Thermal expansion of solid bodies

Measuring using STM equipment

Objects of the experiment

- Observing the linear thermal expansion of aluminum and iron.
- Estimating and comparing the expansion coefficients of the two materials.

Principles

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

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

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

The linear expansion coefficient α is determined by the material of the solid body.

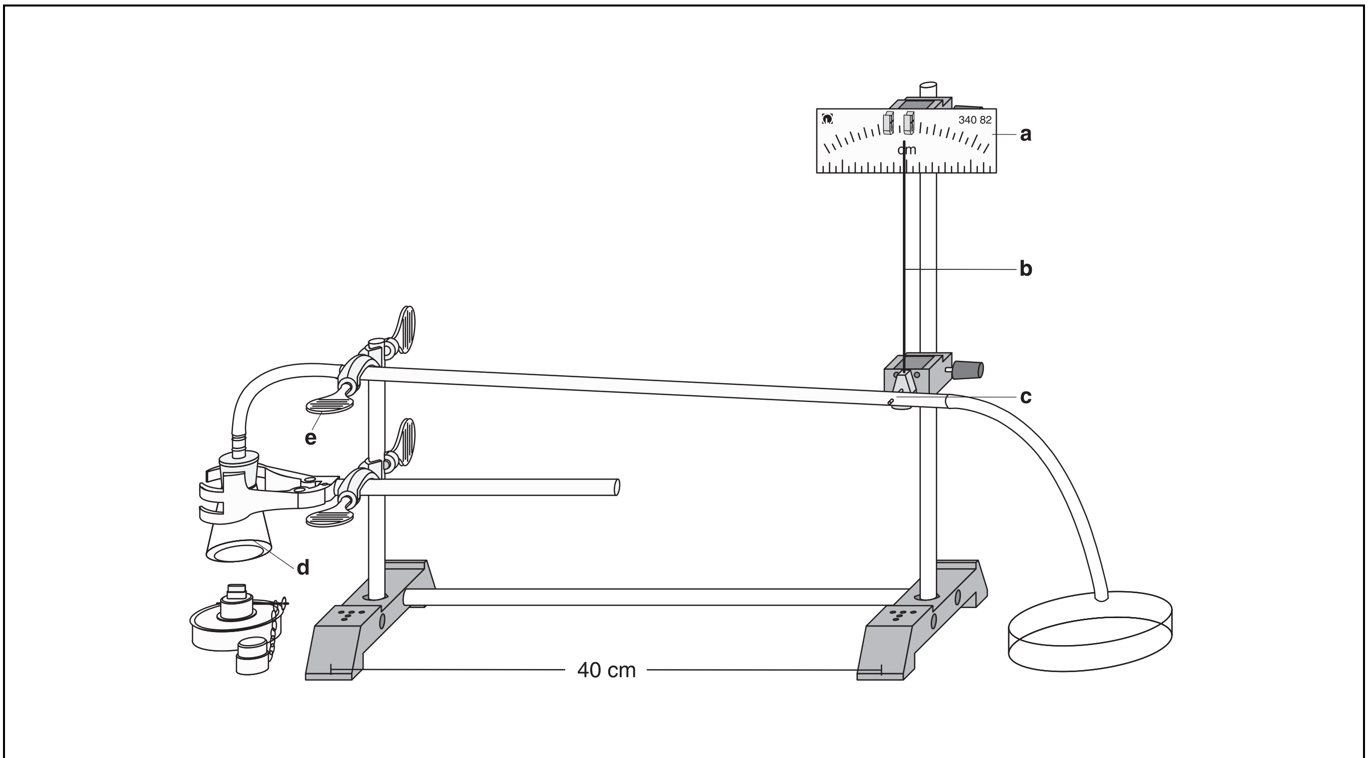
In this experiment, measurements of thermal expansion are conducted on thin metal tubes through which steam is channeled. From the change in length Δs between room temperature ϑ_1 and steam temperature ϑ_2 and the rod length s_1, we can calculate with sufficient accuracy:

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

The change in length is visually magnified by a rotating pointer. The change can be calculated from the deflection Δx of the rotating pointer using the formula

$$\Delta s = \frac{\Delta x}{40} \quad \text{(III).}$$

Fig. 1 Experiment setup for determining the thermal expansion of solid bodies



Apparatus

1 Dual scale 340 82
2 Support clips, for plugging in 314 04
1 Pointer for linear expansion 381 331
1 Al-tube, l = 22 cm, d = 8 mm 381 332
1 Fe-tube, l = 22 cm, d = 8 mm 381 333

2 Stand bases 301 21
2 Clamping blocks MF 301 25
1 Stand rod, 25 cm 301 26
2 Stand rods, 50 cm 301 27

2 Double bossheads 301 09
1 Universal clamp, 0 … 80 mm 666 555

1 Petri dish, 100 × 20 mm 664 183
1 Erlenmeyer flask, 50 ml, nn 664 248
1 Stopper with hole 200 69 304
1 Connector, plastic, straight, 6 … 8 mm dia. 665 226
1 Silicone tubing, dia. 7×1.5 mm, 1 m . . . 667 194
1 Alcohol burner, metal, 60 ml 303 22

1 Tape measure, 1.5 m/1 mm 311 78

Setup

Set up the experiment as shown in Fig. 1.

– Attach the double scale **(a)** to the top clamping block of the right-hand stand rod using two support clips.
– Insert pointer **(b)** in the bottom hole of the bottom clamping block.
– Slide the lateral holes **(c)** of the Al tube over the small lateral pin of the pointer, then carefully clamp the other end of the tube in the top double bosshead of the left stand rod; mount the double bosshead a little higher so that the tube is slightly inclined and condensation can drain out the tube, and align the stand bases, double bossheads and stand block so that the tube is not bent during clamping.
– Align the pointer to the zero point of the scale.
– Fill 20 ml of water in the Erlenmeyer flask **(d)**, seal the flask with the stopper, insert the tubing connector in the topper and connect this to the aluminum tube using a section of silicone tubing approx. 12 cm long.
– Mount the Erlenmeyer flask above the alcohol burner using the universal clamp.
– Slide a section of silicone tubing approx. 25 cm long over the right end of the tube and place a Petri dish below this.

Carrying out the experiment

Note:

During the experiment hot steam is emitted from the metal tube. Hot condensed water can also continue to run out of the tube after the end of the experiment. Danger of scalding!

– Determine the room temperature and write this down.
– Clamp the Al tube on the left side firmly and correct the zero position of the pointer where necessary.
– Measure the length of the tube, i.e. the distance from the clamping point to the lateral hole for the pointer, using a tape measure.
– Light the alcohol burner to boil the water.
– Keep boiling the water until the pointer no longer moves.
– Find the change in length Δs from the pointer deflection Δx using (III) and write this value down.
– Put out the alcohol burner and allow your apparatus to cool.
– Replace the Al tube with the Fe tube, refill the flask with water and correct the zero position of the pointer.
– Repeat your measurement with the Fe tube and write down the tube length s_1 and the change in length Δs.

Measuring example

Room temperature: $\vartheta_1 = 21\ °C$
Steam temperature: $\vartheta_2 = 100\ °C$
Difference: $\Delta\vartheta = 79\ K$

Table 1: Intial length s_1 and change in length Δs of metal tubes

Material	$\frac{s_1}{mm}$	$\frac{\Delta s}{mm}$
Al	400	0.70
Fe (steel)	400	0.35

Evaluation

Table 2 contains the values for the linear expansion coefficient α calculated using equation (II). The corresponding literature values are given for comparison.

Table 2:

Material	α(measurement)	α(literature)
Al	$2.2 \cdot 10^{-5}\ K^{-1}$	$2.38 \cdot 10^{-5}\ K^{-1}$
Fe (steel)	$1.1 \cdot 10^{-5}\ K^{-1}$	$1.2 \cdot 10^{-5}\ K^{-1}$

Results

Solids (generally) expand as the temperature increases.

For the same change in temperature Δϑ, aluminum expands approximately twice as much as iron (steel).

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