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Intelligent Energy Europe

Promotion of the Efficient Use of Renewable Energies in Developing Countries

Chapter II
LeXsolar Experiments (REEPRO set)

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Based on the LexSolar experiment Set www.leXsolar.de

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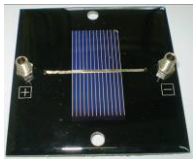
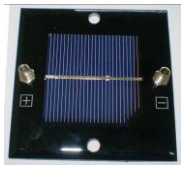
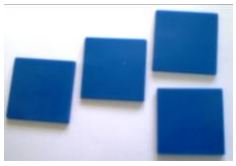
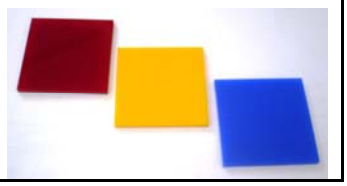
1 The REEPRO LeXsolar-Experiment kit

1.1 List of devices contained in LeXsolar-experiment (small set)

Table 1: List of contents of LeXsolar-experiment kit

No.	Component	Description	Quantity per set	Figure EXAMPLE
1	solar plug-in module	voltage 0,3 – 0,6V (cell size: 50x25mm)	3	
2	solar plug-in module	voltage 0,3 - 0,6V (cell size: 50x50mm)	1	
4	Banana plug cables	2 red and 2 black short cables, lengths: 15 cm, 1 red and 1 black long cable, lengths: 30cm	6	
5	Multimeter	AC, DC, R, A (max 10A), temp.	1	
6	Resistor module	100 Ω	1	
7	Diode module		1	
8	horn / buzzer		1	
9	LexSolar main board	290x150 cm	1	

No.	Component	Description	Quantity per set	Figure EXAMPLE
10	LexSolar connection circuit plate	290x150 cm	1	
11	Set of covers for solar cells	Size: 30x30 mm,	4	
12	Set of color covers for solar cells (red, yellow and blue)	Size: 50x50 mm	3	

1.2 Working with LeXsolar-experiment kit

1.2.1 The plugging system

The basis of LeXsolar-experiment system is the LeXsolar main board (figure 1), onto which up to three solar LeXsolar plug-in modules can be connected simultaneously. Depending on how the modules are plugged in, it is possible to create a parallel or a series connection.

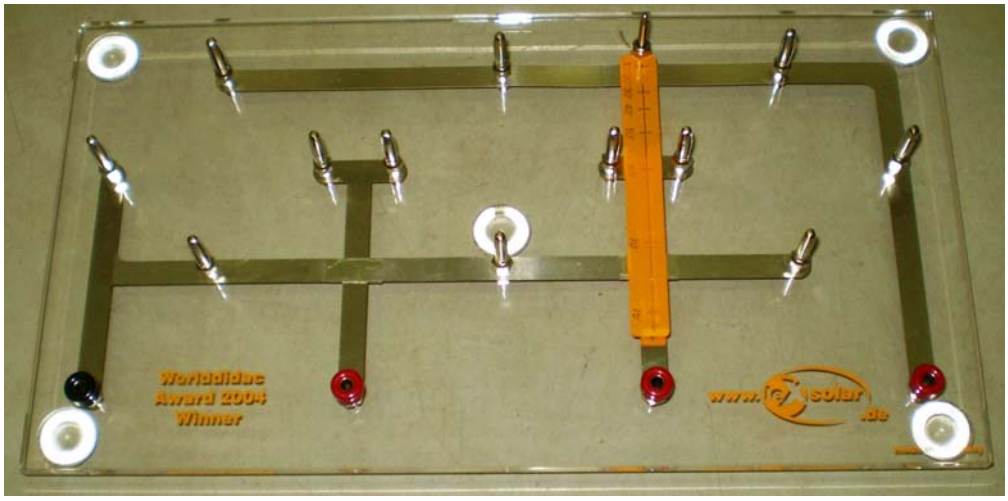


Figure 1: LeXsolar Main board

1.2.2 Connection of the plug-in modules

Due to arrangement of the plugs on the main board three plugging modules can be plugged on the board at the same time in two different ways

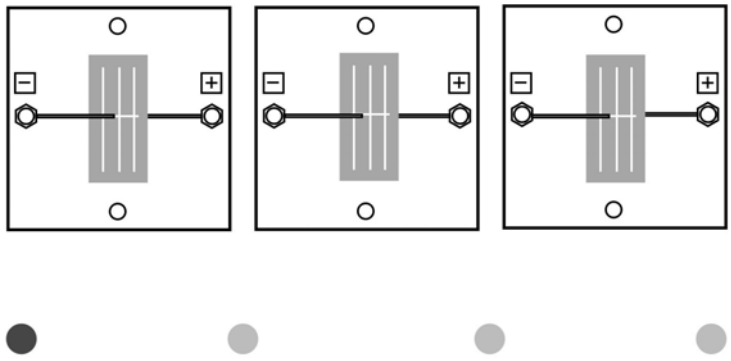


Figure 2: Modules in a series connection

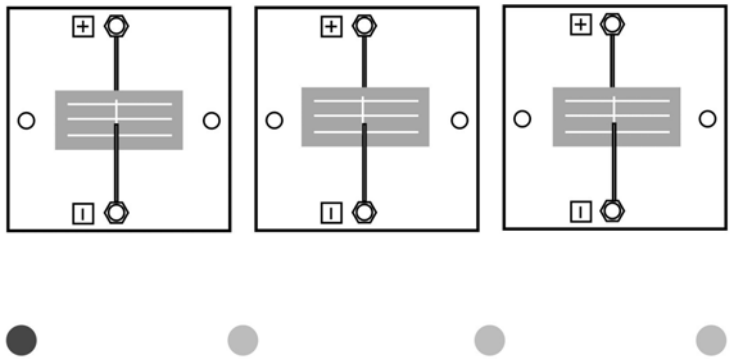


Figure 3: Modules in a parallel connection

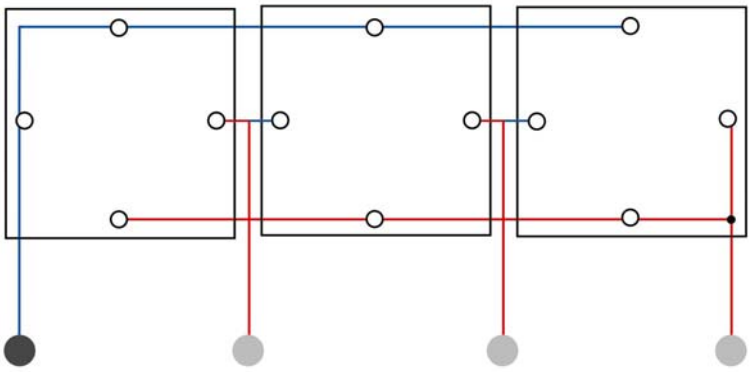


Figure 4: Main board circuit diagram

1.2.3 Changing the angle of incidence of light

There are two possibilities to change the angle of incidence of light: either the experiment is done outside with the natural light source or it is done inside the classroom with an artificial light source. Diffuse light sources are not adequate. It is recommended to carry out this experiment outside using direct sunlight.

