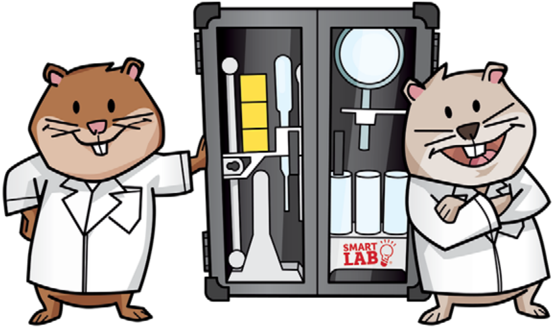
The TINY book of really biG SCIENCE!

written by
Paul Beck



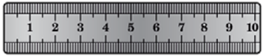
Super Small Science

Welcome to the tiny world of big science! Your lab has real tools to conduct real scientific experiments. You'll unleash chemical reactions, discover news ways of measuring, peer through a magnifying glass, and perform optical illusions. It's real science. Just really tiny.

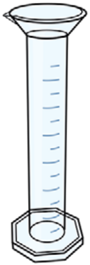
Your Tiny Lab Equipment:

Scoop
(for measuring dry ingredients and for mixing)

Pipette
(for transferring small amounts of liquid)



Ruler

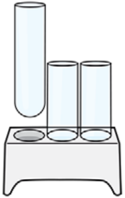


6 mL Graduated Cylinder
(for measuring liquids)

Magnifier

Petri Dish

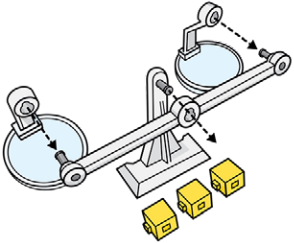
Funnel



Test Tubes and Test Tube Stand

6 mL Erlenmeyer Flask
(for mixing)

6 mL Graduated Beaker



Balance Scale and Weights

Something missing or broken? Call SmartLab Toys Customer Service at **1-866-319-5900**. We will happily resolve your concerns.

Getting Started

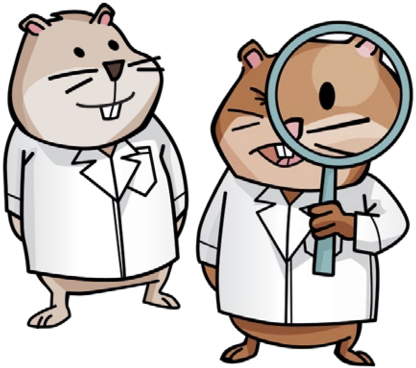
Before you start each experiment, read the instructions all the way through. Make sure you have all the ingredients and equipment you need. For some experiments, you'll need additional household items.

Household Ingredients Used in Some of the Experiments:

- **Alum powder** (find with spices)
- **Baking soda**
- **Black tea**
- **Borax powder** (find with laundry boosters)
- **Breakfast cereal O's**
- **Chocolate chips**
- **Dish soap**
- **Epsom salt**
- **Food coloring**
- **Popcorn kernels**
- **Salt**
- **Sugar**
- **Uncooked rice**
- **White glue**
- **White vinegar**

Best Practices:

- Keep your workspace clean and organized.
- Keep ingredients and small pieces away from small children.
- When you're done experimenting, hand wash your *Tiny Science* equipment and dry thoroughly.
- Share what you've learned with others.



LAB 01

Too Much Tension

Defy gravity with this simple experiment!

Tiny Tools:

- Beaker
- Pipette
- Test tube

Supplies:

- Water

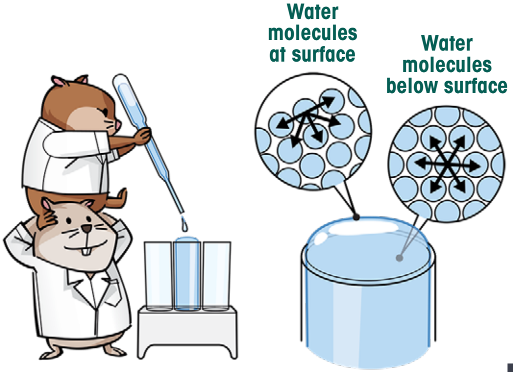
The Experiment:

1. Fill beaker with water.
2. Holding the test tube in one hand, use the pipette and water from the beaker to fill the tube halfway.
3. Pour the water out. Exciting, right? (YAWN!)
4. Fill the test tube again—this time all the way. Then, using the pipette, add water drop by drop until water bulges far above the top.
5. Tip the test tube over the beaker. Does the water run out now? (When you want to empty the tube, give it a little shake.)

