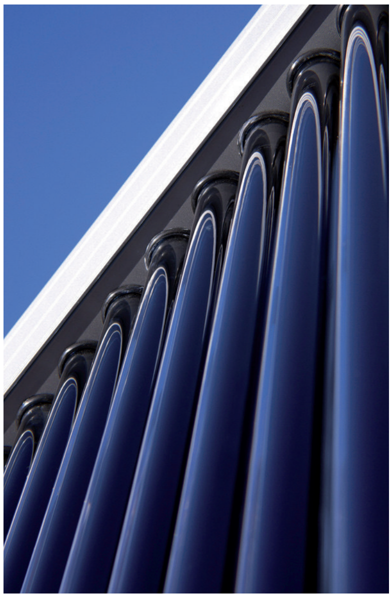
leXsolar-ThermalEnergy Ready-to-go



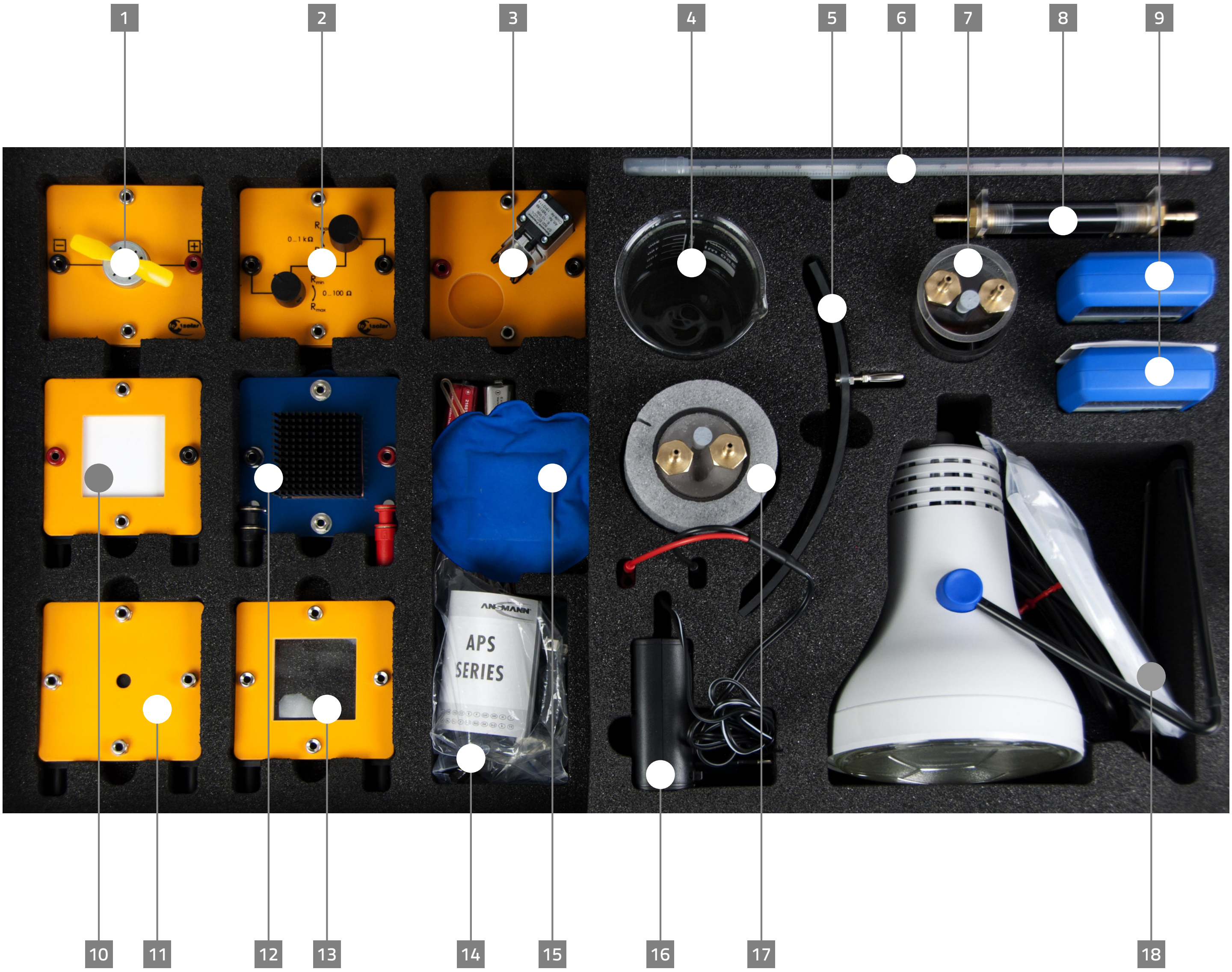
Teacher's Manual

Layout diagram leXsolar-ThermalEnergy Ready-to-go 2.0

Item-No.1304

Bestückungsplan leXsolar-ThermalEnergy Ready-to-go 2.0

Art.-Nr.1304



1	1100-27 Motor module 1100-27 Motormodul L2-02-017 Yellow propeller L2-02-017 Luftschraube (Propeller) gelb
2	1100-23 Potentiometer module 1100-23 Potentiometermodul
3	1300-09 Pump module with 22 1300-09 Pumpenmodul mit 22
4	L2-06-082 Beaker 250 ml L2-06-082 Becherglas 250 ml
5	1300-04 Parabolic reflector 1300-04 Parabolspiegel-Kollektor
6	L2-06-016 Laboratory thermometer L2-06-016 Laborthermometer
7	1300-12 Heat exchanger paraffin 1300-12 Wärmetauscher Paraffin
8	1300-05 Absorber tube 1300-05 Absorberrohr
9	2xL2-06-011 Digital multimeter 2xL2-06-011 Digitalmultimeter
10	1300-08 Absorber B/W 1300-08 Absorber S/W
