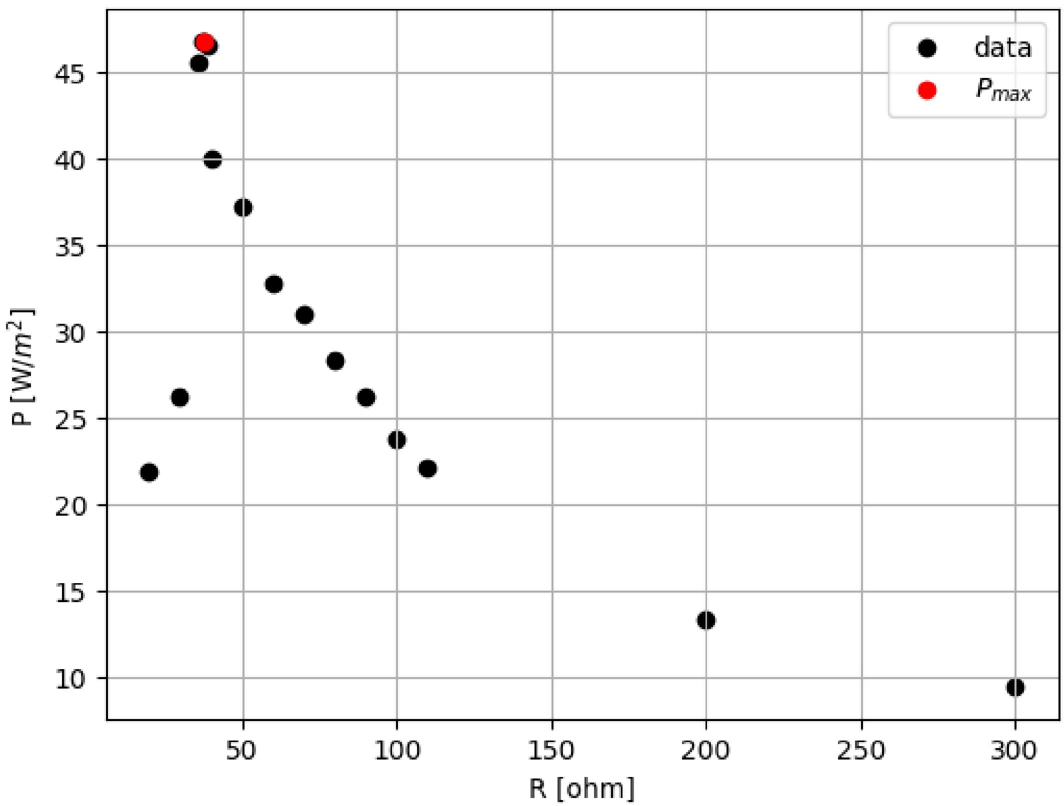
2 Measurement Procedure

In the first part of the experience, we want to find the value of resistance that maximises the power of the solar cell. To do that we connect the photovoltaic cell in series with a multimeter to measure the current, with a decade to vary the resistance of the load and in parallel with another multimeter to measure the voltage. We connect also the Peltier cell to a multimeter to measure the voltage.
We change the resistance of the load to find different values of I and V for different values of R, paying attention to not covering and moving the photovoltaic cell.
We measure also for each value of the current and voltage of the photovoltaic cell the corresponding value of tension of the pyranometer and the Peltier cell that gives us information on the solar intensity for each measurement.
In the second part of the experience we try to find the calibration of the Peltier cell, we connect the Peltier cell in series to the current generator and in parallel to the multimeter to measure the voltage. Varying the current we take measurements of the tension for each value of current.
Finally, we measure the I-V curve for the photovoltaic cell at 3 different light intensities. Firstly we take a measure in the dark, we keep the photovoltaic cell in the box and we connect the cell in series to a voltage generator and a multimeter to measure the current. Then with a lamp close to the photovoltaic cell and the last one far to the lamp.
We vary the voltage and we measure the current.