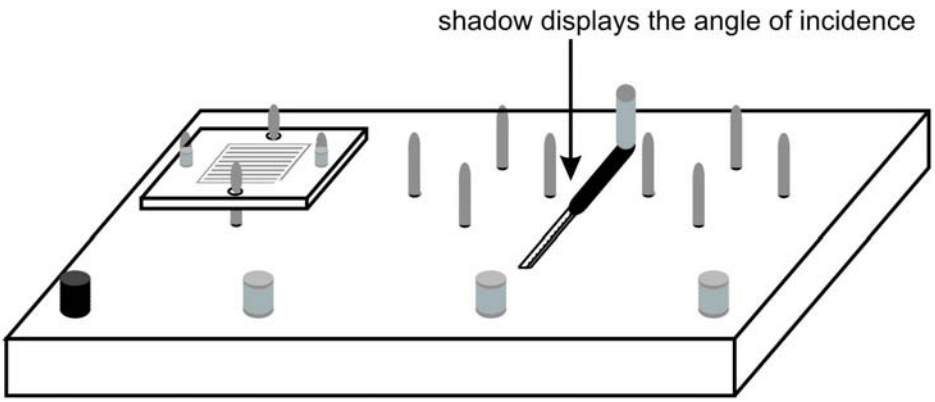


Figure 5: Changing the tilt of the main board using a shadow bar

2 Experiment 1: Series and parallel connection of solar cells

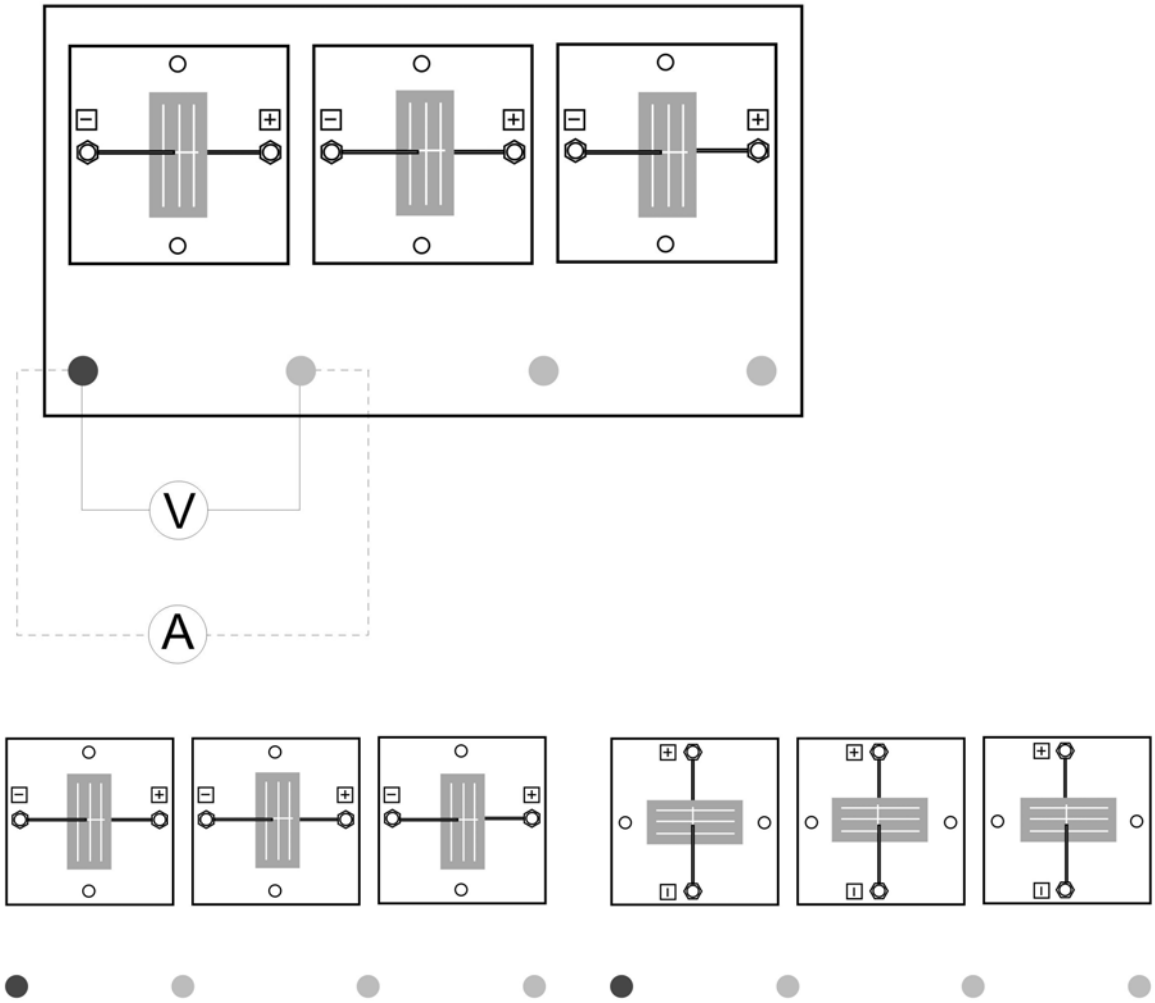
2.1 Task

To determine the behavior of the total voltage and amperage of series- and parallel connected solar cells

2.2 Required devices

- LeXsolar main board
- small solar cells
- 1 voltmeter
- 1 ampere meter

2.3 Arrangement



2.4 Execution

- Measure amperage ($I_{s.c.}$) and voltage ($U_{o.c.}$) of one cell (see circuit diagram)
- Modify the circuit for two and three cells connected in series, and to measure $I_{s.c.}$, $U_{o.c.}$ respectively
- List all measurements in the relevant tables

