Linear expansion of metals

Physics > Thermodynamics > Temperature & Heat

Difficulty level	Group size	Preparation time	Execution time
easy	-	10 minutes	10 minutes

This content can also be found online at:

http://localhost:1337/c/6409fdab43e728000230a81c

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Teacher information

Application

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Experimental setup

Metals, like almost all solid materials, expand uniformly in all directions when heated. Since metals are very important building materials, for example for railway tracks, it is important to be able to calculate this expansion precisely.

The expansion is different for different metals and is described by the coefficient of expansion.

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Other teacher information (1/2)

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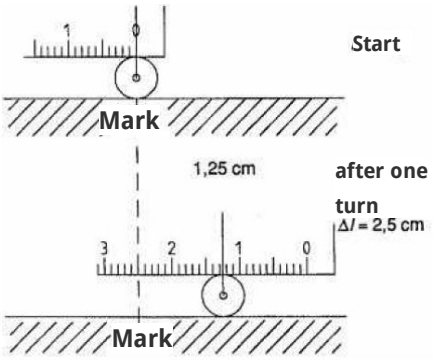
Prior knowledge

Safe handling of the Bunsen burner is a prerequisite.

The students should try out how the rolling pointer works, for example by rolling it 360° with a ruler (see illustration on the right) and discover:

Shifting the ruler $\Delta_l = 2,5cm$

Movement of the roller pointer $\Delta_l = 1,25cm$



Principle

Tubes made of different metals are heated by steam and their linear expansion is measured with the help of a rolling pointer and the coefficient of linear expansion is determined.

Other teacher information (2/2)

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Learning objective

The different degrees of linear expansion of metals should be made clear by measuring and determining the coefficients of linear expansion and compared with the expansion behaviour of gases and liquids. As a prerequisite for this, the functioning of a rolling pointer should be understood.

Tasks

The students should heat the three metal pipes (steel, brass and aluminium) with steam from room temperature to 100 °C and measure the expansion with the help of the rolling pointer. This should be tried out beforehand using a ruler. Finally, the coefficients of linear expansion are to be calculated and the expansion of the metals is to be compared with each other and with the expansion of liquids and gases.

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Safety instructions

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The general instructions for safe experimentation in science lessons apply to this experiment.

To facilitate the insertion of thermometers and glass tubes into the stoppers and to avoid injuries due to glass breakage, glass parts should be rubbed with a little glycerine beforehand. Excess glycerine must be removed before the measurements, otherwise it can influence the behaviour of the substances to be analysed.

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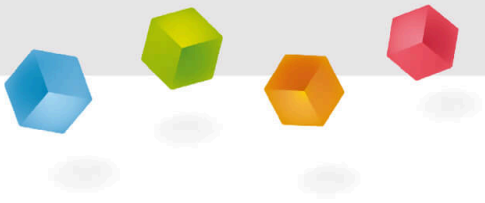

Student information

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Motivation

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Railway tracks

Why do railway tracks have small gaps at regular intervals?

When building railway tracks, small gaps are left between the individual pieces of rail so that the metal rails have room to expand when exposed to heat (e.g. due to strong sunlight), otherwise the resulting tension can cause damage.

The expansion of the material must also be taken into account for other large metal constructions, for example bridges.

Task

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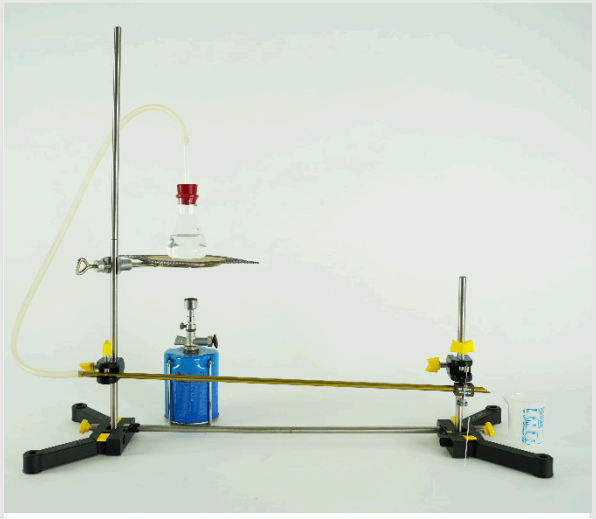

Experimental setup

Measure the linear expansion of steel, brass and aluminium when they are heated from room temperature to 100 °C. To do this, heat the three metal tubes with steam and measure the expansion with the help of the roller pointer. Try out the function of the roller pointer with a ruler beforehand.

