CREATING A VACUUM TO DEMONSTRATE ATMOSPHERIC PRESSURE

TOPIC:

Vacuum and Atmospheric Pressure

SCIENTIST:

Otto von Guericke 1602–1686

INTRODUCTION:

Earth's atmosphere rises for several kilometers above its surface. The air in the atmosphere has weight and exerts a pressure on the earth's surface. This is called atmospheric pressure. Until the eighteenth century, however, the concept of atmospheric pressure was unknown. What we know today to be the effects of atmospheric pressure—for example, air immediately rushing back into a bottle from which the air has been sucked out—were explained in terms of the teachings of the Greek philosopher and scientist Aristotle (384–322 BC). Aristotle stated that "nature abhors a vacuum"—that is, no vacuum can exist in nature. The reason the air rushed back into the bottle, according to this theory, was that "nature could not tolerate" the vacuum produced when the air was sucked out. But in the 1650s and 1660s, some scientists, including the physicist and engineer Otto von Guericke, began to question these old ideas. Guericke invented an air pump that was capable of producing a vacuum in an enclosed space. This he used in a dramatic public experiment, performed before the Imperial Court at Ratisbon (now Regensburg, Germany), designed to show the existence and effect of atmospheric pressure. Guericke used two large, hollow bronze hemispheres, one of which had a stopcock. When he placed them together (the rims were greased to form an airtight joint) and pumped out the air from inside, the external air pressure pressed the two hemispheres tightly together. A team of eight horses was then harnessed to each hemisphere. When driven in opposite directions, the horses failed to separate the two hemispheres. When the stopcock was opened and air was readmitted, however, the two hemispheres fell apart as air filled the vacuum and the internal and external air pressures became equalized. Guericke showed that in one way Aristotle was correct—a vacuum could not exist in nature, but had to be created—but he also proved that air rushes in to fill a vacuum because of atmospheric pressure.

TIME NEEDED:

15 minutes

MATERIALS:

Note: You will need a partner for this experiment.

2 identical plungers (used for unblocking kitchen sinks)
petroleum jelly
small table knife
paper towel

Original Materials:

As can be seen from the Introduction, it is not feasible to use Guericke's materials—brass hemispheres, teams of horses, and a vacuum pump—in the re-creation of this experiment. Guericke included these materials for practical reasons but also to provide a great show for his audience!

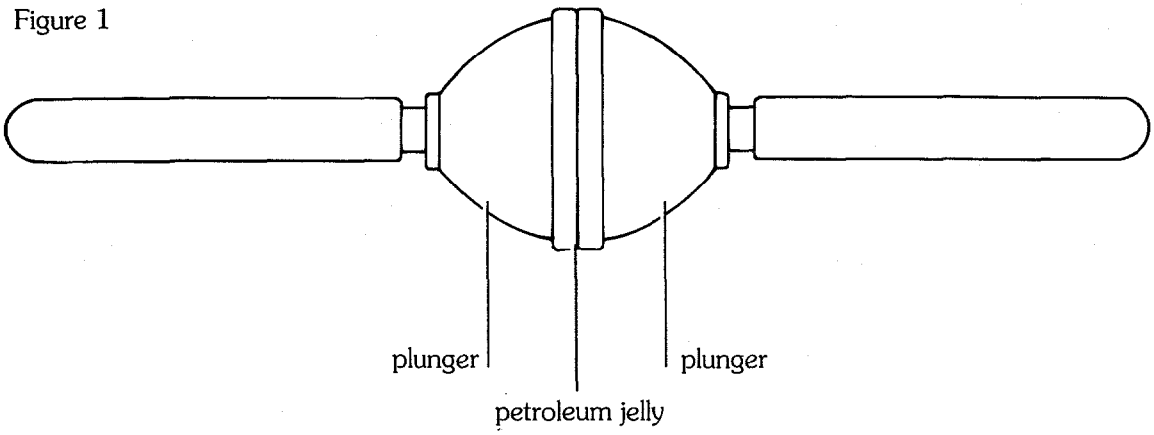
Safety Precautions

Please read and copy the safety precautions at the beginning of this book. Be careful not to get petroleum jelly on clothing as it causes stains.

PROCEDURE:

1. Smear a little petroleum jelly around the rim of both plungers.
2. Take hold of one of the plungers. Tell your partner to do the same with the other.
3. Face each other. Gently push the rims of the two rubber hemispheres together without flattening them (see figure 1). Remove any excess petroleum jelly on the outside using a paper towel.

Figure 1



4. Now press the two rubber hemispheres together firmly so that they flatten (you may want to hold them together with your hand so that they do not slip).
5. Tell your partner to let go of the handle of her/his plunger. Record what happens.
6. Tell your partner to hold the handle of her/his plunger again. Try to pull the two plungers apart. Record what happens.
7. Carefully insert the tip of the knife in the join between the two plungers. Record what happens.

