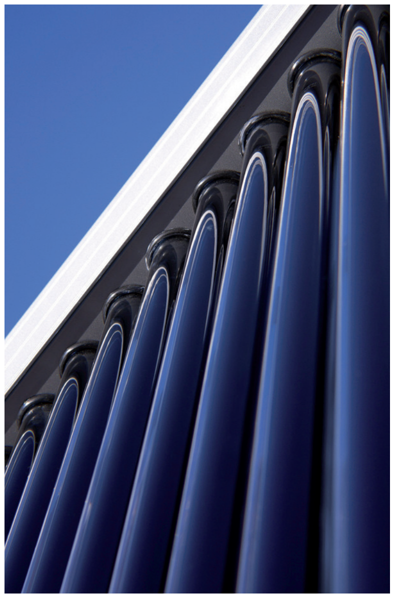
leXsolar-ThermalEnergy Professional



Experiment handbook

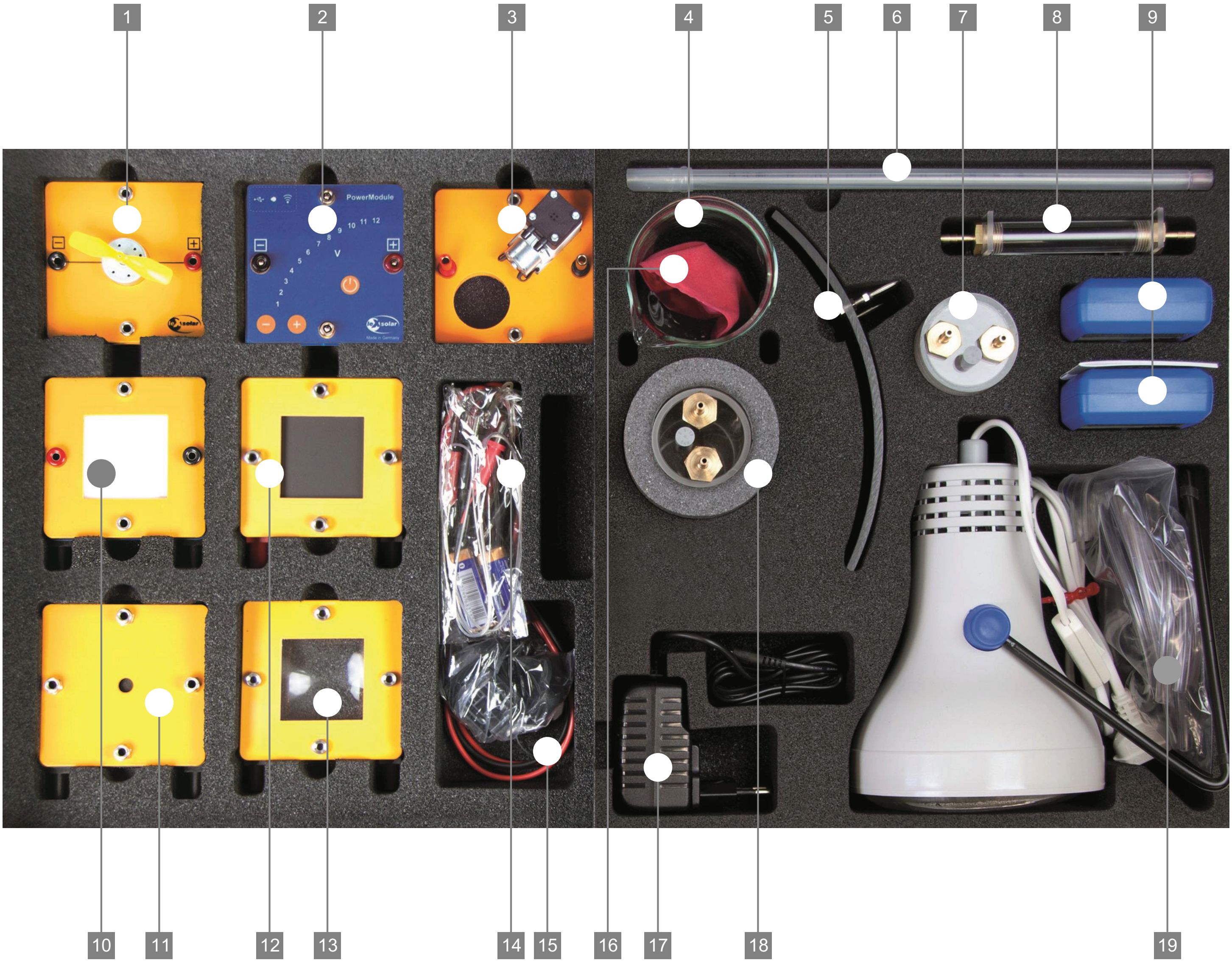
www.lexsolar.de/feedback

Layout diagram leXsolar-ThermalEnergy Professional

Item-No.1306

Bestückungsplan leXsolar-ThermalEnergy Professional

Art.-Nr.1306



1	1100-27 Motor module without gear 1100-27 Motormodul ohne Getriebe L2-02-017 Propeller L2-02-017 Propeller
2	9100-05 PowerModul with 17 9100-05 PowerModul mit 17
3	1300-09 Pump module with 23 1300-09 Pumpenmodul mit 23
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	L2-06-123 Temperature measuring sensor L2-06-123 Temperaturmesssensor
15	2xL2-06-059/060 Test leads red/black 2xL2-06-059/060 Messleitung rot/schwarz
