# COEFFICIENT OF THERMAL CONDUCTIVITY

OBJECT

1. To determine coefficient of thermal conductivity of copper and aluminum.
2. To compare obtained results with the accepted values.
3. To estimate the error of measurements.

THEORY

Heat is transferred from one body to another or from one point to another within a body in three very different processes. These are conduction, in which the heat diffuses through a solid material or a stagnant fluid; convection, in which the moving liquid or gas absorbs, heat at one place and gives it up at another place. Finally there is a radiation, in which the transfer of heat from one place to another is by means of electromagnetic waves. We shall consider here only the transfer of heat by conduction.

When two parts of a body are maintained at different temperatures, there is a continuous gradation of temperature in the material between the two parts. The transfer of heat that occurs through the intervening material is called the heat conduction.
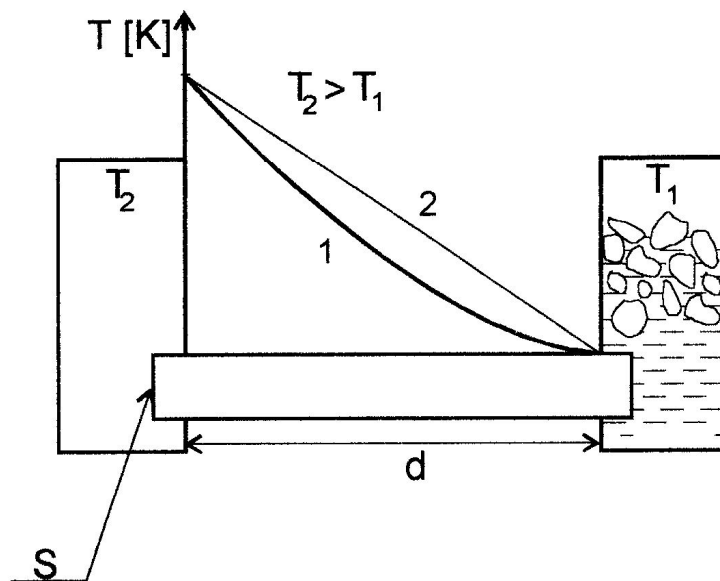
Distribution of temperature along a bar of initial temperature T_1 after the temperature of the left face is raised to T_2 (with the right face remaining at T_1 throughout).

The law of the heat flow due to a temperature difference was first derived experimentally by determining the average time rate of heat flow through the test bars of homogeneous solid materials. If one end face of the bar is kept at constant temperature T_1 and the other is kept at a higher temperature T_2, then after a certain transition time a steady state is reached and the temperature of the bar does not change with time – see curve 2, previous figure.

The *Fourier's law* gives the vector of the heat flux density q as a function of the temperature gradient

$$\mathbf{q} = -\lambda \, grad \, T,$$

where magnitude of q is equal to the amount of heat passing through a unit cross section of the bar per unit of time, T is a temperature and λ is a coefficient of thermal conductivity.

In case of the one-dimensional heat flow along the axis x the previous equation can be rewritten to the following form:

$$q = -\lambda \frac{dT}{dx}.$$

If the heat flux q does not depend on coordinate x, that is it is constant, we can obtain from integration of the previous equation

$$T_1 - T_2 = \Delta T = \frac{q}{\lambda} d.$$

If the temperature along the bar is distributed linearly (the curve number 2) we can determine the amount of heat Q that passes through the cross sectional area S in time interval t from point with coordinate 0 to point with coordinate d in the following way

$$Q = \lambda \frac{\Delta T}{d} St.$$

The heat conduction in a body is called stationary, if the temperature of particular elements of the body does not depend on time, so that the temperature is only a function of the coordinates. In an opposite case the heat conduction is called non-stationary heat conduction. This case happens if $T=T(x,y,z,t)$, where t expresses the time.

Table 1. Coefficients of thermal conductivities of various substances.

