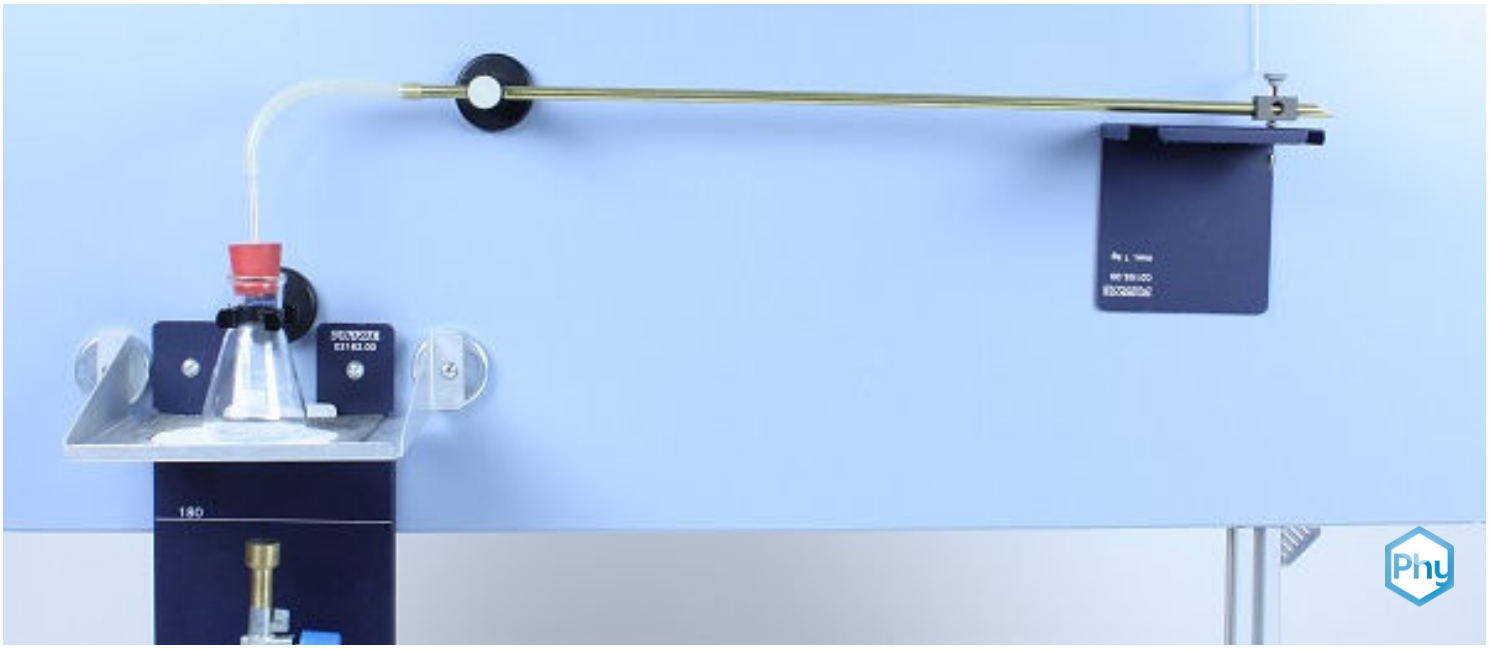
Linear expansion of solid bodies



P1291500

Physics > Thermodynamics > Temperature & Heat

Difficulty level	Group size	Preparation time	Execution time
medium	-	20 minutes	30 minutes

This content can also be found online at:

http://localhost:1337/c/652d453974958c00020b2635

PHYWE

General information

Application

PHYWE

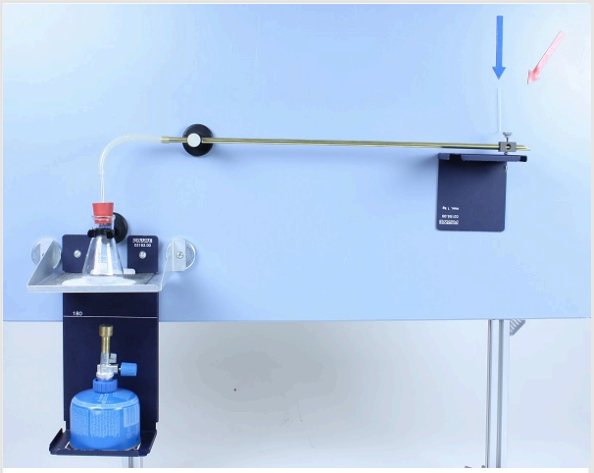


Fig. 1: Experimental setup

Every solid body occupies a certain space at a given temperature. It has a certain volume. If the temperature of a solid body changes, its volume, i.e. its length, width and height, generally changes as well.