The curved surface of the water is called a ***meniscus*** (muh-NISS-kus).

What's Happening?

Water molecules attract each other. They're "sticky." Where water meets air, the water molecules at the surface stick closely to each other to form a "skin" or membrane. That's called surface tension. It's what lets the water bulge above the top of the test tube. The forces of surface tension bulging over the top seal the test tube. This prevents the water from pouring out.



LAB 02

Breaking the Tension

Destroy surface tension with a single drop!

Tiny Tools:

- **Beaker**
- **Test tube**
- **Pipette**
- **Dish soap**

Supplies:

- **Water**
- **Dish soap**

The Experiment:

1. Fill the beaker with water.
2. To the test tube, add 1 tiny drop of dish soap.
3. Use the pipette and water from the beaker to fill the tube all the way. Keep adding water drop by drop until you can't add any more.
4. Tip the test tube over the beaker. Does the water run out? (Hint: It should.)

When you are done, be sure you rinse all the soap out of your test tube. It may take a few rinses.

What's Happening?

Water molecules stick together so tightly that they create a layer of surface tension where water meets air. But soap has a secret weapon that destroys surface tension. Imagine a soap molecule as a snake with a head and tail. The head loves water. The tail hates it. When you add soap to water, the water-hating tails rush toward the surface. As they squeeze between the water molecules, they break the surface tension.

LAB 03

Liquid Rainbow

Create a tiny tower of color!

Tiny Tools:

- Beaker
- Funnel
- Graduated cylinder
- Scoop
- Pipette

Supplies:

- Warm water
- Sugar
- Food coloring

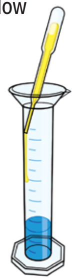
The Experiment:

STRIPE 1:

1. In the beaker, measure 3 mL sugar. Add warm water to the 4 mL mark.
2. Add 1 drop blue coloring. Stir until dissolved.
3. Pour 1.5 mL of the sugar water into the graduated cylinder.
4. Rinse the beaker and scoop.

STRIPE 2:

1. In the beaker, measure 2 mL sugar. Add warm water to the 4 mL mark.
2. Add 1 drop yellow coloring. Stir until dissolved.
3. Fill the pipette with yellow liquid. Put the tip against the inside wall of the graduated cylinder.



4. Carefully drizzle the yellow fluid down the side until the liquid in the cylinder reaches the 3 mL mark.
5. Rinse the beaker and scoop.

STRIPE 3:

1. Repeat the steps for Stripe 2, this time using 1 mL sugar and green coloring. Pour to 4.5 mL mark.

STRIPE 4:

1. Add 4 mL water and 1 drop red coloring to the beaker.
2. Drizzle the red mixture down the side of the cylinder until liquid reaches the 6 mL mark.

What's Happening?

By mixing in different amounts of sugar for each layer, you created liquids with four different *densities*. The density of a liquid refers to the weight. Lower density (lighter) liquids float on top of higher density (heavier) ones.

LAB 04

Tiny Slimy!

How tiny can you make it?

Tiny Tools:

- **Graduated cylinder**
- **Erlenmeyer flask**
- **Funnel**
- **Scoop**
- **Beaker**
- **Pipette**

Supplies:

- **Borax laundry booster powder**
- **White glue**
- **Food coloring (optional)**

The Experiment:

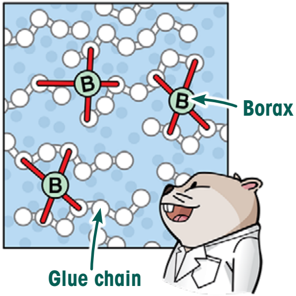
1. In the graduated cylinder, measure 4 mL warm tap water. Pour it into the Erlenmeyer flask. Add coloring.
2. Using the funnel, add 8 heaping scoops of borax powder to the Erlenmeyer flask.
3. To dissolve, place your finger tightly over the top and shake. Some undissolved borax is okay. Wash your hands after measuring and mixing borax powder.
4. In the beaker, add 1 mL glue, then add water to the 2 mL mark.
5. Stir until mixed.
6. Use the pipette to squirt some borax solution into the beaker. Stir.
7. Repeat step 6 until you have a stretchy glob of slime.