2.5 Measured values

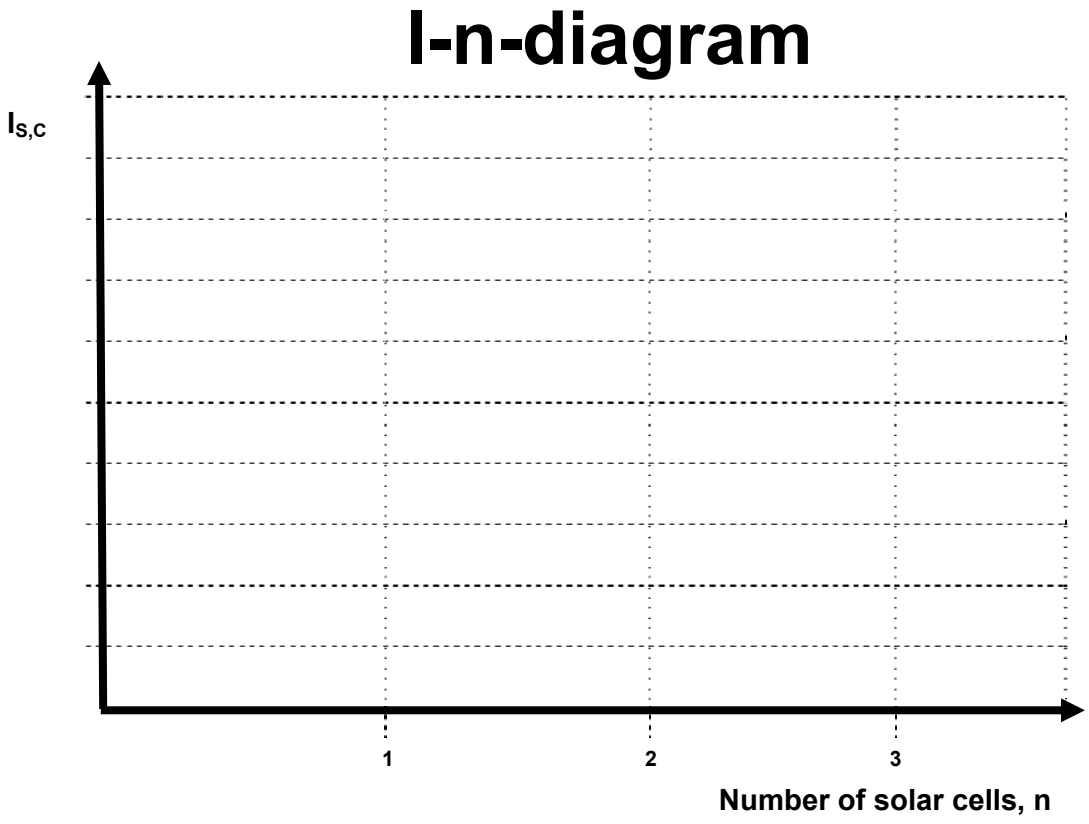
- Series connection

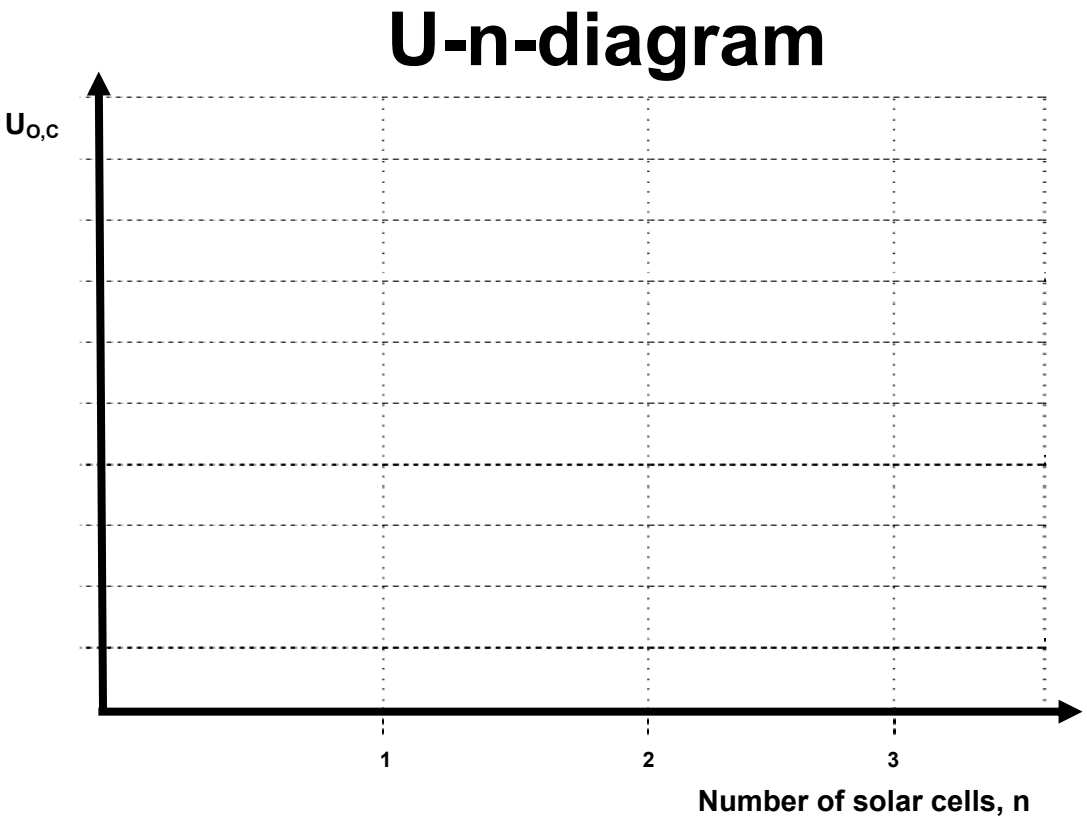
	One solar cell	Two solar cells	Three solar cells
$U_{o.c}$			
$I_{s.c}$			

- Parallel connection

	One solar cell	Two solar cells	Three solar cells
$U_{o.c}$			
$I_{s.c}$			

2.6 Diagrams





2.7 Evaluation

- Draw the I-n -diagram (n-number of solar cells) for series- and parallel-connected cells. Draw both graphs into one diagram
- Draw the U-n -diagram (n-number of solar cells) for series- and parallel-connected cells. Draw both graphs into one diagram
- Give explanations as in followed table

