Linear expansion of metals (Item No.: P1042900)

Curricular Relevance

Area of Expertise: Physics
Education Level: Age 14-16
Topic: Thermal physics
Subtopic: Thermal expansion of solids, liquids and gases
Experiment: Linear expansion of metals

Difficulty	Preparation Time	Execution Time	Recommended Group Size
Easy	10 Minutes	10 Minutes	2 Students

Additional Requirements:

- Butane burner, Labogaz 206 type 32178-00
- Butane cartridge C206, without valve 47535-00
- Glycerol, 250 ml 30084-25
- Boiling beads, 200 g 36937-20
- Matches
- Felt-tip pen
- Sheet of paper (ca. 100 mm x 50 mm)

Experiment Variations:

Keywords:

Task and equipment

Information for teachers

Additional Information

Metal tubes are heated with steam. The linear expansion of three different metals is determined with the aid of a rotating-shaft pointer. From this the metals' coefficient of linear expansion is determined (Supplementary problem). The use of a rolling-shaft pointer is advantageous because the resulting indication of expansion is frictionless. The functional principle of a rotating-shaft pointer can be easily demonstrated in a simple experiment and studied by the students (see Question 4). The students should do this before they calculate the change in length Δl in "Evaluation".

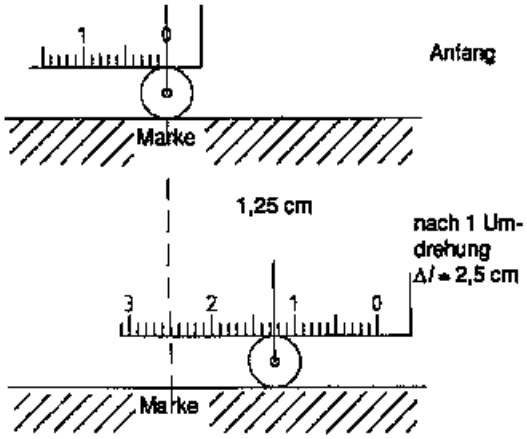
Remarks

1. The setup must not be touched while the tube is being heated; otherwise, the sensitive pointer will be displaced.
2. No condensed water must accumulate in front of or in the metal tube; otherwise the tube will not be heated to a uniform 100 °C.
3. The pointer's deflection must be marked as an extension of the pointer (see Fig. 22).

Notes to the angle determination

The angle φ, which is formed by the pointer's deflection s, can best be determined using the scale in the figure. This scale only applies for a pointer length (to the table surface) of l = 10.5 cm.
The angle can also be calculated with the formula
$\tan \varphi = s/l$.
For this calculation the distance $\Delta l/2$ is neglected with reference to s.

The students should test the functional principle of the rotating-shaft pointer, e.g. by rolling it through an angle of 360° with a ruler (see Fig. 3), and by doing so determine the following:
Movement of the ruler Δl = 2.5 cm.
Movement of the rotating-shaft pointer Δl = 1.25 cm.
In general:
$\Delta l/2 = 2\pi \times r \times \varphi/360°$.


1
0
Anfang
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1,25 cm
nach 1 Umdrehung
Δl = 2,5 cm
3
2
1
0
Marke

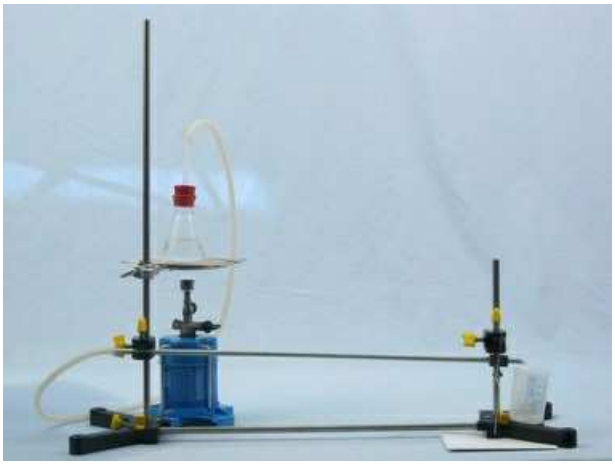
Linear expansion of metals **(Item No.: P1042900)**

