Expansion of air at constant pressure (Item No.: P1042700)

Curricular Relevance

Area of Expertise:	Education Level:	Topic:	Subtopic:	Experiment:
Physik	Klasse 7-10	Wärmelehre	Wärmeausdehnung	Ausdehnung von Luft bei konstantem Druck

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

Additional Requirements:

- Matches
- Felt-tip pen
- Scissors

Experiment Variations:

Keywords:

Task and equipment

Information for teachers

Additional Information

Heating a volume of air can lead to both an increase in volume and an increase in pressure.

In this experiment the pressure must remain constant. This is achieved by ensuring that the water level in both manometer limbs is the same before reading the volume change.

In the supplementary problem the expansion coefficient is calculated and compared with the reciprocal of the absolute temperature.

Remark

1. The stopper must be firmly inserted into the Erlenmeyer flask so that no air can escape during the measurements.
2. The manometer limbs must be set at different heights at the beginning of the experiment so that moving one of them always results in water levels of the same height.
3. The manometer should be filled slowly so that no air bubbles are formed. This can be done using the small beaker. A piece of tubing is slipped over the top of one glass tube to aid in filling.
4. To obtain enough measuring points, each temperature change should only be 1 °C. Therefore, the water should only be heated for a very short time.
5. Since the thermal contact between air and the thermometer is poor, the temperature is measured in water. This requires a painstaking temperature equalisation between the water in the beaker and the air in the Erlenmeyer flask (stirring and waiting).

Supplamantary tasks

1. The volume of air in the tube is neglected since it is not heated.
2. The expansion coefficient should be determined from the slope of the line. It can also be calculated as an average value.

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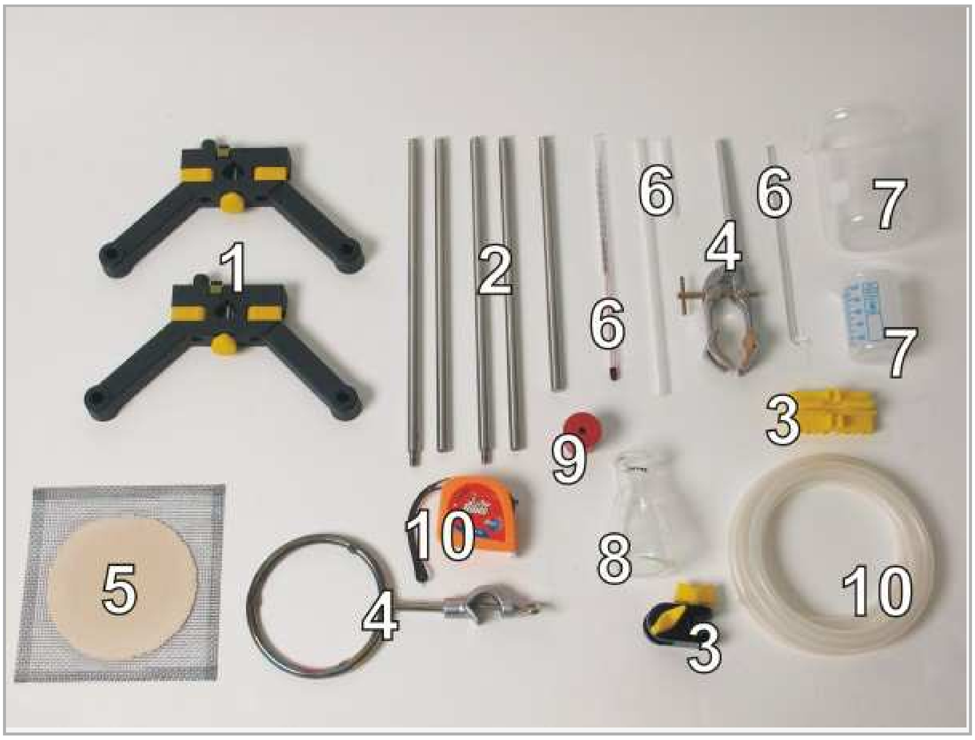
Task and equipment

Task

How does the volume of air change during heating?

Measure the expansion of a volume of air during heating at constant pressure (equal to the surrounding air pressure).