16	L2-06-125 Cooling pad L2-06-125 Kühlkissen
17	Power supply for 2 Stromversorgung für 2
18	1300-11 Heat exchanger water 1300-11 Wärmetauscher Wasser
19	1300-13 Hose set 1300-13 Schläuche-Set

Version number
Versionsnummer

II-01.24_L3-03-190_14.06.2017

CE RoHS2

Layout diagram leXsolar-ThermalEnergy Professional

Item-No.1306

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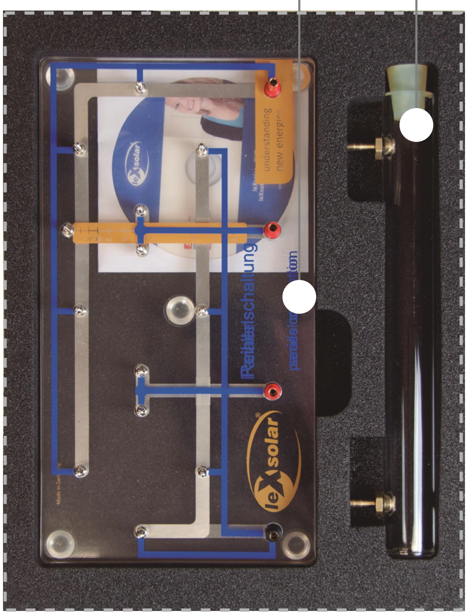

20	1300-03 Solar colector 1300-03 Solar-Kollektor	
21	L2-04-116 Illuminant 120W with L2-04-080 Lamp housing L2-04-116 Leuchtmittel 120W mit L2-04-080 Lampengehäuse	
22	1100-19 leXsolar-basic unit 1100-19 Grundeinheit groß	
23	Balancing container with 3 Ausgleichsgefäß mit 3	