11	1300-07 Absorber module for lens 1300-07 Absorbermodul für Linse
12	1300-10 Peltier module 1300-10 Peltiermodul
13	1300-06 Lens module 1300-06 Linsenmodul
14	2xL2-06-014/015 Test leads black/red 2xL2-06-014/015 Messleitung schwarz/rot
15	L2-06-125 Cooling pad L2-06-125 Kühlkissen
16	2105-00 Power supply 2105-00 Stromversorgungsgerät
17	1300-11 Heat exchanger water 1300-11 Wärmetauscher Wasser
18	1300-13 Hose set 1300-13 Schläuche-Set

Version number
Versionsnummer

L3-03-138_10.12.2014

CE RoHS2

Layout diagram leXsolar-ThermalEnergy Ready-to-go 2.0
Item-No.1304

Bestückungsplan leXsolar-ThermalEnergy Ready-to-go 2.0
Art.-Nr.1304

19

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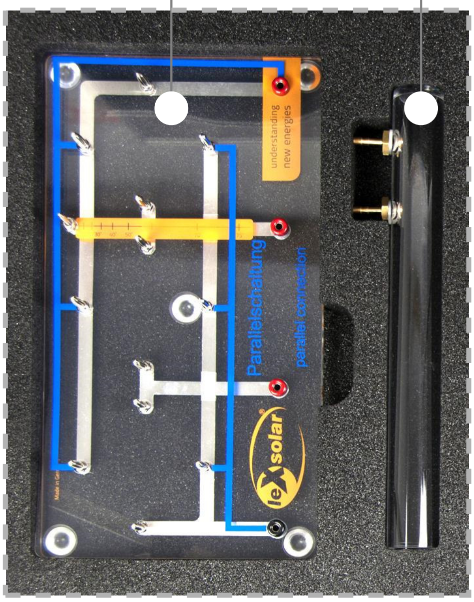
21 22



19	1300-03 Solar colector 1300-03 Solar-Kollektor	
20	L2-04-080 Lamp L2-04-080 Lampe	
21	1100-19 leXsolar-basic unit 1100-19 Grundeinheit groß	
22	Balancing container with 3 Ausgleichsgefäß mit 3	

