Peltier effect – Heat pump

Task and equipment

Information for teachers

Additional information

A heat pump is a device which uses mechanical or electric energy to pump thermal energy from a medium A into a medium B. The heat Q conducted to the medium B is greater than the used mechanical or electric energy E_0. The Q factor (performance) of a heat pump is described by the so-called "coefficient of performance" $\varepsilon = Q / E_0$. It is always necessary to apply $\varepsilon > 1$.

The heat pump is known by the students as an important element for alternative heat-engineering. In this industry, compression heat pumps are primarily used.

In this experiment a Peltier-heat pump is used. The most important quality of a heat pump, that the coefficient of performance is bigger than 1, is also valid here:

The heat pump delivers more thermal energy than utilized electric energy, since it extracts heat from another medium (from the surroundings). For this purpose, solar collectors or geothermal energy, among other things are used.
In the experiment the water heats up while the aluminium block cools down. Thus, the aluminium block takes on the function of the surroundings.

Notes on the Set-up and Procedure

Before the power supply is switched on, you should check that both plates of the Peltier element have the same temperature in the multimeter, i.e. ideally, the thermo voltage in the thermo generator should be 0 V. Furthermore, before beginning with the measurement, the students can use the multimeter to set the current regulator of the power supply unit at exactly 1 A.

Peltier effect – Heat pump

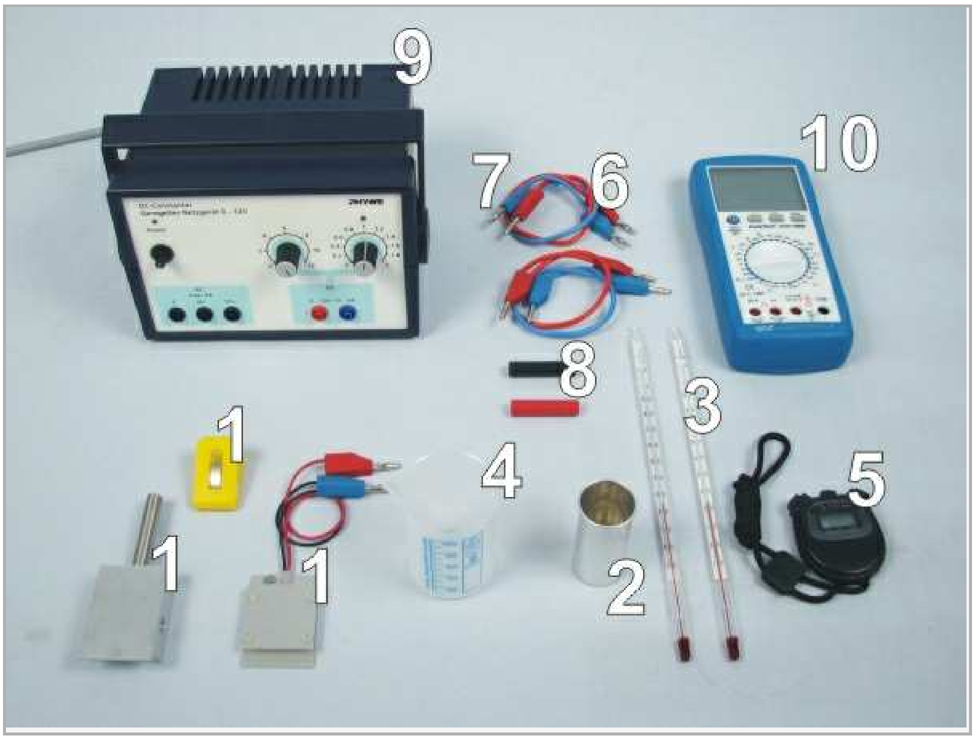
Task and equipment

Task

Is it possible to generate thermal energy while converting electric energy?

A beaker containing water is placed on the upper plate of the thermo generator. Apply a voltage intensity to the thermo generator and choose the polarity so that the upper plate and thereby, the water heat up. Determine the used electric energy and the produced thermal energy.

Equipment



Position No.	Material	Order No.	Quantity
1	Thermal generator for student experiments	05770-00	1
2	Beaker, aluminum, polished	05903-00	1
3	Lab thermometer,-10..+100 °C	38056-00	2
4	Beaker, low form, plastic, 100 ml	36011-01	1
5	Digital stop watch, 24 h, 1/100 s & 1 s	24025-00	1
6	Connecting cord, 32 A, 250 mm, blue	07360-04	2
7	Connecting cord, 32 A, 250 mm, red	07360-01	2
8	Double sockets,1 pair,red a.black	07264-00	1
9	PHYWE power supply DC: 0...12 V, 2 A / AC: 6 V, 12 V, 5 A	13505-93	1
10	DMM with NiCr-Ni thermo couple	07122-00	1
Additional material			
	Water		

Set-up and procedure

Set-up

Fasten the Peltier element to the aluminium block with the help of the yellow clip (Fig. 1). Be sure to place the Peltier element in such a way that its smaller side is on top.

