TEACHERS GUIDE

MAGDEBURG HEMISPHERE

ITEM # 3563-00

MECHANICS - DEMONSTRATION DEVICES

Magdeburg hemispheres, devised in the 1650's to demonstrate and investigate the newly developing concepts of vacuums and air pressure, remain a useful educational tool even today. This updated rubber version allows for use without a vacuum pump. Simply by pressing the two halves together to evacuate the air, a seal is formed that will challenge your students both physically and intellectually.

Materials

- carabiner,
- cord
- basket and weights
- vacuum chamber

Goals & Objectives

See page 7 for Next Generation Science Standards (NGSS)

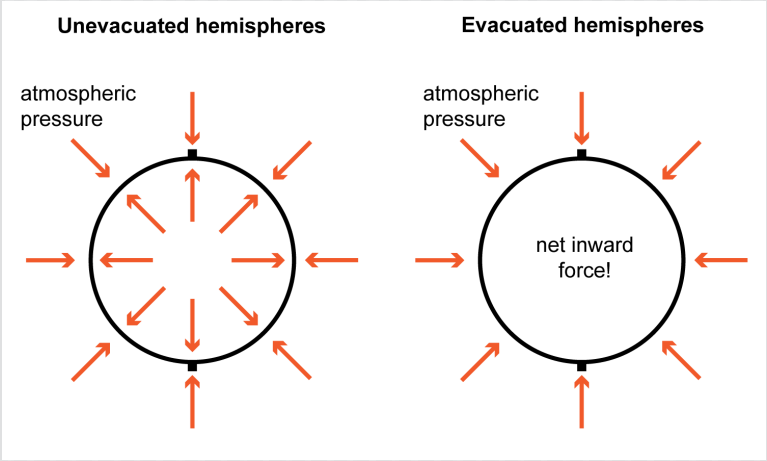
HISTORY

The original Magdeburg hemispheres were true hemispheres (not suction cups) and made of copper with rims that fit together. Otto von Guericke, a scientist and the mayor of Magdeburg, Germany, constructed the hemispheres in 1657 as a way to demonstrate properties of a vacuum and the force of atmospheric pressure. At 20 inches in diameter, once the copper hemispheres had been fit together and the air pumped out, a team of sixteen horses, eight harnessed to each side, could not pull the halves apart!

Engraving showing Otto von Guericke's 'Magdeburg hemispheres' experiment - 1672

How It Works

By squeezing the two Magdeburg hemispheres together and evacuating the air between the halves, a partial vacuum is formed. As a result, the atmospheric air pressure around the hemispheres is significantly greater than the pressure of any minimal remaining air in the space between them. The atmospheric pressure pushes the two halves together, and the smooth, rubber surfaces form a seal that maintain the pressure gradient between the inside and outside of the unit.



Another way to think about the difference in air pressure between inside and outside the two hemispheres is that air pressure is caused by gas molecules zipping around and bouncing off of everything around them. Inside of the Magdeburg hemispheres there are few if any air molecules to bounce around and push the halves apart. On the other hand, in the atmosphere around the outside, there are ample molecules of gas bouncing into the hemispheres and pushing them together.

With the original copper Magdeburg hemispheres, all of the air could be pumped out such that the air pressure inside the two halves was zero – a true vacuum. In the case of these rubber models, a partial vacuum is formed with the potential for a small amount of air, and thus a very low air pressure, remain in the space between the two halves. For this reason, students may note a difference between the estimated and actual strength of the seal.

ACTIVITIES

Activities: For younger students, focus on science practice skills such as predicting, making observations, and explaining at an age appropriate level. More complex physics concepts can be addressed using the same activities with middle school students and higher.

**** Safety note – If the Magdeburg hemispheres release suddenly when two students are pulling in opposite directions, one or both of the students may fall backward. Make sure that obstacles are moved out of the way. If an individual is able to pull the hemispheres apart on their own, the sudden release may lead to elbows or arms flying out to the side. Advise other students to stand back.**

1 *Getting Started:*
Match up the flat faces of the Magdeburg hemispheres and push them together to evacuate as much air as possible.
Try to pull them apart.

- What happens?
- What does it take to pull the two halves apart?
- Is anyone in the class successful?

2 *Equalize the Air Pressure:*
Help students understand that it is air pressure from the atmosphere that pushes the two cups together.
Place the sealed Magdeburg hemispheres in a vacuum chamber. You may want to clip one hemisphere to a base so that the seal is perpendicular to the ground.
Pump the air out of the chamber to demonstrate that when the air pressure on the outside of the sealed hemispheres is lowered to the same air pressure as is inside the hemispheres or to zero, the seal will break. The two halves will fall apart.

- Have students discuss their observations and explanations.

3 *Estimate the strength of the seal:*
Using the equation ***Force = Pressure x Area***, estimate how many pounds of force the atmosphere is exerting on the sealed Magdeburg hemispheres. For atmospheric pressure, students can estimate 14.7 lb/in^2 (psi) or use an online air pressure calculator (see resources section of this guide) to determine the actual air pressure at any given elevation and temperature.

***Note**

It is always wise to DO an experiment ahead of time to be able to best present it to the class.

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ACTIVITIES

Activities continued

The Area is the area of one of the Magdeburg hemispheres (πr^2). Have students identify the correct units of force that they calculate and discuss what this number really means in terms of the strength of the seal.

- How could they test their estimates?

4 *Test the strength of the seal:*
To test the calculated estimates of seal strength, use the following procedure OR challenge students to develop their own.
Suspend the sealed Magdeburg hemispheres so that the seal is parallel to the ground.

Suspend a basket of known weight below the hemispheres. Carabiners and cords may be useful for suspending the hemispheres and/or the basket. Slowly add weights to the basket until the seal breaks.

- How much weight does the seal hold?
- Is the tested strength lesser than, greater than, or the same as the estimated strength from Activity 3?
- What might account for the difference, if there was one?

DISCUSSION

Additional Discussion and Real Life Applications

1. Otto von Guericke's original Magdeburg hemispheres were 20 inches in diameter and could not be pulled apart by eight horses on either side pulling in opposite directions. How strong must the seal have been between the two halves?

2. What are some other situations in which air pressure from the atmosphere is felt or experienced?

3. Develop a model or diagram to show how air pressure holds the two Magdeburg hemispheres together.

GLOSSARY

Vocabulary and Scientific Concepts to discuss:

- air pressure
- force
- pressure
- psi
- vacuum

RESOURCES

- Atmospheric pressure at altitude calculator: http://www.mide.com/pages/air-pressure-at-altitude-calculator

Next Generation Science Standards

Students who demonstrate understanding can:

3-PS2-1. Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

5-PS1-1. Develop a model to describe that matter is made of particles too small to be seen.

MS-PS2-2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

HS-PS2-1. Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.

Standards Key

K = Kindergarten
3 = 3rd Grade
(numbered by grade)
MS = Middle School
HS = High School
PS = Physical Science

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