CE RoHS2

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Experiment handbook

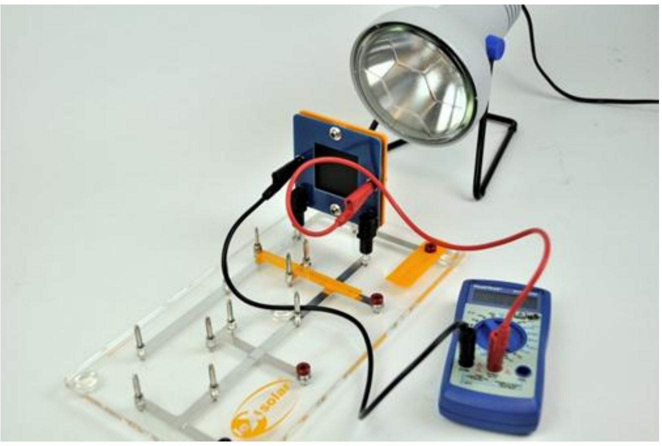
Content

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

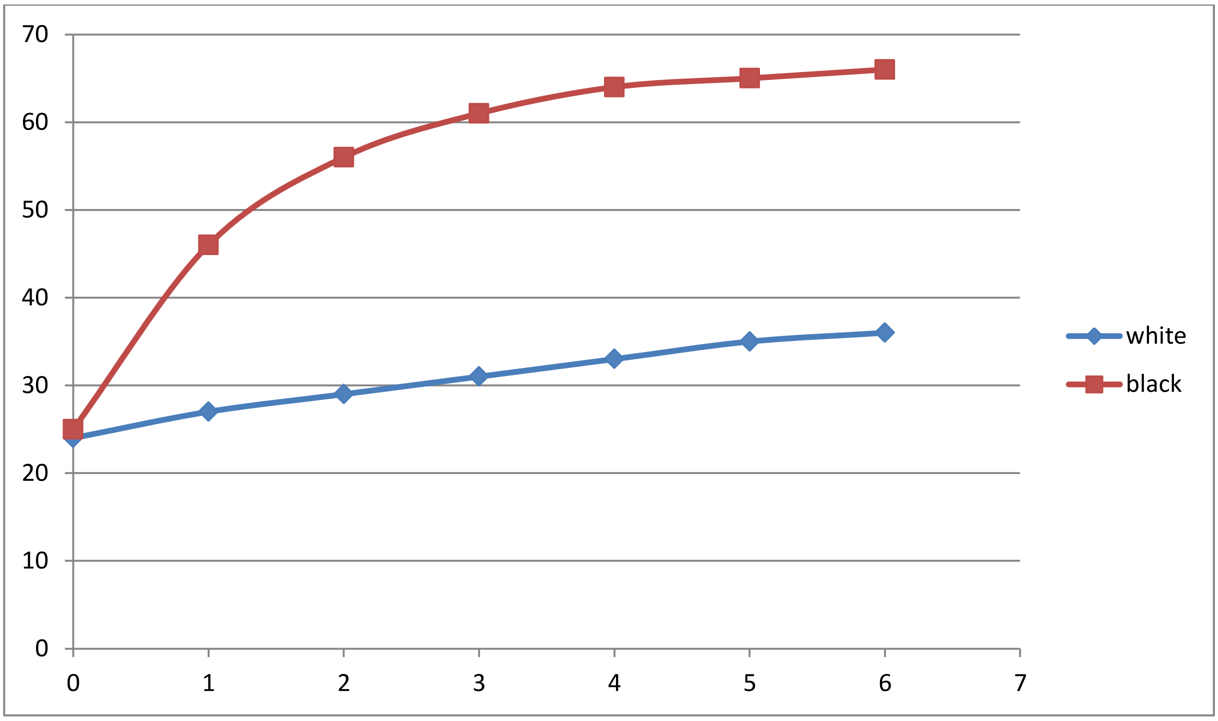


Diagram 1.1 – Development of the temperature at the absorption module black/white.

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.