Fig. 1

Now connect the thermo generator to the power supply with the help of both double sockets and the connection cords (Fig. 2). The power supply is switched off. Make sure that the red connection cord of the thermo generator is connected to the negative pole of the power supply unit (blue socket) and that the black connection cord is connected to the positive pole (red socket).

Fig. 2

Turn the current regulator to 1 A and the voltage regulator to the stop position (Fig. 3).

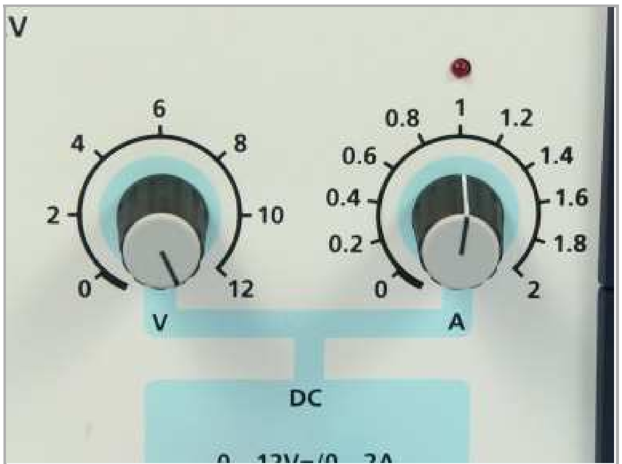


Fig. 3

On one side of the aluminium block there is an opening for the temperature measurement (Fig. 4).

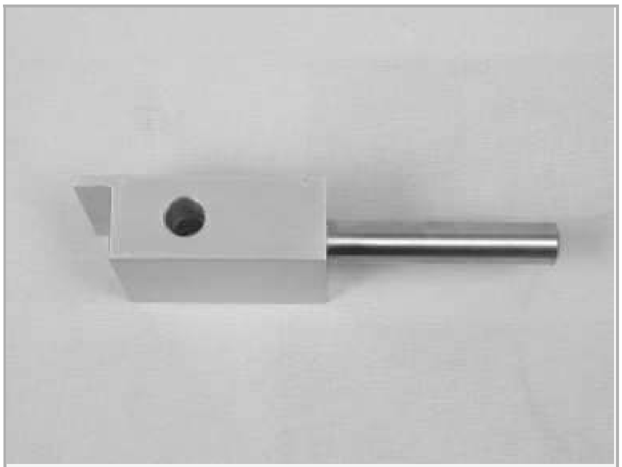


Fig. 4

Insert one of the two thermometers in this opening. Make sure that the measuring tip of the thermometer touches the aluminium block (Fig. 5).

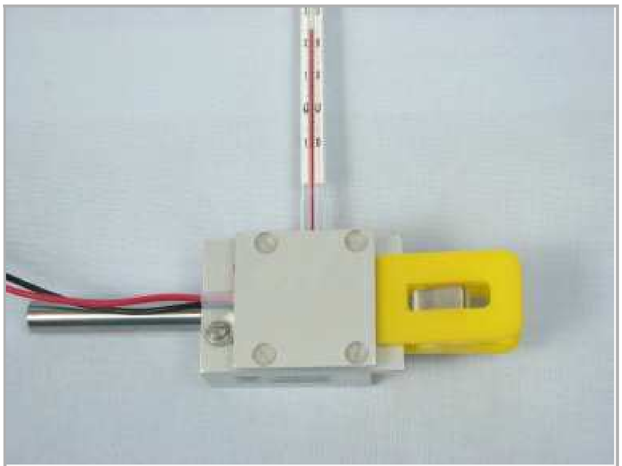


Fig. 5

In order to prevent the thermometer from slipping out of the opening during the experiment, you can rest the other end of the thermometer, for instance, on the cover in which it is kept in the box (Fig. 7).

Fig. 6

Measure 30 ml cold tap water using the small beaker and fill the water into the polished beaker. Afterwards, place the beaker on the Peltier element (Fig. 7).

Fig. 7

Dip the second thermometer in the water (Fig. 8).

