Temperature measurement with a thermocouple

(Item No.: P1042400)

Curricular Relevance

Area of Expertise: Physics
Education Level: Age 14-16
Topic: Thermal physics
Subtopic: Measurement of temperature
Experiment: Temperature measurement with a thermocouple

Difficulty	Preparation Time	Execution Time	Recommended Group Size
Easy	10 Minutes	10 Minutes	2 Students

Additional Requirements:

- Butane burner, Labogaz 206 type 32178-00
- Butane cartridge C206, without valve 47535-00
- Multi-range meter, analogue 07027-01
- Boiling beads, 200 g 36937-20
- Emery paper, medium coarseness, 5 sheets
- Universal pliers
- Scissors
- Matches
- Ice, crushed (ice cubes, hammer and cloth)

Experiment Variations:

Keywords:

Task and equipment

Information for teachers

Additional Information

If two different metals are in contact, a contact potential results from the different electron affinity of the metals' surfaces. The size of this potential is a function of the temperature since the electron’s kinetic energy increases with increasing temperature. These potentials also occur when the thermocouple is connected to a voltmeter. However, they cancel each other (i.e., they do not falsify the measuring results) if both leads which are connected to the meter are of the same material.
A thermocouple consists of a pair of different metals, e.g. iron and constantan. If the two contact points have different temperatures, the difference between the contact potentials can be measured as thermo potential.

$U = - U_1 + U_M - U_0 + U_1$

$U = U_M - U_0$

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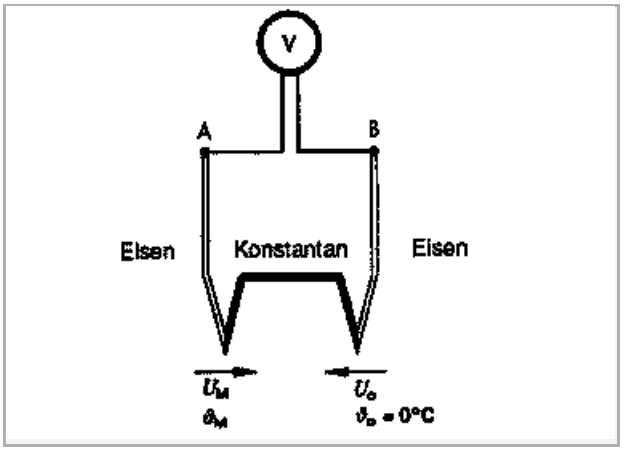


In this experiment the students should become familiar with the functioning of a thermocouple. They should determine that for measurements with a thermocouple two contact points are important: a measuring point and a comparison point (in commercial available thermocouples, the comparison point is usually in the jack). They should observe that the thermo potential increases approximately linearly with the temperature.

Remark

If no thermoelectric voltage appears, the contact points should be checked. The ends of the wires must be well polished. If necessary, the twisted wires should be pressed together with a pair of pliers so that the two thermoelectric wires are in close contact with each other.

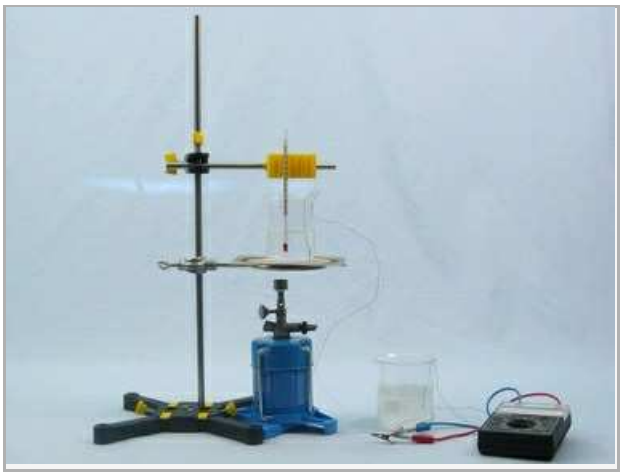
Temperature measurement with a thermocouple **(Item No.: P1042400)**

Task and equipment

Task

How does a thermocouple work?

Construct a thermocouple using iron wire and constantan wire; and investigate how it can be used to measure temperature.



Equipment

Position No.	Material	Order No.	Quantity
1	Support base, variable	02001-00	1
2	Support rod, stainless steel, l = 250 mm, d = 10 mm	02031-00	1
2	Support rod, stainless steel, l = 600 mm, d = 10 mm	02037-00	1
3	Boss head	02043-00	1
3	Glass tube holder with tape measure clamp	05961-00	1
4	Connecting cord, 32 A, 500 mm, blue	07361-04	1
4	Ring with boss head, i. d. = 10 cm	37701-01	1
5	Wire gauze with ceramic, 160 x 160 mm	33287-01	1
6	Students thermometer,-10...+110°C, l = 180 mm	38005-02	1
6	Agitator rod	04404-10	1
7	Glass beaker DURAN®, short, 250 ml	36013-00	1
8	Glass beaker DURAN®, short, 400 ml	36014-00	1
9	Connecting cord, 32 A, 500 mm, red	07361-01	1
10	Alligator clips, bare, 10 pcs	07274-03	(2)
11	Constantan wire, 4 Ohm/m, d = 0.4 mm, l = 50 m	06102-00	1
11	Iron wire, d = 0.5 mm, l = 50 m	06105-00	1
	Butane burner, Labogaz 206 type	32178-00	1
	Butane cartridge C206, without valve	47535-01	1
	Multi-range meter, analogue	07028-01	1
	Boiling beads, 200 g	36937-20	1
Additional material			
	Emery paper, medium coarseness, 5 sheets	01605-02	1 sheet
	Universal pliers	01620-00	1
	Scissors		1
	Matches		
	Ice, crushed (ice cubes, hammer and cloth)		

Set-up and procedure

Set-up

Warning!

1. During the heating of the water the support ring and the wire gauze become extremely hot!
2. When measuring the flame's temperature the wires should be held as far from the measuring point as possible or with a pair of pliers!

Setup

- Set up the support stand according to the following pictures.

Fig. 1

Fig. 2

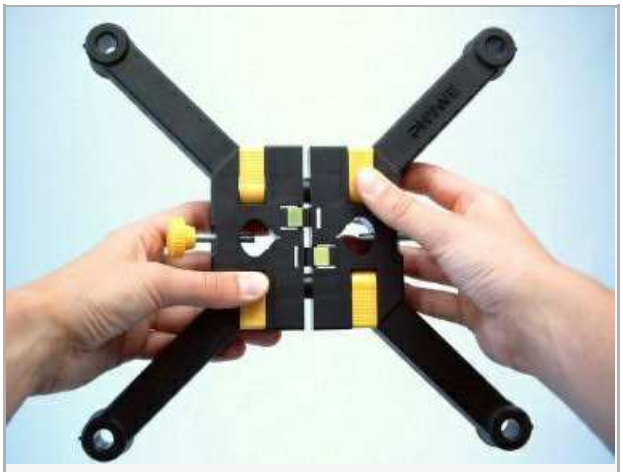


Fig. 3

Fig. 4a

Fig. 4b

Fig. 5

Fig. 6

Fig. 7

Fig. 8

- Cut one piece of constantan wire which is approx. 70 cm long and two pieces of iron wire with the same length.

Fig. 9

- Polish the ends of the wires with sandpaper.

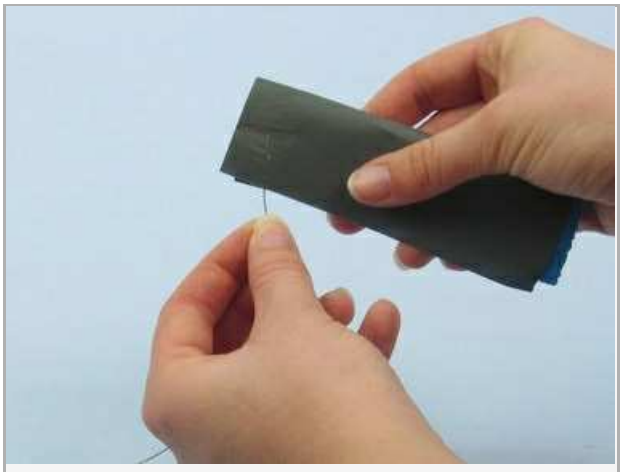


Fig. 10

- Twist one end of the constantan wire and one end of one piece of iron wire together; repeat this with the other end and the other piece of iron wire.

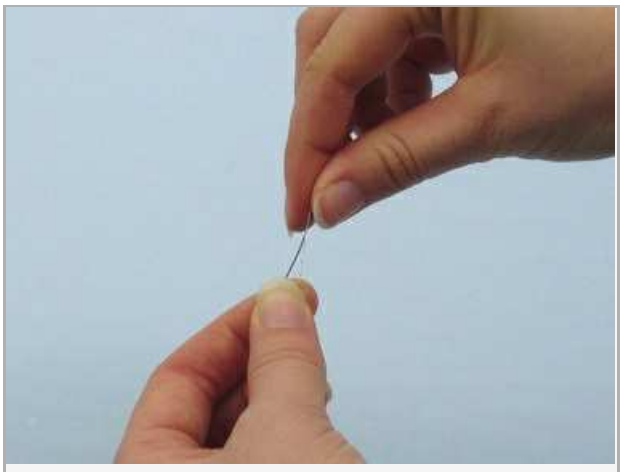


Fig. 11

- The twisted ends should be pressed together with a pair of pliers to improve their contact.

Fig. 12

- Wrap the ice in the cloth (so that the pieces do not scatter) and crush it with the hammer.

Fig. 13

Fig. 14

- Fill the beaker half-full with ice.

Fig. 15

- Place two beads in the beaker.

Fig. 16

- Add enough cold water to the ice to just cover it.

Fig. 17

- Fill the small beaker about half-full with very cold tap water (under 20 °C).

Fig. 18

- Stick one contact point in the ice water, the other in the tap water.

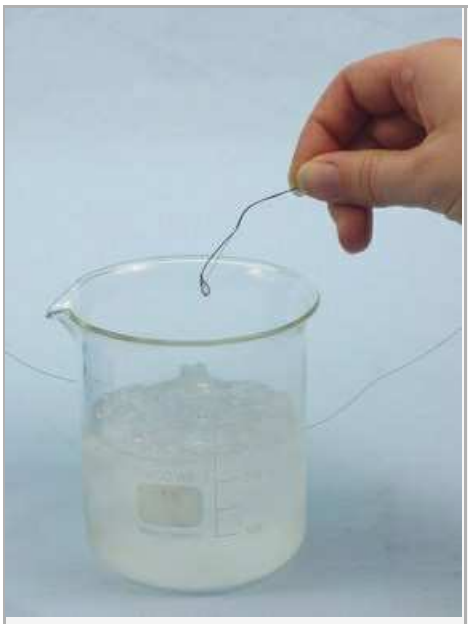


Fig. 19

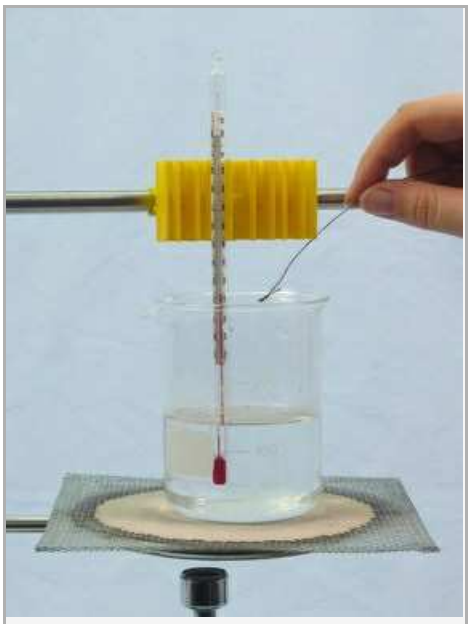


Fig. 20

- Both contact points should be completely immersed in the water.
- Bend the wires over the rim of the beakers so that they do not fall out.
- Connect the wires to the meter as shown in the following pictures and select the 100 mV direct current measuring range.

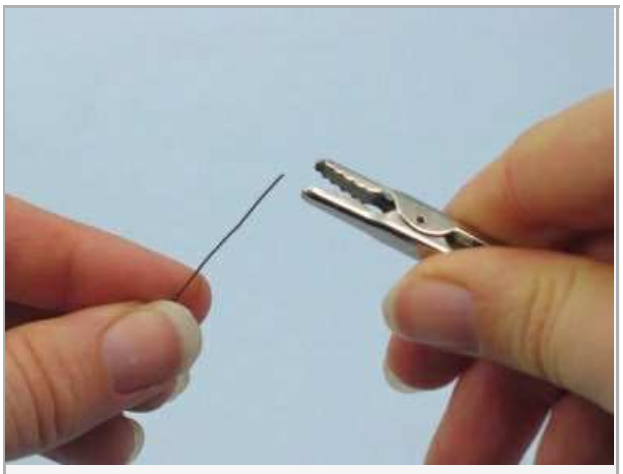


Fig. 21

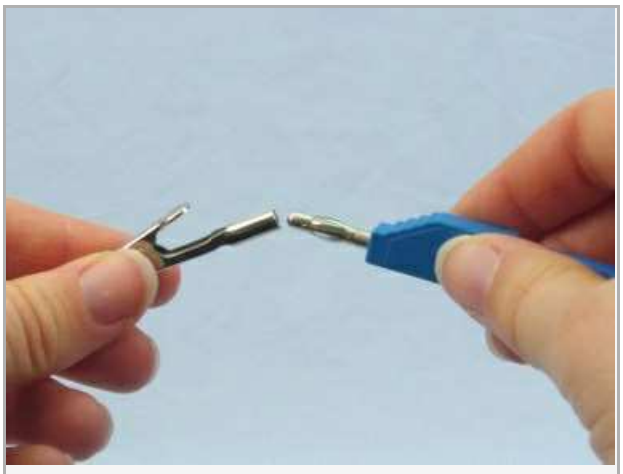


Fig. 22

Fig. 23

Procedure

Experiment 1

- Read the indicated value. If necessary, reverse the polarity of the meter.
- Heat the water until it boils. Measure the thermoelectric voltage in 20 °C-steps and record the values in the table in the report.

Experiment 2

- Remove the comparison contact from the ice water and place it in the hot water. Read the thermoelectric voltage and record the value (report).

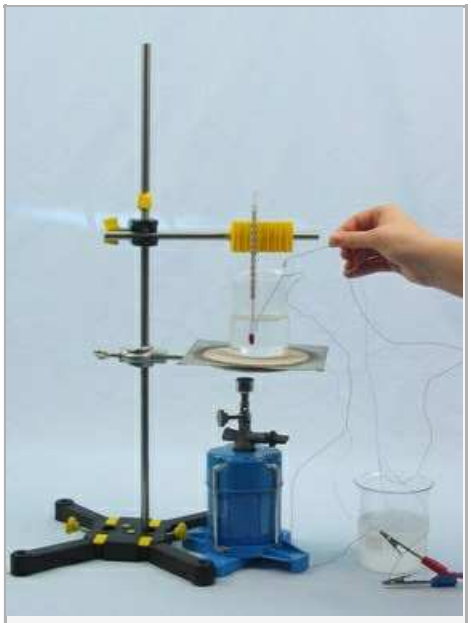


Fig. 24

Experiment 3

- Immerse the comparison contact in the ice water again. Hold the measuring point as completely as possible in the flame. Record the thermoelectric voltage.

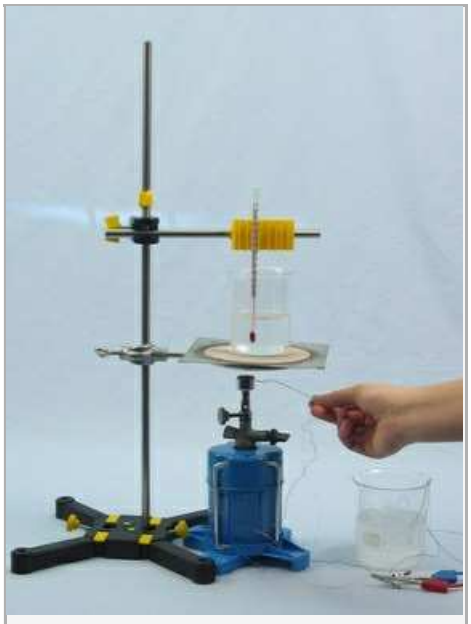


Fig. 25

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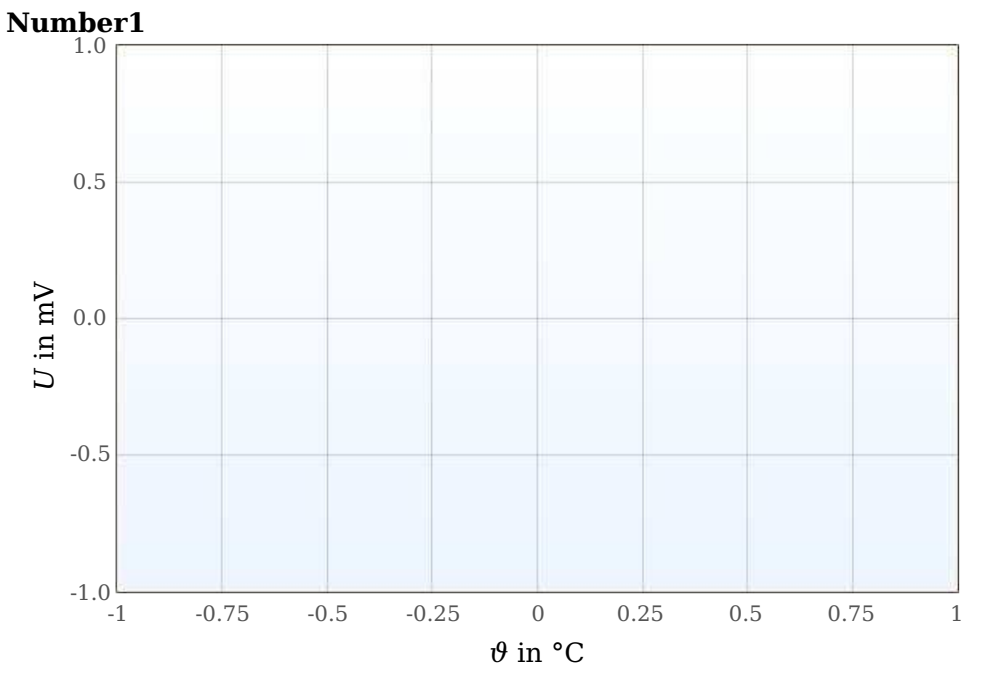
Report: Temperature measurement with a thermocouple

Result – Table 1

Experiment 1: Temperature of the comparison point: 0 °C (ice water). Enter the values for thermoelectric voltages in the table.

ϑ in °C	U in mV
20	1 ±0
40	1 ±0
60	1 ±0
80	1 ±0
100	1 ±0



Result – Observations 1

Experiment 2: What happens to the thermoelectric voltage when both contact points immerse in hot water.

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Result – Observations 2

Experiment 3: Measuring point in the flame.

Temperature of the comparison point: 0 °C (ice water)

Thermoelectric voltage (average value): ..... mV.

Evaluation – Question 1

Describe the correlation between the measured temperatures and the thermoelectric voltages.

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Evaluation – Question 2

What is the importance of the comparison point?

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Evaluation – Question 3

How large is the sensitivity of the thermocouple, i.e. how large is the thermoelectric voltage for a temperature difference of 1 °C?

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Evaluation – Question 4

Approximately how high is the temperature of the flame?

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