SUNdidactics
SolarEnergyDidactics
SolarEducation
SolarEngineering
innovative Solarsysteme für Schule und Ausbildung
innovative solar- systems for school, college, technical education

- Solardidaktik
- Solarzellen
- Solarmodule
- Photovoltaik- Experimentiergeräte
- Photovoltaik- Gerätentwicklung
- Experimentieranleitungen didaktische Konzepte
- Solarberatung
- Solar- Workshops
- Solar- Fortbildung für Lehrkräfte
- solare Aus- und Weiterbildung
- Solarspielzeuge

- solardidactics
- solar cells
- solar modules
- photovoltaic -experiment - devices
- solar- experiment- manuals
- solar- workshops
- solar consulting
- solar education
- solar training for teachers
- solar toys

SUNdidactics Wolf- Rüdeger Schanz, Schaperbleek 15, D-31139 Hildesheim, Germany
Phone: +49(0)5121 86 07 30 Fax: +49(0)3222 370 66 89 Mail: wr.schanz@t-online.de
Mobile: +49(0)175 766 06 07 Web: www.sundidactics.de Mail: info@sundidactics.de

The SUSE solar boat 4

Powerful solar boat with the solar module SUSEmod6
4 solar cells in series connection, solar motor with big air-screw
2 test jacks for PV experiments 2 empty bottles serve as a hull

Experiments with the solar boat 4

8 pages

Name:...School...Date:...........

The solar boat 4 consists of a plexiglass base plate, which is bent to 90° at the site of the motor, there the solar electric motor, the test jacks and the big, red air-screw are located.
On the horizontal plane the solar module SUSEMod6 (2.4 V/ 630 mA) with 4 solar cells connected in series is mounted.
2 empty beverage bottles serve as a hull, on which the plexiglass plate is fixed with adhesive tape.
The solar module SUSEmod6 is very powerful and produces a high propeller revolution speed. The fast spinning propeller creates an airflow and pushes the boat forwards.
At the two test jacks positive (red) and negative (black), below the electric motor, the module voltage is applied, here experiments with voltage, current, power, and current density can be conducted with the aid of lab wires and multimeter. An extensive experimentation manual is included in the scope of delivery.

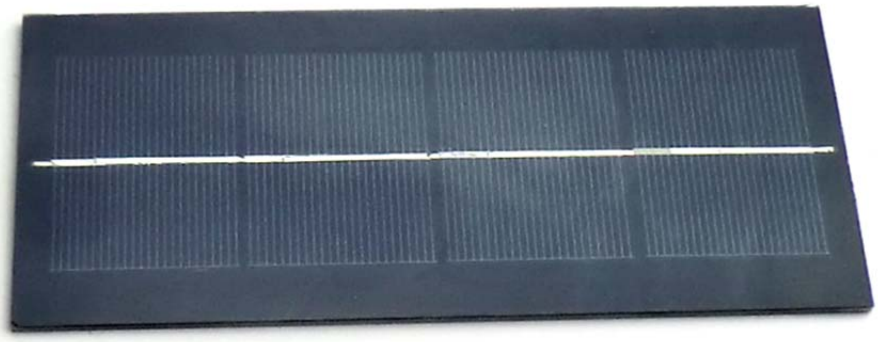
Here 2 boats can also be connected in series (on land) to connect them to e.g. a radio.
Because of the powerful solar cells the boat does not only run with bright sunshine, but also with clouded sky.

1. Required materials for the experiments:

1 solar boat 4, 1 multimeter, 2 measuring cables 1x red and 1x black, 1 LED module SUSE 4.15 red, 1 LED module SUSE 4.15 rainbow, 1 halogen spot lamp 120 W for experiments inside a room, overhead projector, ruler or set square