	Behavior of	
	Voltage	**Amperage**
Series connection		
Parallel connection		

3 Experiment 2: Dependence of the power on the surface of the solar cell

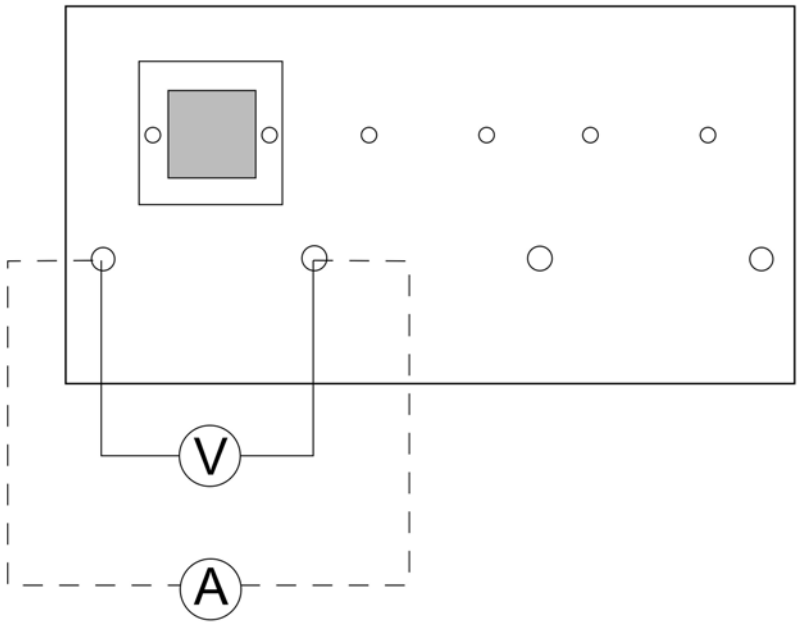
3.1 Task

Measure the voltage and amperage and determine the power of a solar cell with different active areas

3.2 Required devices

- LeXsolar main board
- 1 large solar cell
- 1 voltmeter
- 1 ampere meter
- Several covers of solar cell

3.3 Arrangement



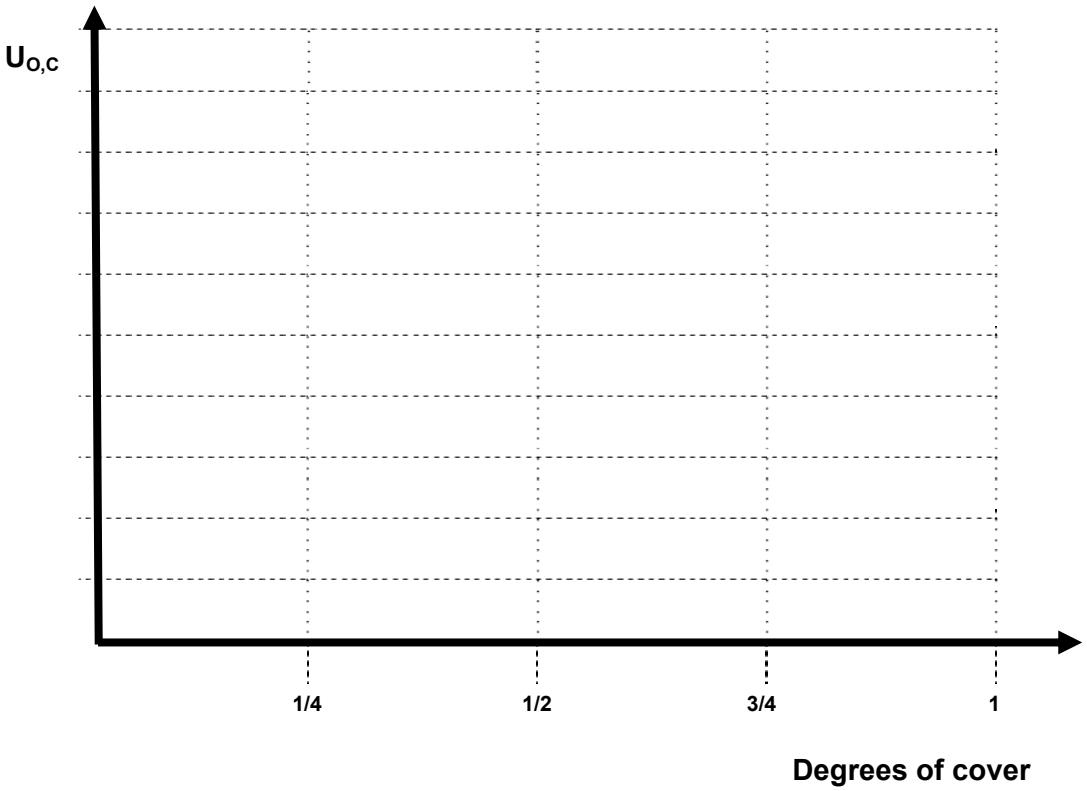
3.4 Execution

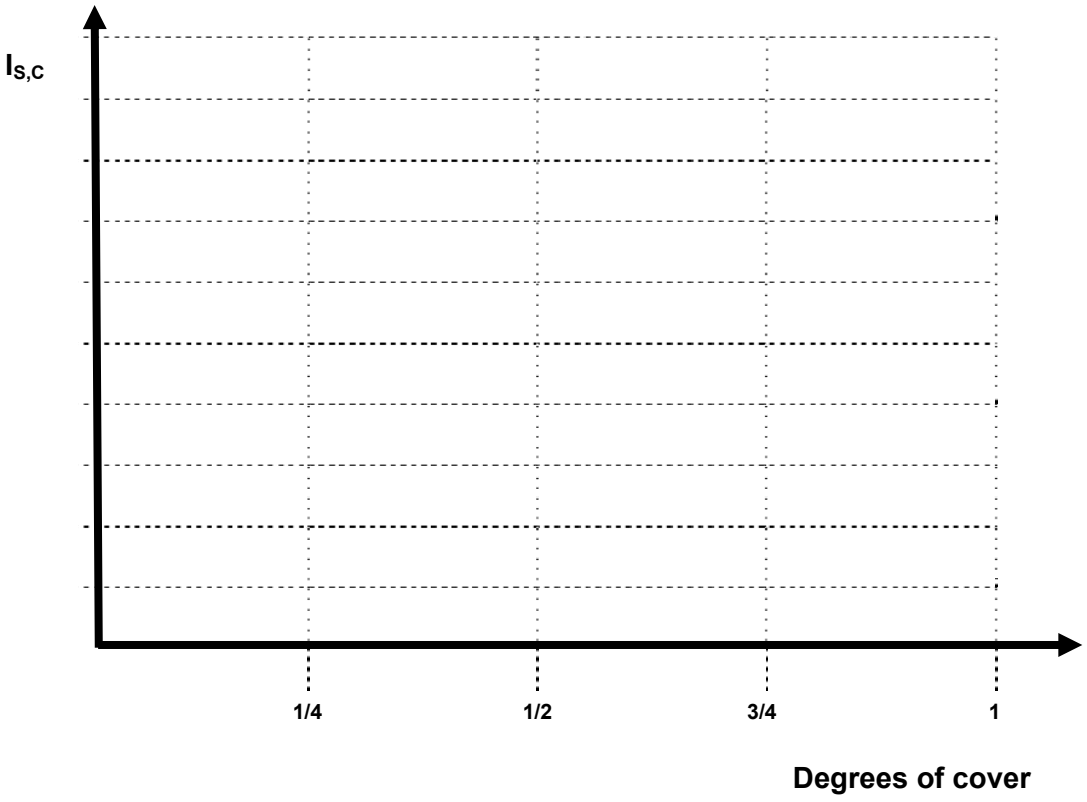
- Set up the circuit according the diagram
- Measure $U_{o.c}$ and $I_{s.c}$,
- Repeat these measures for ¾, ½, ¼ and none shaded (covered) solar cell