In an additional task, determine the coefficients of linear expansion and compare the expansion of the metals with each other and with the expansion of liquids and gases.

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Equipment

Position	Material	Item No.	Quantity
1	Support base, variable	02001-00	1
2	Support rod, stainless steel, l = 250 mm, d = 10 mm	02031-00	1
3	Support rod, stainless steel, l = 600 mm, d = 10 mm	02037-00	2
4	Boss head	02043-00	3
5	Ring with boss head, i. d. = 10 cm	37701-01	1
6	Wire gauze with ceramic, 160 x 160 mm	33287-01	1
7	Universal clamp	37715-01	1
8	Collar for linear expansion	04231-55	1
9	Brass tube	04234-11	1
10	Iron tube	04234-12	1
11	Aluminium tube	04234-13	1
12	Rotating shaft with pointer	04236-01	1
13	Beaker, 100 ml, plastic (PP)	36011-01	1
14	Erlenmeyer flask, stopper bed, 100 mlSB 29	MAU-EK17082301	1
15	Glass tube, straight, l=80 mm, 10/pkg.	MAU-16074541	1
16	Rubber stopper 26/32, 1 hole 7 mm	39258-01	1
17	Silicone tubing i.d. 7mm, 1 m	39296-00	1
18	Students thermometer,-10...+110°C, l = 180 mm	38005-02	1
19	Measuring tape, l = 2 m	09936-00	1
20	Butane burner, Labogaz 206 type	32178-00	1
21	Butane cartridge C206, without valve, 190 g	47535-01	1
22	Glycerol, 250 ml	30084-25	1
23	Boiling beads, 200 g	36937-20	1

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Additional Equipment

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Position	Material	Order Number	Quantity
1	sheet of paper (approx. 100 x 50 mm)		1
2	Matches		1
3	Felt pen		1
4	Butane Burner Labogaz	206 32178-00	1
5	Butane cartridge C 206 without valve,190 g	47535-00	1
6	Glycerine, 250 ml	30084-25	1
7	Boiling stones, 200 g	36937-20	1

Set-up (1/6)

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1. Put the Bunsen burner in the burner base and set it up without wobbling (**Fig. 1 +2**).

2. Connect the two halves of the support base with the help of the short stand rod (**Fig. 3**).

Fig. 1

Fig. 2

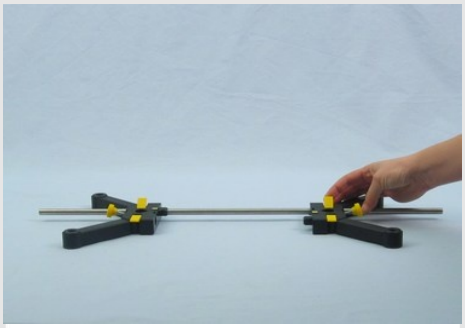

Fig. 3

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Set-up (2/6)

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3. Screw the two halves of the long stand rod together (**Fig. 4**).

4. Attach the long support rod to a support foot (**Fig. 5**).

Attach the stand ring to the stand rod with the wire net and the sleeve. Place the gas burner underneath (**Fig. 6**).

Attach the short stand rod to the other stand foot and attach a boss head to each of the stand rods (**Fig. 7**)

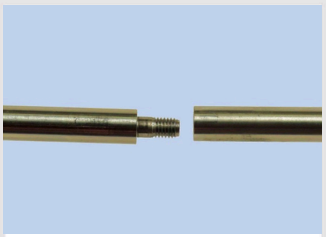

Fig. 4

Fig. 5

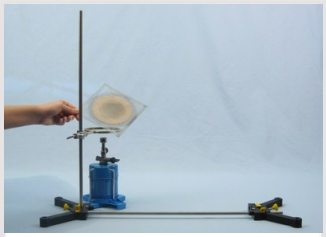

Fig. 6

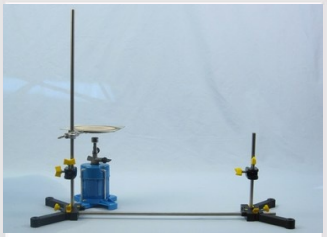

Fig. 7

Set-up (3/6)

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Place the collar for linear expansion on the aluminium tube at the point of the notch (outlet side). (**Fig. 8**).

Attach the pipe on the other side at the location of the notch in the boss head. The metal pipe should run at a slight angle so that the condensed water vapour can drain off. Therefore, fix the boss head on the outlet side so that it touches the collar for linear expansion. (**Fig. 9**).

