# Pascal's Principle

## *Pascal (1623–1662)*

### Topic

Pascal's ideas about fluid pressure can be illustrated with a simple experiment.

### Introduction

In the mid 1600s, Blaise Pascal became curious about *barometers*, instruments used to measure air pressure. Early barometers were made by inverting a sealed glass tube of mercury into a vessel of mercury, causing the liquid in the top of the tube to descend and leave a vacuum at the top. The level of the mercury in the tube would then rise when air pressure increased on the vessel of mercury or drop when air pressure decreased (see Figure 1). Pascal wondered what kept the liquid in the tube of a barometer from being pulled down by gravity. He began experiments with fluids and what are now known as *hydraulics*. Hydraulic fluids are fluids that are non-compressible. In a hydraulic fluid, pressure applied to any area of a fluid is transmitted equally to all of the fluid. This means that a small amount of pressure applied to a small-area piston becomes transferred to a large force in a large-area piston.

When a hydraulic fluid is placed in a tall column, fluid at the bottom of the column is under greater pressure than fluid near the top. This is because the weight of the fluid on top adds pressure to the fluid below. However, if an additional weight is placed on top of the column, all of the fluid pressure increases by the same amount. In this experiment, you will illustrate Pascal's principle with a simple experiment and use your understanding of the experiment to describe what occurs.

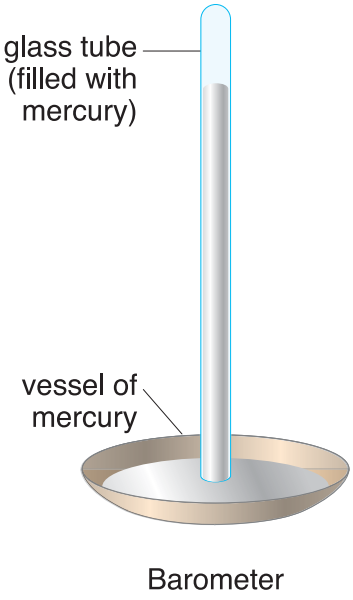
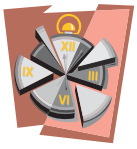
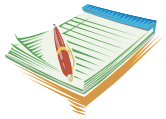



**Figure 1**



## Time Required

20 to 25 minutes



## Materials

- two-liter (L) bottle
- one-hole rubber or cork stopper that fits 2-L bottle
- straw
- 3 pushpins
- water
- ruler
- pan (that can hold 2 L of water)
- science notebook

**Safety Note** **Please review and follow the safety guidelines.**

## Procedure

1. Place pushpins in the side of the 2-L bottle at heights of 1.9, 3.9, and 5.9 inches (in.) (5, 10 and 15 centimeters [cm]) from the bottom. Leave the pushpin in the side of the bottle.
2. Fill the bottle with water to at least 1.9 in. (5 cm) above the top pushpin.
3. Seal the bottle with the stopper.
4. Hold the bottle over the pan.
5. Remove all of the pushpins at once. Observe the relative velocities of the streams of water. Record your observations in your science notebook.
6. Place the straw into the hole in the stopper. Exhale through the straw. Observe any changes to the streams of water. Record your observations in your science notebook.
7. Inhale through the straw. Observe any changes in the streams of water and record observations in your science notebook. Repeat once the water level has dropped below the top hole.

## Analysis

1. Explain the differences in the velocities of the streams of water from each hole in the bottle.
2. What happened to the streams of water when you exhaled through the straw? Explain why.
3. What happened to the streams of water when you inhaled through the straw? Explain why.
4. A hydraulic jack works by exerting pressure onto a small area of fluid connected to a bigger tank of fluid placed underneath the car. Explain why even a weak person can use a hydraulic jack to lift a car.

## What's Going On?

In the bottle, the water at the bottom has greater pressure than the water at the top due to the force of the water above it. The water in the bottom hole comes out fastest, and water in the top hole comes out slowest. Exhaling through the straw adds pressure to all of the water in equal amounts. When the water is above the top hole, it is difficult to inhale through the straw. This is because the pressure has been relieved and there is little force to push the air or water into the straw. This effect lessens the water flow from all of the holes.

Understanding the effect of pressure on and within a fluid lead to the development of hydraulic machines. Spray paint machines, backhoes, cranes, and jackhammers are just a few of the machines that depend on hydraulics. Most machines use oil as the hydraulic fluid.

## Want to Know More?

See Our Findings.

