(Item No.: P1292600)

Curricular Relevance

Area of Expertise: Physics
Education Level: Age 16-19
Topic: Thermodynamics
Subtopic: Gas laws
Experiment:

Difficulty	Preparation Time	Execution Time	Recommended Group Size
Difficult	10 Minutes	30 Minutes	3 Students

Additional Requirements:

Experiment Variations:

Keywords:

Principle and material

Principle

A gas syringe which is sealed with engine oil is used to determine the relationship between pressure and volume.

Preliminary remarks

1. The plunger of the gas syringe slides on a thin air film.
   Because of this, when the air volume inside a gas syringe is under positive or negative pressure, pressure equalization with the surroundings takes place. To avoid this happening in this experiment, the plunger of the gas syringe is sealed with a few drops of engine oil.
   A closed oil film must be formed over the whole of the area of contact of the plunger with the inner wall of the syringe. Multi-purpose oil is more suitable for this than simple paraffin oil or machine oil, because leakage can occur with thin oils (particularly at higher temperatures).
   The oiled gas syringe can be stored for some time for further experiments. When required, the gas syringe can be cleaned with a brush and warm soapy water.
2. The gas syringe is fitted in the glass jacket, which is then filled with water. Because of the high thermal capacity of water, variations in temperature on compressing and expanding the air inside the syringe are avoided.

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Material

Position No.	Material	Order No.	Quantity
1	Demo Physics board with stand	02150-00	1
2	Clamp on fixing magnet	02151-01	2
3	Holder for hand-held meters	02161-00	1
4	Universal clamp with joint	37716-00	2
5	Gas syringe, 100 ml	02614-00	1
6	Glass jacket	02615-00	1
7	Hose clip, diam. 8-16 mm, 1 pc.	40996-02	1
8	Funnel, plastic, dia.50mm	36890-00	1
9	Silicone tubing i.d. 7mm, 1 m	39296-00	1
10	Silicone tubing i.d. 2mm	39298-00	1
11	Tubing adaptor, ID 3-5/6-10 mm	47517-01	1
12	Graduated vessel, 1 l, with handle	36640-00	1
13	Cobra4 hand-held pressure and temperature measuring instrument, Cobra4 Mobile-Link	12736-01	1
14	Large-scale display, digital	07157-93	1

Safety instructions

For this experiment, the general instructions for safe experimentation in science teaching apply.

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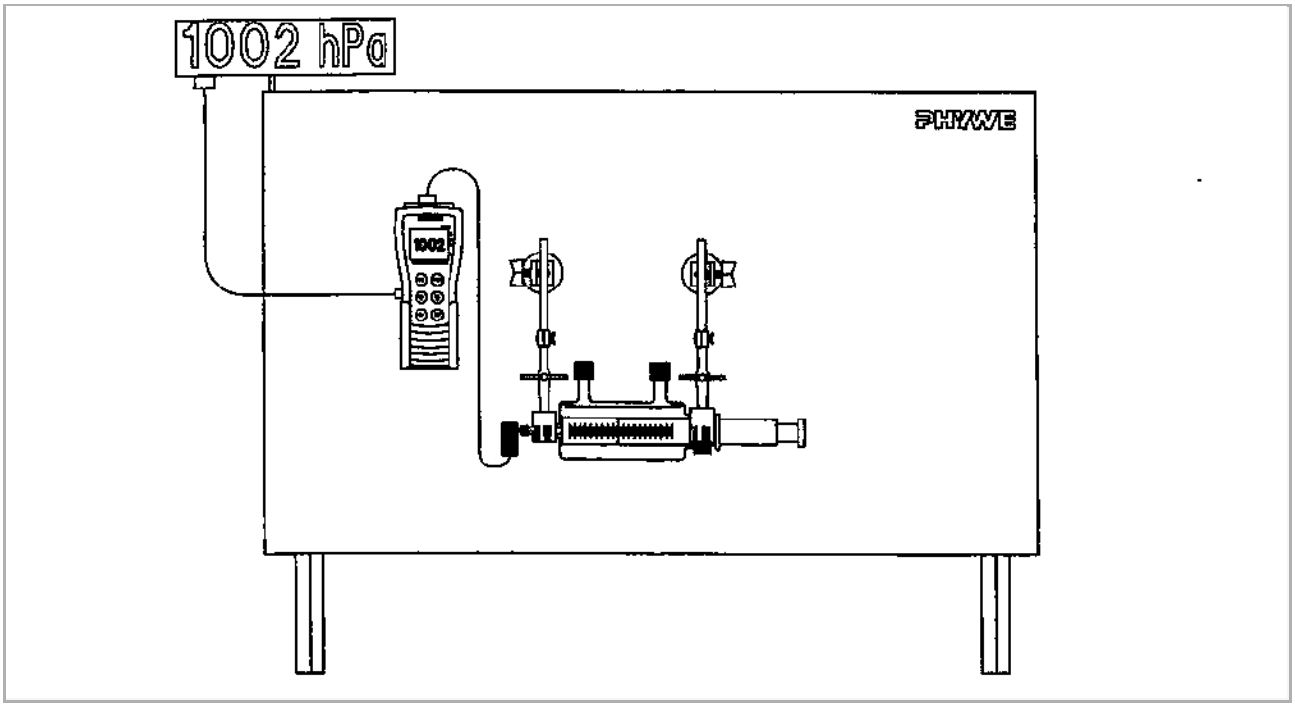
Setup and procedure

Setup

- Place the two clamps on the board at a distance of approx. 20 cm from each other, and fix a universal clamp in each of them (see Fig. 1).