3 Data Analysis

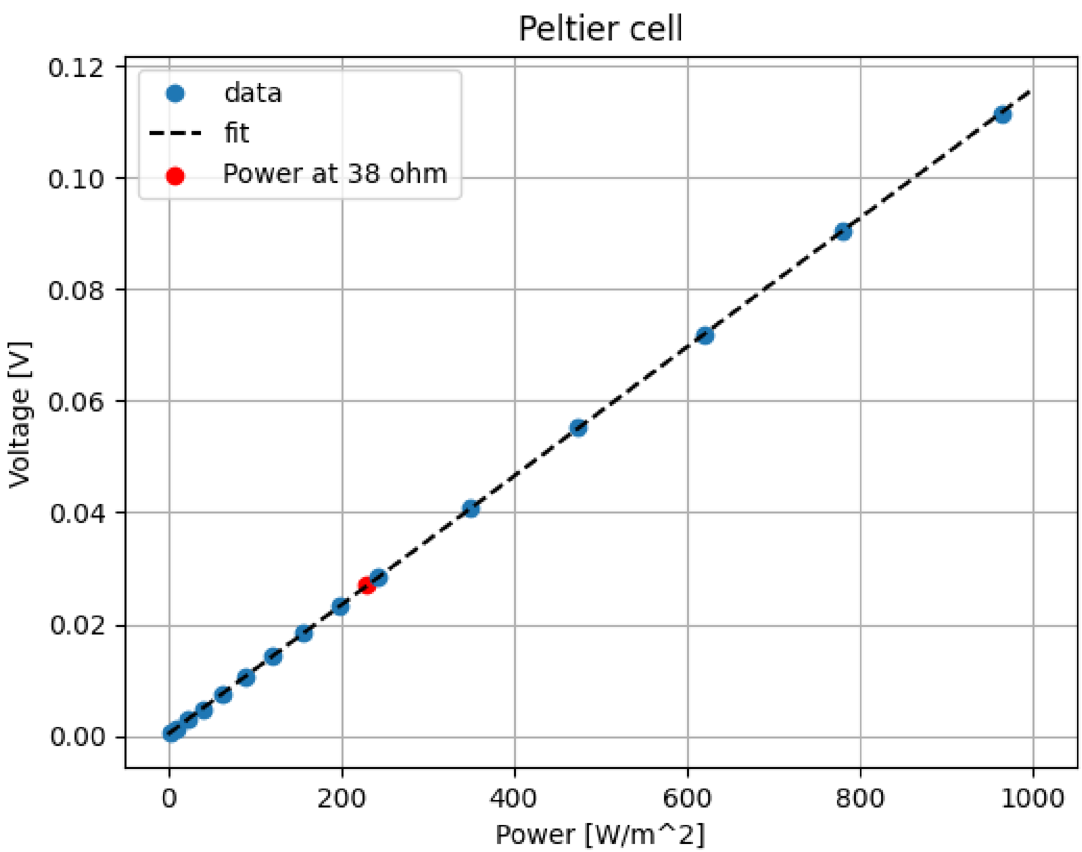
3.1 Maximum of the load

We obtain that the maximum value of photovoltaic cell power is obtained for $R = 38 \pm 1\Omega$: ($P_{38} = \frac{I_{38}V_{38}}{A_{cell}}$, $A_{cell} = 144cm^2$).



3.2 Efficiency of the cell

We find for each value of the voltage of the Peltier cell the corresponding value of power: $P_{peltier} = \frac{I_{pel}^2 R_{pel}}{A_{pel}}$, where $R_{pel} = 21.52 \pm 0.01\Omega$ and $A_{pel} = 9cm^2$.