Task and equipment

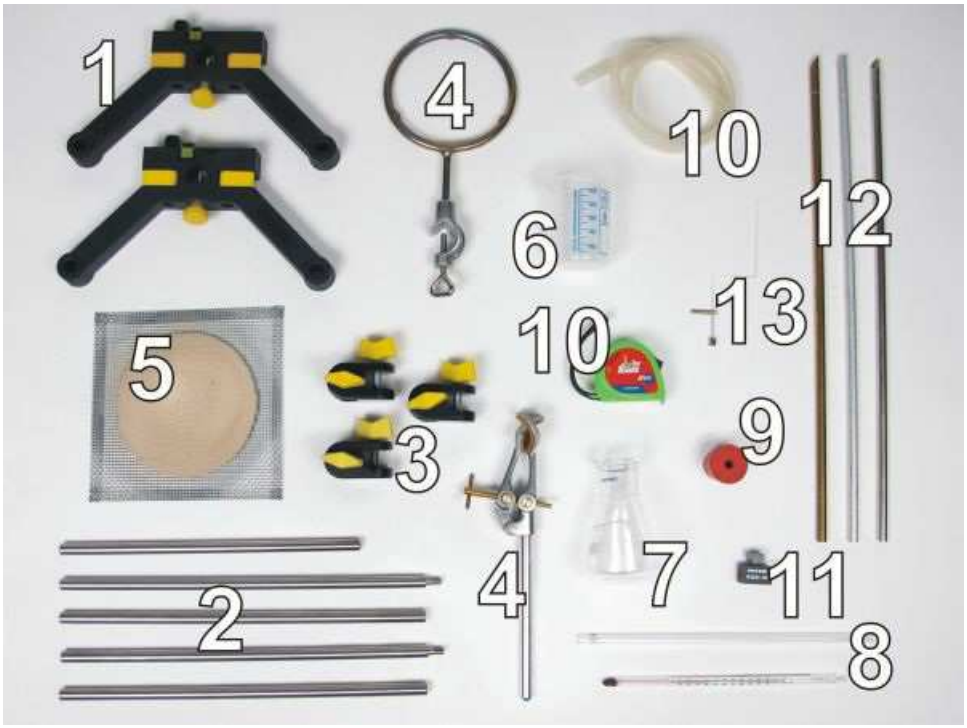
Task

How does the expansion of metals change during heating?

Measure the expansion of steel, brass and aluminium while heating them from room temperature to 100 °C.



Equipment



Position No.	Material	Order No.	Quantity
1	Support base, variable	02001-00	1
2	Support rod, stainless steel, l = 250 mm, d = 10 mm	02031-00	1
2	Support rod, stainless steel, l = 600 mm, d = 10 mm	02037-00	2
3	Boss head	02043-00	3
4	Ring with boss head, i. d. = 10 cm	37701-01	1
4	Universal clamp	37715-00	1
5	Wire gauze with ceramic, 160 x 160 mm	33287-01	1
6	Beaker, low form, plastic, 100 ml	36011-01	1
7	Erlenmeyer flask 100 ml, wide-neck SB 29	36428-00	1
8	Glass tube, straight, l=80 mm, 10/pkg.	36701-65	(1)
8	Students thermometer,-10...+110°C, l = 180 mm	38005-02	1
9	Rubber stopper 26/32, 1 hole 7 mm	39258-01	1
10	Measuring tape, l = 2 m	09936-00	1
10	Silicone tubing i.d. 7mm	39296-00	1
11	Collar for linear expansion	04231-55	1
12	Brass tube	04234-01	1
12	Aluminium tube	04234-03	1
12	Iron tube	04234-02	1
13	Rotating shaft with pointer	04236-01	1
	Butane burner, Labogaz 206 type	32178-00	1
	Butane cartridge C206, without valve	47535-01	1
	Glycerol, 250 ml	30084-25	1
	Boiling beads, 200 g	36937-20	1
Additional material			
	Matches		
	Felt-tip pen		1
	Sheet of paper (approx. 100 mm x 50 mm)		1

Set-up and procedure

Set-up

Warning!

