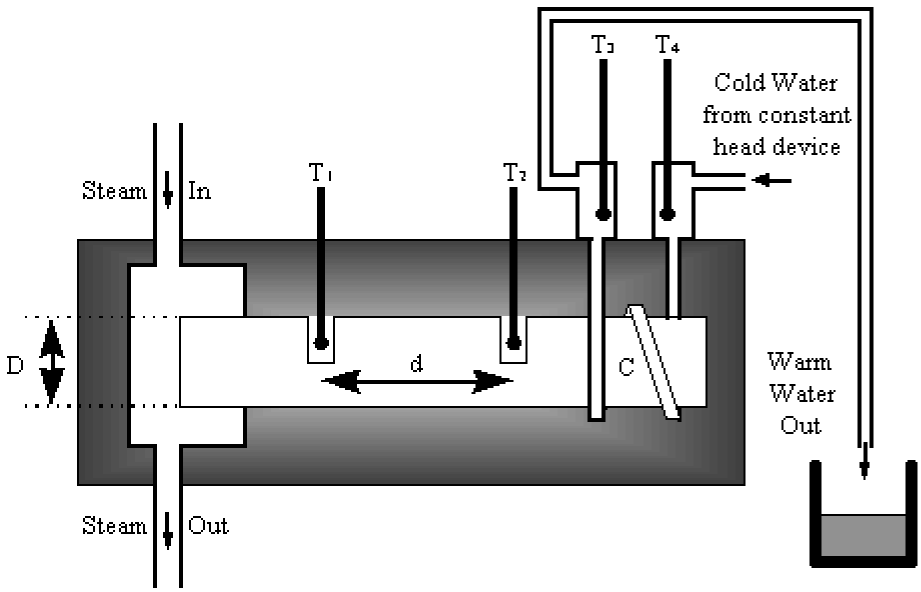
Thermal Conductivity of a good conductor.

Object

Measure the thermal conductivity of Copper using the Searle's bar method.

SAFETY WARNING

This experiment uses steam heating. Be careful to avoid touching the hot surfaces of the steam generator, tubing and the Searle's bar apparatus. Make sure that the steam outlet tube from the apparatus goes to a sink.



Apparatus

Constant-head apparatus, measuring cylinder, stop watch, Searle's apparatus, steam generator, four thermometers T_1, T_2, T_3, T_4, Vernier callipers.

T_1 and T_2 measure the temperature at points on the bar, T_3 and T_4 measure the temperature of water entering and leaving the spiral C.

Method

1. Adjust the constant-head device to give a steady flow of water through the coiled tube.
2. Pass steam from the steam generator through the steam chest. wait until the thermometers have reached a steady state (i.e. no significant increase or reduction of temperature for 10 minutes).
3. Measure T_1, T_2, T_3 and T_4.
4. Measure the rate of water flow through the spiral by measuring the amount of water (m) collected in the measuring cylinder in a given time (t). Collect approximately 1 litre.
5. Using Vernier callipers, measure the diameter of the bar D and the distance d between the thermometers T_1 and T_2.

Theory

Assuming no loss of heat along the bar, it can be shown that:

$$Q = -kA\frac{dT}{dx}t$$

where:

Q is the heat supplied to the bar in time t,

A is the cross-sectional area of the bar,

dT is the difference in temperature between two points in the bar dx apart,

k is the coefficient of thermal conductivity of the bar.

The heat Q warms up a mass m (in kilograms) of water from temperature T_4 to T_3 according to the formula:

$$Q = mc\left(T_3 - T_4\right)$$

where c is the specific heat capacity of water ($c = 4190\ J\ kg^{-1}\ K^{-1}$).

Using: $-dT = T_1 - T_2$, $dx = d$ (d in metres), and $A = \frac{\pi D^2}{4}$ (A in metres squared) we obtain:

$$mc\left(T_3 - T_4\right) = k\left(\frac{\pi D^2}{4}\right)\left(\frac{T_1 - T_2}{d}\right)t$$

$$\therefore k = \frac{4mcd\left(T_3 - T_4\right)}{\pi D^2\left(T_1 - T_2\right)t} \text{ (in W m}^{-1}\text{ K}^{-1}\text{).}$$

Calculate k and the error in k - see below.

Quote your final result for the thermal conductivity as k k with appropriate units.

Error Calculation

1. There is an error in assuming that no heat lost along the bar, but no correction has been made for this, although this will obviously affect the values of T_2 and T_1.
2. The absolute error in each of the temperature differences $\left(T_1 - T_2\right)$ and $\left(T_3 - T_4\right)$ is the sum of the absolute errors in reading the two thermometers.
3. Errors in m arise from errors in determining the mass of water collected.
4. Errors in the time t depend on the accuracy of the stop-watch.
5. Errors in measuring with the Vernier calliper are at least 0.05 mm, but may be bigger (estimate how precisely you can measure D and d).
6. The fractional error in k is given by: $\frac{\Delta k}{k} = \frac{\Delta m}{m} + \frac{\Delta d}{d} + \frac{\Delta T_3 + \Delta T_4}{T_3 - T_4} + \frac{2\Delta D}{D} + \frac{\Delta T_1 + \Delta T_2}{T_1 - T_2} + \frac{\Delta t}{t}$, hence determine the absolute error Δk.

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