Even in the case of long solid bodies, e.g. pipelines, steel bridges, railway tracks, concrete carriageways of motorways or high-voltage power lines, the volume and thus the dimensions change when the temperature changes.

PHYWE

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Other information (1/2)

PHYWE

Prior

Students should have knowledge of thermal expansion and be familiar with the definition of the terms "Coefficient of linear expansion α" should be familiar.

Principle

A solid changes its geometric dimensions under the influence of heat, this is called thermal expansion. In this experiment, various metal pipes are heated by steam and their linear expansion is examined. The change in length is illustrated by a pointer on a rolling axis over which the tube can move. The linear expansion of different metals is compared qualitatively.

Other information (2/2)

PHYWE

Learning

Different materials expand to different degrees under the influence of heat. The linear expansion can be described by the material-specific linear expansion coefficient α. In addition, the functioning of the rolling pointer is to be explained.

Tasks

1. qualitative comparison of the linear expansion of different metal pipes.

2. geometric derivation of the function of the roller pointer.

3. calculation of the material-specific coefficient of linear expansion α.

PHYWE

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Safety instructions

PHYWE

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

PHYWE

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Equipment

Position	Equipment	Item no.	Quantity
1	PHYWE Adhesive board with frame, Demo Physics	02150-00	1
2	Clamp holder, d = 28..36 mm, on holding magnet	02151-06	1
3	Clamp holder, d = 0..13 mm, on holding magnet	02151-07	1
4	Scale for demo board	02153-00	1
5	Pointer for demo board, 4 pieces	02154-01	1
6	Shelf, magnetic	02155-00	1
7	Holder for burners, on holding magnets	02162-00	1
8	Holder for wire net, on holding magnets	02163-00	1
9	Wire mesh with ceramic, 160 x 160 mm	33287-01	1
10	Support bush for linear expansion	04231-55	1
11	Brass tube, d = 8 mm , l = 430 mm	04234-11	1
12	Iron pipe, d = 8 mm , l = 430 mm	04234-12	1
13	Aluminium tube, d = 8 mm , l = 430 mm	04234-13	1
14	Rolling axle with pointer, axle diameter 3 mm	04236-01	1
15	Erlenmeyer flask, Boro, 100 ml, SB 29	MAU-EK17082301	1
16	Glass tubes, d = 8 mm, l = 80 mm, 10 pieces	MAU-16074541	1
17	Rubber plug 26/32, bore 7 mm	39258-01	1
18	Silicone hose, inner d = 6 mm, running m	47530-00	1
19	Butane burner with cartridge, 220 g	32180-00	1
20	Glycerine, 250 ml	30084-25	1
21	Boiling stones, 200 g	36937-20	1
22	Immersion sensor, NiCr-Ni, stainless steel, -50...400°C	13615-03	1
23	PHYWE ADM 3 demo multimeter: current, voltage, resistance, temperature	13840-00	1

PHYWE
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

PHYWE

Setup and procedure

Structure (1/4)

PHYWE

Fig. 2: Materials

Place the magnetic holder for the butane burner on the bottom left of the demo board. (Fig. 3)

Attach the wire net holder with wire net either at the 240 (butane torch) or at the 180 (Bunsen torch) mark.

Fill the Erlenmeyer flask halfway with water and add two boiling stones.

Push the 80 mm glass tube into the rubber stopper with the help of glycerine and close the Erlenmeyer flask with it.

PHYWE

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Structure (2/4)

PHYWE

Put the silicone tube on the end of the glass tube.

Place the Erlenmeyer flask on the plate above the Bunsen burner using the clamp holder (28 to 36 cm) and lower it onto the wire mesh.

Now prepare the metal pipe installation. Insert the pipes each via two notches at a distance of l = 500 mm and a bevelled end. As shown in fig. 3, lock the notch at the bevelled end of the support bush for length expansion and on the other notch the clamping bracket (0 to 13 mm). Start with the aluminium tube, for example.

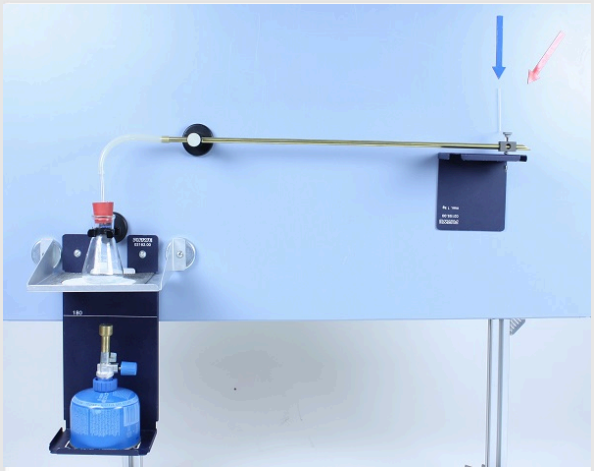


Fig. 3: Experimental setup

Structure (3/4)

PHYWE excellence in science

Now place the surface with the flat side facing upwards on the right side of the board. Position the tube in the middle of the board and connect it with the silicone tube at the straight ends. It rests on the right side of the board.