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
3	Support rod, stainless steel, l = 600 mm, d = 10 mm	02037-00	2
3	Boss head	02043-00	1
3	Glass tube holder with tape measure clamp	05961-00	1
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	Agitator rod	04404-10	1
6	Glass tube, straight, l=80 mm, 10/pkg.	36701-65	1 piece
6	Glass tubes,l.250 mm, pkg.of 10	36701-68	1 piece
6	Students thermometer, -10...+110°C, l = 230 mm	38005-10	1
7	Beaker, low form, plastic, 100 ml	36011-01	1
7	Glass beaker DURAN®, short, 400 ml	36014-00	1
8	Erlenmeyer flask 100 ml, wide-neck SB 29	36428-00	1
9	Rubber stopper 26/32, 1 hole 7 mm	39258-01	1
10	Silicone tubing i.d. 7mm	39296-00	1
10	Measuring tape, l = 2 m	09936-00	1
	Butane burner, Labogaz 206 type	32178-00	1
	Butane cartridge C206, without valve	47535-01	1
	Glycerol, 250 ml	30084-25	15 ml
Additional material:			
	Matches		
	Felt-tip pen		1
	Scissors		1

Set-up and procedure

Set-up

Warning!

1. Always insert the thermometer or glass tubes in the rubber stopper using glycerol.
2. The small beaker is used to fill the manometer. Water can be more easily poured into tubing than into a glass tube; therefore, a short piece of tubing should be slipped over the upper end of the glass tube to aid in filling.
3. During the heating of the water the support ring and the wire gauze become extremely hot.

Setup

- Set up the experiment according to the following pictures.

Fig. 1

Fig. 2

Fig. 3

Fig. 4

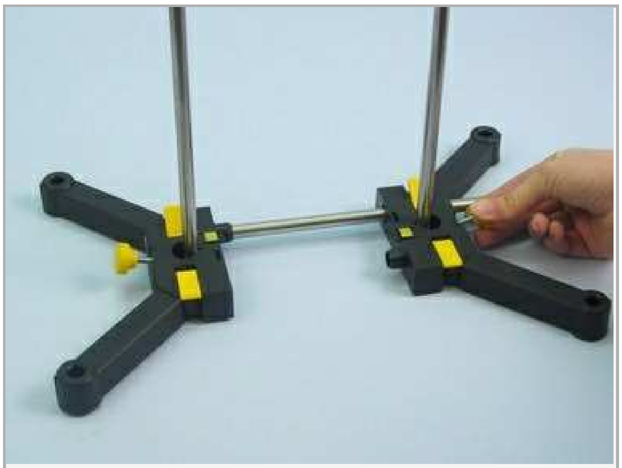


Fig. 5

Fig. 6

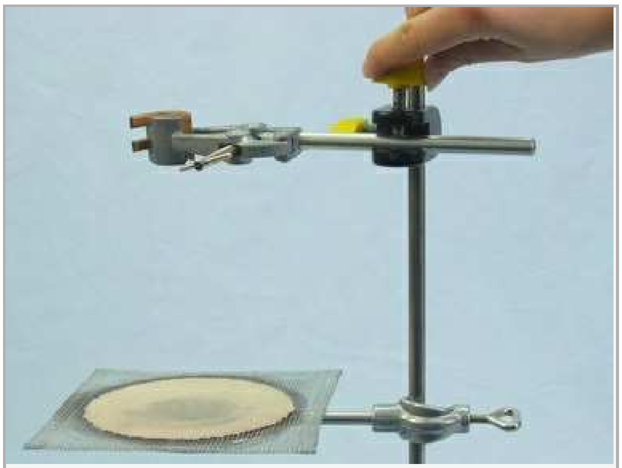


Fig. 7

Fig. 8

Fig. 9

Fig. 10

- Construct a U-tube manometer using the two 250 mm long glass tubes and a piece of tubing (about 50 cm long); clamp it in the glass tube holder with its limbs at different heights.

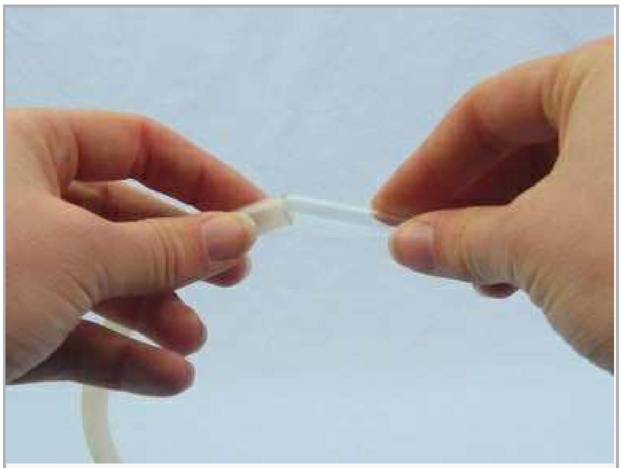


Fig. 11

Fig. 12

- Fill the manometer using the small beaker until the water in limb b has risen to a point directly below the glass tube (about 0.5 cm).

