

Thermal expansion of solid bodies

Measuring using the expansion apparatus

Objects of the experiment

- Measuring the linear thermal expansion of a brass tube as a function of the overall length.
- Measuring the linear thermal expansion of glass, steel and brass tubes and determining their linear expansion coefficients.

Principles

The length s of a solid body is linearly dependent on its temperature ϑ :

$$s = s_0 \cdot (1 + \alpha \cdot \vartheta) \quad (I)$$

s_0 : length at 0 °C, ϑ : temperature in °C

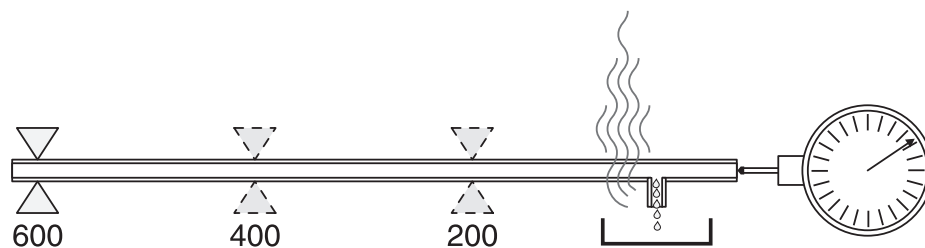
The linear expansion coefficient α is determined by the material of the solid body. For a given temperature difference between room temperature ϑ_1 and steam temperature ϑ_2 , the change in length Δs is closely proportional to the overall length s_1 at room temperature:

$$\Delta s \propto s_1 \quad (II)$$

Specifically, we can say:

$$\alpha = \frac{\Delta s}{s_1} \cdot \frac{1}{\vartheta_2 - \vartheta_1} \quad (III)$$

In this experiment, measurements of thermal expansion are conducted on thin tubes through which steam is channeled. The effective length s_1 of each tube can be set as 200, 400 or 600 mm by mounting it in a corresponding manner. A dial gauge with 0.01 mm scale graduations is used to measure the change in length.



Apparatus

1 Expansion apparatus	381 34
1 Holder for dial gauge	381 36
1 Dial gauge	361 15
1 Steam generator, 550 W/230 V	303 28
1 Silicone tubing, dia. 7×1.5 mm, 1 m	667 194
1 Petri dish, 150 × 25 mm	664 185
1 Thermometer, −10° to + 110 °C	382 34

- Cut off a 20 cm length of silicone tubing, slide the section over the hose nipple (f) and place a Petri dish below this to catch the condensation.
- Use the long tubing section to connect the open end of the brass tube to the steam generator.

Note: Danger of scalding when the steam generator is used improperly. Be sure to read the Instruction Sheet for the steam generator before using this apparatus.

Setup

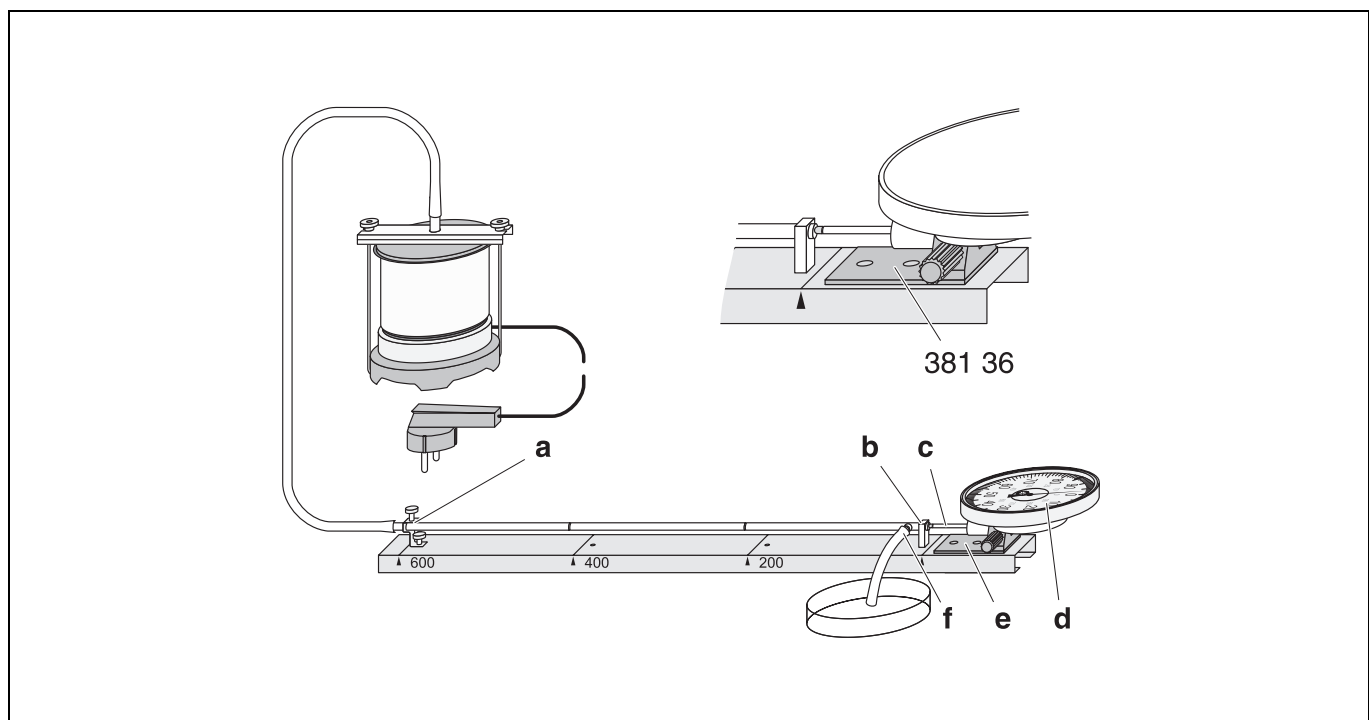
Set up the experiment as shown in Fig. 1.

