Expansion of air at constant volume

Physics	Mechanics	Mechanics of liquids & gases
Physics	Thermodynamics	Temperature & Heat
Physics	Thermodynamics	Kinetic gas theory & gas laws
Chemistry	General Chemistry	Stoichiometry

Difficulty level	Group size	Preparation time	Execution time
medium	2	10 minutes	10 minutes

This content can also be found online at:

http://localhost:1337/c/62e8077099933e000327065a

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Teacher information

Application

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Experimental setup

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 done by keeping the initial water level in leg a of the manometer is marked and the water level is brought back to this mark before reading the pressure.

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Other teacher information (1/2)

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Prior knowledge

Safe handling of the Bunsen burner is a prerequisite.

Principle

Heating can cause substances both to expand in volume at constant pressure and to increase in pressure at constant volume. Gases expand more than liquids when heated. In this experiment, the volume is kept constant in order to observe the increase in pressure.

Other teacher information (2/2)

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Learning objective

The increase in air pressure with heating is to be illustrated and measured. In addition, this process is to be characterised by determining the stress coefficient.

Tasks

The students should heat the air in a closed system (Erlenmeyer flask) and keep the volume constant with the help of the water level. The increasing pressure is to be calculated using the different water levels of the manometer in order to investigate the relationship between temperature and pressure.

In the additional tasks, the stress coefficient is to be calculated and compared with the reciprocal of the absolute temperature.

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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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Flat tyre

Why can bicycle tyres burst in the sun?

When a gas (air is a mixture of gases) is heated, it expands if it can. If it cannot expand (there is only limited space in the tyre), then the pressure of the air increases and the tyre becomes tighter and tighter until it finally bursts.

Often the tyre is inflated tightly in the cool cellar. In the sun the air then heats up and the pressure is increased even more until it can burst.

Task

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Experimental setup

Measure the pressure increase in a volume of air when it is heated and the size of the volume remains constant. Describe the course of the measured value curve and make a statement about the relationship between pressure and temperature of air.

In an additional task, calculate the stress coefficient and compare it with the reciprocal of the absolute temperature.

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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	1
5	Glass tube holder with tape measure clamp	05961-00	1
6	Ring with boss head, i. d. = 10 cm	37701-01	1
7	Wire gauze with ceramic, 160 x 160 mm	33287-01	1
8	Universal clamp	37715-01	1
9	Agitator rod	04404-10	1
10	Beaker, 100 ml, plastic (PP)	36011-01	1
11	Beaker, Borosilicate, low-form, 400 ml	46055-00	1
12	Erlenmeyer flask, stopper bed, 100 mlSB 29	MAU-EK17082301	1
13	Glass tube, straight, l=80 mm, 10/pkg.	MAU-16074541	1
14	Glass tubes,l.250 mm, pkg.of 10	MAU-16074544	1
15	Rubber stopper 26/32, 1 hole 7 mm	39258-01	1
16	Silicone tubing i.d. 7mm, 1 m	39296-00	1
17	Students thermometer, -10...+110°C, l = 230 mm	38005-10	1
18	Measuring tape, l = 2 m	09936-00	1
19	Butane burner, Labogaz 206 type	32178-00	1
20	Butane cartridge C206, without valve, 190 g	47535-01	1
21	Glycerol, 250 ml	30084-25	1

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Additional material

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Position	Material	Quantity
1	Pair of scissors	1
2	Matches	1
3	Felt pen	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 stand foot 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 halves of the two long stand rods together (**Fig. 4**).

4. Attach the tripod rods to the halves of the tripod legs and fix them in place with the help of the screws (**Fig. 5**).

5. Attach the tripod ring with the wire net using the sleeve and the universal clamp using the double sleeve, one above the other, to a tripod pole (**Fig. 6**).

6. Place the gas burner underneath and attach the glass tube holder to the other stand rod (**Fig. 7**)

Fig. 4

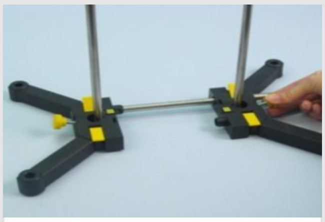

Fig. 5

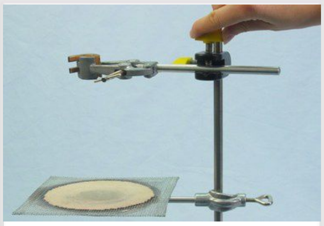

Fig. 6

Fig. 7

Set-up (3/6)

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7. Attach the tape measure to the glass tube holder (**Fig. 8**).

8. Make a U-tube manometer with the two 250 mm long glass tubes and a piece of tubing (approx. 50 cm long) and clamp it with legs of different heights in the glass tube holder (**Fig. 9 + 10**).