1. Always insert the thermometer or glass tubes into the rubber stopper using glycerol.
2. During the heating of the water the support ring and the wire gauze get extremely hot!
3. The metal tube is hot, steam escapes at its end!
4. The setup must not be touched during the course of the experiment; otherwise, the sensitive pointer will be displaced.

Setup

- Set up the support stand according to the following pictures.

Fig. 1

Fig. 2

Fig. 3a

Fig. 3b

Fig. 4

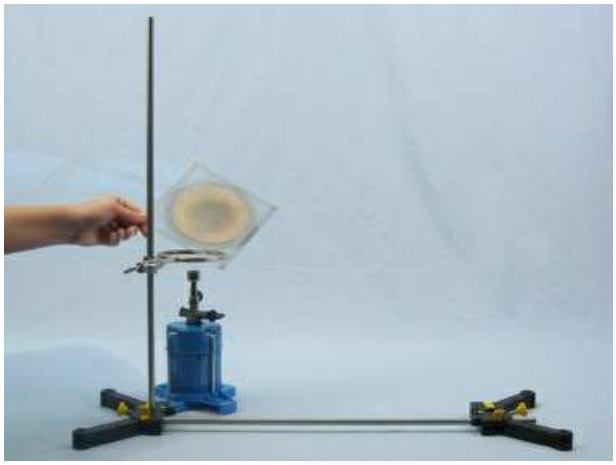


Fig. 5

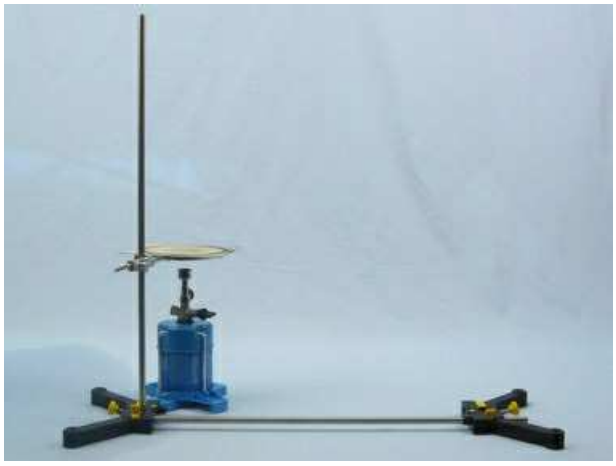


Fig. 6

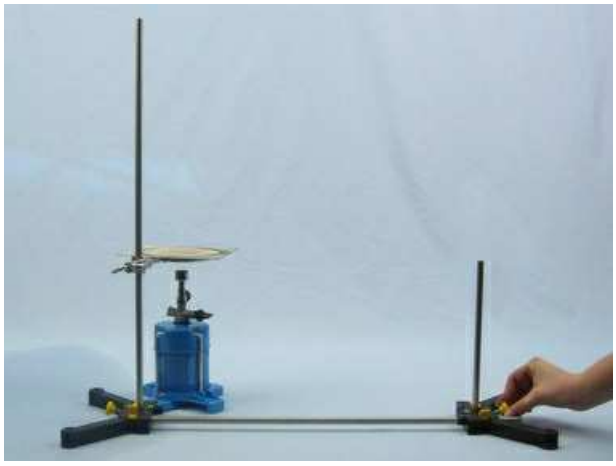


Fig. 7

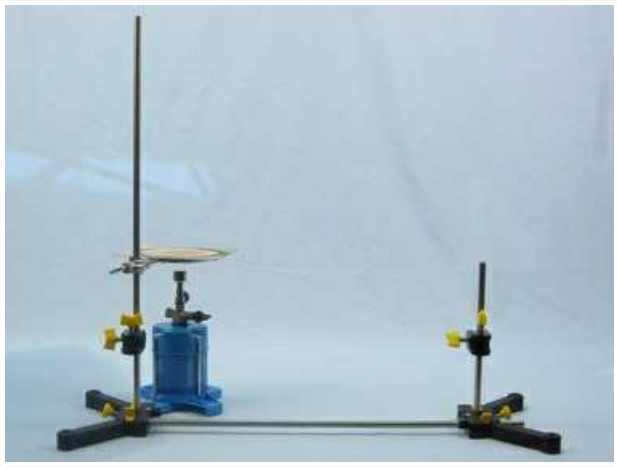


Fig. 8

- Place the collar for linear expansion in the notch (spout side) on the aluminium tube.