CE RoHS2

leXsolar-ThermalEnergy

Teacher's instructions

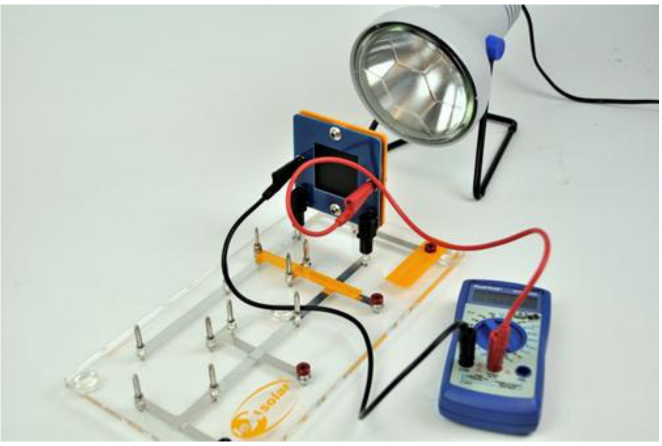
Content

1. Absorptivity and reflectivity of different materials

Task

Find out the differences in absorptivity and reflectivity of thermal radiation for a copper plate with white and black coating.

Setup



Equipment

- Basic module
- Spotlight
- Digital meter
- Absorption module black/white
- Cables

Procedure

1. Put the absorption module black/white into the basic module with the white side facing the spotlight. The distance between absorption module and spotlight should be 15 cm.
2. Connect the digital meter with the absorption module black/white as shown in the figure.
3. Adjust the digital meter to the symbol °C to start the temperature measurement. Also keep a clock ready for time measurements during the experiment.
4. Note down the temperature T(0) at the beginning and start the measurement by turning on the spotlight. Write down the temperature, which is measured electrically on the metal surface, every minute.
5. Turn the spotlight off and let the absorption module black/white cool down until it has returned to its approximate starting temperature.
6. Repeat the measurement with the black side of the absorption module. Take care that the distance to the spotlight is again 15 cm.

Data

Table 1.1 – Development of the temperature on the white side

Time in minutes	0	1	2	3	4	5	6	…
Temperature	24	27	29	31	33	35	36	

Data

Table 2.1 – Development of the temperature on the black side

Time in minutes	0	1	2	3	4	5	6	…
Temperature	25	46	56	61	64	65	66	

Analysis

1. Enter your results in the depicted diagram.
2. Compare the results of the two parts of the experiment and explain the observed differences.
3. Explain which conclusions can be drawn from your results for the construction of solar thermal collectors.