Fig. 8

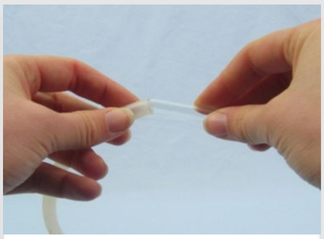

Fig. 9

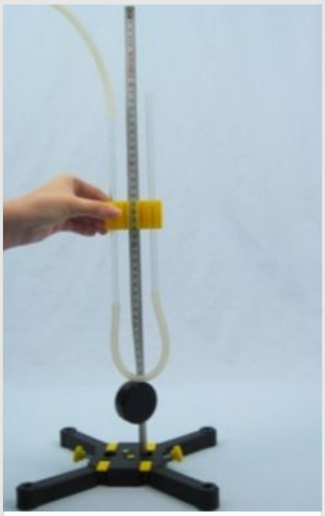

Fig. 10

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Set-up (4/6)

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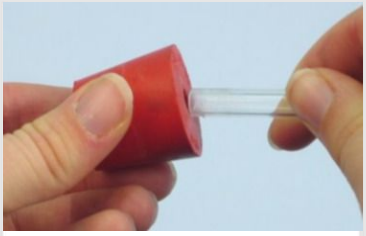

Fig. 11

Fig. 12

9. Push the small glass tube into the rubber stopper and carefully close the Erlenmeyer flask with the stopper (**Fig. 11 + 12**).

10. Fill the manometer slowly with the help of the small beaker until the water in both glass tubes is 1 cm high (**Fig. 13).** No air bubbles should form. A piece of tubing on the glass tube can serve as a filling aid.

Fig. 13

Set-up (5/6)

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11. Place the Erlenmeyer flask in the 400 ml beaker and secure it with the universal clamp so that it is as deep as possible (**Fig. 14**).

12. Fill the beaker completely with water (**Fig. 15**).

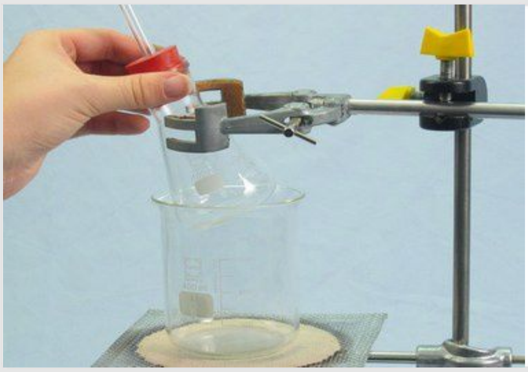

Fig. 14

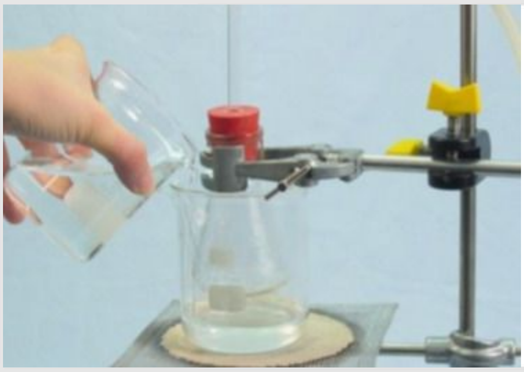

Fig. 15

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Set-up (6/6)

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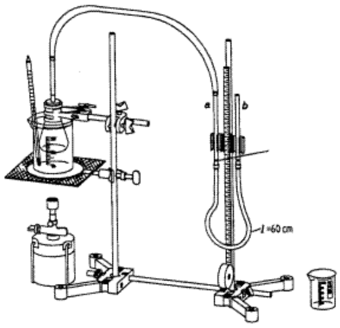
Fig. 16

13. Connect the glass tube in the stopper via a tube (approx. 50 cm long) to the leg a of the manometer (**Fig. 16**).

14. The finished experimental set-up should finally look like the one in the figure on the right.



Procedure (1/3)

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Fig. 17

1. Note the initial temperature ϑ_0 of the water in the beaker into the table in the report.

2. Bring the water levels in leg a and b to the same height (initial pressure equal to the external air pressure, **Fig.17**).

3. Mark the water level in leg a with a felt-tip pen (**Fig. 18**).

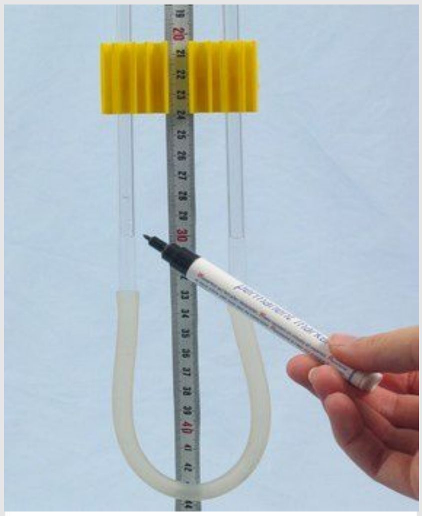

Fig. 18

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Procedure (2/3)

4. Heat the water briefly (approx. 15 s) and then remove the burner (the temperature should only rise by 1 °C if possible).