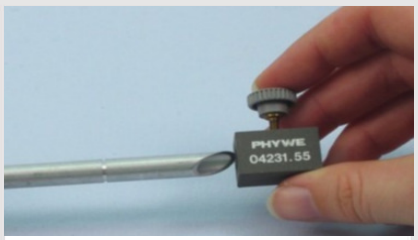

Fig. 8

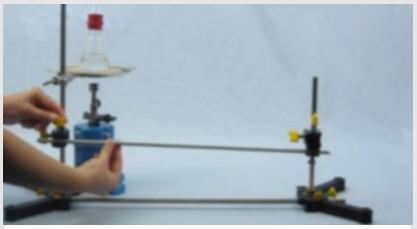

Fig. 9

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Set-up (4/6)

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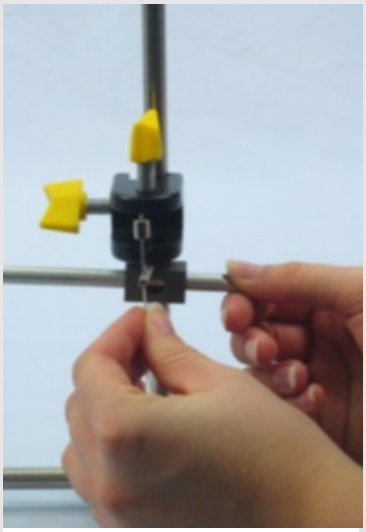

Fig. 9

9. Place the rolling axle with pointer between the boss head and the collar for linear expansion (**Fig. 9**).

Select the height of the metal tube so that the tip of the pointer is as close as possible to the table and place the beaker under the outlet of the tube. (**Fig. 10**).

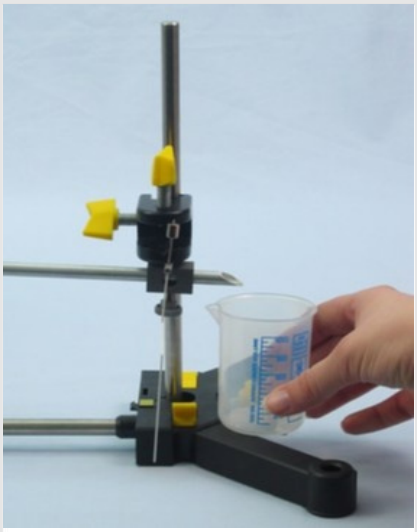

Fig. 10

Set-up (5/6)

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Fill the Erlenmeyer flask halfway with water and add 2 boiling stones. (**Fig. 11 + 12**).

Fig. 11

Fig. 12

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Set-up (6/6)

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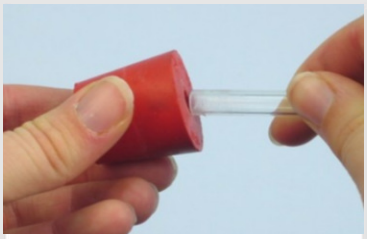

Fig. 13

Fig. 14

Push the glass tube into the stopper and close the Erlenmeyer flask (**Fig. 13 + 14**).

Connect the glass tube to the metal tube with the help of the hose and lay it in such a way that no condensation can collect in front of the tube (**Fig. 15**)

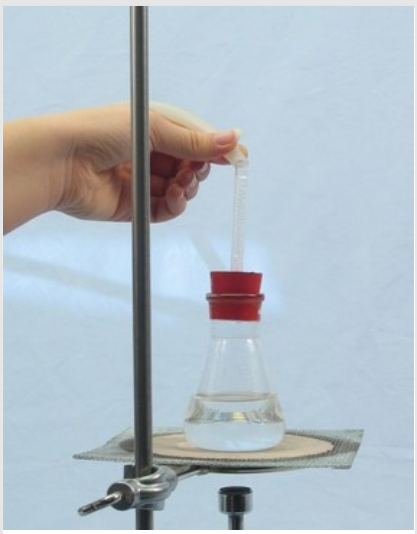

Fig. 15

Procedure (1/2)

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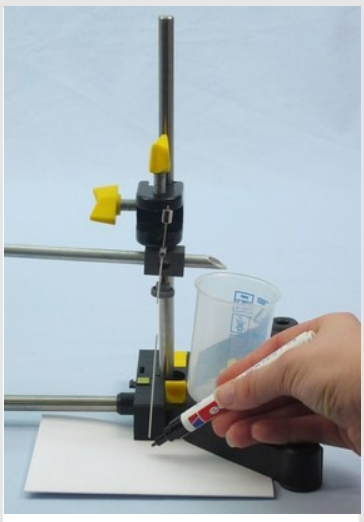

Fig. 16

1. Attach a piece of paper (approx. 5 cm x 10 cm) to the table under the tip of the pointer.

2. Position the pointer vertically and mark the initial position of the pointer tip (**Fig. 16**).

3. Measure the length of the pointer from the axis of rotation to the table surface. This length should be l = 10.5 cm. Correct the construction if necessary.