- Seal the gas syringe with engine oil.
- Fit the gas syringe in the glass jacket.
- Fill the glass jacket with water.
- Hold the glass jacket with the universal clamps.
- Fit the hand-held measuring instrument onto the board by means of the magnetic holder. Connect the instrument to the large-scale display.
- Adjust the initial volume of the gas syringe to 50 ml.
- Connect the pressure measuring instrument to the gas syringe:
  Fit a short piece of tubing on the glass tube of the syringe and fix it with a tubing clamp. Insert the larger end of the reducing piece in the open end of the tubing, then the smaller end in a piece of thin tubing and fit the sensor of the pressure measuring instrument in this.

Note

The complete connection of the gas syringe to the pressure sensor must be held as short as possible, so that this additional volume can be neglected. It is absolutely essential to ensure that the tubing connections are absolute leakproof and will hold up to increased pressure. To check that they are leakproof, push the plunger a little into the syringe, wait a moment, and then withdraw it to its initial position. The pressure must also return to the initial value.

Procedure

- Determine the initial volume (50 ml) and the initial pressure and enter them in a Table.
- Increase the volume stepwise by 1 ml up to 55 ml, measuring the corresponding pressures.
- Adjust the volume back to 50 ml and check the initial pressure.
- Reduce the volume stepwise by 1 ml down to 40 ml, measuring the corresponding pressures.

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Observation and evaluation

Observations and evaluation

Results

Table 1: Expansion, ϑ = 20 °C

V [cm³]	p [hPa]	pV [Nm]
50	1002	5.01
51	984	4.97
52	966	5.02
53	950	5.04
54	931	5.03
55	918	5.05

Table 2: Compression, ϑ = 20 °C

V [cm³]	p [hPa]	pV [Nm]
50	1002	5.01
49	1022	5.01
48	1045	5.02
47	1063	5.00
46	1086	5.00
45	1108	4.99
44	1132	4.98
43	1159	4.98
42	1195	5.02
41	1214	4.98
40	1240	4.96

Evaluation

Air behaves as an ideal gas, as long as the density is not too high and the temperature is not too low. The behaviour of an ideal gas is described by the Ideal Gas Law.

$$\frac{pV}{T} = \text{const.} = \frac{p_1 V_1}{T_1} \quad (1)$$

Whereby the initial state is determined, e.g., by the quantities p_1, V_1 and T_1 and the final state by p, V and T.
At constant temperature, according to the Boyle-Marriotte Law volume:

$$p \cdot V = \text{const.} \quad (2)$$

or

$$p = \frac{p_1 V_1}{V} \quad (3)$$

The products of pressures and volumes are entered in the Tables, and they confirm the relationship described in equation (2).
At constant temperature, the product of pressures and volurne is constant.
The relationship between pressure and volume shown in Fig. 2 is a hyperbola according to equation (3).

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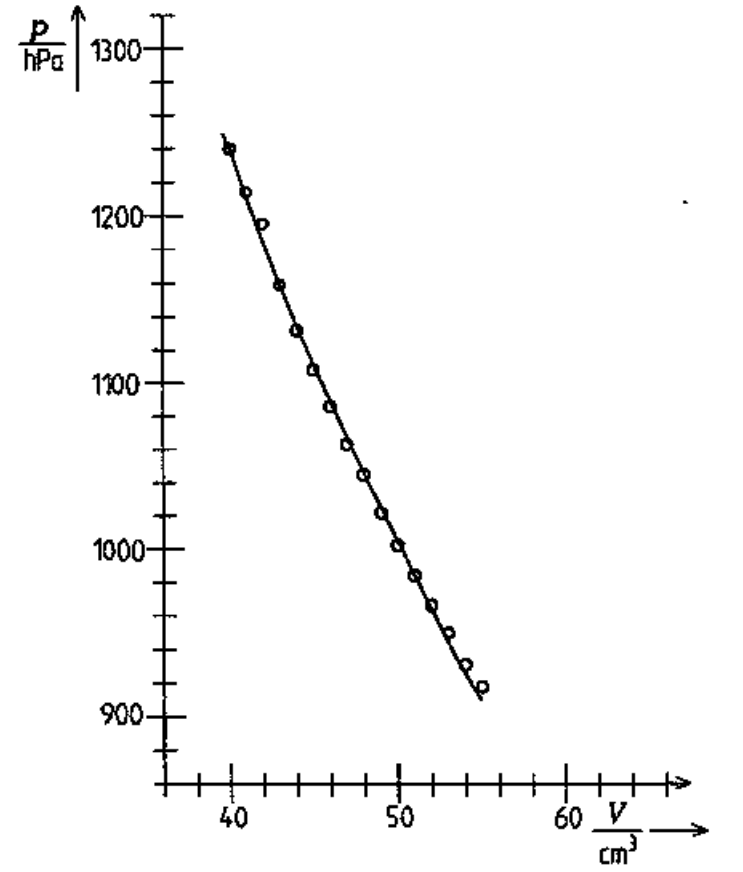

Fig. 2: The relationship between pressure and volume at constant temperature ϑ = 20 °C

Notes

1. During expansion, the volume should not go above 55 ml, as the area of contact between the plunger and the inner wall of the syringe would then be too small to seal off the air volume held inside.
2. On use of a heating apparatus (order no. 32246-93) held under the glass jacket by a holder (order no. 02162-00), the water bath can be warmed and the experiment be carried out at a different temperature.

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