# OUR FINDINGS

## PASCAL'S PRINCIPLE

### Blaise Pascal (1623–1662)

**Suggestion for class discussion:** Have students brainstorm a list of devices that rely on the power of hydraulics. Some suggestions might include large pieces of construction equipment like backhoes, bulldozers, and dump trucks, as well as automobile brakes and jackhammers. Point out that all hydraulic equipment works on the same principle.

### Analysis

1. The water at the bottom of the bottle has greater pressure than the water at the top due to the force of the water above it. The water in the bottom hole flows out fastest, and water at the top the slowest.
2. Exhaling through the straw increases the velocity of the streams of water. Exhaling through the straw adds pressure to all of the water in equal amounts.
3. When the water is above the top hole, it is hard to inhale through the straw. This is because the pressure has been relieved and there is little force to push the air or water into the straw. This also lessens the flow of water from all of the holes. After the water falls below the top hole this should have little to no effect.
4. The fluid transfers the small amount of pressure in a small area to a large amount of pressure in a large area.

# SAFETY PRECAUTIONS

**Review Before Starting Any Experiment**

Each experiment includes special safety precautions that are relevant to that particular project. These do not include all 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 and remain mindful of the General Safety Precautions that follow this note. Experimental science can be dangerous, and good laboratory procedure always includes following basic safety rules. Things can happen very quickly while you are performing an experiment. Materials can spill, break, or even catch fire. There will be no time after the fact to protect yourself. Always prepare for unexpected dangers by following the basic safety guidelines during the entire 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. 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.

Read the safety precautions here and at the beginning of each experiment before performing each lab activity. It is difficult to remember a long set of general rules. By rereading these general precautions every time you set up an experiment, you will be reminding yourself that lab safety is critically important. In addition, use your good judgment and pay close attention when performing potentially dangerous procedures. Just because the book does not say “Be careful with hot liquids” or “Don’t cut yourself with a knife” does not mean that you can be careless when boiling water or using knives. Notes in the text are special precautions to which you must pay special attention.

## GENERAL SAFETY PRECAUTIONS

Accidents caused by carelessness, haste, insufficient knowledge, or taking an unnecessary risk can be avoided by practicing safety procedures and being alert while conducting experiments. Be sure to check the individual experiments in this book for additional safety regulations and adult supervision requirements. Anytime you are working with an electrical current, it becomes possible to shock yourself on exposed wires. If you will be working in a lab, do not work alone. When

you are working off-site, keep in groups with a minimum of three students per group, and follow school rules and state legal requirements for the number of supervisors required. Ask an adult supervisor with basic training in first aid to carry a small first-aid kit. Make sure everyone knows where this person will be during the experiment.

## 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, eyewash, and first-aid kit.
- Make sure there is adequate ventilation.
- Do not horseplay.
- Keep floor and workspace neat, clean, and dry.
- Clean up spills immediately.
- If glassware breaks, do not clean it up by yourself; ask for teacher assistance.
- Tie back long hair.
- Never eat, drink, or smoke in the laboratory or workspace.
- 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 or other sharp, pointed instruments with care.
- Pull plugs, not cards, when removing electrical plugs.
- Clean glassware before and after use.
- Check glassware for scratches, cracks, and sharp edges.
- Let your teacher know about broken glassware immediately.
- Do no use reflected sunlight to illuminate your microscope.
- Do not touch metal conductors.
- Use alcohol-filled thermometers, not mercury-filled thermometers.

## 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 safety glasses, lab apron, and gloves).
- Do not touch chemical solutions.
- Wash hands before and after using solutions.
- Wipe up spills thoroughly.

## HEATING SUBSTANCES

- Wear safety glasses, apron, and gloves when boiling water.
- Keep your face away from test tubes and beakers.
- Use test tubes, beakers, and other glassware made of Pyrex™ glass.
- Never leave apparatus unattended.
- Use safety tongs and heat-resistant gloves.
- If your laboratory does not have heat-proof workbenches, put your Bunsen burner on a heat-proof mat before lighting it.
- Take care when lighting your Bunsen burner; light it with the airhole closed, and use a Bunsen burner lighter rather than wooden matches.
- Turn off hot plates, Bunsen burners, and gas when you are done.
- Keep flammable substances away from flames and other sources of heat.
- Have a fire extinguisher on hand.

## FINISHING UP

- Thoroughly clean your work area and any glassware used.
- Wash your hands.
- Be careful not to return chemicals or contaminated reagents to the wrong containers.
- Do not dispose of materials in the sink unless instructed to do so.
- Clean up all residues 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!