What's Happening?

Like most sticky, stretchy, or slimy substances, white glue is a *polymer* (PALL-uh-mer). Polymers have long, chain-like molecules. In wet glue, the molecules slide past each other easily, so it's runny. When you add borax solution, the borax molecules link the glue chains together, and the glue becomes gooey, stretchy slime.

Slime Challenge: Can you adjust the proportions to make an even tinier ball of slime?

If you want to be really scientific, weigh your slime on the balance scale. See page 30.



When you're finished, throw the slime in the trash—NOT the drain or toilet.

LAB 05

Little Fizz

The fizz foams in this chemistry classic!

Tiny Tools:

- **Beaker**
- **Funnel**
- **Scoop**
- **Test tubes in stand**
- **Pipette**

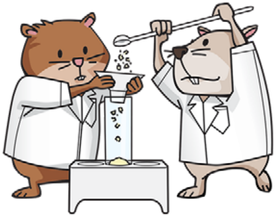
Supplies:

- **Baking soda**
- **White vinegar**

Pancake recipes often include baking soda along with something acidic like buttermilk. The chemical reaction creates tiny CO_2 bubbles that make the batter rise.

The Experiment:

1. Pour 3 mL vinegar into the beaker
2. Place the funnel over the mouth of the test tube.
3. Pour two heaping scoops of baking soda through the funnel into the test tube.
4. Standing over a sink or a bowl, use the pipette to squirt vinegar onto the soda.

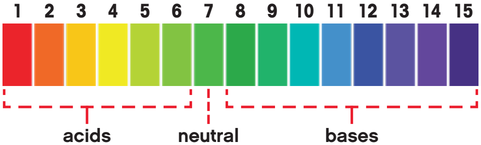


What's Happening?

Vinegar is a type of chemical called an *acid*. Baking soda is a *base*. When mixed, they combine in a chemical reaction that forms new substances. In this reaction, a gas called carbon dioxide, or CO_2, comes out of the liquid as hissing, fizzing bubbles.

watch the fizz!

pH Scale:



The strength of an acid or base is given by a measurement called pH. A very low pH means a very strong acid. A very high pH means a very strong base.

- **Baking soda = 8**
- **Vinegar = 2**
- **Water = 7**
- **Hand soap = 10**

LAB 06

Detector Tea

Acid or base? Ask the tea leaves!

Tiny Tools:

- 3 test tubes in stand
- Funnel
- Scoop
- Pipette

Supplies:

- Cup
- Spoon
- Toothpick
- Tea bag (black tea)
- Warm water
- Baking soda
- White vinegar

The Experiment:

1. In the cup, add the tea bag and just enough warm water to cover it. Let it sit 10 minutes.
2. In the first test tube, use the funnel to add 2 heaping scoops of baking soda. Leave the middle test tube empty. It will be your control.
3. Use the pipette to fill the third test tube halfway with vinegar.
4. Squeeze out the tea bag and stir the tea.

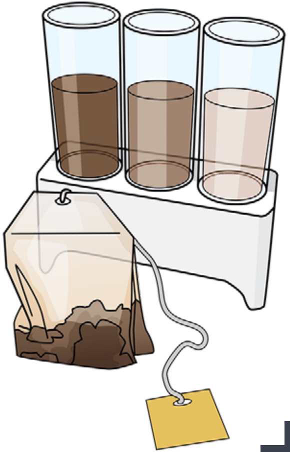
Save the tea bag for the next experiment.

5. Use the pipette to fill each test tube with tea. Stir the baking soda tube with a toothpick.
6. Compare the colors of the liquids. How do the baking soda and vinegar tubes compare with the tea in the middle tube?

Two other indicator solutions are grape juice and hibiscus herb tea. If you have them, try them out!

What's Happening?

Acids lighten the tea. Bases darken it. Because tea can indicate whether a liquid is an acid or base, it is called an indicator solution.



LAB 07

Invisible Ink

Create secret messages!

Tiny Tools:

- Erlenmeyer flask
- Funnel
- Scoop
- Beaker

Supplies:

- Cup
- Spoon
- Paper
- Cotton swabs or thin-tipped paintbrush
- Black tea (see Detector Tea experiment)
- Purple grape juice
- Warm water
- Baking soda

The Experiment:

1. Prepare tea as you did in Lab 06: Detector Tea.
2. Using the funnel, measure 2 scoops baking soda into the Erlenmeyer flask.
3. Use the beaker to measure 3 mL of water. Pour it into the flask.
4. Cover the mouth of the flask with your finger and shake to dissolve. This is your ink.
5. Use a cotton swab or paintbrush to write a message or draw a design on the paper.
6. Set paper aside to dry.
7. To reveal the message, paint the tea or juice across the whole paper with a clean cotton swab.