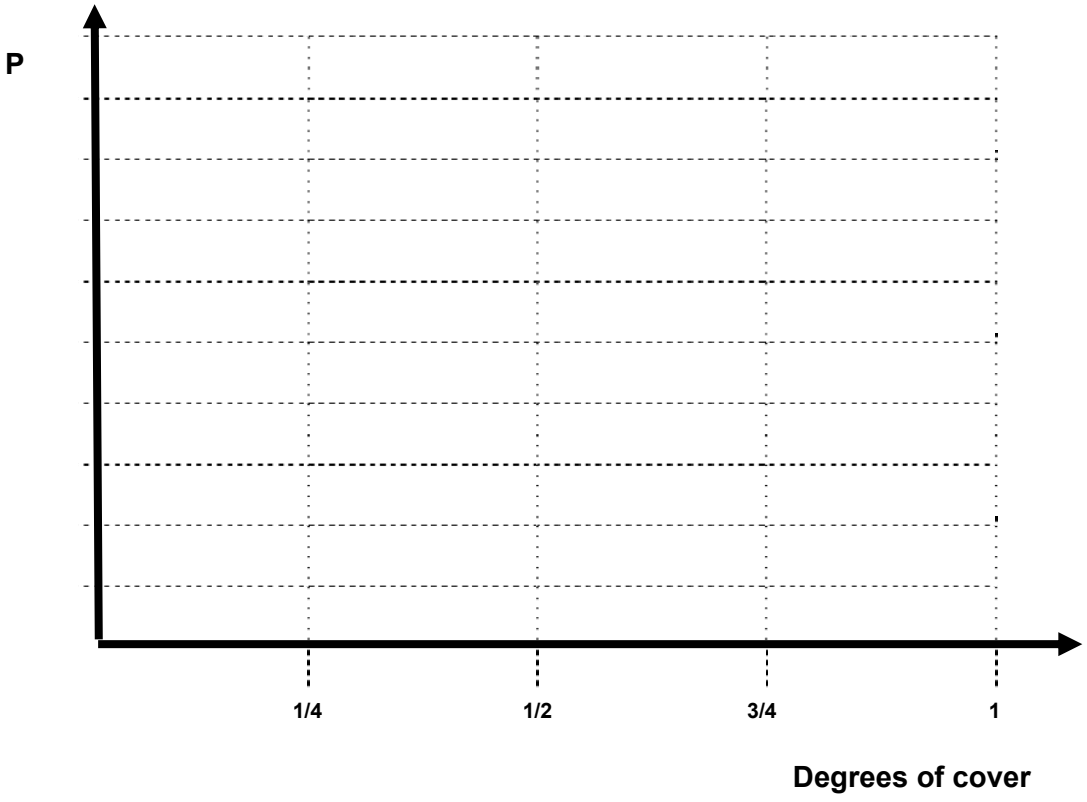
3.5 Measured values

	Solar cell covered to				
	0 (not covered)	**1/4**	**1/2**	**3/4**	**1 (completely covered)**
$U_{o.c.}$					
$I_{s.c.}$					
P (calculated)					

3.6 Diagram




$I_{s,c}$
1/4
1/2
3/4
1
Degrees of cover


P
1/4
1/2
3/4
1
Degrees of cover

3.7 Evaluation

- Calculate respective power of solar cell according to the measurements
- Plot results in diagram (x-axis: covered proportion 0, ¼, ½, ¾ and 1; y-axis: power(P), current(I) and voltage(U))
- What relation can be found between I, as well as between U and the covered areas of the solar cell?

- How can this be explained?

- What relation can be found between the power and the covered areas of the solar cell?