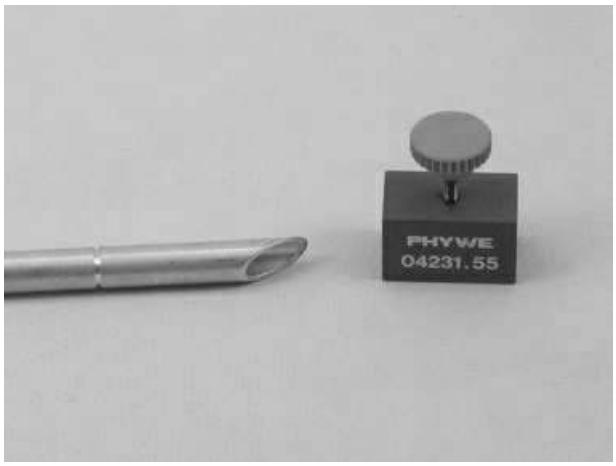


Fig. 9

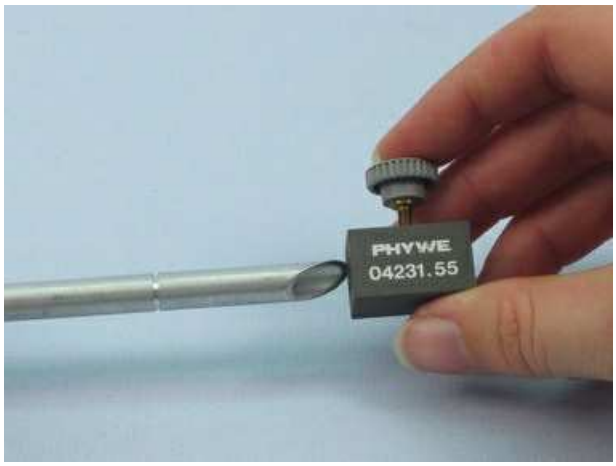


Fig. 10

- Attach the tube on the other side of the location of the notch in the bosshead.

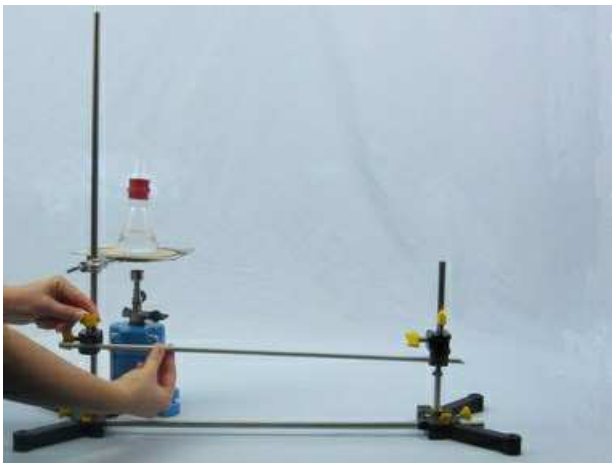


Fig. 11

- The metal tube should be slightly slanted so that condensed water vapour (steam) can run out.
- For this reason attach the bosshead on the spout side so that it touches the collar.

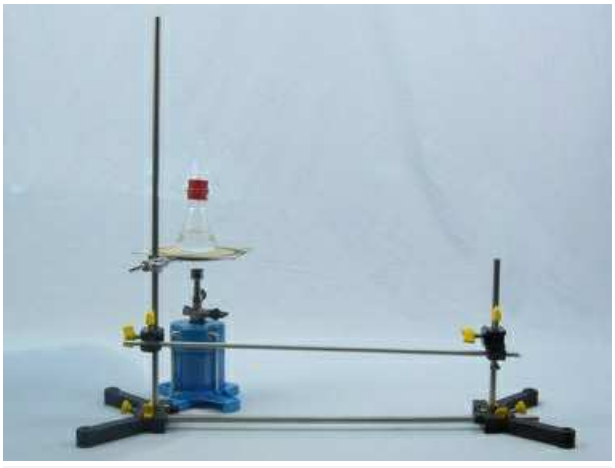


Fig. 12

- Place the rotating shaft with pointer between the bosshead and the collar.