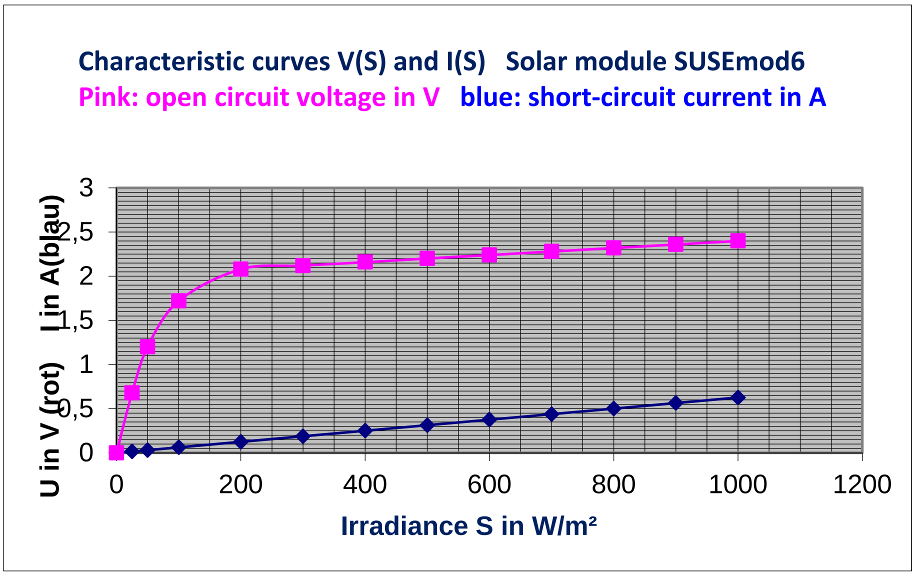
2. The technical data of the solar module SUSEmod6

4 solar cells in intern series connection
Open circuit voltage V_{oc} = 2.48 V Short-circuit current I_{sc} = 630 mA with S = 1000 W/m², 25°C, AM 1.5



External dimensions 160 x 75 mm

The solar module is especially suited for solar boats or for experiments about charging a GoldCap, because the module voltage of 2.48 V fits exactly for the maximum charging voltage of a GoldCap with 2.5 V. 4 multicrystalline solar cells with the dimensions 52 x 35 mm are connected in an intern series connection. On the back there are 2 Cu solder connections for + and -. The solar filling station SUSE 4.34 is also equipped with this module, suitable for the SUSE solar vehicles 1 and 4. The module can easily be fixed on smooth surfaces with double-faced adhesive tape.



The x-axis is the light intensity = irradiance S in W/m². 0 is absolute darkness, 1000 is bright sunshine with deep blue sky in the summer half-year.

The module voltage (pink graph) first strongly increases from 0 on and slowly approximates the value 2.48 V, mathematically it's an exponential function.

The short-circuit current I_{sc} increases in a linear fashion from 0 to its maximum value 0.63 A = 630 mA.
Because of the linear trend the irradiance of the light can easily be determined from the short-circuit current, this is done in the experiments.

Energy conversion processes

While operating the solar boat several energy conversion processes take place, edit the following "energy boxes" and fill them with your own text:

Light Energy form Properties of the energy form light

↓

Solar cell Energy converter Energy conversion processes in the solar cell

↓

Electric motor Energy converter Energy conversion processes in the electric motor

↓

Propeller Energy converter Energy conversion processes by the propeller

4. The Experiments

4.1 Verification of the series connection of the solar cells in the module

The 4 solar cells in the module are electrically connected in series. Draw the electric circuit diagram here:

The circuit symbol for the solar cell is: 
+ -

The 4 solar cells in the module are electrically connected in series.
Draw the electric circuit diagram here:

Take a good look at the solar module, how can the correct series connection be recognized (If you don't know, a solar cell's positive pole is on top (blue side with lines) and the negative pole is the lower surface)?

Note your observations here:

4.2 Measurements of the module voltage

Because the electric motor is firmly connected to the solar module, we cannot measure the open circuit voltage of the solar module (that would be the voltage of the module without a connected “consumer load”). But we can measure the module voltage with the connected solar motor with different light intensities.
Turn on the multimeter, rotate the selector switch into the measurement range 20 V DC and plug the red positive wire into the jack V and the black negative wire into the jack com.
The other two wire plugs are plugged into the test jacks of the boat, red wire into the red positive jack, black wire into the black negative jack, please pay attention that the wires do not run over the solar module, because otherwise they create shadows, that decrease the module's power!

Measurement location	Outdoors with sunshine, module adjusted torwards the sun or on an overhead projector	Outdoors with sunshine in the shadows	Outdoors with clouded sky	Inside a (lit) room near window
Open circuit voltage V in V				

What do you notice? Evaluate the values in comparison to the open circuit voltage!
Note your conclusions here:

4.3 Measuring the short-circuit current

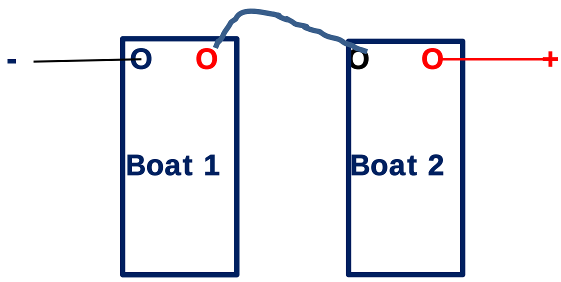
For measuring the short-circuit current the multimeter in the measurement range 10 A DC is connected to the module. The solar motor doesn't interfere here, because the whole current flow runs over the measurement device. We can measure the short-circuit current with different light intensities.
Turn the multimeter on, rotate the selector switch into the measurement range 10 A DC and plug the red positive wire into the jack 10 A and the black negative wire into the jack com.
The other two wire plugs are plugged into the test jacks of the boat, red wire into the red positive jack, black wire into the black negative jack, please pay attention that the wires do not run over the solar module, because otherwise they create shadows, that decrease the module's power!

Measurement location	Outdoors with sunshine, module adjusted torwards the sun or on an overhead projector	Outdoors with sunshine in the shadows	Outdoors with clouded sky	Inside a (lit) room near window
Short-circuit current I_{sc} in A				

What do you notice? Evaluate the values in comparison to the short-circuit current!
Note your conclusions here:

4.4 Connection of devices to a series connection of 2 solar boats

2 solar boats can be connected in series with a lab wire, the red positive jack of the first boat is connected to the black negative jack of the second boat. The positive jack of the second boat and the negative jack of the first boat now form the total voltage V_{tot}.



Determine the value of the total voltage V_{tot} with the aid of the multimeter:

V = ...V

Now connect a) the solar radio and b) the LED rainbow to the total voltage, what can you observe?

Note the observations and explanations here:

Additional experiments (sophisticated)

4.5 Determination of the light intensity (irradiance S in W/m²)

With the short-circuit current of the solar module you can determine the light intensity (brightness), the irradiance S in W/m². As shown in the blue characteristic curve on page 1 the short-circuit current is directly proportional to the irradiance, a linear function, and so S can be determined with a simple rule of three calculation, if we measure the short-circuit current.

Therefor the following applies here:

$$\frac{\mathbf{0.63}\ \text{A}}{\mathbf{1000}\ \text{W/m}^2} = \frac{I_{mes}\ \text{in A}}{S_x\ \text{in W/m}^2}$$

or reorganized for S_x:

$$S_x = \frac{I_{mes}\ \text{in A} * \mathbf{1000}\ \text{W/m}^2}{\mathbf{0{,}63}\ \text{A}}$$

0.63 A is the short-circuit current of the module with 1000 W/m².

I_{mes} in A the measured short-circuit current with the irradiance S_x

S_x in W/m² the irradiance of the light

Derive the framed equation here:

Measurements outdoors and with light source Measurement range 10A DC
You can use the calculator in your cell phone/smartphone for the calculations.

Light radiation	**Short-circuit current I_{sc} in A**	**Irradiance S_x in W/m²**
Outdoors Bright sunshine Measured directly towards the sun		
Outdoors Bright sunshine Measured in the shadows		
Outdoors Clouded sky		

Outdoors Very gloomy weather		
On the plate of an overhead projector		
Inside a room (use measurement range 20 mA DC here)		

What do you notice? Evaluate your findings here:

4.6 Determination of the current density j = quality characteristic of solar cells

This experiment does not need its own measurements, but instead uses the technical data.
The quality of a solar cell is the higher, the more current 1 cm² of this solar cell produces with a solar irradiation of 1000 W/m².
This value is called current density j and is the quotient of the short-circuit current in mA over the cell area in cm²:

$$\textbf{Current density } j = \frac{\textbf{Short-circuit current} \text{ in mA}}{\textbf{Solar cell area} \text{ in cm}^2}$$

Therefor we measure the length and the width of **one** solar cell of our module to the nearest mm with a ruler or a set square and multiply the values to get the area:

Length:......................cm Width:.......................cm Area:.........................cm²

We take the short-circuit current from the technical data and give the value in mA:

I_{sc} = ...mA

Now we calculate the current density j: **j = ------------------------ in mA/cm²**

With a comparison chart you can assess your value:

Current densities j of solar cells:
Very good: > 40 mA/cm²
Good: 32- 40 mA/cm²
Average: 24- 32 mA/cm²
Bad: < 24 mA/cm²
With an irradiance of 1000 W/m² !!
Maximum possible theoretical value:
44 mA/cm²

Judge the quality of the solar cell here:

Why don't you have to do this calculation again for the other 3 solar cells? Explain:

