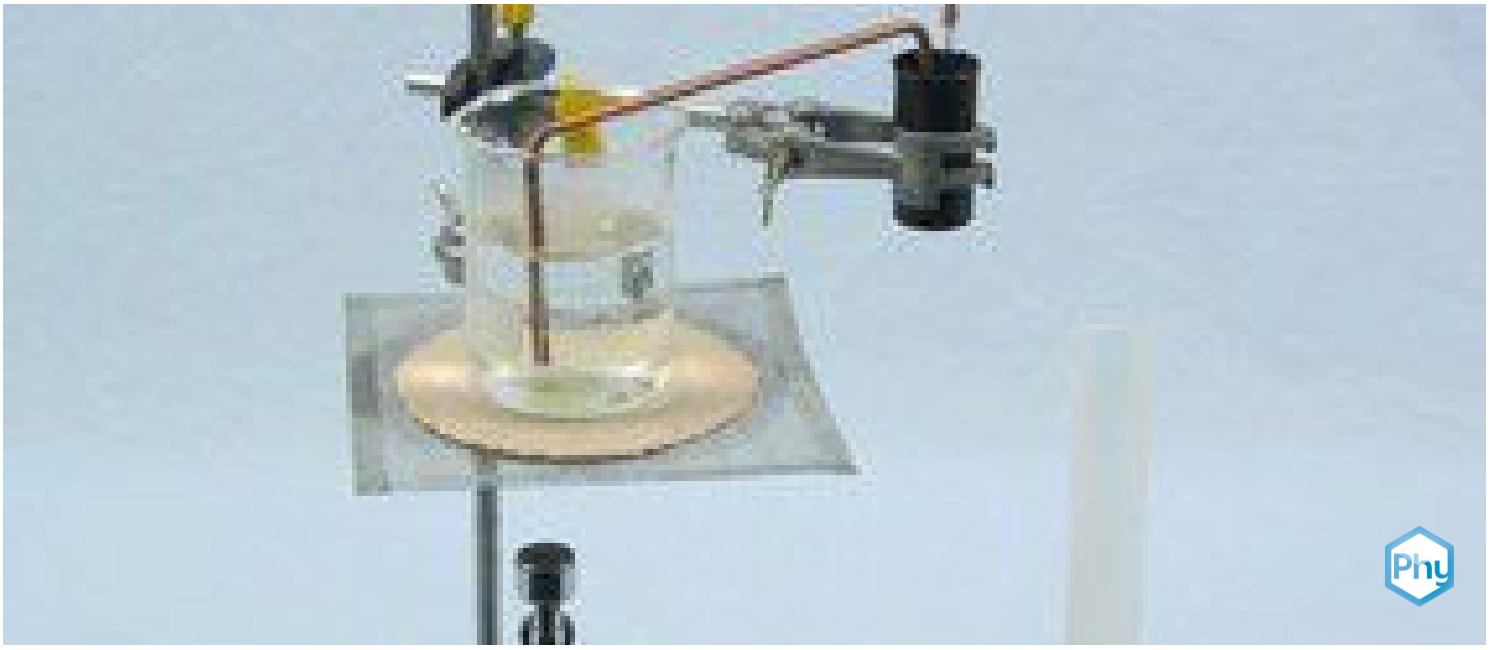
Thermal conduction coefficient of metals



P1043200

Physics > Thermodynamics > Heat transfer

Difficulty level	Group size	Preparation time	Execution time
medium	-	10 minutes	10 minutes

This content can also be found online at:

http://localhost:1337/c/640dbd54d6d5450002eb18c3

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Teacher information

Application

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Experimental setup

Energy can be transferred by heat flow, heat radiation or heat conduction.

The greater the thermal conductivity of a material, the better this material can conduct heat. However, the heat flow along a rod additionally depends on its proportions.

The students learn these connections with the help of this experiment.

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Other teacher information (1/5)

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Prior knowledge

Students should be familiar with a butane burner.

Principle

A u-shaped metal rod is immersed in boiling water on one side and cold water on the other. From the heating of the cold water, qualitative and quantitative statements can be made about the influence of the material, length and diameter of the rod on the heat flow.

Other teacher information (2/5)

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Learning objective

The students should learn the influence of material, length and diameter of the rod on the heat flow.

With the help of the additional tasks, the connection to the heat conduction coefficient can be made.

Tasks

Investigate the heat conduction in metals depending on the material and the dimensions of the rod.

Place a metal rod between two cups of hot and cold water and measure the temperature change in the cold water.

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Other teacher information (3/5)

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Additional information

Since carrying out the experiment is time-consuming, the measurements should be carried out in a division of labour: At least four working groups are formed. One working group carries out the experiment with only one rod at a time and the results of all working groups are compiled for evaluation.

On set-up and procedure:

1. Beaker and metal cup are to be arranged so that the metal rod can easily be placed over both when the water is boiling. However, it is not there during the heating phase of the water!
2. When reading the temperatures, intermediate values of 0.5 °C should also be estimated; In the metal beaker, stir regularly.
3. For this experiment, a thermometer with 1 / 10 - degree division is recommended, as very small temperature differences have to be evaluated (see material list).

Other teacher information (4/5)

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About the additional tasks:

With the additional tasks, the quantitative confirmation of the formula for the heat flow is carried out. The calculation of the specific thermal conductivity is not performed, as the results are subject to large errors for the reasons mentioned below.

The heat flow through a metal rod depends on its length, its cross-section and the difference in temperatures on both sides of the rod. The proportionality factor is the spec. thermal conductivity λ of the material.

$$\frac{\Delta Q}{\Delta t} = \lambda \cdot (T_w - T_c) \cdot \frac{A}{l} = \lambda \cdot (T_w - T_c) \cdot \frac{\pi}{4} \cdot \frac{d^2}{l}$$

Thereby $\frac{\Delta Q}{\Delta t}$ = heat flow through the rod, T_w= temperature of the boiling water, T_c= temperature of the cold water, l= length of the rod, A = cross-sectional area of the bar, d = Diameter of the rod

The dependence of the heat flow on d2 and on 1/l can be shown from the students' measurement results. In each case, the copper rod with d0 = 5 mm and b0 = 175 mm is taken as a comparison rod.

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Other teacher information (5/5)

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About the additional tasks:

The dependence of the heat flow on $d_2$and from $\frac{1}{l}$ can be impressively shown from the students' measurement results. In each case, the copper rod with d_0 = 5mm and b_0 = 175mm can be taken as a comparison rod.

Literature values for spec. thermal conductivities:

copper: 384 J/m°C

Aluminium: 220 J/m°C

The deviation of the value determined from the measurement from the literature value is relatively large because the rod is very thin in relation to its length and therefore gives off a lot of heat to the environment. However, the comparison of the rods under the same experimental conditions is quite successful: the spec. thermal conductivity of aluminium is only half that of copper. This is also the result of the experiment.

Safety instructions

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The general instructions for safe experimentation in science lessons apply to this experiment.

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Student information

Motivation

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Cooking pot with hard plastic handles

If we touch a pane of glass in summer after the sun has shone on it, it is warm, but by no means hot. The situation is different with a metal plate or a copper pipe (e.g. a rain gutter). If we touch these after a day of sunlight, we can get a burn in the worst case.

Surely you have also had a pot on the cooker that got hot on the handles while another had cold handles.

These differences are due to the different thermal conductivity of the substances, which will be observed in more detail in the following experiment.

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Tasks

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Experimental setup

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Equipment

Position	Material	Item No.	Quantity
1	Support base, variable	02001-00	1
2	Support rod, stainless steel, l = 250 mm, d = 10 mm	02031-00	1
3	Support rod, stainless steel, l = 600 mm, d = 10 mm	02037-00	1
4	Boss head	02043-00	2
5	Glass tube holder with tape measure clamp	05961-00	1
6	Ring with boss head, i. d. = 10 cm	37701-01	1
7	Wire gauze with ceramic, 160 x 160 mm	33287-01	1
8	Universal clamp	37715-01	1
9	Agitator rod	04404-10	1
10	Beaker, aluminum, polished	05903-00	1
11	Aluminium rod,U-shaped	05910-00	1
12	Copper rod, U-shaped	05910-01	1
13	Copper rod, U-shape,d 3mm,w.175mm	05910-03	1
14	Copper rod, U-shape,d.5mm,w.120mm	05910-04	1
15	Beaker, Borosilicate, low form, 250 ml	46054-00	1
16	Pipette with rubber bulb	64701-00	1
17	Graduated cylinder 100 ml, PP transparent	36629-01	1
18	Students thermometer,-10...+110°C, l = 180 mm	38005-02	1
19	Digital stopwatch, 24 h, 1/100 s and 1 s	24025-00	1
20	Measuring tape, l = 2 m	09936-00	1
21	Butane burner, Labogaz 206 type	32178-00	1
22	Butane cartridge C206, without valve, 190 g	47535-01	1
23	Boiling beads, 200 g	36937-20	1

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10	Beaker, aluminum, polished	05903-00	1
11	Aluminium rod,U-shaped	05910-00	1
12	Copper rod, U-shaped	05910-01	1
13	Copper rod, U-shape d 3mm w 175mm	05910-03	1

Set-up (1/3)

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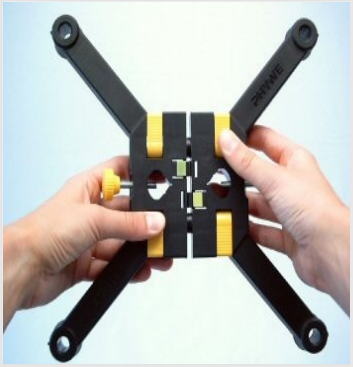
Set up the experiment according to the illustrations in order from left to right.

