

ARCHIMEDES' PRINCIPLE

TOPIC:

The Law of Buoyancy

SCIENTIST:

Archimedes c.287–212 BC

INTRODUCTION:

One of Archimedes' greatest discoveries—Archimedes' Principle or the Law of Buoyancy—arose from his friendship with Hieron II, ruler of Syracuse, the Greek colony on Sicily where Archimedes was born and spent most of his life. Hieron had a gold crown made for him by a local goldsmith, but he suspected the goldsmith of cheating him by adding silver (which was less valuable) to the gold, so reducing the crown's value. He turned to Archimedes for advice, asking him to determine whether the crown was made of pure gold without damaging it in any way. Despite applying himself fully to the problem, Archimedes could not come up with an answer until, a few days after Hieron had consulted him, he stepped into his full bathtub and noticed water overflowing the sides. He suddenly saw the answer to Hieron's problem and was so overjoyed that, so the story goes, he jumped out of his bath and ran naked down the street shouting "Eureka, Eureka!" (I've found it, I've found it!). He had realized that the volume of water displaced when he stepped into the bathtub was equal to the volume of his body. To solve the problem of the crown he measured the volume of water displaced when the crown was immersed in water. Next he obtained some *pure* gold with the same mass as the crown. Then he immersed the pure gold in water and measured the volume of water displaced. If the volumes were the same, the crown was pure gold; if they were not the same (because the addition of silver, which is less dense than gold, to the crown would increase its volume) then he had proved the impurity of the gold without damaging the crown. Unfortunately for the goldsmith, Archimedes showed the crown was not made of pure gold. Hieron had the man executed. Archimedes later extended this principle to introduce the idea of "upthrust." Upthrust is equal to the difference between the object's weight in air and its weight in water and so is equivalent to the amount of water displaced. In its modern and most general form, Archimedes' Principle states: "When a body is wholly or partially immersed in a fluid it experiences an upthrust equal to the weight of the fluid displaced."

TIME NEEDED:

30 minutes

MATERIALS:

scale	piece of lead sheet (that can be cut with metal shears), approximately 15 cm x 15 cm (from plumbing supply store)
disposable aluminum dish, approximately 15 cm x 15 cm x 5 cm deep	250-ml graduated cylinder
spool of thread	metal shears
scissors	paper towel
small iron or brass weight, between 4 and 8 ounces (<i>e.g.</i> , from an old-fashioned balance)	metric ruler

Original Materials:

In the first part of the experiment Archimedes used a bathtub, filled with water, and himself. In the second part, when testing his theory and solving Hieron's problem, he used a gold crown (containing some silver, as it turned out) and a block of pure gold with the same weight as the crown.

Safety Precautions

Please read and copy the safety precautions at the beginning of this book.

PROCEDURE:

Note: In this experiment the iron/brass weight represents the “maybe pure” gold crown of unknown purity, and the lead weight represents pure gold.

1. Weigh the iron or brass weight. Record its mass.
2. Cut a piece of lead from the lead sheet using the metal shears and weigh it. If it weighs more than the brass weight, trim some of the lead away until it weighs the same. If it weighs less than the iron/brass weight, cut some more lead from the sheet and add it to the lead in the scale pan until it equals the mass of the iron/brass weight; then mold the pieces of lead into one piece using your fingers.
3. Place the graduated cylinder in the aluminum dish. This will catch any overflow of water.
4. Carefully fill the graduated cylinder with water to the 150-ml mark.
5. Measure the height of the cylinder. Cut a piece of thread 50 cm longer than the height of the cylinder and tie it around the iron/brass weight, leaving enough thread free with which to hold the thread above the top of the cylinder.
6. Repeat step 5 with the lead weight.
7. Carefully lower the iron/brass weight into the graduated cylinder until it is touching the bottom. DO NOT drop it into the graduated cylinder because a) you will damage it and b) water will splash out. Record the new volume of water.
8. Carefully remove the weight from the graduated cylinder. If necessary, add more water to the graduated cylinder to restore the volume to 150 ml.
9. Repeat step 7 with the lead weight. Again, record the new volume.
10. Carefully remove the lead weight from the cylinder.
11. Wash your hands thoroughly after you are done.

ANALYSIS:

1. What happened when the iron/brass weight was lowered into the graduated cylinder?
2. What happened when the lead weight was lowered into the graduated cylinder?
3. Calculate the change in volume when the iron/brass weight was lowered into the graduated cylinder as follows:

$$\text{change in volume} = \text{volume after adding weight} - 150 \text{ ml}$$

Now, calculate the change in volume when the lead weight was lowered into the graduated cylinder.

4. The change in volume is equal to the volume of water displaced. Was there any difference in the volume of water displaced by the iron/brass weight and the volume of water displaced by the lead weight?
5. If the iron/brass weight represents the crown, and the lead weight represents the pure gold, how would you, as Archimedes, explain the result of your experiment to King Hieron II? Use the words *volume* and *density* to explain.

OUR FINDINGS:

See Section VIII.

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