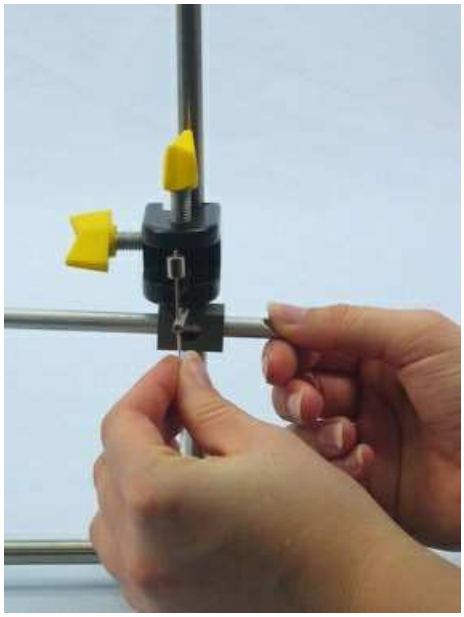


Fig. 13

- Select the height of the metal tube so that the pointer tip is as close to the table surface as possible.

Fig. 14

- Place the beaker under the tube's spout.

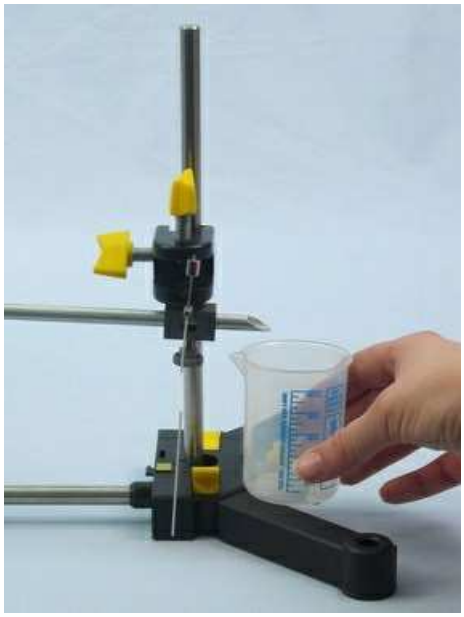


Fig. 15

- Fill the Erlenmeyer flask half-full with water and add two beads.

Fig. 16

Fig. 17

- Insert the glass tube into the stopper and seal the flask.

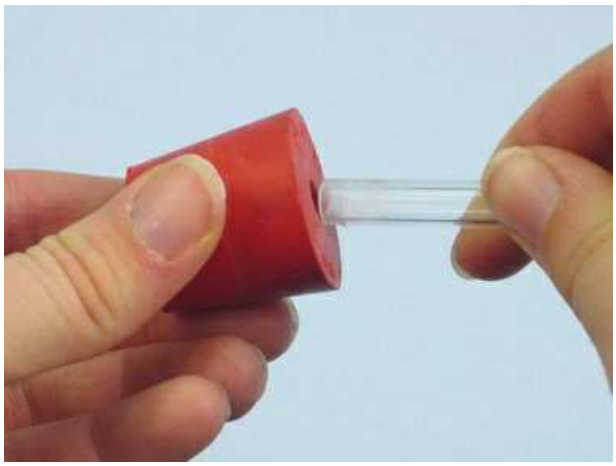


Fig. 18

Fig. 19

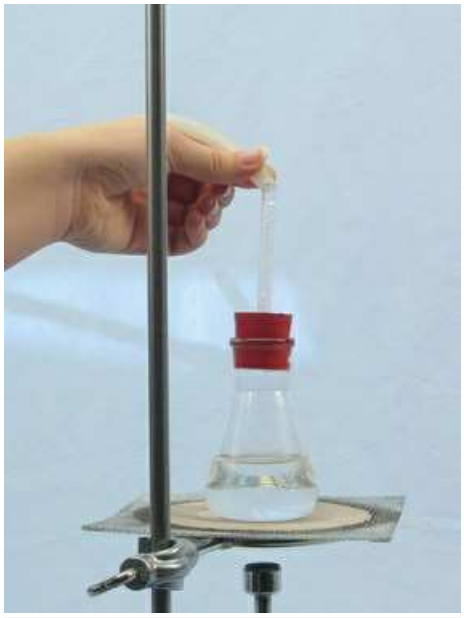


Fig. 20

- Position the tubing in such a way that no condensed water accumulates in front of the tube.