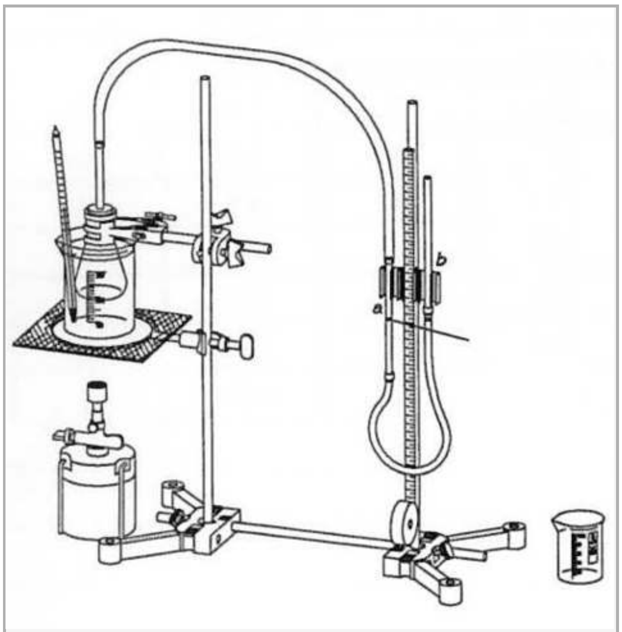


Fig. 13

Fig. 14

- Insert the short glass tube in the rubber stopper and seal the Erlenmeyer flask carefully with the stopper.

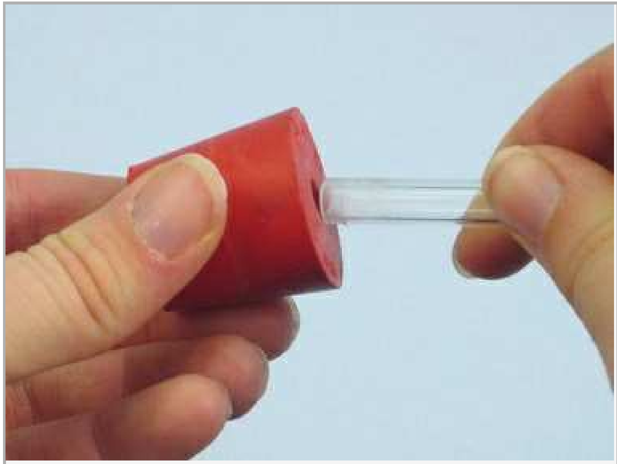


Fig. 15

Fig. 16

- Place the Erlenmeyer flask into the 400 ml beaker and clamp it into position with the universal clamp so that it extends as deep as possible into the beaker.

Fig. 17

- Fill the 400 ml beaker completely with water.

Fig. 18

- Connect the glass tube in the stopper with a piece of tubing (about 50 cm long) with the glass tube a of the manometer.

Fig. 19

Procedure

- Note the initial temperature ϑ_0 of the water in the beaker in the report.
- Move one of the manometer limbs until the water level in both of them (*a* and *b*) is the same (pressure in the Erlenmeyer flask equals surrounding air pressure).

Fig. 20

- Mark the water level in limb a with the felt-tip pen.

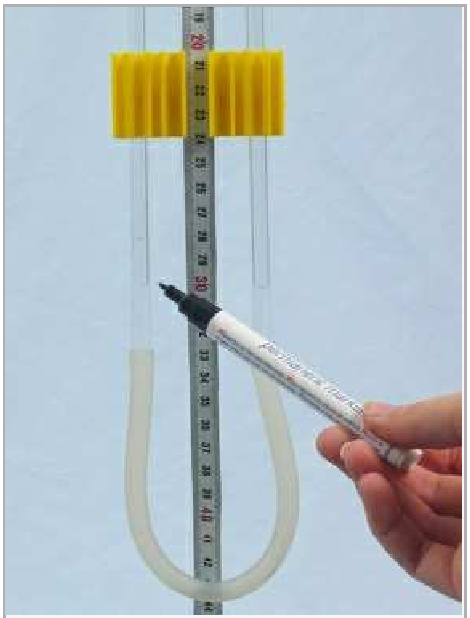


Fig. 21

- Heat the water for a short time (about 15 s) and then move the burner away from the beaker (the temperature should not rise more than 1 °C).
- Stir carefully for about 1 to 2 minutes so that the air in the flask has the same temperature as the water.

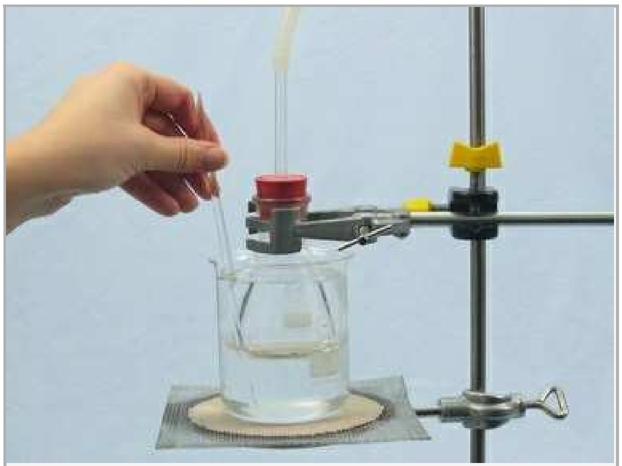


Fig. 22

- Record the water temperature in the table in the report.
- Set the water level in the manometer's limbs at the same height (move limb *b* downward).
- Measure the distance Δl in limb *a* from the mark to the water level and record it in the table.
- Heat the air progressively further and determine additional values for Δl as a function of the temperature.