4. Measure the room temperature ϑ_0 and note them in the report.

Attention! During the experiment, the set-up must not be touched, otherwise the sensitive pointer will move.

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Procedure (2/2)

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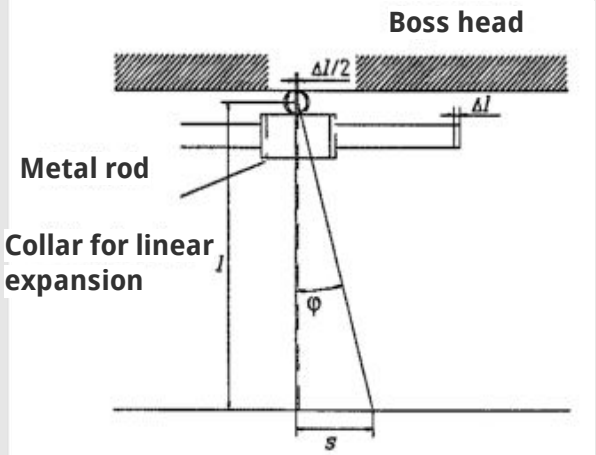

Fig. 17

5. Bring the water to boil and wait until condensation and steam come out of the pipe.

6. Observe the pointer until it stops moving and mark the pointer position (distance s in **Fig. 17**: extend the pointer to the paper).

7. Turn off the burner, wait until the pipe has cooled down a bit and repeat the experiment with the other pipes (remove the hot pipe with a cloth!).

Attention! When the water heats up, the stand ring, the gauze and the tube become very hot!

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Report

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Observation

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1. length of the metal pipes: $l_0 = 50\ cm$

2. temperature of the heated pipes: $\vartheta_1 = 100\ ^\circ C$

3. radius of the rolling axis of the pointer: $r = 0,2\ cm$

4. pointer length (to table top): $l = 10,5\ cm$

5. room temperature: $\vartheta_0 =$

Results

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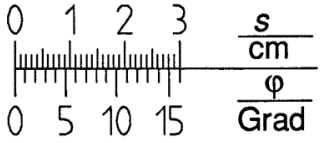
Equipment	$s\ (cm)$	$\varphi\ (^\circ)$	$\Delta l\ (cm)$
Aluminium			
Brass			

Steel



1. Measure on the paper the pointing deflections s for the three pipes and enter them in the table.

2. With the help of the left-hand scales, read the angle φ to each pointer deflection s and enter it.

3. As the metal tube moves around the track Δ_l , the roll pointer moves by the distance $\Delta_l\ /\ 2$. The arc is therefore as large as the distance

$$\Delta l\ /\ 2 = 2\pi \cdot r \cdot \varphi\ /\ 360^\circ.$$

Calculate the expansion Δ_l for the different metal pipes and enter them.

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Task 1

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Equipment	$\alpha\ (10^{-6}\ /\ ^{\circ}C)$ Literature value	Measurement
Aluminium 23.7		
Brass 18.3		
Steel 10		

The linear expansion of rods or pipes is determined by the linear expansion coefficient α characterised. The following relationship applies:

$$\Delta_l = \alpha \cdot l_0 \cdot (\vartheta_1 - \vartheta_0)$$

Calculate the coefficient in each case α and enter it in the table.

Task 2

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Expansion strength

Sort the metals according to expansion strength.

1.
2.
3.

Steel

Aluminium

Brass

Check

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Task 3

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Which statement(s) is/are correct?

- [ ] Solids expand more than liquids when heated.
- [ ] Liquids expand less than gases when heated.
- [ ] Gases expand more than solids when heated.

Check

Task 4

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The extension Δ_l is dependent on the temperature difference $\vartheta_1 - \vartheta_0$ and from the total length l_0 dependent. Could this be proven with this experimental set-up?

- ○ Yes
- ○ No

Check

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Slide	Score / Total
Slide 23: Expansion strength	0/3
Slide 24: Expansion comparison of states of aggregation	0/2
Slide 25: Possibility of proving Δ_l	0/1

Total 0 / 6

Solutions | Repeat | Export text

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