2. Focusing of light by a Fresnel lens

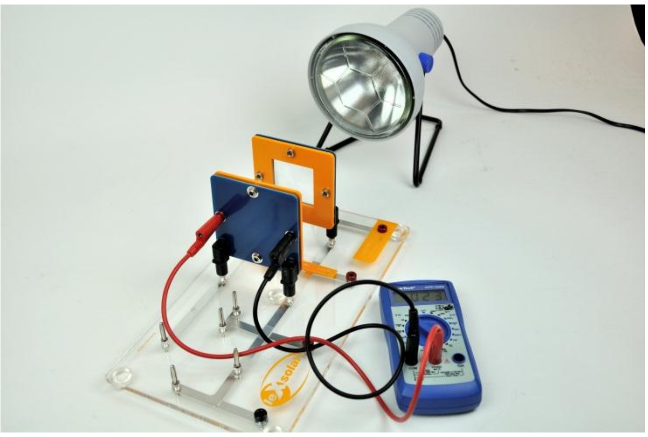
Task

Demonstrate the influence of the focusing of sunlight on the heating of an absorber material.

Setup

2.1 Heating without Fresnel lens

2.2 Heating with Fresnel lens



Equipment

- Basic module
- Spotlight
- Digital meter
- Lens module
- Lens absorption module
- Cables

Procedure

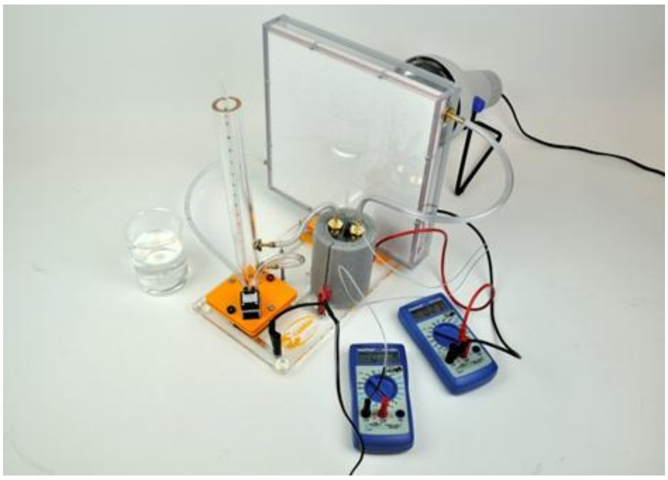
1. Put the lens absorption module into the basic module with the opening facing the spotlight. Adjust the distance to the spotlight to approx. 25 cm.
2. Then connect the digital meter with the lens absorption module as shown in figure 2.1.
3. Adjust the digital meter to the symbol °C to start the temperature 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 lens absorption module cool down until it has returned to its approximate starting temperature.
6. Now put the lens module between the spotlight and the absorber as shown in figure 2. Take care that the distance to the spotlight is again 15 cm.
7. 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.

9. Collector circuit with heat exchanger

Task

Show that water outside the circuit can be heated up using the heat exchanger. How quickly can the heat transitions be realized in the system?

Setup



Equipment

- Basic module
- Pump module
- Solar collector
- Hoses
- 2x digital meter with connection lines
- Temperature probe
- Liquid thermometer
- Spotlight
- PowerModule
- Heat exchanger with insulation

Procedure

1. Put the solar collector and the pump module with the balancing container onto the basic module and connect the modules with the enclosed hoses as shown in the figure.

   Advice: It must be ensured that the left pump connection is connected to the lower connection of the collector.

2. Use the upper connection of the collector to connect the heat exchanger with the balancing container and close the water circuit. Use the heat exchanger with the enclosed insulation to reduce thermal losses.
3. Now fill water into the balancing container and connect the PowerModule to the pump (9V). This feeds water into the circuit.

   Advice: If necessary, refill the beaker with water until a stable water circuit with 200ml is reached. Swing the collector carefully, to remove residual water bubbles from the collector.

4. Now fill the heat exchanger with water and note, with the aid of the scale of the measurement cup, the weight of both water systems.
5. Place the liquid thermometer into the balancing container and keep a clock ready for timing. Adjust the digital meters to “°C” to start the measurement.
6. Connect the included temperature probes with one of the devices. Connect the other meter with two cables directly to the collector, which has an internal temperature sensor. Place the spotlight 15 cm away from the collector and switch it on.