Diagram

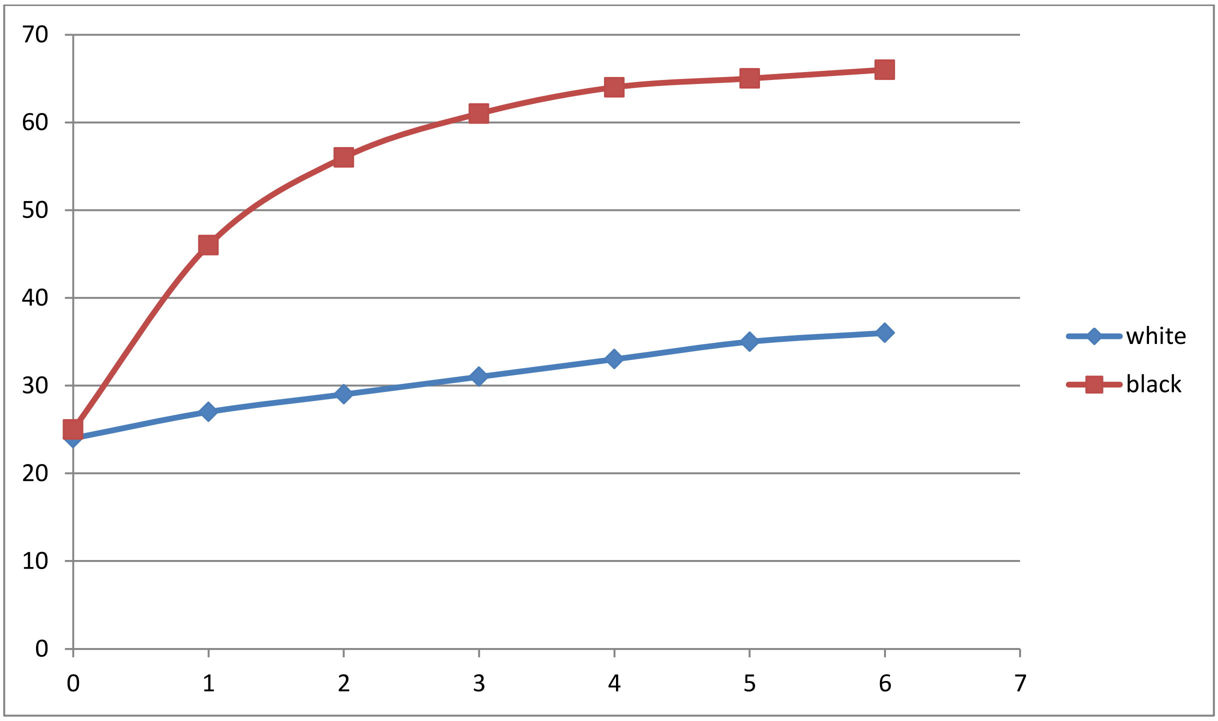


Diagram 1.1 – Development of the temperature at the absorption module black/white.

Analysis

2.

The white side heats up significantly more slowly than the black side. Black surfaces absorb the incoming light especially well and reflect only a small fraction of the incoming radiation in the visible regime. Therefore, the human eye barely observes any light from the surface so that the material in question appears black. The ability of a material to absorb or reflect light is given by the order of the atomic structure, whose excitation by incoming light in the visible regime is variably strong. The absorption of light therefore depends on the frequency and the material.

After heating, black materials in particular radiate part of their absorbed energy again in the form of thermal radiation. This thermal loss is greater the bigger the temperature difference between material and surroundings.

The shape of the two heating curves is given by the thermal energy received during absorption and the loss in form of thermal radiation. For the white surface, the slope of the losses is approximately proportional to the absorbed thermal energy, so that the curve is nearly linear. For the measurement of the black surface the portion of absorbed energy predominates at first, until the thermal losses become so large that the heating effect is reduced further and further. During the measured interval, the curve is therefore non-linear.

3.

Solar thermal collectors are required to convert as much as possible of the incoming sunlight into useable thermal energy. In order to absorb much light, the fraction of reflected radiation should be small. Therefore, solar thermal collectors are usually covered with a black coating. As observed in the experiment, these simple black surfaces have the severe problem of re-radiating most of the energy in the form of heat. Today, so-called selective coatings, which absorb the sunlight like a black surface, but provide a highly reduced radiation, help to solve this problem. However, these coatings are difficult to process because they cannot be sprayed or painted like conventional lacquers.

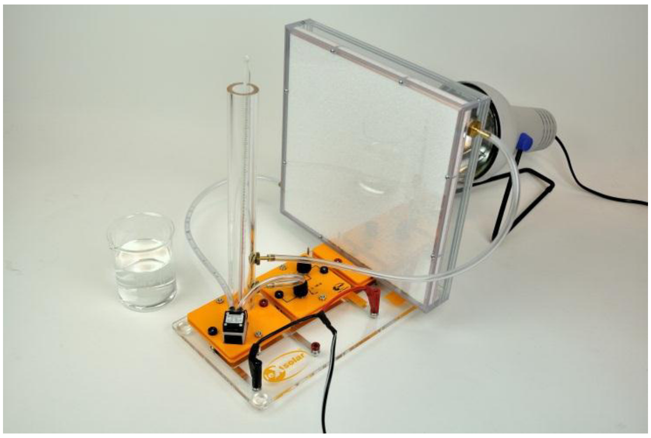
8. Variation of the flow speed

Task

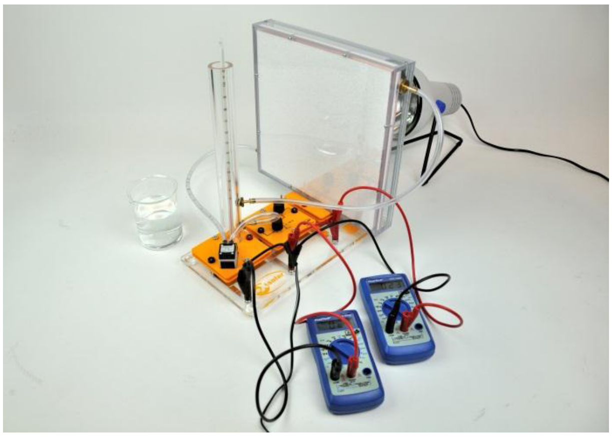
Find out at what flow speed through the solar thermal circulation the solar collector works most effectively.

