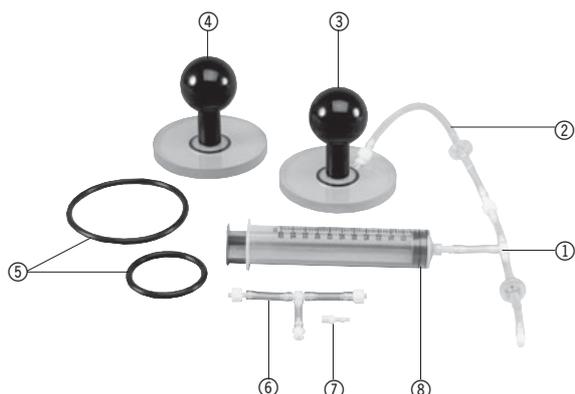


U45054 Magdeburg Plates

Instruction Sheet

7/03 ALF



- ① Hose with T-piece and valve
- ② Hose with valve
- ③ Transparent acrylic plate with flange for hose attachment
- ④ Transparent acrylic plate
- ⑤ Rubber sealing rings
- ⑥ T-piece
- ⑦ Spare hose connector
- ⑧ Hand pump

Complete set of equipment for conducting Guericke's historical experiment to show the effect of atmospheric pressure. The experiment can be performed as a demonstration or as a student practical.

1. Safety Instructions

- Do not try to pry the two evacuated hemispheres apart using tools.
- Do not try to separate the hemispheres using ropes or similar, because when they do separate they can turn into projectiles.
- Ample space should be left behind the persons trying to separate the Magdeburg plates
- Do not use excessive force when connecting the hose. Do not use any more force than you can generate from your fingers to connect the hose.
- When ventilating the hemispheres hold on tight to the apparatus so that you can avoid any damage from the hemispheres falling.
- Be careful not to scratch the inner surfaces of the plates.
- To clean, only use warm water with a small amount of washing-up liquid. Never use solvents.

Description, technical data

The Magdeburg plates kit consists of two transparent acrylic plates with handles and a rubber sealing ring to be placed between them. They can be pushed to-

gether with a coarse vacuum between them. Sealing rings of two different sizes allow comparison between the effects of atmospheric for two differing contact areas. One plate is equipped with a flange for attaching a plastic hose so that a vacuum can be generated. Evacuation is performed using a simple hand pump. This can be connected via a plastic-hose with a built-in valve. An additional T-piece allows a pressure sensor (e.g. U44220) to be connected for measuring pressure in conjunction with a suitable interface (e.g. LabPro U44000).

The advantage of the Magdeburg plates over the hemispheres usually used in lessons is that, due to the flat design, all forces act parallel to the plates allowing the forces to be calculated easily.

Transparent acrylic plates: 13 mm x 97 mm Ø
 Sealing rings: 5 mm x 85 mm Ø_{inside}
 and 95 mm Ø_{outside}
 5 mm x 50 mm Ø_{inside}
 and 60 mm Ø_{outside}

2.1 Scope of delivery

- 2 Transparent acrylic plates with handles
- 2 Rubber sealing rings of different diameters
- 1 Hand pump in storage case
- 1 Hose with valve
- 1 Hose with T-piece and valve
- 1 T-piece
- 1 Spare hose connector

3. Operating principle

A protective mantle of air called the atmosphere surrounds the earth. The air molecules like all other materials are subject to the force of gravity and thus become concentrated at the earth's surface. The atmospheric pressure, which is exerted by the air mass, is highest at sea level and gradually decreases with increasing distance from the earth's surface. Air pressure like any liquid exerts equal and constant pressure on all sides of an object. In an open object equilibrium always prevails between internal and external pressure. If the internal pressure drops more than the external pressure, the state of equilibrium is reestablished by letting air in. Conversely, if the internal pressure becomes greater than the prevailing external pressure, there is the same tendency to escape. In an enclosed object the force resulting from the difference between the internal and external pressures affects the object's surface either causing it to compress or in the latter case causing the object to explode.

The physicist and mayor of Magdeburg Otto von Guericke was the first to demonstrate the effect of atmospheric pressure. His vacuum experiments commenced around 1650 and reached their zenith in 1654 in a spectacular experiment attended by Kaiser Ferdinand III in the town of Regensburg: the famous Magdeburger hemispheres. To do this von Guericke evacuated the air out of two copper hemispheres of 42 cm diameter and sealed with an oil and wax saturated leather lining. The air pressed the hemispheres together with such force that even 16 horses were unable to pull them apart.