9. the pipe should slope slightly to the right so that condensing water can drain off.

Now assemble the rolling axis (fig. 4). Put the pointer with the side of the counterweight through the hole in the base. The rolling axis then rests on the surface. Make sure that the angle between the rolling axis and the board is right so that the pointer does not rub against the board and can move freely.

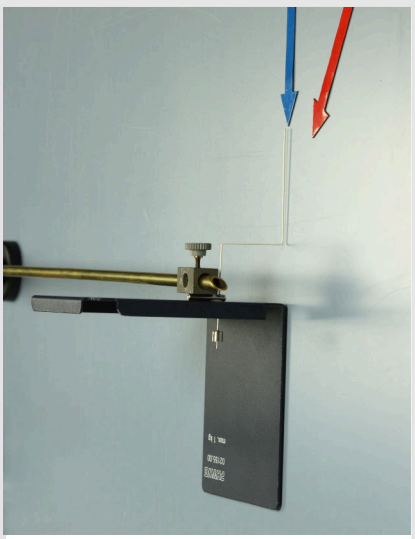


Fig. 4: Roller pointer

PHYWE

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Structure (4/4)

PHYWE

Turn the tube at the end with the clamp with the support bush onto the roll axis so that sufficient support pressure is guaranteed. The position of the roll axis can be carefully optimised later.

Connect the plug from the temperature sensor to the ADM 3. Use the ADM 3 to measure the room temperature.

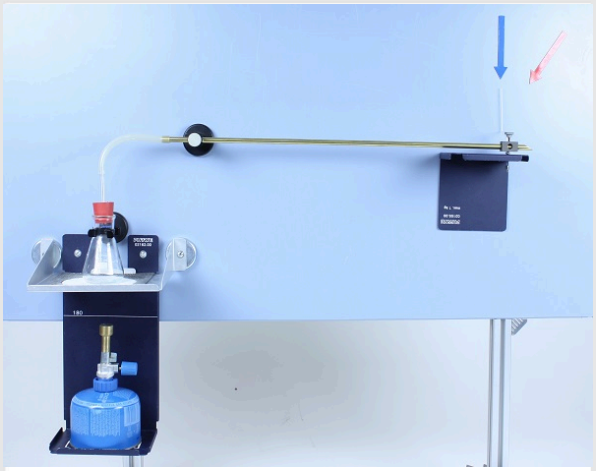
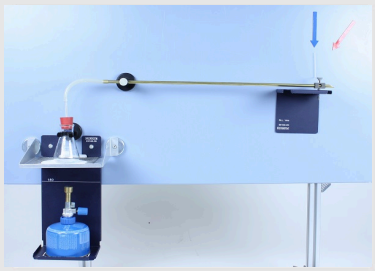


Fig. 5: Experimental setup

Procedure (1/2)

PHYWE



Attention! The tube as well as the water vapour that will come out at the end are hot. There is a risk of burns!

Place the pointer vertically and mark its starting position close to the pointer with a blue arrow. Do not bump the tube or the pointer during the experiment!

Switch on the Bunsen burner, bring the water to the boil and wait until steam comes out of the end of the tube. Place a beaker underneath to catch condensation.

Observe the pointer and wait until it stops moving. Mark the end position with a red arrow close to the pointer.

4. measure the distance s between the red and blue arrows.

PHYWE

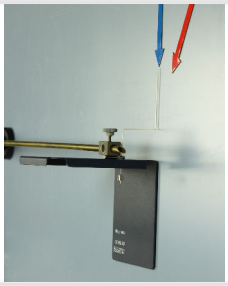
Robert-Bosch-Breite 10
37079 Göttingen

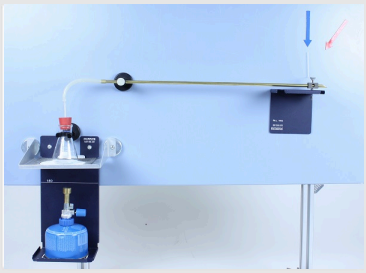
Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Procedure (2/2)

PHYWE





Let the tube cool down a little and remove it with the help of a rag.

Repeat the experiment with the tubes made of different materials.

Also:

Determine the room temperature with the ADM 3.

2. measure the pointer length a from the centre of the rolling axis to the tip.

PHYWE

Report

PHYWE

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Observation

PHYWE

The roller pointer moves when the tube heats up and reaches a maximum deflection.

Aluminium causes the greatest maximum deflection, steel the least.