Setup

8.1 Voltage control at the power supply unit



8.2 Voltage control with voltage divider circuit



Equipment

- Basic module
- Pump module
- Balancing container
- Solar thermal collector
- Potentiometer module
- Spotlight
- Hoses
- Liquid thermometer
- Power supply unit
- Beaker
- Digital meter with cables and temperature sensor

Preparation

Put the solar thermal collector and the pump module with the balancing container onto the basic module as shown in figure 8.1 and connect the modules with the enclosed hoses. Take care that the left pump connection is plugged into the lower connection of the collector and that the right connection is plugged into the balancing container. Afterwards, connect the balancing container with the upper connection of the collector in order to close the water circuit.

Procedure

Variation A – Setting at the power supply unit: Set the voltage necessary for the experiment directly at the power supply unit. The voltage control here, however, is not continuously variable.

8. Variation of the flow speed

Procedure

Variation B – With voltage divider circuit:

1. Put the potentiometer module onto the last empty slot of the basic module so that it is connected in series to the pump.
2. Connect digital meters for the voltage measurement, one each in parallel with the pump and the potentiometer (measurement range 20 V).
3. Now fill water into the balancing container with the aid of the beaker and connect the power supply unit via the pump and the potentiometer (12 V) (see figure 8.2).
4. Turn the potentiometer to control the pump flow continuously. The pump then transports water into the circulation.

   Advice: If necessary, add some water with the beaker until a stable water circuit with approx. 200 ml liquid is reached. To remove remaining air inclusions from the collector, you can carefully tilt it.

5. To start the experiment, put the liquid thermometer into the balancing container and keep a clock ready for time measurements. A voltage of 5 V is set at the pump.
6. Position the spotlight in front of the collector (15 cm distance) and turn it on. Measure the temperature development inside the balancing container during heating up of the collector and enter the respective values into the table.
7. Repeat the experiment with a voltage of 9 V, if you directly set it on the power supply unit, or with 10 V, if you use the potentiometer. Enter these values into the table also.

Data

Table 8.1 – Heating up at 5 V

Time in minutes	0	2	4	6	8	10	12	…
Temperature in C°	24	28	31	34	37	39	41	

Table 8.2 – Heating up at 9 V (10 V, respectively)

