8.2 Using solar cells to run an electric motor

Basic information and collecting ideas 	Students will investigate the connection of solar cells in series and in parallel under load conditions. They will also learn how partial shading of solar cells affects the current and voltage. **Additional information** The experiment requires prior knowledge of complex electrical circuits (in series, in parallel); see experiment 6.5. It is recommended that students have conducted experiment 6.5 and that the learning outcomes of the experiments are reviewed. The experiment setup offers numerous teaching opportunities. It leaves room for a number of subexperiments, observations and inferences. You as the teacher can guide the students during the experiment to make as many observations as possible, or you can discuss all possible observations when reflecting on the experiment. If the motor does not rotate, students should check for correct wiring, try different lighting conditions, or connect the solar cells differently. Solar cells convert radiant energy of the sun to electrical energy, as can be seen by the solar cell's generation of voltage and current. Note that solar cells differ slightly; most cells generate a maximum no-load voltage of 0.55 V. Regarding current, a short-circuited solar cell generates a maximum current of approximately 0.11 A. In contrast, an alkaline manganese AA battery has a short-circuit current of up to 80 A. In contrast to alkaline batteries, the voltage in solar cells drops significantly if a load (e.g. solar motor) is inserted in the electrical circuit. The difference between a manganese battery and a solar cell is due to the internal resistance of the solar cell. The internal resistance of a solar cell is greater than 20 Ω, half the motor's resistance. In comparison, the internal resistance of an alkaline battery ranges around 0.1 Ω. With current flowing, the voltage in the solar cells drops considerably. In addition, unlike batteries, the internal resistance of the solar cell depends on lighting conditions. When doing experiments with solar cells and electrical motors, bear in mind that the correlations become complex.
Observing and documenting 	Depending on lighting conditions, the motor rotates faster or slower, or, if lighting conditions are too weak, not at all. In direct sunlight, the motor rotates the fastest when the solar cells are connected in parallel. Depending on the wiring, the motor rotates left or right, which demonstrates that solar cells are polarized (like batteries).

Analyzing and reflecting

If two solar cells are connected in series, the voltages of each solar cell add up to a total voltage. The current remains almost the same.

If two solar cells are connected in parallel, the voltage remains the same and the total current adds up.

Connecting solar cells in parallel ensures that sufficient current will be provided, which is a requirement for certain technical applications.

In this experiment, energy is first converted from radiant energy (light) to electrical energy in the solar cell, and then from electrical energy to kinetic energy in the electric motor.

Doing further research

Table of measurements with sample values

	Solar cells in parallel		Solar cells in series	
	U (V)	**I (A)**	**U (V)**	**I (A)**
Uncovered, full light on cells	0.52	38	1.03	19
Both cells half covered	0.49	23	0.97	12.5
One cell completely covered	0.49	23	0.93	3.8

Technical and vocational application

Connecting solar cells in series offers the possibility of providing minimum voltages for certain technical applications; e.g. to get the approximately 2 V required for charging rechargeable battery cells.

Depending on the purpose, solar cells are interconnected to form solar modules. Particularly in remote areas which are not connected to the main power grid, solar cell may provide the electrical energy to run low-voltage household appliances like lamps, chargers, radios, refrigerators, etc.

Note: Low-voltage technology has been developed extensively. There are even cars that run completely on solar cells although this technology is still in the beginning stages. Particularly in countries with areas off the main power grid, “off-grid” technology provides good job and business opportunities.