Evaluation (1/6)

PHYWE

Equipment	s in mm
Aluminium	23
Brass	19
Steel	12

Tab. 1

The following are examples of measurement results (Table 1):

Length of the metal tubes = 500 mm

Radius of the rolling axis = 2 mm

Length of the pointer = 102 mm

Room temperature = 23 °C

Boiling temperature = 100 °C

PHYWE

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Evaluation (2/6)

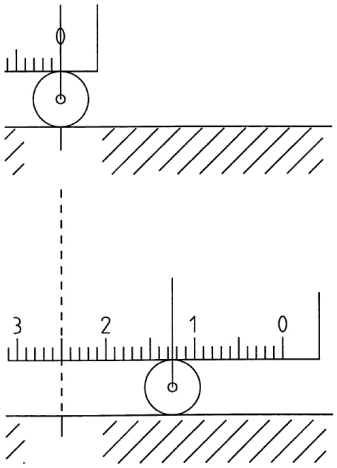


Fig. 10: Rolling movement

a) Geometry of the roller pointer

1. a relationship should be established between the deflection of the roller pointer ***s*** and the linear expansion $\triangle l$ can be derived.

Figs. 10 and 11 help with this

Evaluation (3/6)

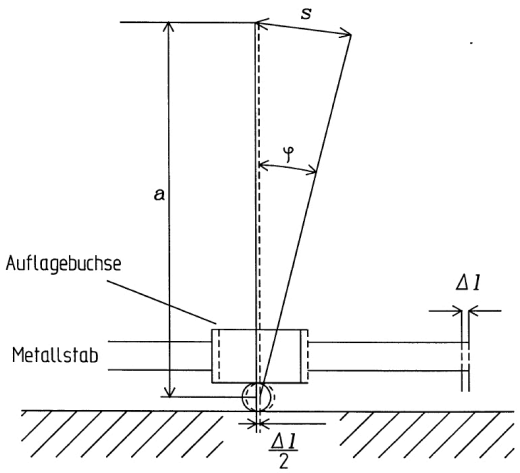


Fig. 11: Geometry of the roller pointer

2. to familiarise themselves with the way it works, the students should use a ruler (representing the tube with support bush) to rotate the rolling axis 360 ° on one edge. The result is shown in Fig. 10:

Displacement of the ruler 2.5 cm

Movement of the roller pointer 1.25 cm

Circumference of the roller pointer 1.25 cm

PHYWE
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Evaluation (4/6)

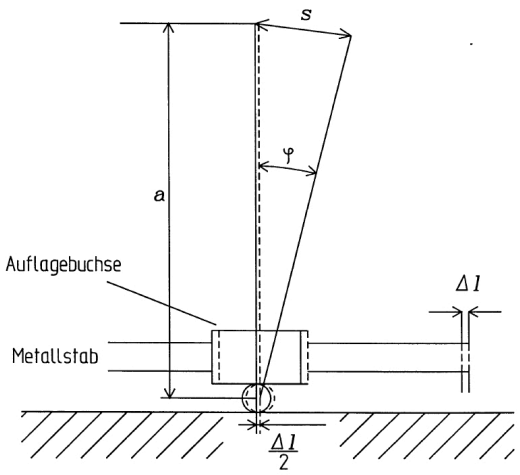


Fig. 12: Geometry of the roller pointer

3. the ruler moves around the line $\Delta l$the roll pointer moves by the distance $\Delta l/2$. The rolled distance can be measured over the circumference of the axle. $2\pi r$in relation to the deflection angle ϕ be set:

$$\Delta l/2 = 2\pi \cdot r \cdot \frac{\phi}{360^\circ}$$

4. now the track ***s*** in relation to the angle. It corresponds to the arc of a circle that forms the angle ϕ heard. Thereby the route $\Delta l/2$ is neglected. (A calculation via tangent or sine of the angle of rotation would yield the same results within the scope of the measurement accuracy).

$$\phi = s \cdot \frac{360^\circ}{2\pi a}$$

Evaluation (5/6)

b) Now the linear expansion is to be Δl and the coefficient of expansion α can be calculated.

1. the linear expansion is dependent on the temperature difference $(T_1 - T_0)$ and the length of the clamped pipe l_0Both quantities are determined by the coefficient of linear expansion. α related:

$$\Delta l = \alpha \cdot l_0 \cdot (T_1 - T_0)$$

2. the above formulas can be combined into one final formula:

$$\alpha = s \cdot \frac{2 \cdot r \cdot s}{a \cdot l_0 \cdot (T_1 - T_0)}$$

The final results are shown in Table 2 below, as is the literature value for α :

PHYWE
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Evaluation (6/6)

Equipment	s in mm	ϕ in degrees	Δl in mm	α in 10^{-6} l/K	Literature value α in 10^{-6} l/K
Aluminium	23	12,9	0,90	23	23,7
Brass	19	10,7	0,75	19	18,3
Steel	12	6,7	0,47	12	10

Tab. 2

Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de