Procedure

- Under the pointer's tip tape a piece of paper (approx. 5 cm x 10 cm) to the table.
- Set the pointer perpendicular and mark the initial position of the pointer's tip.

Fig. 21

- Measure the pointer's length from its pivot point to the table top. This distance *l* should be 10.5 cm. If it is not, correct your experimental setup.
- Measure the room temperature ϑ_0 and record it in the report.
- Bring the water to a boil.
- Wait until condensed water and steam escape from the tube.
- Watch the pointer until it stops moving.
- Mark the pointer's new position (distance *s* in Fig. 2: use your ruler to determine where the point would now touch the paper).
- Turn off the burner, wait until the tube has cooled somewhat and then repeat the experiment with other tubes (remove the hot tube with a cloth).

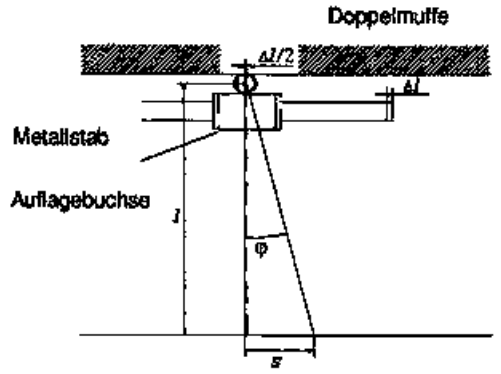


Fig. 22

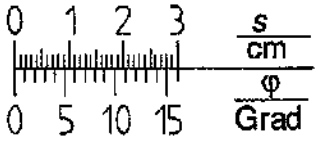


Fig. 23

Report: Linear expansion of metals

Result – Observations 1

1. Length of the metal tube: l_0 = 50 cm
2. Temperature of the heated tube: ϑ_1 = 100 °C
3. Radius of the pointer's rotating shaft: r = 0,2 cm
4. Length of the pointer (to table top): l = 10,5 cm
5. Room temperature: ϑ_0 = ... °C

Result – Table 1

1. For each of the three metal tubes measure the pointer's deflection s on the sheet of paper and record them in the table.
2. Determine the angle φ (in degrees) for each pointer deflection s (in cm) with the aid of the scale in the figure 23 and record it in the table.
3. When the metal tube expanded by the length Δl, the rotating pointer moved a distance $\Delta l/2$ further. The arc of angle is therefore as large as the distance $\Delta l/2$:

   $\Delta l/2 = 2\pi \cdot r \cdot \varphi/360°$

   Calculate the linear expansion Δl for the different metal tubes and record it in the table.

Material	s in cm	φ in Degrees	Δl in cm
Aluminium	1 ±0	1 ±0	1 ±0
Brass	1 ±0	1 ±0	1 ±0
Iron	1 ±0	1 ±0	1 ±0

Evaluation – Question 1

Compare the metals in terms of their expansion, i.e. arrange them in order of decreasing expansion.

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Evaluation – Question 2

Compare the thermal expansion of metals to that of liquids or gases.

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Evaluation – Additional Task 1

The linear expansion Δl is a function of the temperature difference $(\vartheta_1 - \vartheta_0)$ and of the total length l_0. Could this be shown with your experimental setup?

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Evaluation – Additional Task 2

The linear expansion of rods and tubes is characterised by the coefficient of linear expansion α. It is expressed by the equation:

$\Delta l = \alpha\, l_0\, (\vartheta_1 - \vartheta_0)$.

Calculate the coefficient α and record it in the table.

	Literature value	Measurement
Material	α in $10^{-6}/°C$	α in $10^{-6}/°C$
Aluminium	23,7	23
Brass	18,3	17
Iron	10	11

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