Procedure

7. Plug the temperature probe into the heat exchanger and close it with the cork. Pay attention that the measurement probe does not touch the copper block and is positioned at the centre of the heat exchanger.
   Now measure the temperature development at all three measuring positions simultaneously and enter your data into the table.

Data

Weight of water in the balancing container: m_{Au} =0,2kg

Weight of water in the balancing container: $m_{Wä}$ =0,1kg

Time in minutes	Temperature collector T_1 in C°	Temperature heat exchanger T_3 in C°	Temperature balancing container T_2 in C°	Temperature difference balancing container – heat exchanger $T_2 - T_3$ in K	Temperature difference collector – balancing container $T_1 - T_2$ in K
0	23	23	23	0	0
2	36	23	24,5	1,5	11,5
4	38	23	27	4	11
6	40	26	29	3	11
8	42	27	31	4	11
10	43	29	32	3	11
12	45	31	33,5	2,5	11,5
14	46	32	35	3	11
16	47	34	36,5	2,5	10,5
18	48	36	37,5	1,5	10,5
20	49	37	39	2	10
22	50	38	40	2	10
24	51	39	41	2	10
26	52	40	42	2	10
28	52	41	43	2	9
30	53	42	44	2	9

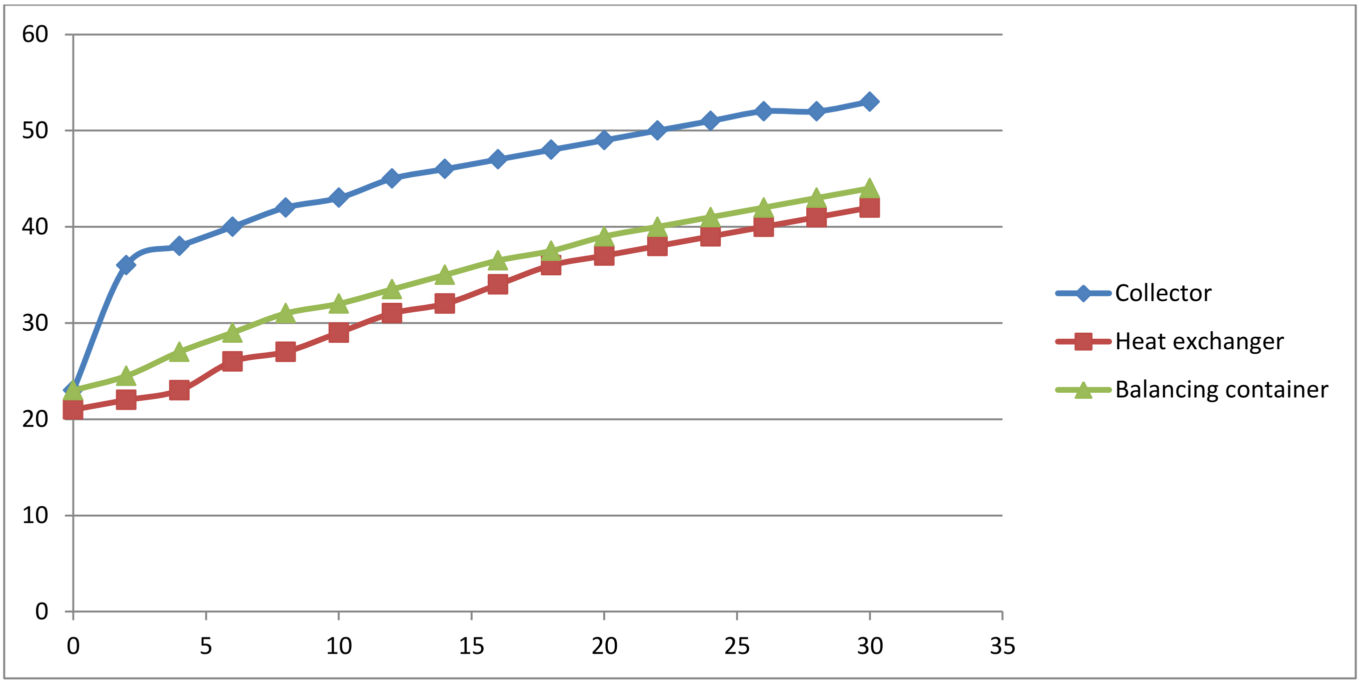
Analysis

1. Record your results in the pictured diagram.

Analysis

2. Compare the results at different measuring positions. Comment on the measured temperature differences between collector and water circuit and between water circuit and heat exchanger.
