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Solar Cell Investigation

The following procedure enables you to:

- Measure the **maximum power P_{max}** that a photovoltaic (PV) cell can deliver to a resistive load under given conditions of illumination.
- Calculate the **maximum cell efficiency** η_{max} and the **load resistance R_{Lmax} for maximum power output**.
- Measure **short-circuit current I_{sc}**, **open-circuit voltage V_{oc}** and calculate the **fill factor FF.**
- See the variation of output power with time during the day as the sun moves across the sky and as the distance that the solar radiation has to travel through the atmosphere varies.

You will need:

- PV cell.
- Direct current voltmeter and milliameter, or multimeter (internal resistance of voltmeter should be at least 1000Ω/V to permit measurement of open-circuit voltage).
- Assorted resistors in the range 1 to 250Ω to provide the resistive load and represent the device or system that you want power by solar electricity.
- Light source - preferably direct sunlight (or a bright lamp may be used).
- Connection wire.
- Light intensity meter - *not essential*

Key formulae:

V = I x R	voltage (volts) = current (amps) x resistance (ohms)	**Ohm's Law**
P = I x V	power (watts) = current x voltage	

Procedure:

Connect the solar cell and meter as shown in fig.1 - at this stage leaving out a load resistor.

Illuminate the cell with your light source.

Record meter readings for open-circuit voltage V_{oc} and short-circuit current I_{sc}.

The values will depend on the area of the cell and the intensity of illumination.

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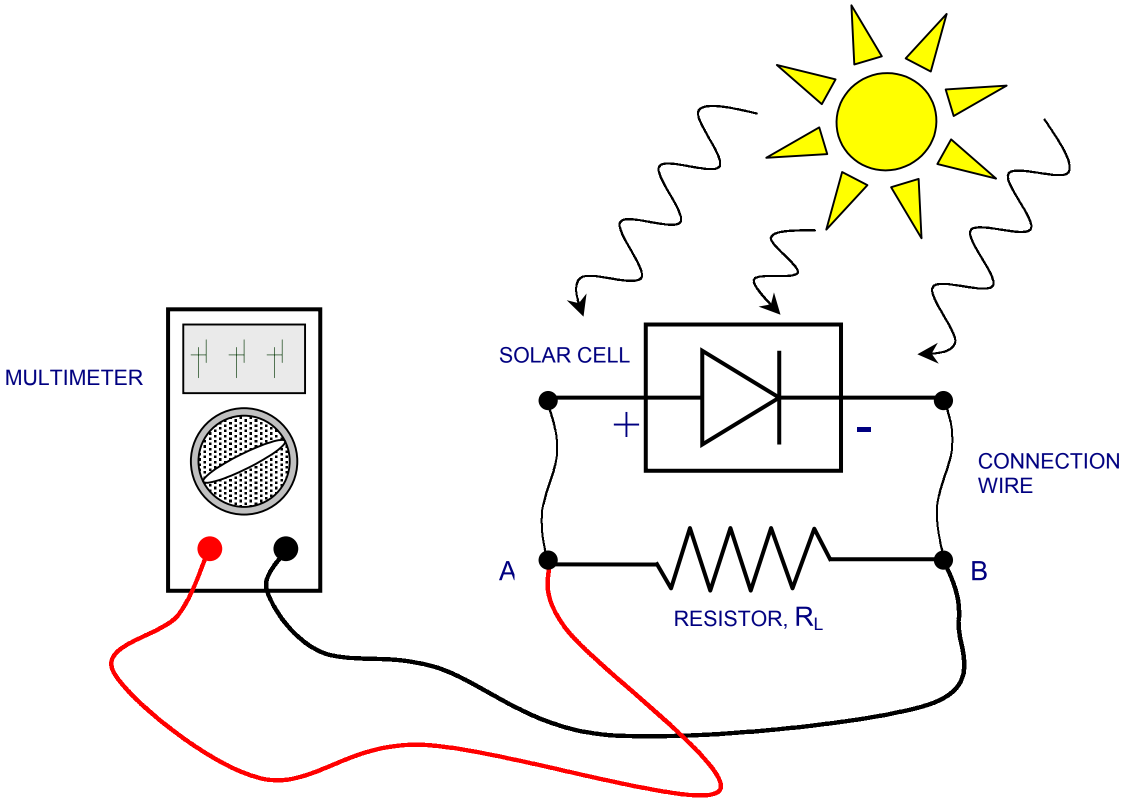

Fig.1 set-up for experiment

To find the cell output under various load conditions, connect different resistors R_L (1 to 250Ω) as shown in fig.1.

For each value R_L record on the table below, voltage across the load (at points A-B), and current through the load (i.e. break the circuit and put the meter in series with R_L).