- Screw on the holder for dial gauge (e) (see Instruction Sheet for expansion apparatus) and clamp the dial gauge in place.
- Attach the fixed bearing (a) of the expansion apparatus at the 600 mark and slide the open end of the brass tube into the fixed bearing.
- Slide the closed end of the brass tube into the guide fitting (b) so that the hose nipple (f) is pointing laterally downwards.
- Tighten the screw to fix the brass tube in the fixed bearing (the screw must engage the ring groove of the tube).
- Insert the extension piece (c) (see Instruction Sheet for dial gauge).

Carrying out the experiment

- Determine the room temperature ϑ_1 and write this down.
- Read off and write down the zero position of the dial gauge.
- Fill the steam generator with about 2 cm of water, close the apparatus and plug it in.
- Read off and write down the maximum pointer deflection of the dial gauge.
- Allow the brass tube to cool down to room temperature.
- Attach the fixed bearing of the expansion apparatus at the 400 mark and tighten the screw so that it engages the ring groove of the tube.
- Refill the steam generator with water, check the zero position of the dial gauge and repeat the measurement.
- Move the fixed bearing to the 200 mark and repeat the experiment.
- Replace the brass tube with the steel tube; attach the fixed bearing at the 600 mark and repeat the measurement.
- Conduct the same measurement on the glass tube.

Fig. 1 Experiment setup for measuring the linear thermal expansion with the expansion apparatus



Measuring example

$$\vartheta_1 = 21 \text{ }^\circ\text{C}$$

Table 1: Linear expansion Δs between room temperature ϑ_1 and steam temperature ϑ_2 as a function of the effective length s_1 of the material

Material	$\frac{s_1}{\text{mm}}$	$\frac{\Delta s}{\text{mm}}$
Brass	600	0.86
Brass	400	0.57
Brass	200	0.29
Glass	600	0.15
Steel	600	0.58

Evaluation and results

$$\vartheta_1 = 21 \text{ }^\circ\text{C}$$

$$\vartheta_2 = 100 \text{ }^\circ\text{C}$$

$$\vartheta_2 - \vartheta_1 = 79 \text{ K}$$

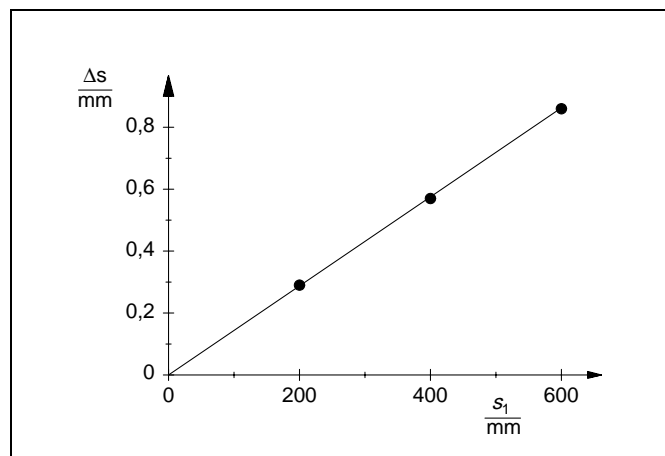
a) Linear expansion of brass tubes of different lengths

Fig. 2 Thermal change in length Δs of a brass tube as a function of the overall length s

Fig. 2 shows a graph of the change in length Δs plotted as a function of the effective length s_1 . As the measured values lie along the line drawn through the origin, this verifies the proportionality described in equation (II).

b) Linear expansion of tubes of different materials

The linear expansion coefficients are calculated from the measuring results of Table 1 in accordance with (III). Table 2 shows the results together with the literature values.

Table 2: Linear expansion coefficient α for different materials

Material	$\frac{s_1}{\text{mm}}$	Measurement $\frac{\alpha}{\text{K}^{-1}}$	Literature $\frac{\alpha}{\text{K}^{-1}}$
Brass	600	$18.1 \cdot 10^{-6}$	$18 \cdot 10^{-6}$
Steel	600	$12.2 \cdot 10^{-6}$	$11 \cdot 10^{-6}$
Glass	600	$3.1 \cdot 10^{-6}$	$3 \cdot 10^{-6}$