4 Experiment 3: The dependence of the power on the angle of incidence of the light

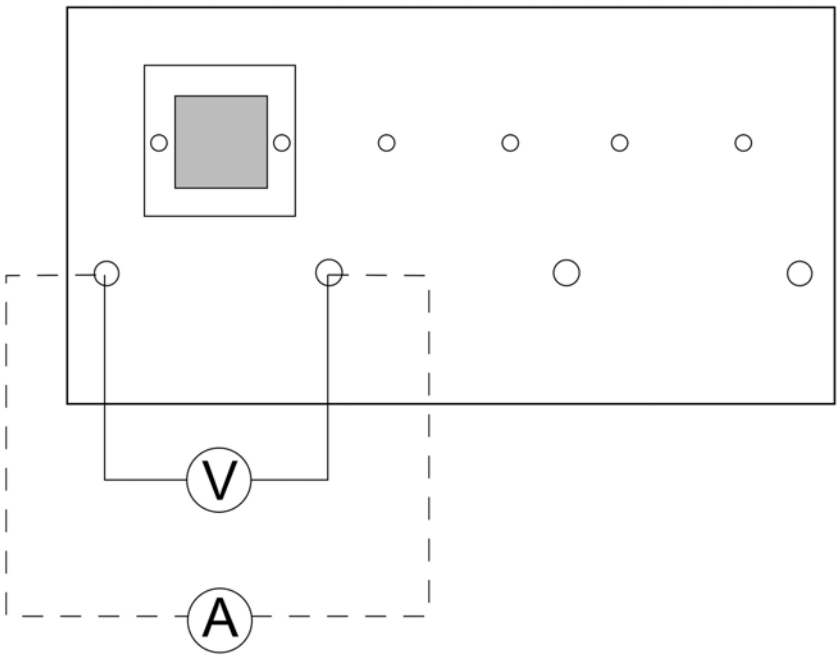
4.1 Task

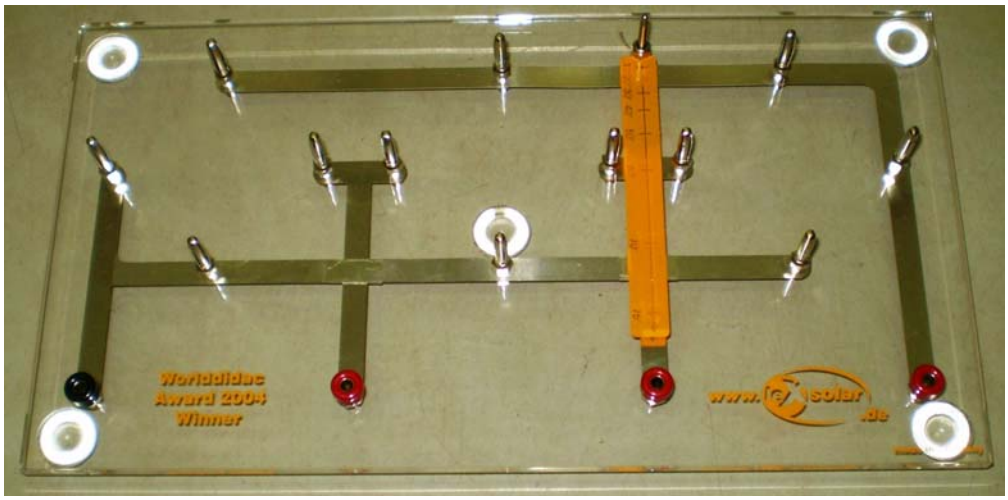
Measure the $I_{s.c}$ and $U_{o.c}$ (and to calculate power) of the solar cell depending on the angle of incidence of the light

4.2 Required devices

- LeXsolar main board
- Large solar cell
- 1 voltmeter
- 1 amperemeter

4.3 Arrangement





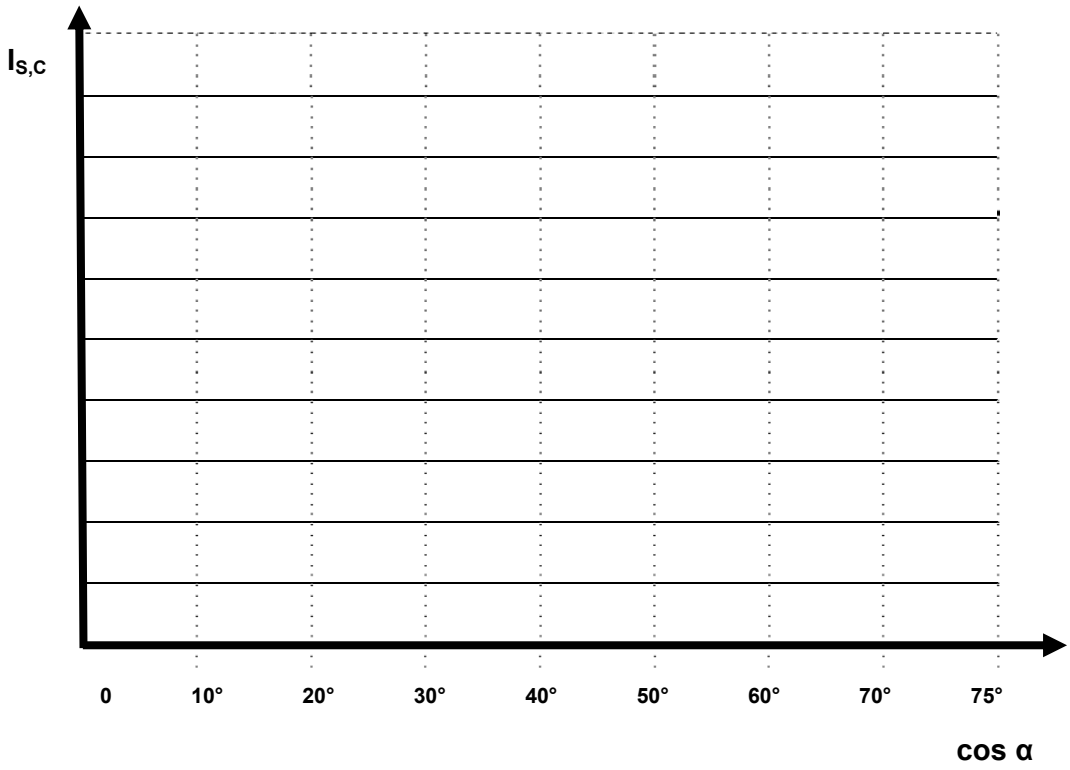
4.4 Execution

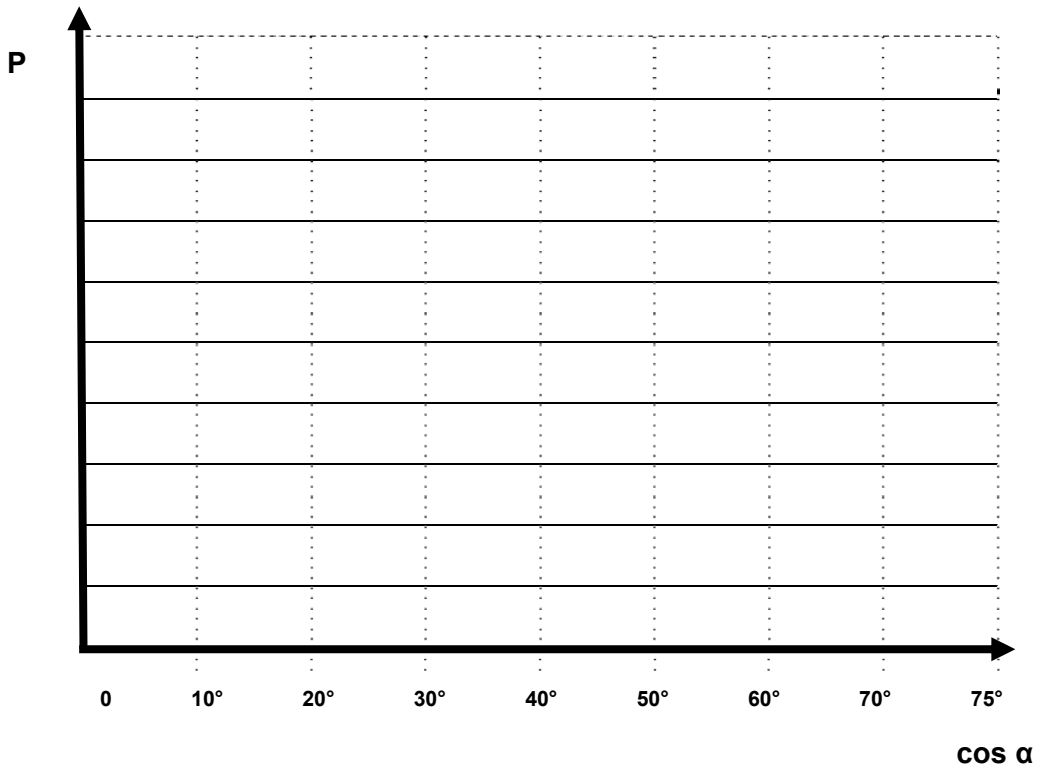
- Hold the LeXsolar main board with the solar cell in the direction of the sun (or main source of light in the room), so that a clearly defined shadow can be seen
- Align the LeXsolar main board to the main light source so that the angle between the base plate and the incident light is 90o. There should be no shadow visible.
- Choose measurable angles and measure the respective Is.c. and Uo.c. for each.
- Record the results in table