What's Happening?

The baking soda solution is a base. The tea is an indicator solution. When you paint the paper with tea, the baking soda turns the tea darker in the areas where you wrote or drew. If you use grape juice, the acid in the juice interacts with the baking soda.

LAB 08

Your Two Cents' Worth

Shine up those tarnished pennies!

Tiny Tools:

- Erlenmeyer flask
- Funnel
- Scoop
- Petri dish

Supplies:

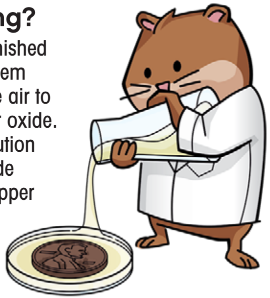
- 2 dull, tarnished pennies (copper coins)
- Salt
- White vinegar

The Experiment:

1. Measure 20 scoops of salt into the flask.
2. Add vinegar to fill the flask about halfway.
3. Cover the mouth of the flask with your finger and shake to dissolve.
4. Put one of the pennies in the petri dish. Fill the dish with the salt/vinegar mixture.
5. Wait 5 minutes.
6. Rinse off the penny and compare it with the one that didn't get a bath.

What's Happening?

Pennies get dull and tarnished because the copper in them reacts with oxygen in the air to form a coating of copper oxide. The salt and vinegar solution dissolves the copper oxide and reveals the shiny copper surface underneath.



Before 1982 United States pennies were made of 95% copper. Now they're made of zinc with a thin copper coating. Use your balance scale to compare the weight of pennies made before 1982 with pennies made after 1982. It takes four copper pennies to equal the weight of five zinc ones!

LAB 09

The Green Penny

A little chemical reaction!

Long Experiment

Tiny Tools:

- **Petri dish**

Supplies:

- **A penny**
- **Vinegar**
- **Paper towel**

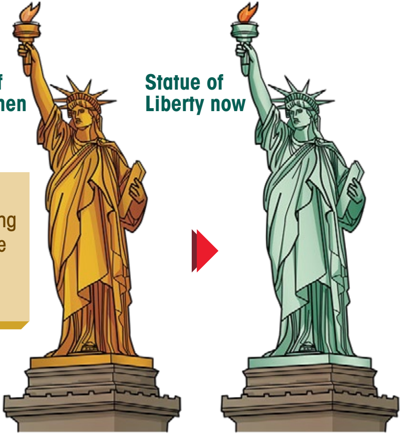
The Experiment:

1. Fold a tiny piece of the paper towel into a small, thick square that fits inside the petri dish.
2. Add enough vinegar to the dish to soak the paper.
3. Put the penny on top of the paper towel.
4. Set the dish aside overnight. (Don't put the cover on.)
5. Check your penny the next day. It should have a green coating on the surface.

The longer you leave the penny, the greener it will get. You can turn it over to coat both sides. Use the pipette to add more vinegar if the towel starts to dry out.

What's Happening?

Vinegar is water and acetic acid. The acetic acid reacts with copper in the penny and oxygen in the air to form a coating of green-colored copper acetate. It's similar to the compound that makes the Statue of Liberty green.



The statue's copper covering is less than the thickness of two pennies!

LAB 10

Alum Octahedron

Grow a big crystal in a tiny petri dish!

Adult assistance required!

Long Experiment

Tiny Tools:

- **Petri dish**
- **Pipette**
- **Magnifier**

Supplies:

- **Pyrex measuring cup with spout**
- **Measuring spoons**
- **Spoon for stirring**
- **Saucer or small, flat-bottomed dish**
- **Paper or foil to cover the dish**
- **Tweezers**
- **Coffee filter or paper towel (optional)**
- **Extra container such as a small jar (optional)**

The Experiment:

DAY 1:

1. Have an adult boil 60 mL of water and pour it into the measuring cup.
2. One teaspoon at a time, add 4 teaspoons (20 mL) of alum powder. Stir after each teaspoon.
3. Stir to dissolve as much alum as possible.
4. Set aside for 5 minutes, so undissolved alum settles to the bottom.
5. Carefully pour about half of the solution into the saucer or dish. Do not pour any undissolved alum.
6. Cover the dish loosely to keep dust out. Set it in a safe place and leave overnight.
7. Save the remaining alum solution for later. Filter out any undissolved alum by pouring the liquid through a coffee filter or folded paper towel into a new container.

