The solar panel – Characteristics and power

Experiment number	139230-EN	*Topic*	Sustainable energy, electricity				
Version	2018-12-19 / HS	*Type*	Student exercise	*Suggested for*	Grade 9-11	*p.*	1/4

Objective
To investigate how a solar panel utilizes the solar energy best.
The characteristic curves for both a single cell and the whole panel are drawn and the maximum output power is found.

Principle
Voltage and current from the solar cell are measured with varying load. For each data point, the cell's output power is calculated. Voltage and power are plotted against current.

Equipment
(Detailed equipment list on p. 4)

Solar panel
Load box
Multimeters (Qty. 2)

Lab leads

(Possibly a large halogen lamp)

Multimeter as ammeter
(This description covers our multimeter 386135 – other multimeters have similar features.)

Usually, you choose the range that gives the best resolution – but in this application it is more important to get the *inner resistance as low as possible.*

Use therefor the "A" range and the "10 A" socket (and the "COM" socket).

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Procedure

First, connect all the solar cells on the panel in series:

Black socket on the top cell connects to red socket on the one below – etc.
This leaves one red socket at the top and one black socket at the bottom unconnected.

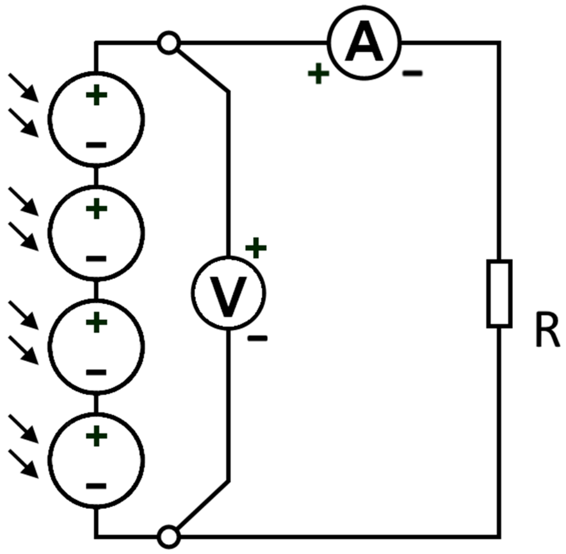
The leads must of course not cross the solar cells.

Select one multimeter as a voltmeter and connect it to the panel so it measures the voltage directly at the panel.

Set the other multimeter as an ammeter and select the largest range as described on the front page. Connect the ammeter between the solar panel and the load box.

Complete the circuit by connecting the load box to the solar panel.

See photo on front page and schematics to the right. The load box is drawn as a resistor.



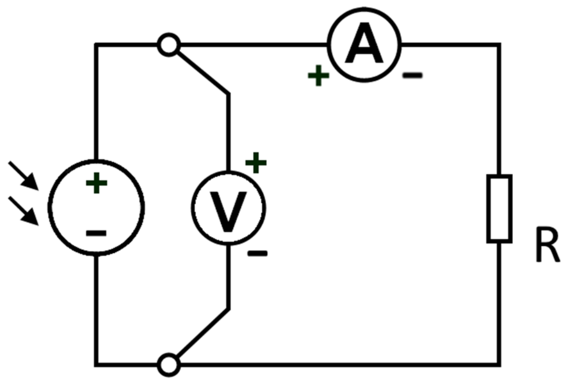
Light from the sun or from a lamp should fall perpendicular on the panel.

Measurement conditions should not vary. Therefore, the panel must not be moved relative to the light source. Likewise, it is not acceptable if a shadow falls on the panel (e.g. from a cloud) – in this case: Repeat the complete measurement series.

Write down the values of current *I* and voltage *U* for each of the possible loads (0 – 220 Ω). Take also a voltage reading with zero current (unplug one of the leads to the load box).

Present the results in a table as the one below.

After that, the complete measurement series is repeated with only a single cell. *Without moving the panel*, remove the leads that make up the series connection and re-connect the meters and the load box (schematics to the right).



The load resistance is again varied through all the possible values. Again, take a reading with current completely cut off.

Place these results in a new table.

Measured		Calculated
U	*I*	*P*
V	A	W

Extension (for fast students)

If you've got time, try to repeat the measurements on the complete panel (series connection) – but with less incoming light.

If you use a lamp, move it about 20 % further away; if the sun is used, turn the panel 40-45° away from the sun.

Theory

The purpose of solar cells is to convert as much incoming solar energy as possible into electric energy. We will look at energy per time, i.e. the power P.

$$P = U \cdot I$$

The power is zero if the current is zero or if the voltage is zero – corresponding to a load resistor that is infinitely large, resp. zero. Any other resistance means a non-zero output power.

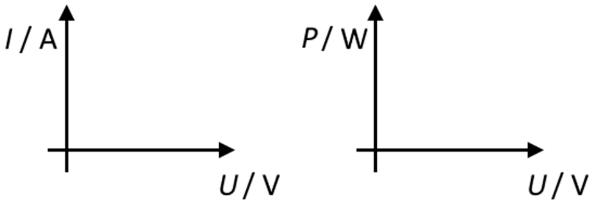
This makes it reasonable that a certain value for the load resistance will lead to maximum power.

Calculations

For all measurements, calculate the electric power P produced by the solar panel.

Next, plot I as a function of U in a coordinate system. This is called a characteristic curve. Plot both measurement series in the same coordinate system to make it easy to compare the whole panel with a single cell. Extend the curves to reach the axes.

Make similar plots of P as a function of U.



Determine the following values for both the series connection and the individual cell:

- Idle voltage, i.e. voltage when current is zero.
- Short circuit current, i.e. current when voltage Is zero.
- The maximum power produced.
- Note also at which current and voltage the power is maximum.

(If you performed the *Extension* part: Plot these measurements in the same two coordinate systems as the other. Find again the values mentioned above.)

Discussion and evaluation

Describe how the characteristic curves look for the measurements you have performed.

Which entities vary a lot from the series connection to the single cell – and which are almost unaltered?

If you made the *Extended* part: Compare similarly the behaviour of the complete solar panel in optimum and dimmer light.

What should you be aware of if you want to get as much power as possible from a given solar panel?

Teacher's notes

Concepts used

Current
Voltage
Power

Mathematical skills

Graphs

About the equipment

The multimeters in the equipment list are suitable for this experiment but many other types can be used.

The important parameters are internal resistance when used as an ammeter – and the corresponding resolution of the reading.

The voltage from a single solar cell is only up to about 0.5 V, making even a small voltage drop in the ammeter significant. This could shift the graph quite a bit away from the Origo of the coordinate system.

You should be able to read the ammeter with a precision of about 1 mA in order to get acceptable results.

Detailed equipment list

Specifically for the experiment

488505	Solar panel
422310	Load box
280130	Halogen lamp, 120 W (Not needed if the sun is shining from a cloudless sky.)

Standard lab equipment

386135	Multimeter DMM-135	(Qty. 2)
105713	Safety cable, 25 cm, blue	(Qty. 3)
105721	Safety cable, 50 cm, red	
105740	Safety cable, 100 cm, black	(Qty. 2)
105741	Safety cable, 100 cm, red	(Qty. 2)