4.5 Measured values

α	10°	20°	30°	40°	50°	60°	70°	80°
$U_{o.c}$								
$I_{s.c}$								
Calculate								
cos α								
P								

4.6 Diagrams





4.7 Evaluation

- Draw the I-α -diagram (α-angle of incidence of light)
- Draw the P-α -diagram

5 Experiment 4: Diode's character of the solar cell - Reverse and forward direction with darkening and illumination

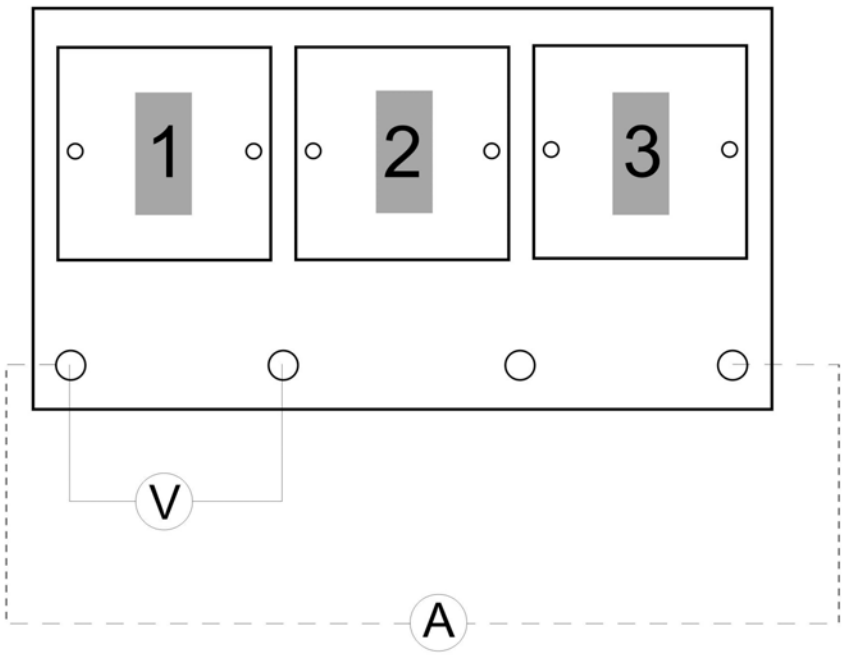
5.1 Task

Analyze diode nature of the solar cell

5.2 Required devices

- LeXsolar main board
- 3 small solar cells
- 1 voltmeter
- 1 amperemeter
- 2 covers for the solar cell

5.3 Arrangement

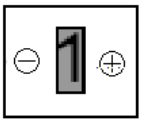
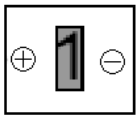
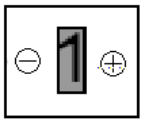
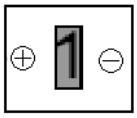


5.4 Execution

- Set up the experiment with three small solar cells according to circuit diagram. Since cell 1 act as a load, no additional load resistor is needed
- Determine the resistance of the solar cell with different polarity and when being darkened
- Carry out similar measurements with illumination.
- Record the results in table

Note: Changing the polarity is achieved by turning the cell by 180°. Use solar cells 2 and 3 as power source for determination of the resistance

5.5 Measured values

	Darkened		**Illuminated**	
				
U				
I				
R (calculated)				

Note: polarity of solar cells 2 and 3 is not changed

5.6 Evaluation

- Behavior when darkened (solar cell here can be viewed as a diode)

- Behavior when darkened

6 Experiment 5: Shadowing of series-connected solar cells and influence of a the connection of cells to diodes

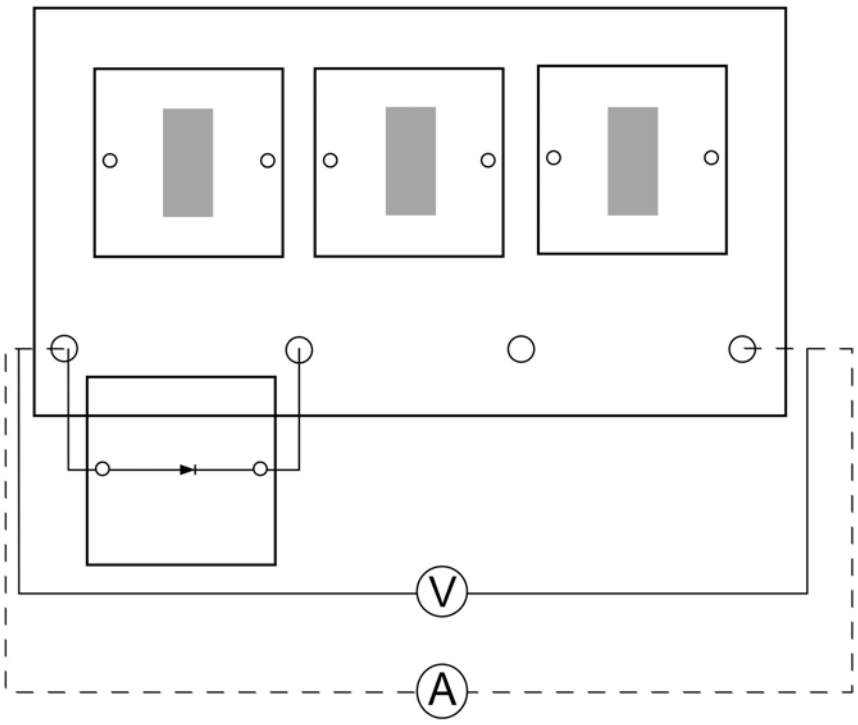
6.1 Task

How do the total voltage and amperage of three solar cells connected in series change when one of the cells is darkened? How do these values change if the solar cell with parallel-connected diode is darkened?

