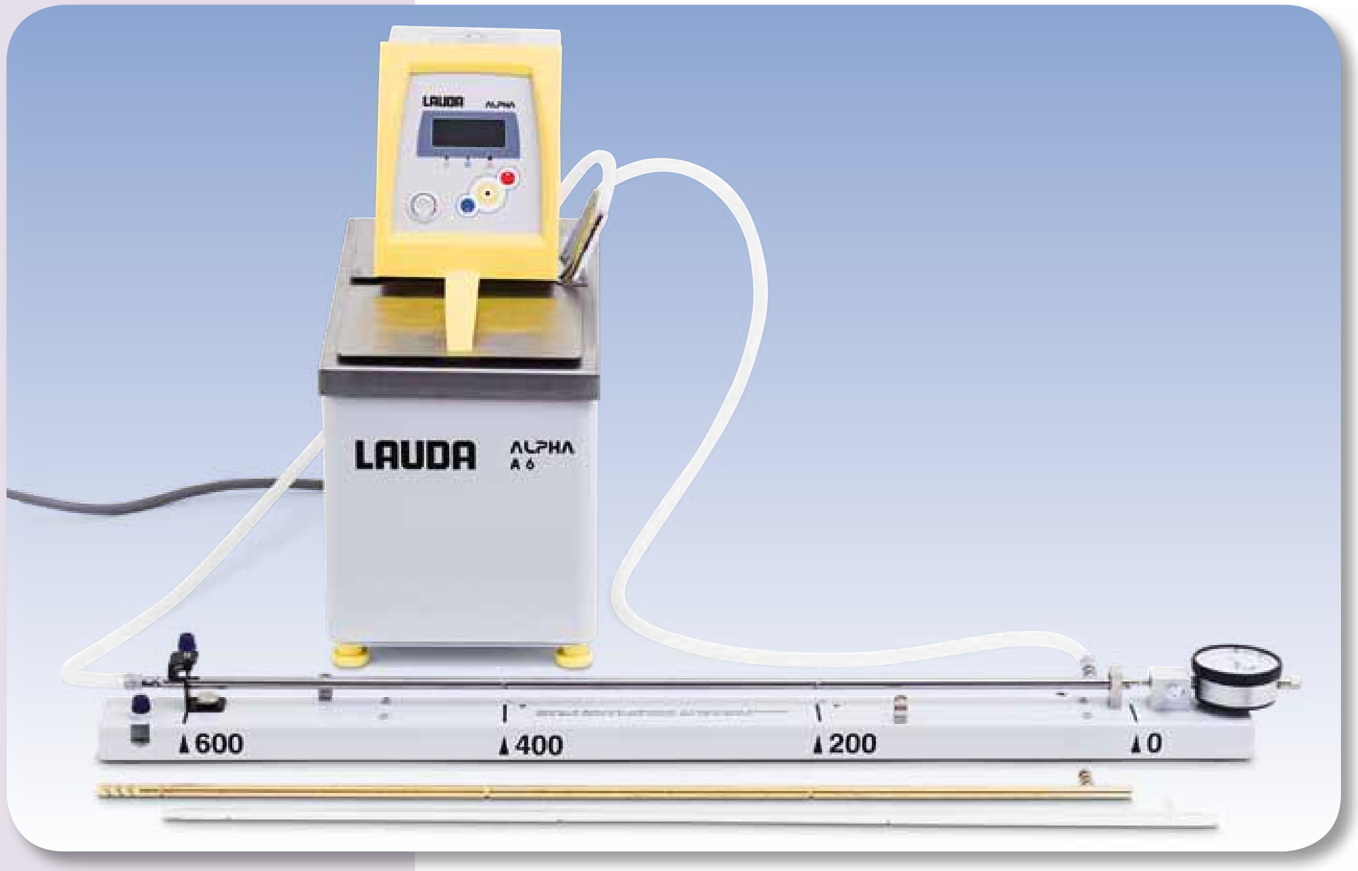
THERMAL EXPANSION OF SOLID BODIES



EXPERIMENT PROCEDURE

- Measure thermal expansion in length for tubes made of brass, steel and glass.
- Determine linear expansion coefficients for these materials and compare them with values quoted in literature.

OBJECTIVE

Determine the coefficients of expansion for brass, steel and glass

SUMMARY

If solid bodies are heated up, they generally expand to a greater or lesser degree. In this experiment, hot water is allowed to flow through tubes made of brass, steel and glass. The expansion in their length is measured using a dial gauge. The linear expansion coefficients for the three materials are then calculated from the change in their length.