4. Operation

4.1 Demonstration of the effect of atmospheric pressure

- Check the sealing ring and the plates for damage before the experiment.
- Connect the hose between the hand pump ⑧ and the Magdeburg plate ③ as shown in Figure 1.
- Slip the hose connectors inside one another and push them together by turning lightly with the fingers.
- Place the desired sealing ring on one plate and press the plates together.
- When the smaller diameter ring is chosen, it is easier to separate the plates by pulling them apart. An experimental comparison can be made using the two rings one after the other to show how force depends on the surface area.
- A second person may start the process of evacuating the space between the plates.
- Most of the air will have been evacuated after a few pumps to form a sufficient vacuum for the experiment.
- Demonstrate the effect of atmospheric pressure by attempting to tug the plates apart.
- Loosen the hose connection to the Magdeburg plate to let air into the apparatus.

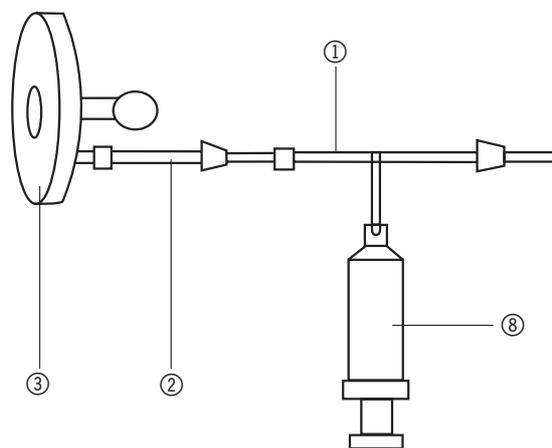


Fig.1

4.2 Quantitative measurement

4.2.1 Approximate determination of atmospheric pressure by experiment

- Assemble the equipment as in section 4.1.
- Pump out the air between the plates.
- The person holding the Magdeburg plates should step onto some bathroom scales and observed the weight indicated as a second attempts to separate the plates by pulling the bottom handle vertically downwards.
- Note the weight indicated by the scales when the plates separate.
- The following formula is used for the calculation
 $\text{Pressure} = \text{Force}/\text{Area}$
- To determine the force, subtract the weight of the Magdeburg plates and the person holding them from the weight shown at separation. To convert the force into Newtons, multiply the weight in kilograms by 9.8
- The force pressing the plates together corresponds to the atmospheric pressure being exerted on the area encompassed by the sealing ring. Calculate the area in m^2 from the inner diameter of the ring.
- $1 \text{ N}/\text{m}^2$ is equivalent to 1 Pa . Since the value will come out to be rather large, you can convert your answer into kilopascals.
- It is recommended that the result be compared to the actual atmospheric pressure as measured using a barometer.
- Discuss with the students what might be causes for any deviations (e.g. inaccuracies in the scales and the reading of them, not pulling vertically downwards when separating the plates or residual air between them).

Also required:

1 Set of bathroom scales

4.2.2 Determining the force acting on the Magdeburg plates with a data logger

- Connect the hoses as in Figure 2.
- Connect the pressure sensor (e.g. U 44220) and a barometer (e.g. U 44300) to a data logger (e.g. U 44000).

- Pump out the air between the plates.
- The force acting on the Magdeburg plates can be determined by the equation $\text{Force} = \text{Pressure} \times \text{Area}$. It should be noted that some residual air remains between the plates that acts against the atmospheric pressure. This should be considered when calculating the force:
 $\text{Force} = (\text{Atmospheric pressure} - \text{Residual pressure}) \times \text{Area}$
- Use the pressure sensor to work out the pressure due to the residual air between the plates.
- Measure the atmospheric pressure using a barometer.
- Calculate the area in m^2 from the inner diameter of the ring.
- Perform your calculations.
- Repeat the experiment using the second sealing ring and compare the results.

Also required:

- 1 Data logger LabPro U44000
- 1 Pressure sensor U44220
- 1 Barometer U44300

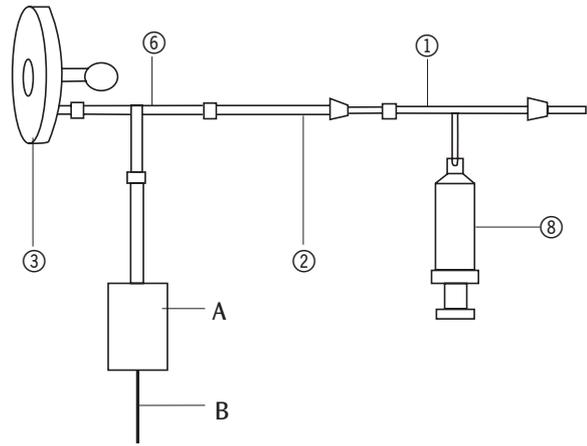


Fig.2

A: Pressure sensor (e.g. U44220)

B: Connection to data logger (e.g. LabPro U44000)