Expansion of air at constant volume (Item No.: P1042800)

Curricular Relevance

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

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

Additional Requirements:

- Matches
- Scissors
- Felt-tip pen

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 volume must be kept constant. This is achieved by marking the initial water level in limb a of the manometer and resetting the water level to this mark before reading the new pressure.

Remarks

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 clamped close to the lower ends of their respective glass tubes at the beginning of the experiment.
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).

Supplementary problem

In a supplementary problem the temperature-pressure coefficient is calculated and compared with the reciprocal of the absolute temperature.

In supplementary problem 2 the temperature-pressure coefficient should be determined from the slope of the line. It can also be calculated as an average value.

Expansion of air at constant volume (Item No.: P1042800)

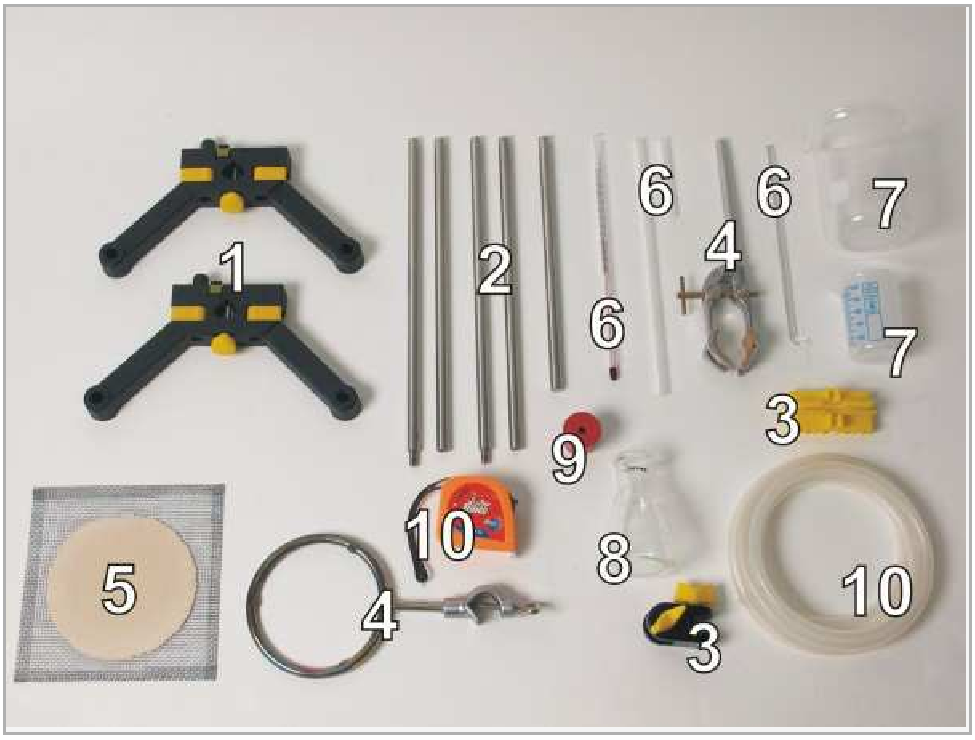
Task and equipment

Task

How does the pressure of a volume of air change during heating?

Measure the pressure change in a specific volume of air during heating at constant volume.

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	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 a 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 support stand according to the following pictures.


Fig. 1


Fig. 2


Fig. 3


Fig. 4

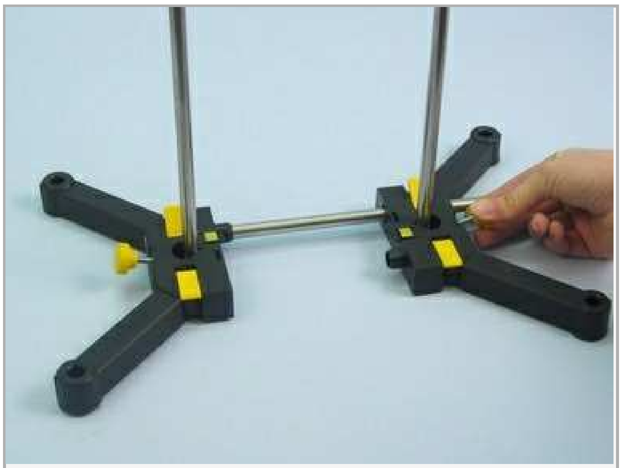


Fig. 5

Fig. 6

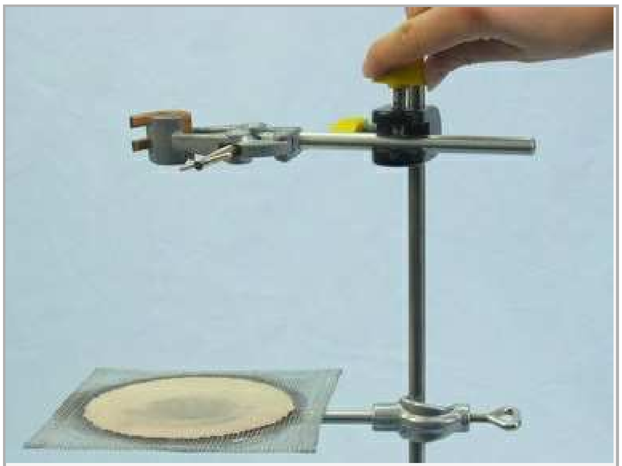


Fig. 7

Fig. 8

Fig. 9

- Fix the measuring tape in the glass tube holder.