Then we use the value of the voltage of the Peltier cell, which we have measured before, corresponding to the maximum value of power for the solar cell(which corresponds to $R = 38 \pm 1\Omega$) namely: $V^*_{pel} = 0.03 \pm 0.03V$ to find the value of sun power.
In order to do this, we fit the data with a line:

$$V(P) = mP + q \tag{2}$$

and we find that P^{pel}_{sun} is:

$$P_{sun} = \frac{V^*_{pel} - q}{m} = 230 \pm 100 \frac{W}{m^2} \tag{3}$$

So we can calculate the value of efficiency of the solar cell:

$$\epsilon^{Pel}_{cell} = \frac{P_{38}}{P^{pel}_{sun}} = 0.2 \pm 0.1 \tag{4}$$

Using the pyranometer instead of the Peltier cell to determine the solar power:

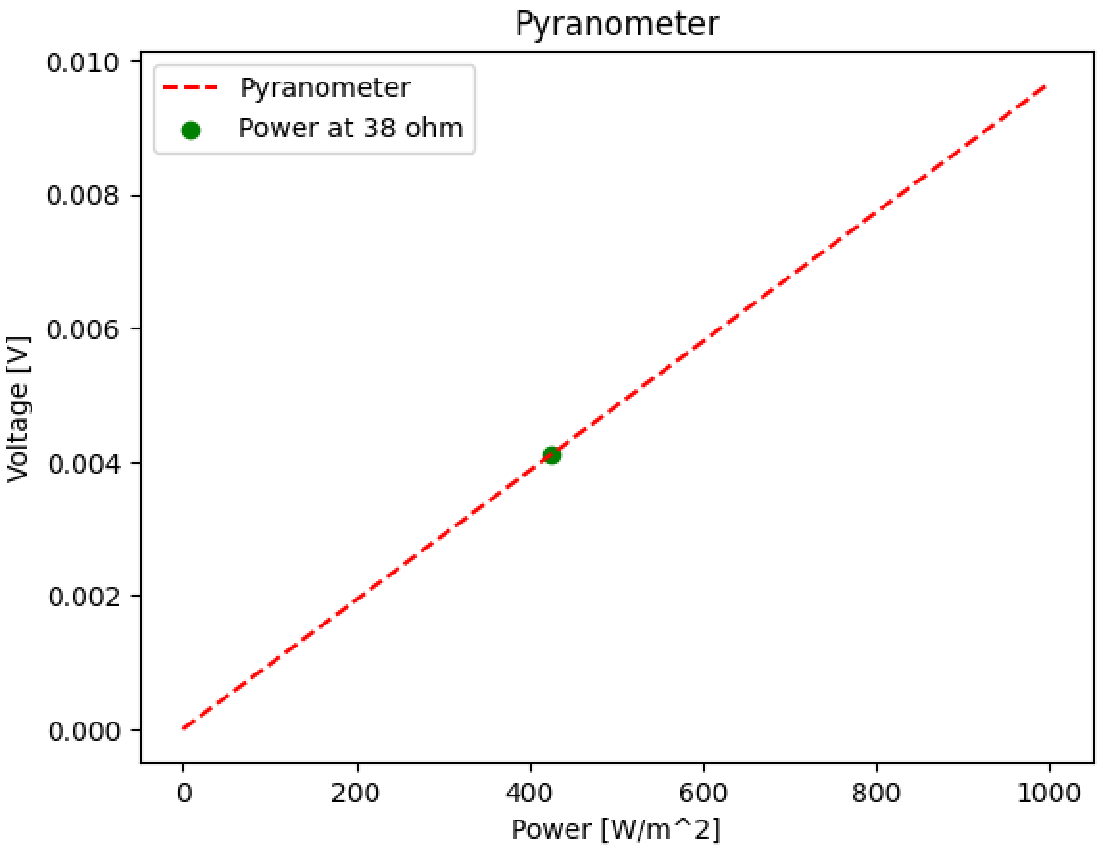
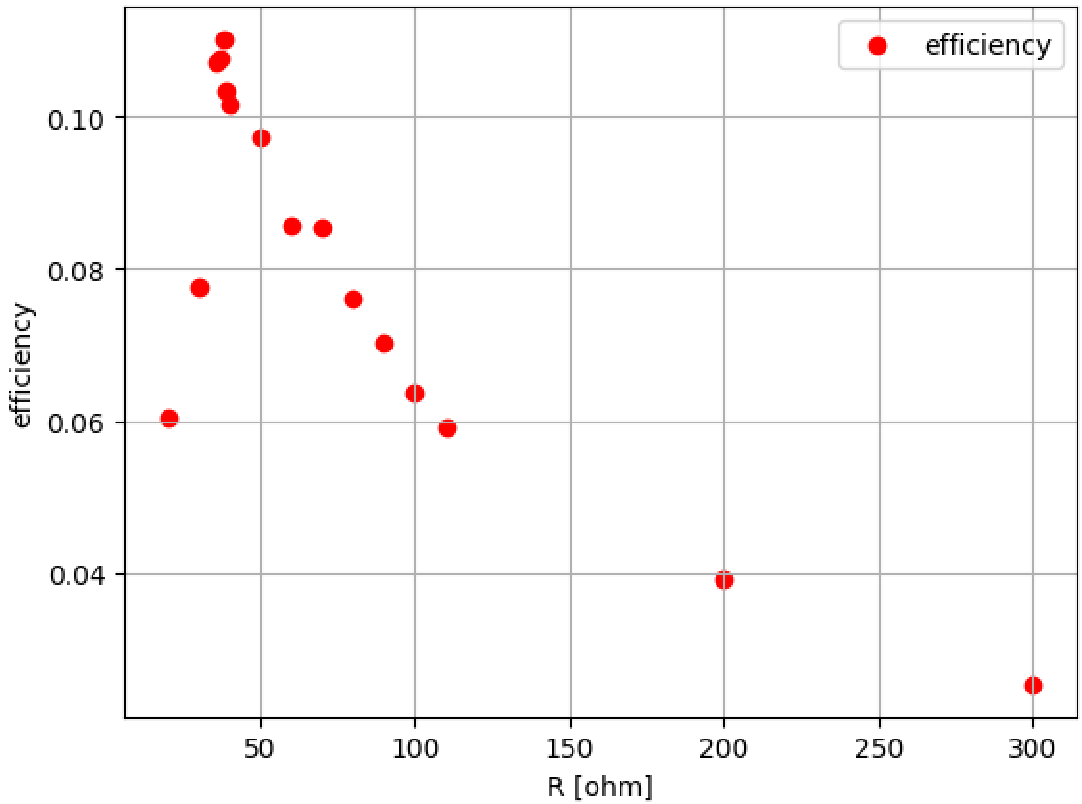