ANALYSIS:

1. What do you think happened when you pushed the two rubber hemispheres together? What part of Guericke's original experiment does this replace?
2. Why were the rims greased with petroleum jelly?
3. What happened when your partner let go of the handle of the plunger? Why do you think this happened?
4. What happened when you tried to pull the two plungers apart? Why do you think this happened?
5. What happened when the tip of the knife was inserted between the two rubber hemispheres? Why do you think this happened?

OUR FINDINGS:

Click on above link to see what we found.

SPECIAL SAFETY NOTE TO EXPERIMENTERS

Each experiment includes any special safety precautions that are relevant to that particular project. These do not include all of the basic safety precautions that are necessary whenever you are working on a scientific experiment. For this reason, it is absolutely necessary that you read, copy, and remain mindful of the General Safety Precautions that follow this note.

Experimental science can be dangerous, and good laboratory procedure always includes carefully following basic safety rules. Things can happen very quickly while you are performing an experiment. Things can spill, break, even catch fire. There will be no time after the fact to protect yourself. Always prepare for unexpected dangers by following basic safety guidelines the *entire* time you are performing the experiment, whether or not something seems dangerous to you at a given moment.

We have been quite sparing in prescribing safety precautions for the individual experiments. We made this choice for one reason: We want you to take very seriously every safety precaution that is printed in this book. If you see it written here, you can be sure that it is here because it is absolutely critical to your safety.

One further note: The book assumes that you will read the safety precautions that follow, as well as those in the box within each experiment you are preparing to perform, and that you will *remember* them. Except in rare instances, these precautions will not be repeated in the procedure itself. It is up to you to use your good judgment and pay attention when performing potentially dangerous parts of the procedure. Just because the book does not say BE CAREFUL WITH HOT LIQUIDS or DON'T CUT YOURSELF WITH THE KNIFE does not mean that you should be careless when simmering water or stripping an electrical wire. It does mean that when you see a special note to be careful, it is extremely important that you pay attention to it.

If you ever have a question about whether a procedure or material is dangerous, wait to perform it until you find out for sure that it is safe.

GENERAL SAFETY PRECAUTIONS

Accidents caused by carelessness, haste, insufficient knowledge, or taking unnecessary risks can be avoided by practicing safety procedures and being alert while conducting experiments. Be sure to check the experiments in this book for additional safety regulations and adult supervision requirements. If you will be working in a lab, do not work alone.

PREPARING:
—Clear all surfaces before beginning experiments
—Read the instructions before you start
—Know the hazards of the experiments and anticipate dangers

PROTECTING YOURSELF:
—Follow the directions step-by-step; do only one experiment at a time
—Locate exits, fire blanket and extinguisher, master gas and electricity shut-offs, eye wash, and first-aid kit
—Make sure there is adequate ventilation
—Do not horseplay
—Wear an apron and goggles
—Do not wear contact lenses, open shoes, loose clothing, or loose hair
—Keep floor and work space neat, clean, and dry
—Clean up spills immediately
—Never eat, drink, or smoke in laboratory or work space
—Do not eat or drink any substances tested unless expressly permitted to do so by a knowledgeable adult

USING EQUIPMENT WITH CARE:
—Set up apparatus far from the edge of the desk
—Use knives and other sharp or pointed instruments with caution
—Pull plugs, not cords, when removing electrical plugs
—Don't use your mouth to pipette; use a suction bulb
—Clean glassware before and after use
—Check glassware for scratches, cracks, and sharp edges
—Clean up broken glassware immediately
—Do not use reflected sunlight to illuminate your microscope
—Do not touch metal conductors
—Use only low voltage and current materials such as lantern batteries
—Be careful when using stepstools, chairs, and ladders

USING CHEMICALS:
—Never taste or inhale chemicals
—Label all bottles and apparatus containing chemicals
—Read labels carefully
—Avoid chemical contact with skin and eyes (wear goggles, apron, and gloves)
—Do not touch chemical solutions
—Wash hands before and after using solutions
—Wipe up spills thoroughly

HEATING SUBSTANCES:
—Use goggles, apron, and gloves when boiling water
—Keep your face away from test tubes and beakers
—Never leave apparatus unattended
—Use safety tongs and heat-resistant mittens
—Turn off hot plates, bunsen burners, and gas when you are done
—Keep flammable substances away from heat
—Have fire extinguisher on hand

FINISHING UP:
—Thoroughly clean your work area and glassware
—Be careful not to return chemicals or contaminated reagents to the wrong containers
—Don't dispose of materials in the sink unless instructed to do so
—Wash your hands
—Clean up all residue and put in proper containers for disposal
—Dispose of all chemicals according to all local, state, and federal laws

BE SAFETY CONSCIOUS AT ALL TIMES