5. Stir carefully for about 1 to 2 minutes so that the air in the Erlenmeyer flask takes on the temperature of the water (**Fig. 19**).

6. Note the water temperature in the table in the report.

Caution! When the water heats up, the tripod ring and the wire net become very hot!

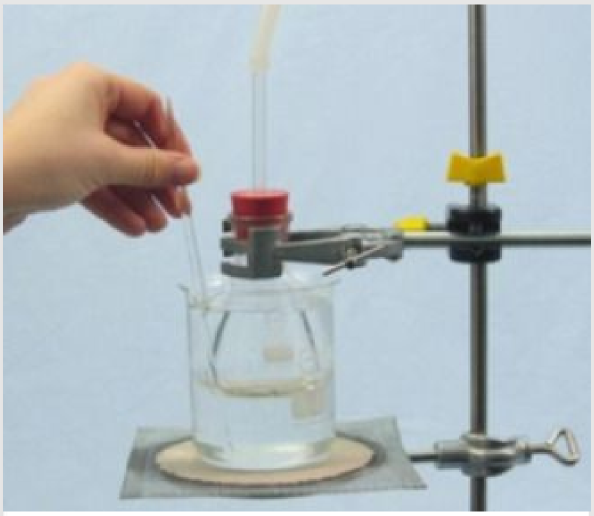

Fig. 19

Procedure (3/3)

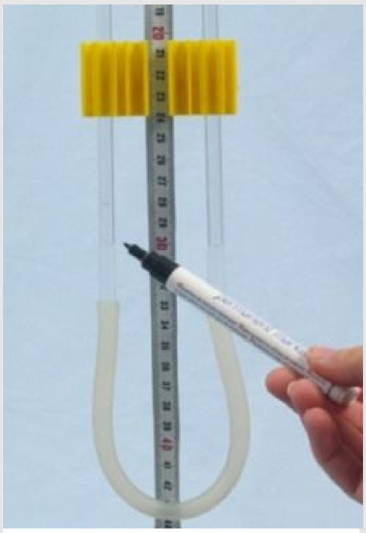

Fig. 20

7. Bring the water level into leg a of the manometer back to the marking (slide the leg a downwards).

8. Measure the distance Δ_l of the two water levels in the legs of the manometer and note it in the table (**Fig. 20**).

9. Continue to heat the air in 1°C steps and determine further values for Δ_l as a function of temperature.

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Report

Observation

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What is the initial temperature ϑ_0 (°C)?

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Results

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$\vartheta\,(C^\circ)$	$\Delta l\,(cm)$	$\Delta\vartheta\,(C^\circ)$	$\Delta p\,(hPa)$

1. Note your readings for Δl in the table.

2. Calculate the temperature difference in each case $\Delta\vartheta = \vartheta - \vartheta_0$ and enter them.

The pressure is measured with the water column in the manometer. For this experiment the following conversion is sufficient Δl (cm) = Δp (hPa). Enter the values for the pressure Δp in hPa into the table.

Task 1

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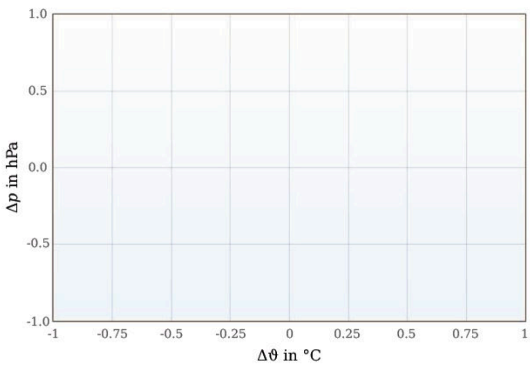
Draw a coordinate system on a sheet of paper according to the example below and enter the measured values for Δp and $\Delta\vartheta$ into the graph.



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Task 2

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Read the current air pressure p_0 on a pressure gauge or calculate the following tasks with

$p_0 = 1013\ hPa$.

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

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

From the measured values in the table, calculate the voltage coefficient β of air at constant volume.

Task 3

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What influences the water pressure in the pressure gauge?

- [ ] The air pressure
- [ ] The height of the water column
- [ ] The total mass of the water

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Task 4

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What is the relationship between pressure and temperature change (see task 1)?

- ○ Exponential
- ○ Varies depending on temperature
- ○ Proportional

Check

Task 5

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Calculate the initial temperature ϑ_0 in Kelvin (T_0) and form the quotient $1/T_0$

What is the relationship between the numerical values of β and $1/T_0$?

- ○ They are reciprocals of each other
- ○ About the same size
- ○ γ is the root of $1/T_0$

Check

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Slide	Score / Total
Slide 25: Influencing the water pressure	0/2
Slide 26: Ratio of pressure and temperature change	0/1
Slide 27: Ratio of \(β\) and \(1/T_0\)	0/1

Total 0 / 4

Solutions Repeat Export text

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