DAY 2:

8. Check your dish. You should see some eight-sided crystals in the bottom.
9. Use your magnifier to find the biggest, most evenly shaped crystal.

The crystal you chose will act as a *seed crystal*. It will grow bigger as more alum crystallizes onto it.

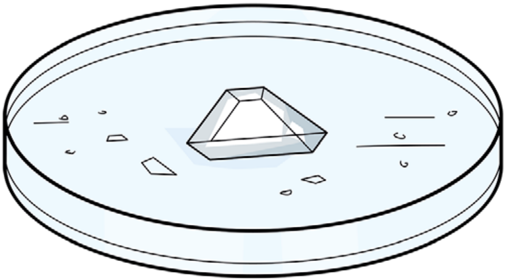
10. Use tweezers to carefully pick up this crystal and set it in the center of the petri dish.
11. Use the pipette to fill the petri dish almost to the top with alum solution. Be careful not to transfer any extra crystals, even tiny ones.
12. Loosely cover the petri dish and set it in a safe place overnight.

DAY 3 AND BEYOND:

13. Check your crystal! Over the next few days you'll see it grow.
14. Measure its progress with your ruler and write down the results.
15. If there are extra crystals in the petri dish, take them out with the tweezers. You only want one crystal.
16. If the amount of solution gets low, add more from your saved, filtered solution, or make some more. Be sure to let it cool before adding it to the petri dish!

What's Happening?

Different substances form crystals of different shapes. Alum forms eight-sided crystals. An eight-sided solid shape is called an *octahedron* (ock-tuh-HEED-run).



LAB 11

Ice Paint

Create sparkling paintings with Epsom salt!

Long Experiment

Tiny Tools:

- **Graduated cylinder**
- **Beaker**
- **Scoop**
- **Magnifier**

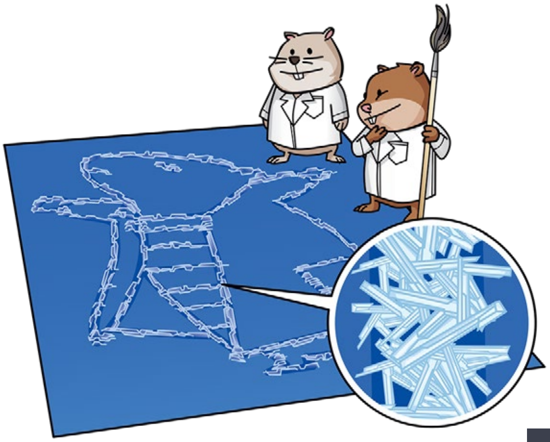
Supplies:

- **Paper**
- **Cotton swab or thin-tipped paintbrush**
- **Epsom salt**
- **Hot tap water**
- **Food coloring (optional)**

The Experiment:

1. Measure 2 mL Epsom salt into the graduated cylinder.
2. Pour the salt into the beaker.
3. Add 2 mL of hot tap water to the beaker. Stir until the Epsom salt is dissolved. It's okay to have some un-dissolved salt in the bottom. Add coloring, if you want to.
4. Use the swab or paintbrush to draw on the paper.
5. Set the paper aside to dry. If there is room in the refrigerator, set the paper inside. Within hours your art will appear in shiny white "ice" crystals.
6. Study the crystal formations through your magnifier.

A crystal is a special kind of solid. Its molecules arrange themselves in a repeating 3-D pattern. Each type of crystal has its own unique shape. Epsom salt crystals are thin, needlelike structures.



LAB 12

Comparison Challenge!

How do weights compare?

Tiny Tools:

- **Balance scale**

Supplies:

Things to weigh. Here are some suggestions:

- **Coins**
- **LEGO bricks or figures**
- **Cereal O's**
- **Chocolate chips**
- **Feathers**
- **Beads**
- **Dried beans or peas**
- **Rice grains**
- **Popcorn (kernels and popped)**
- **Your slime ball**

Anything that fits in the balance trays will do!