Fig. 10

- Construct a U-tube manometer using the two 250 mm long glass tubes and a piece of tubing (about 60 cm long); clamp it in the glass tube holder with its limbs at the same height.

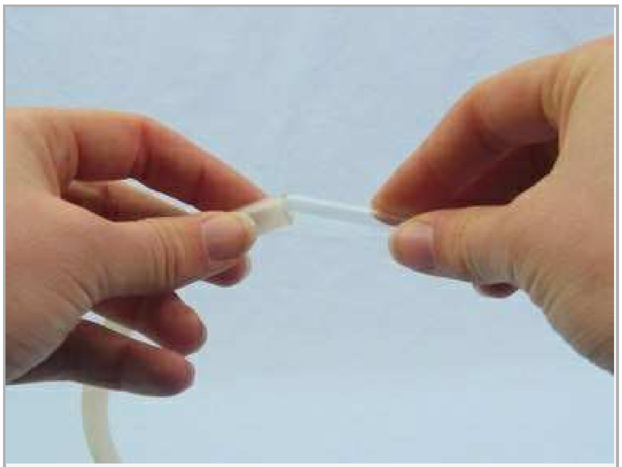


Fig. 11

Fig. 12

- Fill the manometer using the small beaker until the water level in both limbs is just 1 cm high.


Fig. 13

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

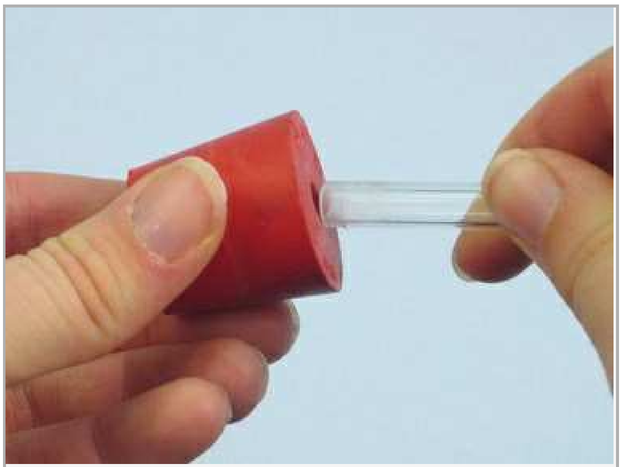


Fig. 14


Fig. 15

- 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. 16

- Fill the 400 ml beaker completely with water.


Fig. 17

- Connect the glass tube in the stopper with a piece of tubing with limb a of the manometer.

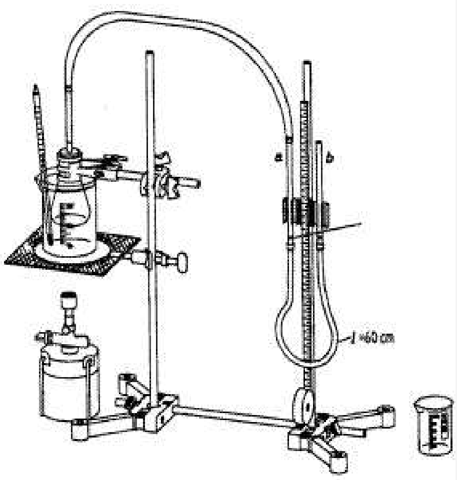


Fig. 18


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.

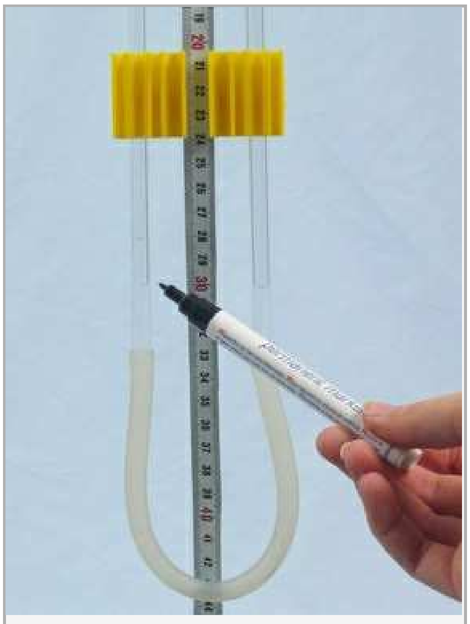


Fig. 21

- 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. Record the water temperature in the table in the report.