6.2 Required devices

- LeXsolar main board
- 3 small solar cells
- LeXsolar diode module
- 1 voltmeter
- 1 amperemeter
- 2 covers for solar cell

6.3 Arrangement



6.4 Execution

- Measure the initial voltage and amperage at the three cells without cover (1).
- Cover one of the two solar cells without parallel-connected diode completely and measure the voltage and amperage (2)
- Cover the solar cells with the parallel-connected diode completely and measure the voltage and amperage (3)

6.5 Measured values

	Three series-connected solar cells		
	(1) all illuminated	**(2) one not connected to the diode covered**	**(3) one parallel-connected to the diode covered**
$U_{o.c}$			
$I_{s.c}$			
P (calculate)			
Power drop compared to measurement (1)		_____%	_____%

6.6 Evaluation

- Calculate the power drop for the shaded cell, which is not connected to the diode (2) and for the one, which is parallel connected to the diode (3)
- Reason for the results of measurement (2)

- Reason for the results of measurement (3)

- Explain the measured values by means of the function of the semiconductor diode (note: when darkened, its resistance exceeds the resistance of the semiconductor diode in forward direction)

- How can this effect be used when connecting solar modules?

7 Experiment 6: Shadowing of parallel-connected solar cells

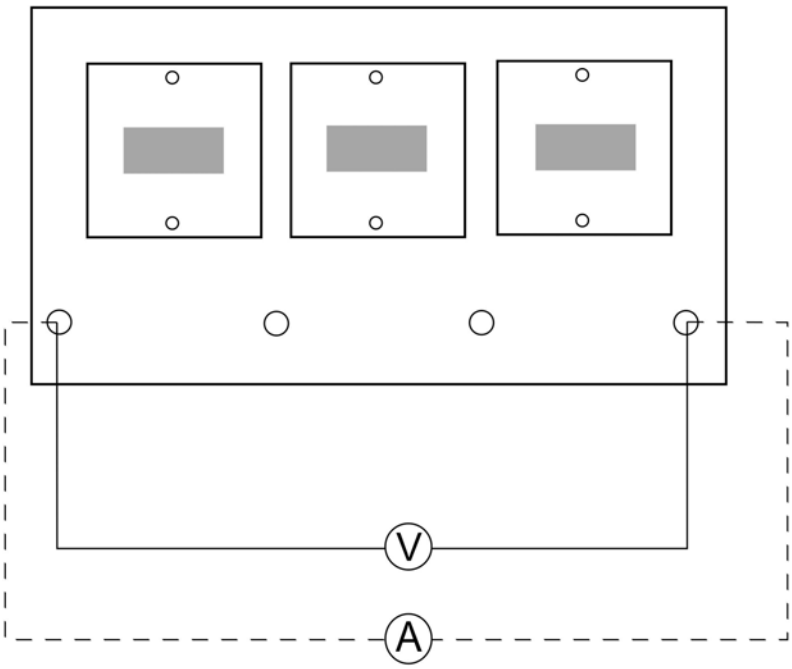
7.1 Task

How do the total voltage and amperage of three solar cells connected in parallel change when one of the cells is darkened?

7.2 Required devices

- LeXsolar main board
- 3 small solar cells
- 1 voltmeter
- 1 amperemeter
- 2 covers for solar cell

7.3 Arrangement



7.4 Execution

- Measure the initial voltage and amperage at the three cells without cover.
- Repeat the measurement with one and respectively two covered solar cells

7.5 Measured values

	Three parallel-connected solar cells		
	(1) all illuminated	**(2) one shaded**	**(3) two shaded**
$U_{o.c}$			
$I_{s.c}$			
P (calculate)			
Power drop compared to measurement (1)		_____%	_____%

7.6 Evaluation

- Calculate the percentage by which the power drops in relation to the initial power (1) when one the solar cell is covered (2) and when two solar cells are covered (3)
- Compare the result to the effect of series connection and explain the difference

8 Experiment 7: Solar cell as transmittance measuring devices

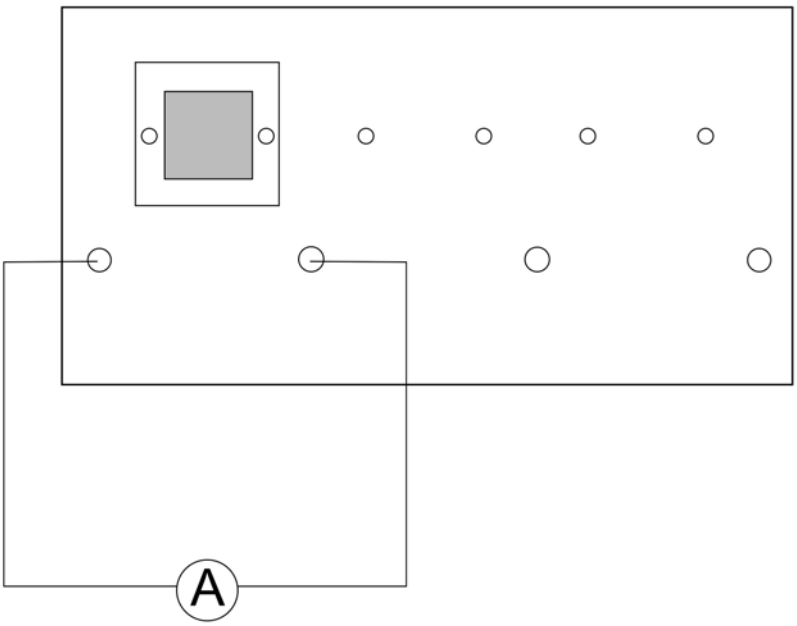
8.1 Task

Determine the degree of transmittance of different foils by mean of the solar cell

8.2 Required devices

- LeXsolar main board
- 1 large solar cell
- 1 amperemeter
- Set of colored foils: any 3 plastic foils of different color, sized 50x50 mm and thickness not more then about 0.5 mm. If colored foils are not available, instead grey foils of different darkness or different thickness can also be used.

8.3 Arrangement



8.4 Execution

- Measure the short circuit amperage of the big solar cell without cover
- Then repeat the measurements for solar cell, covered by different foils
- List the result on the table

8.5 Measured values

	No cover	**foil 1**	**foil 2**	**foil 3**	**foil 4**
$I_{s.c}$					
Drops %	_____%	_____%:	_____%	_____%	_____%

8.6 Evaluation

- Determine the percentage of transmittance for each covering. Note: the short-circuit current is proportional to the illumination
- Additional task: Students can determine transmittance of other material, e.g., window pane glass

9 Reference

Student’s instructions for LeXsolar-experiment. Copyright © by LeXsolar GmbH 2006