The Experiment:

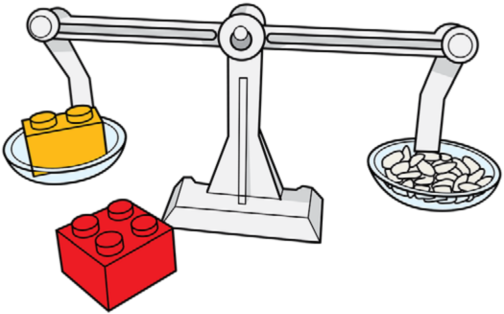
1. Choose two objects.
2. Try to figure out which is heavier. What do your senses tell you?
3. Test your answer with the balance scale. Were you right?
4. Test more objects!

Sometimes your senses can fool you. The size and shape of an object can affect your sense of its weight. It's also hard to judge tiny weight differences without a precise tool like a scale.

Balance Challenge:

Use different objects to try to get both sides of the scale to balance. For example:

- **How many pennies balance a quarter?**
- **How many cereal O's balance 2 chocolate chips?**
- **Compare the weight of popcorn kernels before and then after they are popped.**



LAB 13

Weighty Matters

How much does it weigh?

Tiny Tools:

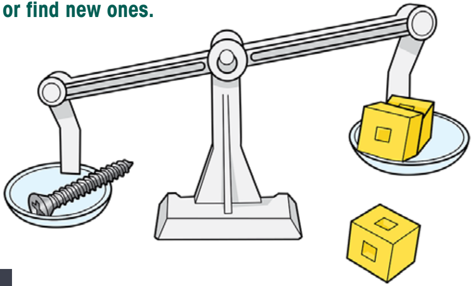
- **Balance scale**
- **Gram cubes**

Supplies:

Things to weigh. You can use the same objects you used for the last experiment, or find new ones.

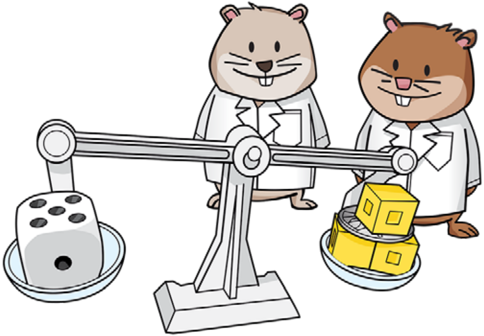
The Experiment:

1. Put your object in the tray on one side of the scale.
2. Add gram weights to the other side until the scale balances. Each weight weighs 1 gram, so the number of weights equals the weight of your object in grams.



Extra Challenge:

What do you do if your object weighs more than 3 grams? One way is to add objects with weights you already know. For example, try weighing a dime. Once you know the weight of the dime, you can use a combination of dimes and gram weights to weigh heavier objects.



LAB 14

A New Way to Weigh

Grains not grams!

Tiny Tools:

- **Balance scale**

Supplies:

- **Things to weigh. You can use the same objects you've been using, or find new ones.**
- **Cereal pieces, such as cereal O's, all the same size.**
- **Rice grains, all the same size.**

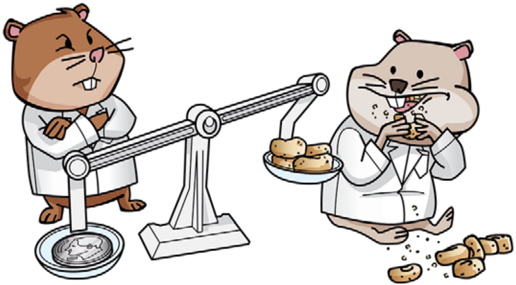
The Experiment:

1. Check to see that all the rice grains are about same weight. Balance them against one another, and remove any that are lots lighter or heavier.
2. Do the same for the cereal pieces.
3. Now weigh your objects. How much does a dime weigh in cereal O's? How much does it weigh in rice grains?

What's Your Unit?

In Lab 13, you measured the weights of your objects using the metric system. In this experiment, you invented two new measurement systems: the Rice System and the Cereal System.

In any measurement system, everyone agrees to use the same units. In the metric system, small weights are measured in grams. In your Rice System, the standard unit of weight is a rice grain. In the Cereal System, the standard unit is a cereal O.



LAB 15

The Water Standard

How much does water weigh?

Tiny Tools:

- Balance scale
- Gram cube
- Pipette
- Graduated cylinder
- Beaker

Mass is not the same as weight, but it's related. Mass is the amount of matter an object contains. Weight means the effect of gravity on that mass. So you would weigh a different amount on the moon, but your mass stays the same.