You need a constant intensity of radiation for these measurements so keep the PV cell facing the same direction in relation to the light source.

Calculate the various power outputs $P(R_L) = I(R_L) \times V(R_L)$ - each dependant on the value R_L.

	R_L	V	I	P = I x V
1				
2				
3				
4				
5				
6				
7				
8				

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Plot (as in figure 2 below) the pairs of values I and V you measure when the cell is delivering power to the load. Also plot the values of P against V

Draw a smooth curve through the points, and find the maximum power point P_{max} (where I x V is at a maximum).

Note that with this method - following the current and voltage conventions in fig.2 - you will only obtain points in the fourth quadrant of the I-V characteristic. Often this quadrant is shown inverted for ease of representation.

The optimum load resistance for the cell R_{Lmax} (when it gives maximum power output P_{max}) is given by:

$$R_{Lmax} = V_{max} / I_{max}$$

where V_{max} and I_{max} are the voltage and current associated with the maximum power point.

If you know the intensity of illumination at the cell (measured in Watts per square metre) and the surface area of the cell (in m^2), then you can calculate the total input power to the PV cell.

Measure illumination at the cell with a light intensity meter if you have one.

The maximum cell efficiency η_{max} is the ratio of maximum power produced to total input power:

$$\eta_{max} = P_{max} / \text{total input power}$$

If you do not have a light-intensity meter then estimate cell efficiency (or radiant energy to electrical energy conversion factor) η_{max} to be between 0.10 (10%) and 0.14 (14%). Then use the equation above for a simple estimate of the Sun's intensity.

The power the cell could provide if it had a “square-shaped” I-V characteristic (which it won’t have), is given by multiplying V_{oc} by I_{sc}.

Calculate the fill factor:

$$FF = P_{max}/I_{sc}V_{oc}$$

a measure of how “square” the I-V characteristic is.

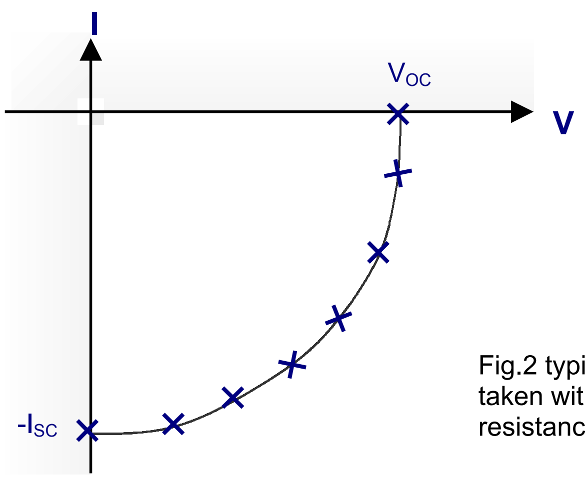
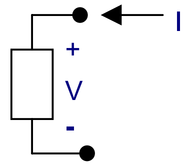


Fig.2 typical plot of I verses V taken with different load resistances R_L connected to cell.



current and voltage conventions

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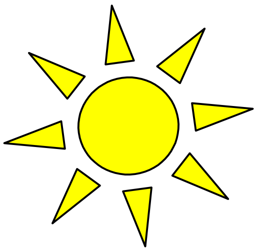
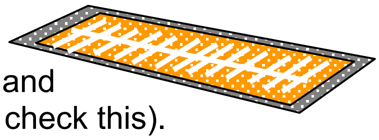
To compensate for fluctuations in solar radiation intensity (therefore the total input power), some PV systems include an electronic maximum power point tracking circuit. This automatically varies the load "seen" by the PV cell so that it always operates around the maximum power point and delivers maximum power to the load.



In space solar radiation has a power density of approximately 1365 W/m^2.

At the earth's surface the atmosphere attenuates solar radiation, more so as the distance that it travels through the atmosphere increases.



In a further experiment you could measure short-circuit current, I_{sc} each hour through the day with the cell illuminated by sunlight and orientated horizontally, (use a spirit level to check this).

Plot and interpret the results, considering that to the first order, I_{sc} is proportional to intensity of illumination and that the intensity reaching the cell decreases as the sun goes lower in the sky and as the angle of incidence on the cell increases.

A PV cell mounted on a tracking device that followed the sun across the sky would receive greater illumination throughout the day as the cell is always facing the sun.

However, nothing can be done on the earth's surface to account for the 'thicker' atmosphere lower in the sky.

Notes:

Maximum power P_{max} is represented by the area of the largest rectangle that can be fitted inside the curve of the IV characteristic, i.e where I x V is at a maximum.

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