Figura 1: $V_{pyr} = P_{sol} \cdot m_{pyr}$

We measure for the resistance of 38Ω: $V_{pyr} = 4.2 \pm 0.1 mV$, we know the sensitivity of pyranometer: $m_{pyr} = 9.66 \frac{\mu V m^2}{W}$, so the solar power will be: $P^{pyr}_{sun} = \frac{V_{pyr}}{m_{pyr}} = 424 \pm 10 \frac{W}{m^2}$.
Now we can find the efficiency of the solar cell:

$$\epsilon^{pyr}_{cell} = \frac{P_{38}}{P_{pyr}} = 0.11 \pm 0.01 \tag{5}$$

We can plot also for the different values of R the difference values of efficiency, calculated using the pyranometer, to determine if the value at 38Ω is the one that maximises the photovoltaic cell efficiency.

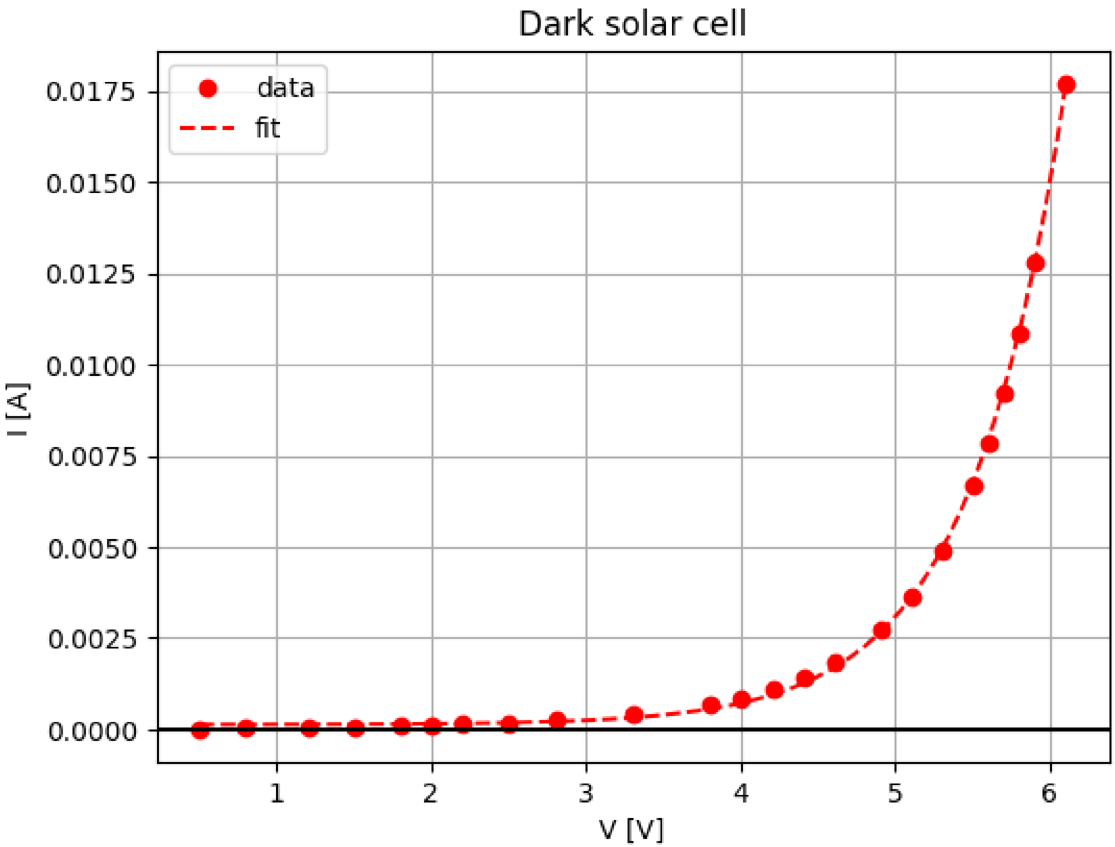


We find that the maximum efficiency is obtained for $R = 38 \pm 1\Omega$.