3. Determine the transferred quantity of heat by using the recorded values and the overall time
4. Determine the relevant heat flows at the heat junctions in the system and calculate the corresponding heat transmission resistance.
5. Compare the heat transmission resistances and discuss possible, technical solutions to minimize it.

Diagram



Analysis

2.
After a short time period, the heat exchanger and the collector heat up nearly equally fast. Therefore, one can conclude that the heat transfer between the collector and the water circuit is very efficient. The temperature in the heat exchanger on the other hand is continuously lagging behind that of the water circuit by approximately 4K. The heat transfer at the heat exchanger must consequently be working much more slowly.

3.
Temperature difference balancing container – heat exchanger $T_2 - T_3$ = 2,3 K

Temperature difference collector – balancing container $T_1 - T_2$ = 9,8K

14. Investigation of the thermoelectric generator

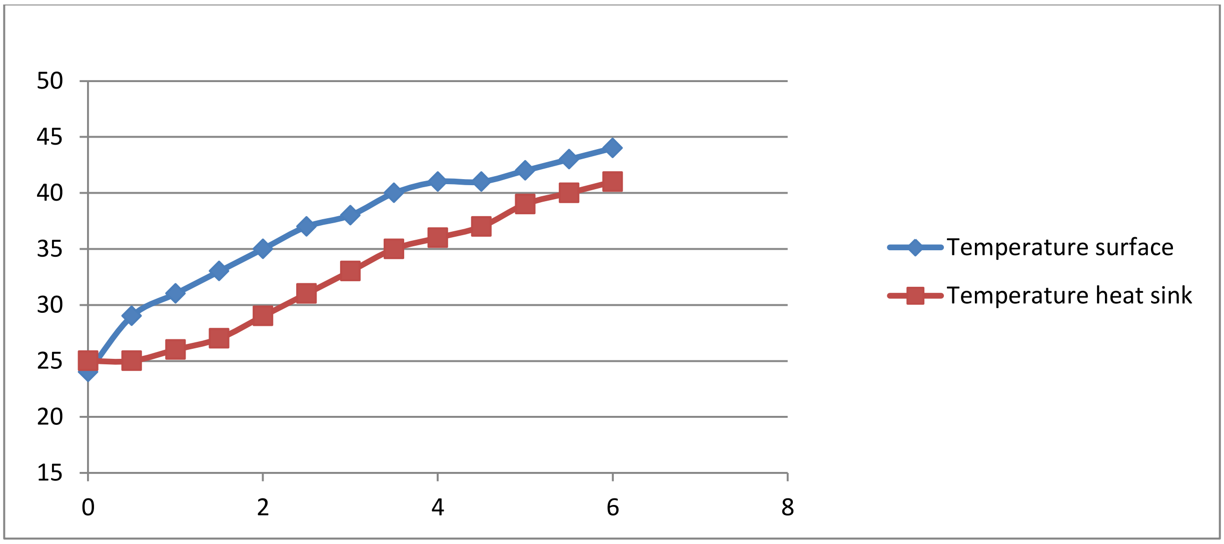
Data

Time in minutes	Surface temperature in °C	Temperature heat sink in °C	Temperature difference in °C
0	24	25	1
0.5	29	25	4
1	31	26	5
1.5	33	27	5
2	35	29	6
2.5	37	31	6
3	38	33	5
3.5	40	35	5
4	41	36	5
4.5	41	37	4
5	42	39	3
5.5	43	40	3
6	44	41	3