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Set-up (2/3)

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- Fill the beaker with 200 ml of water and add two boiling beads.
- Arrange the ring and the beaker with universal clamp so that the metal rod with which the measurement is to be taken can be placed between them (cf. fig. right).

Set-up (3/3)

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Hold the thermometer so that its measuring tip is about 1 cm above the bottom of the beaker.

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Procedure

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- Heat the water until it boils and then lower the flame slightly. Note material, thickness *d* and length *b* of the examined metal rod in Table 1 in the report.
- Fill the metal beaker with 20 ml of water (measure exactly with a measuring cylinder and pipette!) (cf. fig. right) and measure the water temperature in the beaker and note it in Table 1 at *t*= 0 min.
- Hang the metal rod with one leg in the boiling water, with the other in the beaker with cold water and start the stopwatch. Stir the water in the beaker regularly.
- Measure and record the water temperature in the beaker every minute and stop the measurement after 12 minutes.

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Report

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Task 1

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Enter your water temperature readings T into the table at the appropriate times.

The following designations apply: Diameter d, length b

- Cu_1 (Copper, d=5mm, b=175mm)
- Cu_2 (Copper, d=3mm, b=175mm)
- Al (Aluminium, d=5mm, b=175mm)
- Cu_3 (Copper, d=5mm, b=120mm)

	Cu_1	Al	Cu_2	Cu_3
t in min	T in °C	T in °C	T in °C	T in °C
0				
1				

	Cu_1	Al	Cu_2	Cu_3
t in min	T in °C	T in °C	T in °C	T in °C
2				

Table continues on the next page.

Task 2

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	Cu_1	Al	Cu_2	Cu_3
t in min	T in °C	T in °C	T in °C	T in °C
3				
4				
5				
6				
7				

	Cu_1	Al	Cu_2	Cu_3
t in min	T in °C	T in °C	T in °C	T in °C
8				
9				
10				
11				
12				

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Task 3

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Plot all measured values in a time-temperature diagram.

Why does the water temperature rise only slightly in the first two minutes?

- ☐ Only when a more or less constant temperature ratio has been established above the metal rod can statements about heat conduction be obtained from the measured values.
- ☐ The heat is first needed to heat the metal rod.
- ☐ In the first few minutes, a lot of heat is lost to the environment. You have to wait for this period.
- ☐ The thermometer takes a while to adjust to a temperature change.

Task 4

PHYWE

How big is the temperature increase ΔT in the period between t_1 = 2 min and t_2 = 12 min?

Equipment	d in mm	b in mm	ΔT in °C
Cu	5	175	
Al	5	175	
Cu	3	175	
Cu	5	120	

Which metal conducts heat better?

- ☐ Aluminium conducts heat about twice as well as copper.
- ☐ Aluminium
- ☐ Copper
- ☐ Copper conducts heat about twice as well as aluminium.
- ☐ Copper conducts heat about half as well as aluminium.

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Task 5

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Drag the words into the correct boxes!

Both the _____ and the _____ of the rod affect the heat flow through the rod. The _____ the diameter of the rod, the _____ the heat flow. The _____ the length of the rod, the _____ the heat flow.

larger
length
larger
diameter
smaller
larger

Check

Task 6

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Additional tasks

It therefore applies $l = b + s_1 + s_2$. Use this to complete the table (all values with index 0 are valid for the comparison bar! The values for ΔT are taken from the table in question 2).

Equipment	d in mm	b in mm	l in mm	$(d/d_0)^2$	l_0/l	ΔT in °C	$\Delta T/\Delta T_0$
Cu	5	175	260				
Al	5	175	260				
Cu	3	175	260				
Cu	5	120	205				

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Task 7

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Additional tasks

Express the relationship between the heat flow (amount of heat per unit time) and the rod dimensions with a proportionality.

What influence does the temperature difference between the two ends of the rod have on the heat flow through the rod? (If necessary, carry out a corresponding experiment by holding the rod directly in the flame on one side instead of boiling water and then measuring the temperature increase of the cold water. Caution! The rod will then become very hot!)

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