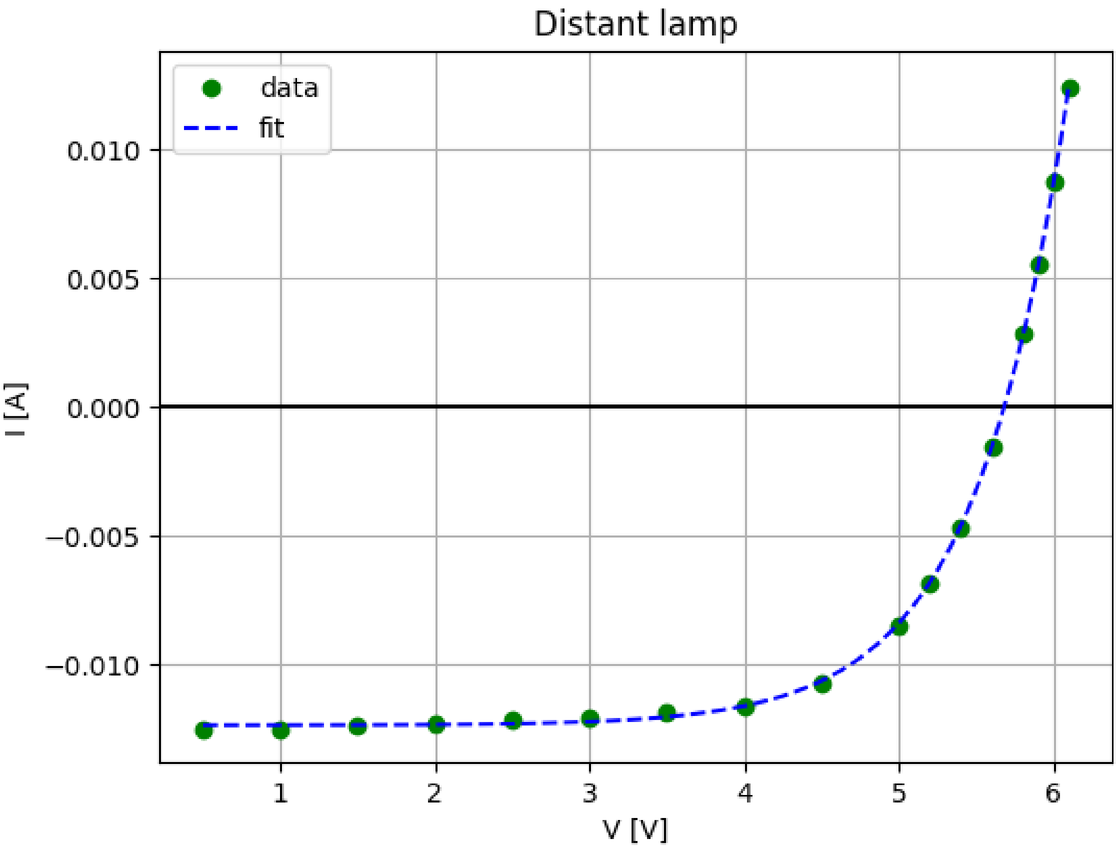
3.3 Fill Factor

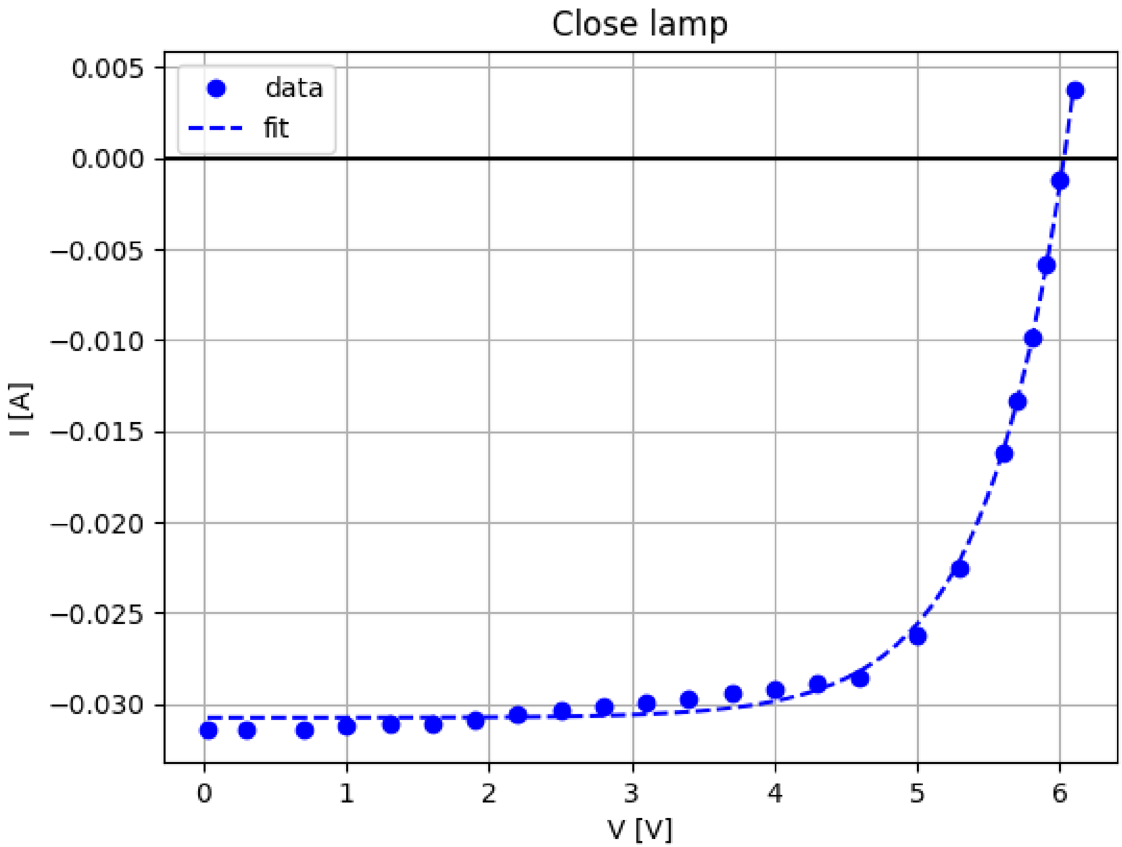
We plot for the 3 different light intensities the I-V curve using the fit of Shockley law:

$$I = a\left(e^{bx} - 1\right) + d \tag{6}$$

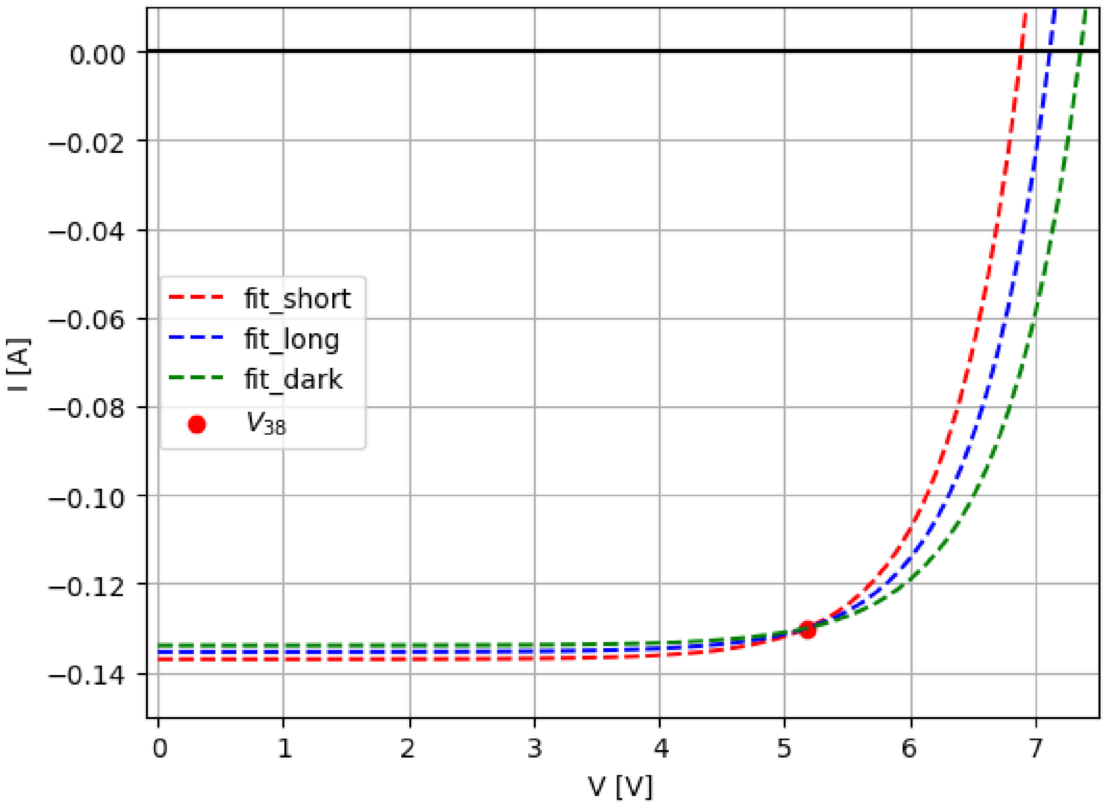


Dark solar cell
data
fit
0.0175
0.0150
0.0125
0.0100
0.0075
0.0050
0.0025
0.0000
I [A]
1
2
3
4
5
6
V [V]