Time in minutes	0	2	4	6	8	10	12	…
Temperature in C°	25	28	30	32	34	36	37	

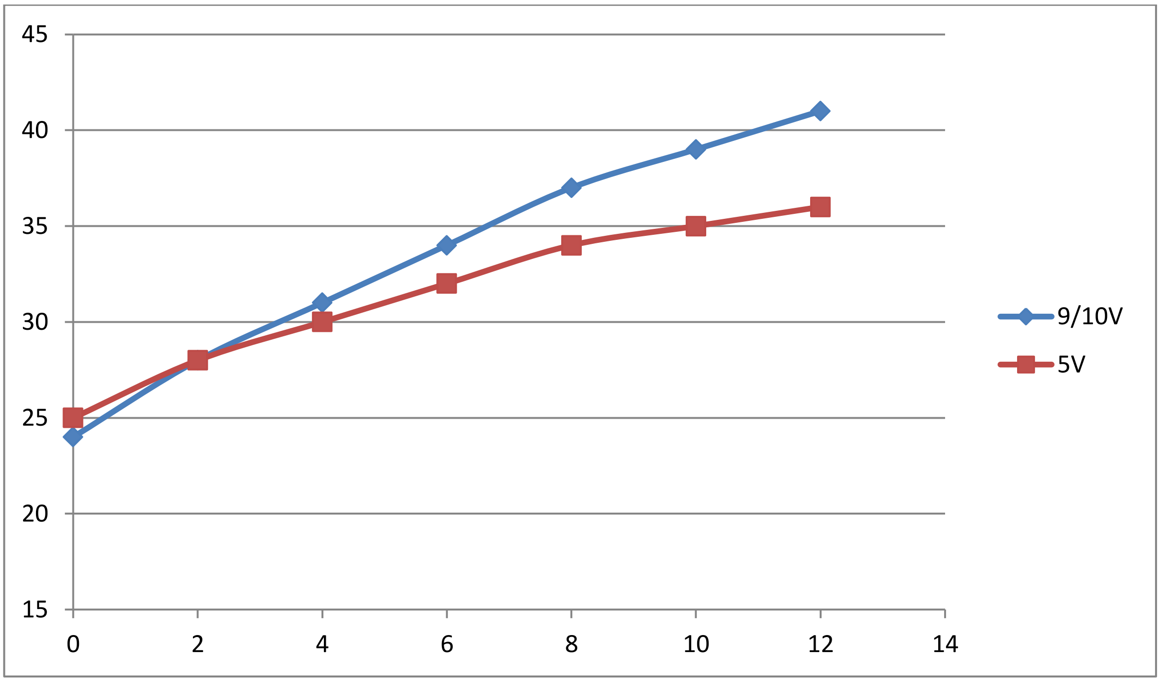
Analysis

1. Transfer your results from the table into the shown diagram.
2. Compare the results from both parts of the experiment by describing the development of the temperature for both cases.

Procedure

3. Explain why the variation in flow speed has an effect on the heating of the collector circuit.
4. To integrate your findings from this experiment into real-life systems, name possible improvements for collector systems.

Diagram



Analysis

2.

The temperature development in the balancing container is approximately linear in the shown measurement range. The slight flattening of the curve is just about visible. There is a systematic difference between the two temperature development curves at different flow speeds. The two curves differ in their average temperature rise. This means that the effectiveness of a solar thermal system depends on the flow rate.

3.

Between two reservoirs with different temperatures that are in thermal contact with each other, a temperature convergence takes place. Here, the cooler reservoir is heated up, while the warmer is cooled down, until both temperatures are equal. The bigger the temperature difference between the reservoirs, the faster the process takes place. In the case of the solar collector, the hot surface of the collector tube is attached to the water circuit. If the flow speed is too low, too little water is supplied to efficiently transfer heat

Analysis

Between the collector tube and the water circuit. Furthermore, a higher water flow speed reduces the thermal losses during the transport to the heat reservoir. Solar thermal systems with high flow rates are called high-flow solar collectors. A disadvantage of this system is the higher energy consumption of the water pump. Furthermore, the absolute temperature of the collector is lower, because the system is heated up uniformly. In low-flow solar collectors with stratified storage, a better temperature spreading takes place, so that the stratified storage can be heated up faster.

4.

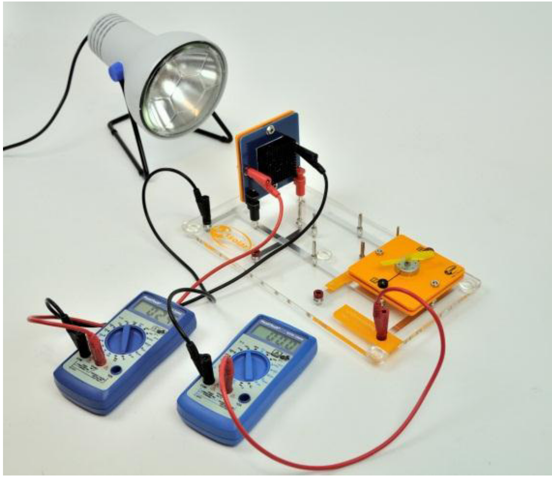
To utilize the optimal flow rate for each application and temperature state of the solar thermal system, the pump power can be varied. Such systems are available under the name “matched-flow solar system”, but have as yet a low market share due to the higher costs.

15. Quantitative determination of the electrical power

Task

Show quantitatively that, by heating one side of the Peltier element, a voltage is generated, which can be used to operate a small electrical consumer.

Setup



Equipment

- Basic module
- Peltier module
- 2x digital meter
- Cables
- Spotlight
- Motor module

Procedure

1. Place the Peltier module onto the basic module as shown.
2. Furthermore, connect both digital meters to the basic module and the Peltier module as depicted.

   Advice: The digital meter at the Peltier module is used to measure the temperature. Voltage and current are measured with the second digital meter.

3. Place the spotlight 15 cm away from the Peltier element and start the measurement.
4. Observe the development of temperature, voltage and current and write your data into the table.