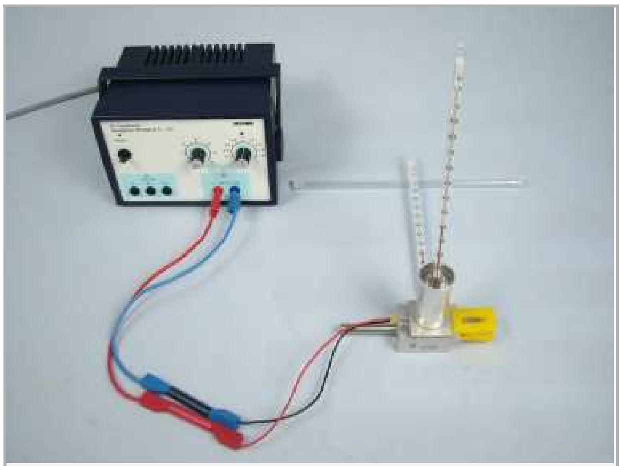


Fig. 8

Connect the multimeter parallel to the thermo generator (Fig. 9).

Fig. 9

Adjust the measuring range to 20 V of DC voltage (Fig. 10).

Fig. 10

Procedure

Switch on the power supply and measure the tension U, the temperature ϑ_1 of the water and the temperature ϑ_2 of the aluminium block directly after the switching it on (*t* = 0 min). Start the stopwatch and measure then *U*, ϑ_1 and ϑ_2, after t = 1, 2, 3, 4, 5 min, and write down the values in Table 1 (Fig. 11).

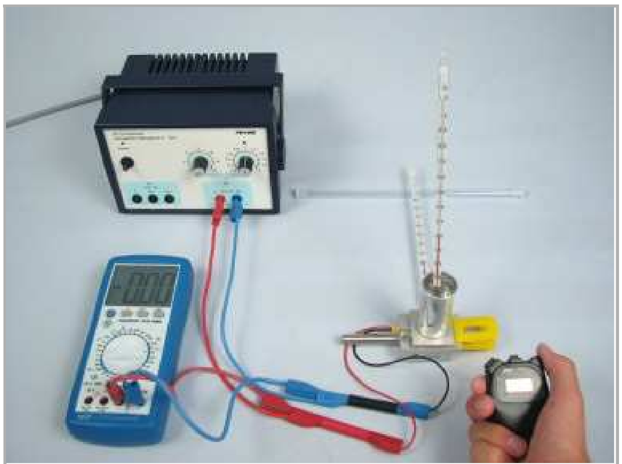


Fig. 11

Report: Peltier effect – Heat pump

Result - Table 1

Record your measured values in the table.

t in min	*U* in mV	ϑ_1 in °C	ϑ_2 in °C
0	1 ±0	1 ±0	1 ±0
1	1 ±0	1 ±0	1 ±0
2	1 ±0	1 ±0	1 ±0
3	1 ±0	1 ±0	1 ±0
4	1 ±0	1 ±0	1 ±0
5	1 ±0	1 ±0	1 ±0

Evaluation - Question 1

Calculate the electric energy Q_{el} which is supplied to the thermo generator using the formula

$Q_{\mathrm{el}} = U_{av} \cdot I \cdot t$

Take into account that U_{av} is the average of the measured voltages, I is the current and t = 300 sec.

Evaluation - Question 2

Calculate the heat Q_W which is added to the water using the following formula:

$Q_W = c_W \cdot m_W \cdot \Delta\vartheta_1$

c_W = 4,2 J/g·K is the heat capacity of the water, m_W is the mass of the water and $\Delta\vartheta_1$ is the temperature difference in which the water has heated up during 5 minutes. Take into account that 1ml water weighs 1 g.

....

....

....

....

Evaluation - Question 3

Calculate the coefficient of performance $\varepsilon = Q_W / Q_{el}$ and describe what this value means.

....

....

....

....

Evaluation - Question 4

Calculate the heat Q_{Al} which is extracted from the aluminium block using the formula

$Q_{Al} = c_{Al} \cdot m_{Al} \cdot \Delta\vartheta_2$.

Take into account that c_{Al} =0.9 J/g·K is the heat capacity of aluminium, m_{Al} is the mass of the aluminium block and $\Delta\vartheta_2$ is the heat difference in which the aluminium block cools down during 5 minutes. In order to simplify matters you can ignore the stainless steel shaft and the hole in the aluminium block, and consider it as an aluminium cuboid with lateral lengths of 5 cm, 4 cm and 2 cm. The density of aluminium amounts to 2.7 g/cm^3.

....

....

....

....

Evaluation - Question 5

Determine the efficiency factor η of the heat pump using

$\eta = Q_W / (Q_{el} + Q_{Al})$.

....

....

....

....

Evaluation - Question 6

Explain on the basis of the previous results, why, in this case, the test set-up is identified as a heat pump.

....

....

....

....