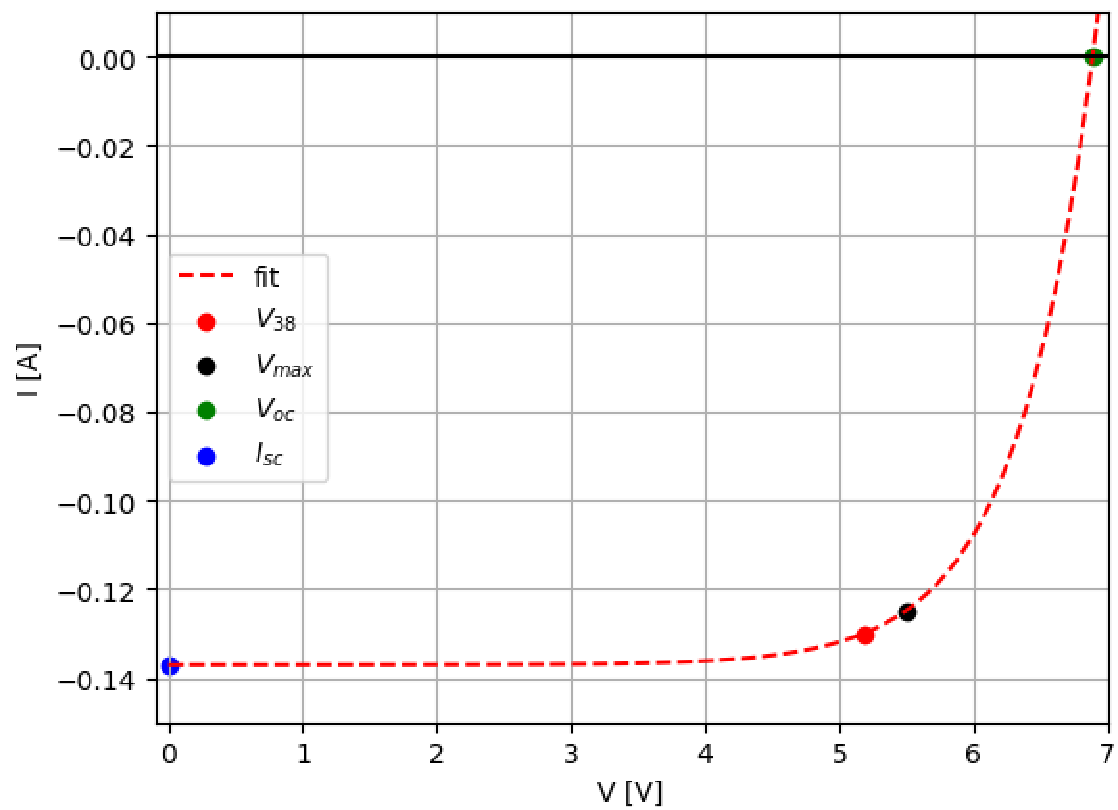

Distant lamp
data
fit
0.010
0.005
0.000
−0.005
−0.010
I [A]
1
2
3
4
5
6
V [V]



Then we shift the 3 curves in such a way that they pass by I and V corresponding at 38Ω.



Now we can find the open circuit Voltage: $V_{oc} = 6.9 \pm 0.1V$, the short circuit current: $I_{sc} = -0.137 \pm 0.005A$ and the values of V and I that maximise the power: $V_{max} = 5.5 \pm 0.1V$ and $I_{max} = -0.125 \pm 0.005A$.



So finally we can find the Fill Factor as:

$$FF_{theory} = \frac{I_{max}V_{max}}{I_{sc}V_{oc}} = 0.73 \pm 0.03 \tag{7}$$

and

$$FF_{exp} = \frac{I_{38}V_{38}}{I_{sc}V_{oc}} = 0.69 \pm 0.03 \tag{8}$$

4 Conclusions

Regarding the efficiency calculated using the Peltier cell, it probably is overestimated because the solar intensity is underestimated. The Peltier cell is very sensible of changes in temperature, just a breath of wind is enough to change a lot the voltage measured value.
The value of efficiency calculated through the pyranometer can be reasonable with classical photovoltaic cells.
The Fill Factor calculated for the cell is compatible with commercial silicon photovoltaic values which are around 0.7-0.8.