Supplies:

- Water

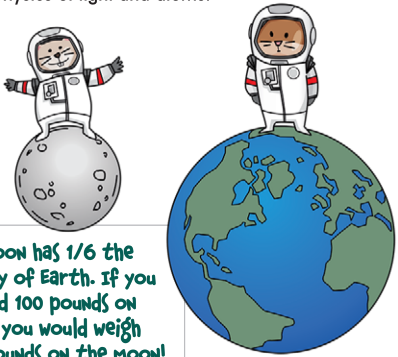
The Experiment:

1. Place a gram cube in one tray of the balance scale.
2. Add 3 mL of water to the beaker.
3. Using the pipette, add water from the beaker to the other tray until the scale balances.
4. Now use the pipette to transfer the water from the tray to the graduated cylinder. How much water did it take to equal 1g?

What's Happening?

As you discovered, 1 mL of water weighs 1 g. That's no accident. It's part of the original definition of the metric system. A milliliter is the volume of a cube that measures 1 cm on each side. A gram was originally defined as the mass of 1 mL of water.

Before 2018, the official kilogram was the mass of a special cylinder of metal. Now it's defined by numbers and the physics of light and atoms.



The moon has 1/6 the gravity of Earth. If you weighed 100 pounds on Earth, you would weigh 16.5 pounds on the moon!

LAB 16

The Magnification Situation

Make tiny things look HUGE!

Tiny Tools:

- **Magnifier**

The Experiment:

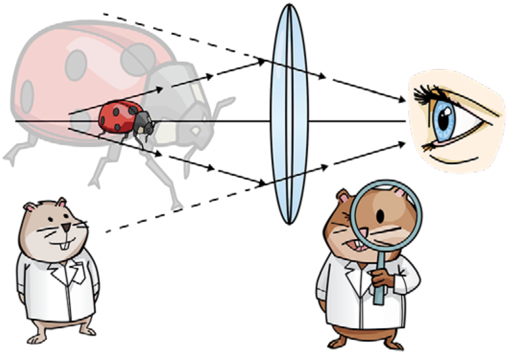
Examine objects with your magnifying lens.

- The fingerprint ridges on the ends of your fingers
- The skin on the back of your hand
- A piece of wood
- The surface of a leaf
- A blade of grass
- The cloth of your jeans and shirt
- Grains of salt, sugar, or sand
- Tiny pebbles
- Big rocks
- The printed letters in this book
- A magazine or newspaper picture
- The carpet
- A feather
- Almost anything!

Never look at the sun, with or without a lens! Looking at the sun can permanently damage your eyes.

What's Happening?

You see objects when light reflects off of them and enters your eyes. Lenses work by bending light. When an object is close to your magnifying lens, the light rays reflected from the object bend outward as they pass through the lens, so they spread apart before reaching your eye. Your eye sees an image that's bigger than the real object.



LAB 17

Measuring Magnification

How big can things get?

Tiny Tools:

- Magnifier
- Ruler

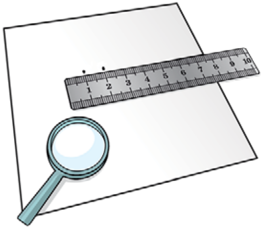
Supplies:

- Paper
- Pencil

The Experiment:

PART 1:

1. Look at the print on this page through your magnifier.
2. Move the lens closer to and farther from the page. What happens?
3. Try moving your eye closer to and farther from the lens. What happens?
4. Try to find the distances for the book, lens, and your eye that give the biggest magnification.

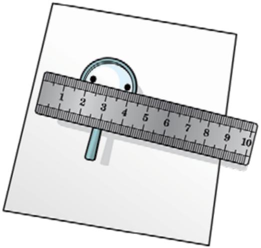


What's Happening?

The magnification depends on how far the lens is from the object and how far your eye is from the lens.

PART 2:

1. Using the ruler and pencil, make two marks 1 cm apart on the paper.
2. Look through the lens at the marks. Move the lens out to get the biggest image you can that's still in focus.
3. Using the ruler across the front of the lens, measure the distance between the two marks in the image. It's easiest to do if you close one eye. Write down the measurement.



This is the magnification of your lens.

What happens if you hold the lens right up to your eye? Move the book closer or farther until the print is in focus.