Report: Expansion of air at constant pressure

Result - Observation 1

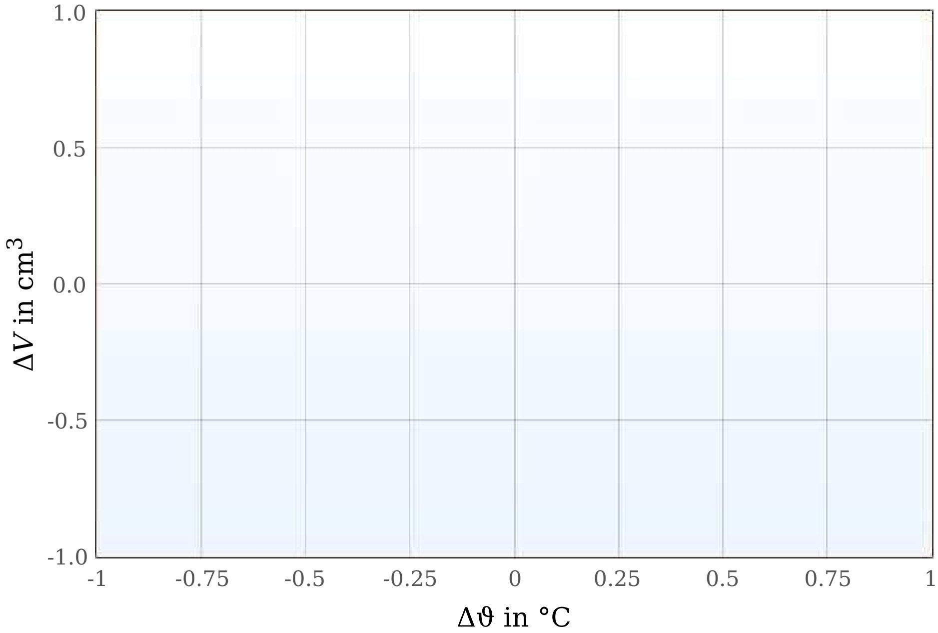
Initial temperature ϑ_0 = ... °C.

Result - Table 1

1. Note your measured values Δl in the table.
2. Calculate the temperature difference $\Delta\vartheta$ with reference to the initial temperature ϑ_0. $\Delta\vartheta = \vartheta - \vartheta_0$.
3. The inner diameter of the glass tube is d = 0.5 cm. Using the change in length Δl, calculate the change in volume $\Delta V = (d/2)^2 \times \pi \times \Delta l$

ϑ in °C	Δl in cm	$\Delta\vartheta$ in °C	ΔV in cm^3
1 ±0	1 ±0	1 ±0	1 ±0
1 ±0	1 ±0	1 ±0	1 ±0
1 ±0	1 ±0	1 ±0	1 ±0
1 ±0	1 ±0	1 ±0	1 ±0
1 ±0	1 ±0	1 ±0	1 ±0
1 ±0	1 ±0	1 ±0	1 ±0
1 ±0	1 ±0	1 ±0	1 ±0
1 ±0	1 ±0	1 ±0	1 ±0

Number1



Evaluation - Question 1

Watch the chart of table 1. What kind of correlation exists between volume change and temperature change?

Evaluation - Supplementary problem 1

Determine the volume of air V_0 in the Erlenmeyer flask (up to the stopper) by filling it with water (graduated cylinder).

V_0 = ... ml.

Evaluation - Supplementary problem 2

The expansion of air at constant pressure is described by the following formula:

$\Delta V = \gamma \times V_0 \times \Delta\vartheta$.

Calculate the expansion coefficient of air using the values in the chart.

γ = ...$\cdot 10^{-3} (°C)^{-1}$.

Evaluation - Supplementary problem 3

Express the initial temperature ϑ_0 in Kelvin:

T_0 = ... K

and form the quotient:

$1/T_0$ = ... $\cdot 10^{-3} (K)^{-1}$.

Evaluation - Supplementary problem 4

Compare your result of the previous problem with γ.

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Robert-Bosch-Breite 10
D - 37079 Göttingen
Tel: +49 551 604 - 0
Fax: +49 551 604 - 107
info@phywe.de
www.phywe.com