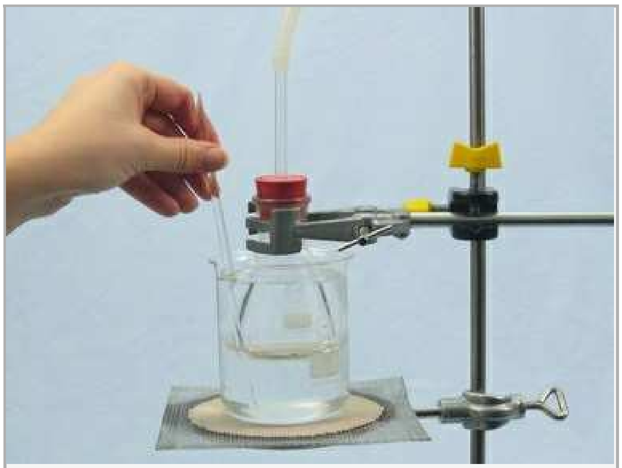


Fig. 22

- Adjust the water level in limb *a* so that it is again at the mark (move limb *a* downward).
- Measure the distance Δl between the two water levels 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 volume

Result - Observation 1

Initial temperature ϑ_0 = ... °C.

Robert-Bosch-Breite 10
D - 37079 Göttingen

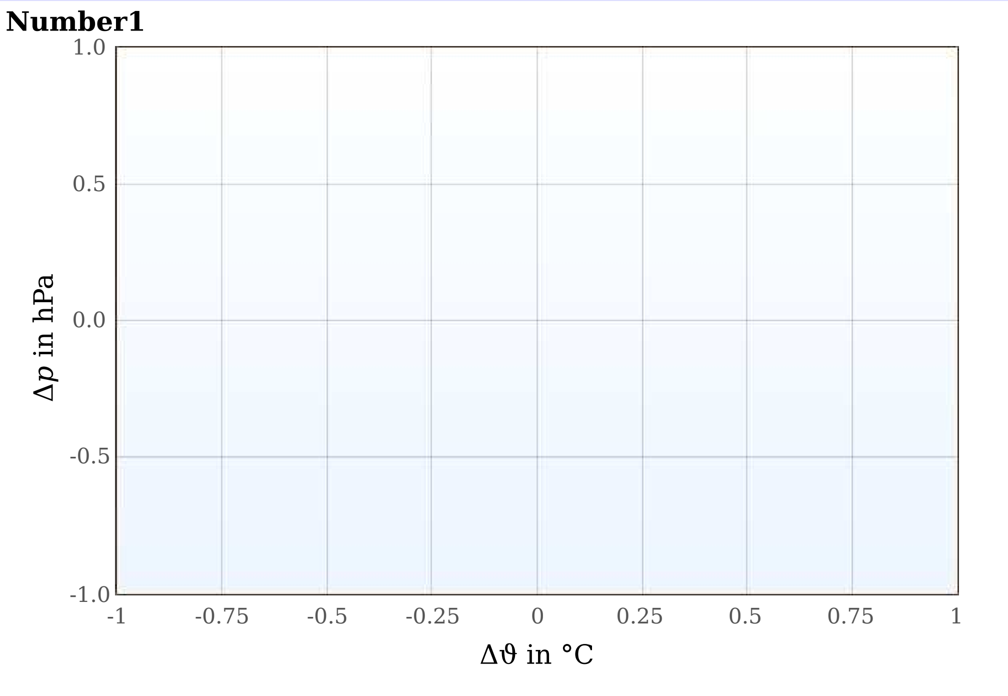
Tel: +49 551 604 - 0
Fax: +49 551 604 - 107

info@phywe.de
www.phywe.com

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 $\Delta\vartheta_0$. $\Delta\vartheta = \vartheta - \Delta\vartheta_0$.
3. The pressure is measured with the manometer's water column. In this experiment the conversion of Δl in cm = Δp in hPa is sufficient.

ϑ in °C	Δ*l* in cm	Δϑ in °C	Δ*p* in hPa
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



Evaluation - Question 1

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

....

....

....

....

Evaluation - Supplementary problem 1

Read today's air pressure p_0 from a barometer or use p_0 = 1013 hPa for your calculations.

p_0 = ... hPa.

Evaluation - Supplementary problem 2

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

$\Delta p = \beta \times p_0 \times \Delta\vartheta$.

Calculate the temperature-pressure coefficient β of air using the values in the chart.

β = ... $\cdot 10^{-3} (°C)^{-1}$.

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 from the previous problem with β.

....

....

....

....

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