LAB 18

The Lens Flip

Turn your world upside down (and backward)!

Tiny Tools:

- **Magnifier**

Supplies:

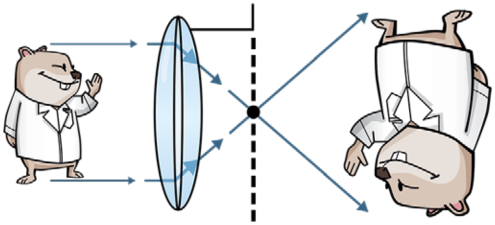
- **Pencil**

The Experiment:

1. Place the pencil flat on the table.
2. Hold the magnifier over the point and look through the glass. Move the lens until the point is in focus.
3. Keeping the distance between yourself and the magnifier the same, move the lens away from the point.
4. At first the image will get larger and then blurrier. Keep moving away until the point comes back into focus. What do you notice? The pencil appears to have flipped! It's pointing in the opposite direction!

What's Happening?

When an object is far from the lens, the light rays reflected from it bend inward as they pass through the lens. If your eye is far enough from the lens, the light rays have crossed one another before reaching your eye, so you see a flipped image of the object.



LAB 19

Upside-Down Image Projector

Project an image onto paper!

Tiny Tools:

- **Magnifier**

Supplies:

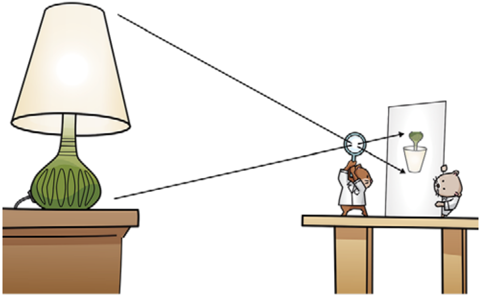
- **Lamp (Table, floor, or ceiling—any lamp will work)**
- **A sheet of white paper**

The Experiment:

1. Turn on the lamp.
2. Stand a few feet away and hold the lens between the lamp and the sheet of paper.
3. Move the lens so that you can see a spot of light projected on the paper.
4. Now move the lens back and forth to adjust the focus. When you find just the right distance, you'll see an image of the lamp on the paper!

What's Happening?

The light rays pass through the lens and cross to create a real image of the lamp on the other side. The point where the image is sharp and in focus is called the image point. Just as in the last experiment, the crossing path of the light rays creates a flipped image.



Bonus Experiment:

Try this same experiment using a bright window as the light source. You'll need to be far enough away for the whole window to be visible in the lens. See if you can project an image on the paper of the view outside.

LAB 20

Money Secrets

Discover hidden messages!

Tiny Tools:

- **Magnifier**

Supplies:

- **Penny with the Lincoln Memorial on the "tails" side**
- **$5 bill**
- **$10 bill**
- **$20 bill**

NOTE: Many countries have micro printing on their currency. See what you can find!

The Experiment:

1. **Penny, "tails" side:** See if you can spot the statue of Abraham Lincoln inside the Lincoln Memorial.
2. **$5 bill, front:** Examine the teardrop shapes along the right and left edges. Can you read the tiny letters there?

   $5 bill, back: Look at the end of the tail of the big, purple number 5.
3. **$10 bill, front:** Examine inside the borders at the right and left edges.

   Look just above the name "Hamilton" at the bottom of Alexander Hamilton's picture.

   Find the tiny writing on the lower edge of the big, red torch, just to the right of Hamilton's chin.
4. **$20 bill, front:** Examine the border between Andrew Jackson's left shoulder and the number 20.

   Look at the bottoms of the letters in the very faint, wavy printing to the right of Jackson's face.

What You're Seeing

The tiny writing is called micro printing. It's nearly impossible for counterfeiters to copy, so it lets you know that the bill is real.

Micro Printing Text:

$5 bill, front:
FIVE DOLLARS

$5 bill, back:
USA FIVE

$10 bill, front, edges:
THE UNITED STATES
OF AMERICA
TEN DOLLARS USA

$10 bill, front, above Hamilton's name:
THE UNITED STATES OF AMERICA TEN DOLLARS

$10 bill,front, torch:
USA 10

$20 bill, front, left side:
THE UNITED STATES OF AMERICA 20 USA 20 USA

$20 bill, front, faint wavy letters:
THE UNITED STATES OF AMERICA 20 USA

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