REQUIRED APPARATUS

Quantity	Description	Number
1	Linear Expansion Apparatus D	1002977
1	Immersion/Circulation Thermostat (230 V, 50/60 Hz)	1008654 or
	Immersion/Circulation Thermostat (115 V, 50/60 Hz)	1008653
1	Gauge with Adapter	1012862
2	Tubing, Silicone 6 mm	1002622

NOTE

If it is deemed sufficient to measure the difference in length between room temperature and the temperature of boiling water, a steam generator can be used instead of the circulation thermostat bath. The requisite list of accessories can be found under order number UE2010135 (see Fig. 3).

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GENERAL PRINCIPLES

In a solid body, each atom vibrates around its equilibrium position. The oscillation is not harmonic because the potential energy is greater when two atoms which have moved from their equilibrium positions happen to get close to one another as opposed to when they are further apart. At higher temperatures, where the oscillation energy is also greater, the atoms vibrate in such a way that the average distance between two neighbouring atoms is greater than the distance between their equilibrium positions. This effect becomes more predominant as the temperature increases, causing the solid body to expand ever more as the temperature rises. It is normal in these circumstances to observe relative changes in length and to calculate the change in volume from this.

The coefficient of linear expansion is defined as:

$$\alpha = \frac{1}{L(\vartheta)} \cdot \frac{dL}{d\vartheta} \tag{1}$$

L: length
ϑ: temperature in °C

This coefficient depends strongly on the nature of the material and is usually less responsive to the temperature. This leads to the following conclusion:

$$L(\vartheta) = L_0 \cdot \exp(\alpha \cdot \vartheta) \tag{2}$$
$$L_0 = L(0\ °C)$$

If the temperature is not very high:

$$L(\vartheta) = L_0 \cdot (1 + \alpha \cdot \vartheta) \tag{3}$$

In this experiment measurements are carried out on thin tubes made of brass, steel and glass, through which hot water is passed in order to increase their temperature. A circulation thermostat is used to ensure that the water temperature can be adjusted to a constant value. Since one end of the tubes will be fixed in the expansion apparatus, a dial gauge can be used to read off the increase in length at the other end, using room temperature as the reference temperature.

EVALUATION

In the temperature range under investigation $\alpha \cdot \vartheta \ll 1$. Equation (3) can therefore be modified

$$\Delta L = L(\vartheta_1) \cdot \alpha \cdot \Delta\vartheta \text{ where } \Delta\vartheta = \vartheta_2 - \vartheta_1,\ L(\vartheta_1) = 600 \text{ mm}$$

The linear expansion coefficients we are seeking can therefore be determined from the gradient of the straight lines through the origin, as shown in Fig. 1.
The derivation of equation (3) breaks down, though, when higher temperatures are observed, since α proves to be no longer constant, instead being dependent on the temperature. Indeed, strictly speaking that is also the case at the temperatures we are observing. Since the measurement of the linear expansion is measured to an accuracy of 0.01 mm, precise analysis shows that the measurements are not exactly linear, especially for brass, and that the linear expansion coefficients increase slightly with temperature.

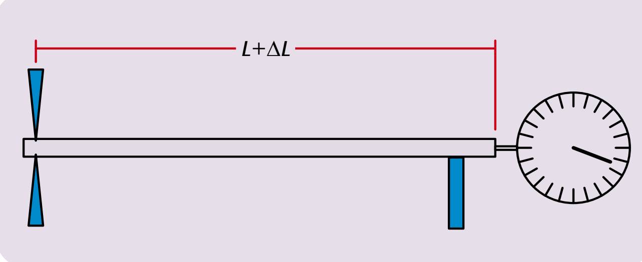

Fig. 1: Schematic of the set-up for the measurements

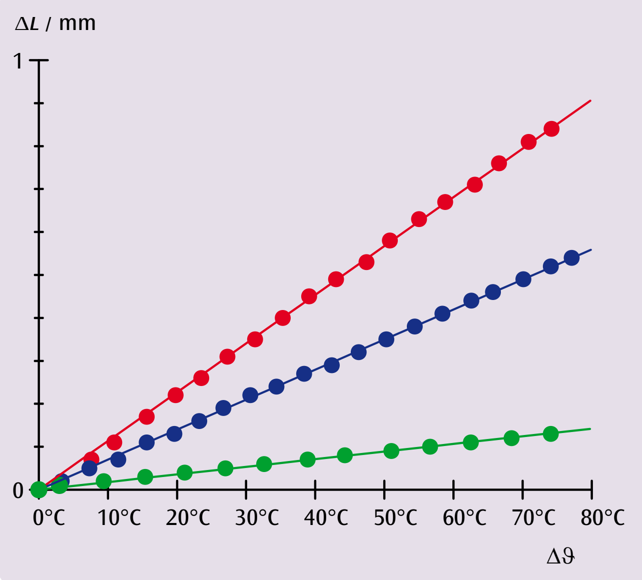

Fig. 2: Change in length of brass (red), steel (blue) and glass (green) as a function of the difference in temperature

Fig. 3: Set-up with steam generator