Substance	Coefficient of thermal conductivity $\left[Wm^{-1} K^{-1} \right]$
Silver (98.98%)	418
Iron (99.92%)	73
Copper	395
Aluminum (99.75%)	229
Lead	34.7
Platinum	70.3
Brass	106
Bakelite	0.23
Polystyrene	0.16
Water	0.63
Air	0.03

PROCEDURE

To determine the coefficient of thermal conductivity of copper and aluminum we use the experimental arrangement, which is shown in the following figure. The lower end of the bar made either from copper or aluminum is kept at constant temperature T=273 K in

the Dewar flask. The upper end of the bar is heated by the heating element. After the transition time the distribution of the temperature in the bar from the heating element to the Dewar flask is linear. To determine the temperature gradient on the length of the bar d the two thermocouples are used. Using the voltmeter and ammeter in the circuit of the heating element we can determine the power, which is used for the heating of the bar.
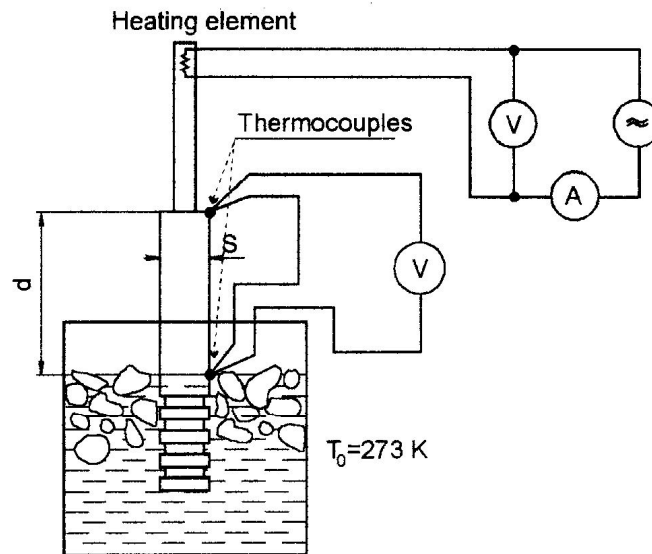
Experimental apparatus.

1. Fill the Dewar flask with a mixture of ice and water. Plunge the first bar into the mixture in such a way that the lower thermocouple will be at the surface of this mixture. Stir the mixture constantly and wait till the temperature of the mixture stabilizes at 0° C.
2. Measure the initial thermoelectric voltage between the thermocouples (that is difference of temperatures) between the cold and heated end of the bar.
3. Using the graph change the thermoelectric voltage into temperature.
4. Switch on the heating element.
5. Read the values of thermoelectric voltage each two minutes until it reaches constant value.
6. Read the values of voltage and current of the heating element; calculate the power delivered to the heating element.
7. Stir constantly the mixture of ice of water. In case of lack of ice in the Dewar flask add the ice.
8. A stationary state of heat conduction is reached when the temperature gradient on the bar is constant. This state corresponds to the situation when the amount of heat delivered from the heating element is equal to the amount of heat delivered from the bar to the mixture of ice with water.
9. Plot the graph of the temperature gradient versus time and determine the transition time, that is the time required to reach the stationary heat conduction.
10. Use the obtained experimental data to calculate the coefficient of thermal conductivity of the first substance

$$Q = \lambda \frac{\Delta T}{d} St .$$

11. Repeat the same procedure for the bar from the second substance.

SEMESTER WORK INSTRUCTIONS

Create a program, which will calculate and depict the time dependence of the temperature difference between ends of the bar. Additional task: suppose, that the bottom end of the bar is not "stabilized" in the mix of water and ice, but is sunk in the limited amount of water with defined initial temperature.

<u>Variable parameters:</u> cross-section area of the bar, active length of the bar, thermal conductivity of the bar material, power of the heater and for the additional task also water amount and its initial temperature.