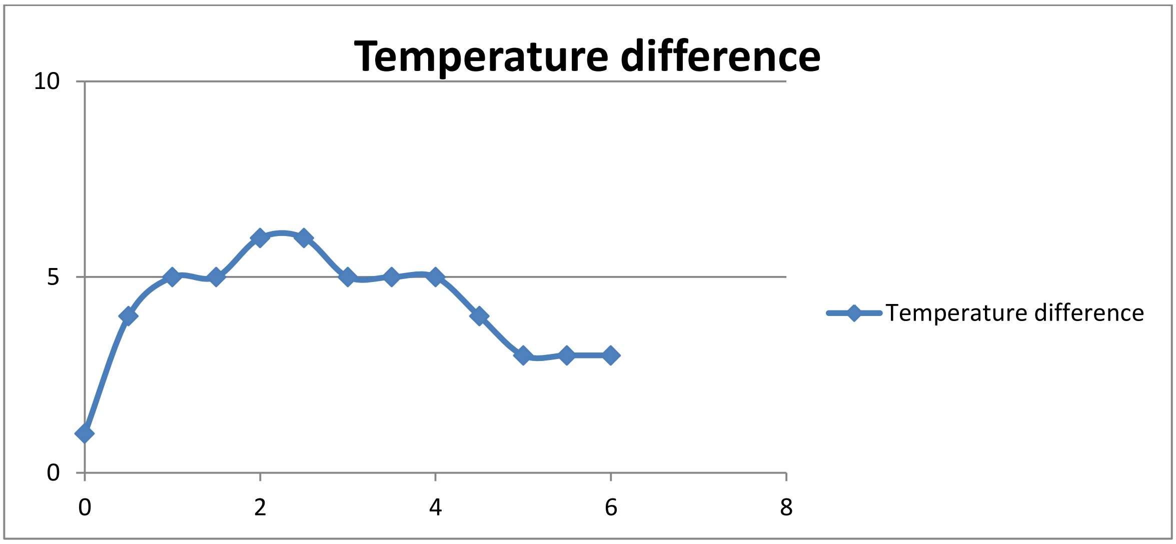
Analysis

1. Calculate the development of the temperature difference between the front and back during the experiment and write the values into the table.
2. Transfer your data into the depicted diagram.
3. Describe your observations and explain the influences of heat conduction and heat radiation on the experiment.

Diagram



Diagram



Analysis

3.

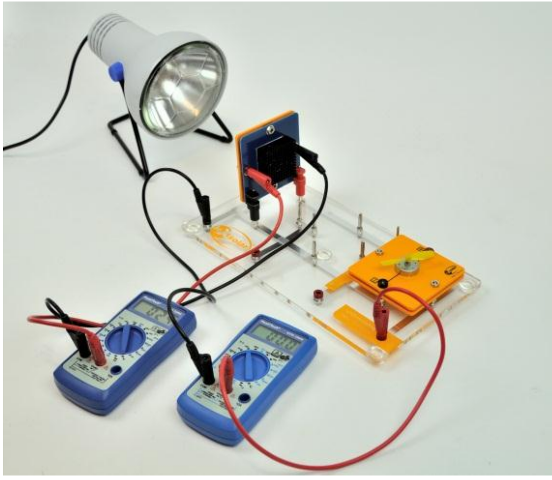
At the beginning, the surface of the thermoelectric generator heats up very quickly. During this time period, the temperature of the heat sink is constant. The heating of the heat sink is delayed due to the heat transmission resistance of the module. The heating of the surface is attenuated during the measurement because the thermal radiation losses increase with temperature. The heat sink heats up continuously by thermal conduction. The heat dissipation of the heat sink to the ambient air is lower than the heat absorption by the thermoelectric generator. By looking at the temperature differences, one can recognise a decline after the strong increase at the beginning of the experiment. This heating up of the thermoelectric generator reduces the performance of the module and can be circumvented only by the expansion of the cooling construction.

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

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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