Data

Time in minutes	Current in mA	Voltage in mV	Power in mW	Temperature Peltier element in °C
0	0.1	-1.5	$0.15*10^{-3}$	25
0.5	6	100	0.6	26
1	150	8.8	1.32	28
1.5	180	11	1.98	30
2	190	11	2.09	31
2.5	204	12	2.45	32

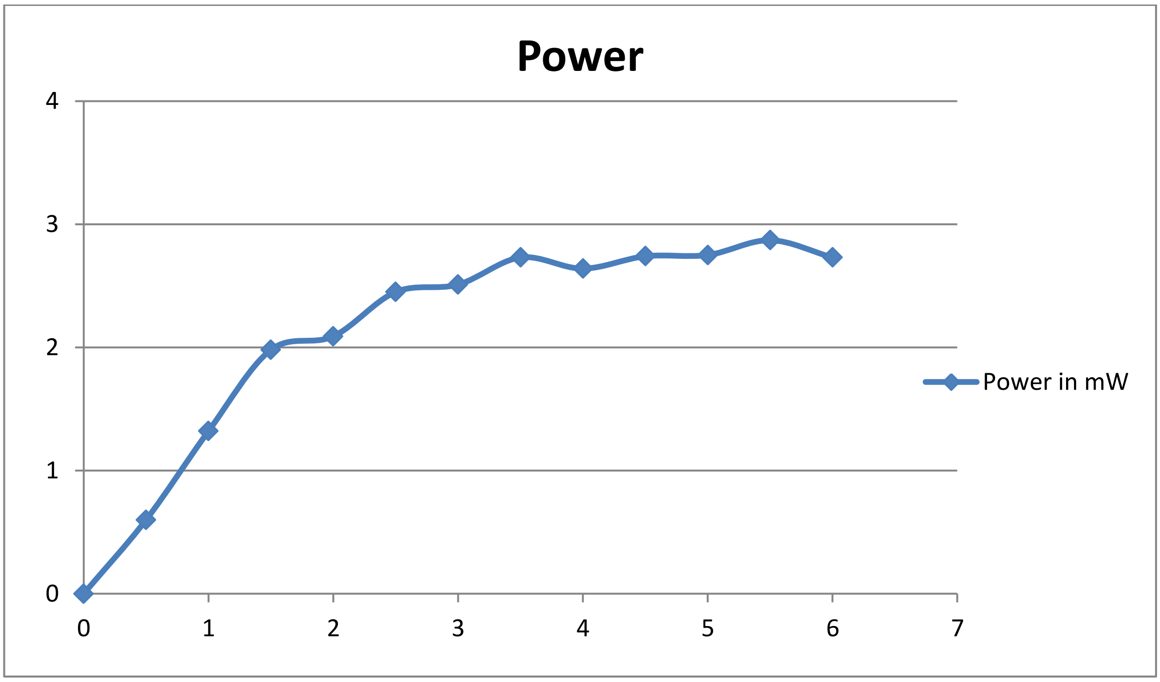
Data

3	209	12	2.51	33
3.5	215	12.7	2.73	34
4	215	12.3	2.64	35
4.5	219	12.5	2.74	35
5	220	12.5	2.75	36
5.5	224	12.8	2.87	37
6	218	12.5	2.73	37

Analysis

1. Calculate the power for each data row and write the result into the respective column.
2. Enter your results in the depicted diagram.
3. Estimate the permanent power of the thermoelectric generator by using the measurement data and calculate the power conversion efficiency of the measurement setup.
4. Name a few possible applications where the thermoelectric generator can be used even though its power conversion efficiency is low.

Diagram



Analysis

3.
After a short time period, the power of the thermoelectric generator adjusts itself to 2.75 mW. Considering the electrical power of the spotlight (120 W), the power conversion efficiency is 0.000023%.

4.
Even when excluding thermal losses due to the small effective illumination area and the emission of thermal radiation, efficiencies in the per mill range are found. Therefore, the technical applications of thermoelectric generators are limited to special applications in the field of decentralized energy supply. Another possible application would be the autarkic operation of small sensors at hot machine or vehicle parts. The advantage would be the low installation efforts and the reliable, low maintenance operation of such measurement systems.

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