Experiment 1 — We create the Harry Potter wand!

Topic: Static electricity

Approximate duration: 15–20 minutes

Didactic objective

This experiment introduces the concept of static electricity in a visual and participatory way. Students will see firsthand how an electrostatically charged PVC bar can deflect a stream of water, move a can, and attract bits of paper. The metaphor of the wand in Harry Potter serves to capture attention and generate curiosity before introducing the scientific explanation.

Necessary material

- PVC Bar
- Tap with running water
- Piece of wool or cotton fabric
- Empty, clean soda can (optional)
- Paper scraps (optional)

Procedure

1. **Rub the PVC bar** vigorously against the wool or cotton fabric for several seconds. The more you rub in, the more charge builds up.
2. **Open the tap** so that a fine and constant stream comes out. Bring the bar closer without touching the water: the jet will be diverted towards the bar.
3. *(Optional)* Place the can on a smooth surface and bring the bar closer on one of its sides: the can will be repelled by the bar.
4. *(Optional)* Bring the bar closer to pieces of paper on the table: these will stick to the bar.

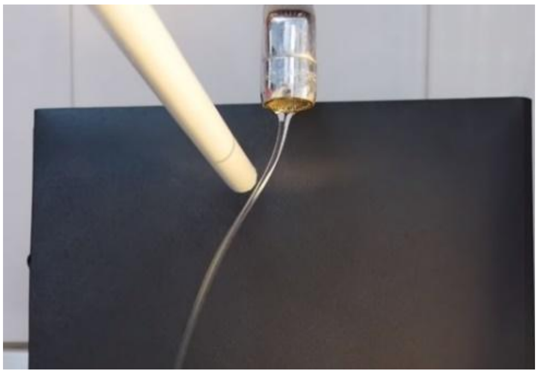

Image 1: *Result of the experiment*

Scientific explanation

Rubbing the PVC bar with the fabric results in electron transfer. Electrons are very small particles that are part of our atoms and have a negative charge. PVC tends to **capture** electrons, while wool or cotton tends to **give them** up. As a result, the bar is negatively charged, as it now has more electrons that it has "stolen" from the fabric.

- **Attraction (waterjet and papers):** When the charged bar is brought closer to a neutral object, the negative charge of the bar **repels the electrons of the object to the opposite side**, leaving the nearest surface positively charged. As opposite charges attract, the object is attracted to the bar (electrostatic induction).
- **Repulsion:** Metals contain free electrons, like a kind of cloud with many electrons. When the negative bar approaches the can, **the electrons in the can flee to the opposite side**, leaving the next side positively charged. Thus, although the can is globally neutral, the side closest to the bar is attracted and the can is moved away from the bar.

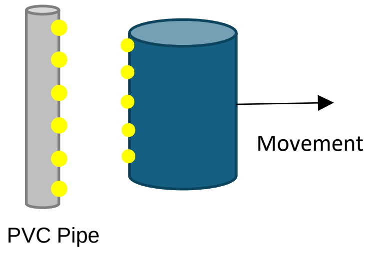

Image 2: *Representation of how the extra electrons from the bar and the electrons from the metal repel each other.*

Tips for dynamization

Before revealing the explanation, you can present the bar as a "magic wand" and ask students to formulate hypotheses about why the water and the can move.

Security

The experiment does not present significant risks. Static electricity generated with a PVC bar and fabric does not produce dangerous electric shocks.

Experiment 2 — When electricity and magnetism meet: the electromagnet

Topic: Electromagnetic Induction

Approximate duration: 20–30 minutes

Didactic objective

This experiment illustrates the relationship between electricity and magnetism. The students will build a homemade electromagnet and see how an electric current circulating through a coiled wire is capable of generating a magnetic field.

Necessary material

- 9V battery
- A large iron screw
- Enameled copper wire (galvanized)
- Small iron objects (paper clips, thumbtacks, etc.)

Procedure

It is recommended that the teacher prepare a sample electromagnet in advance to show the final result before the students build their own.

1. **Wrap the copper wire around the screw** patiently, forming a compact coil. It is important that the coils are close together and in the same direction. Leave two ends free of about 10 cm each.
2. **Lightly scrape the enamel** off the free ends to ensure good electrical contact.
3. Connect each end of the cable to one of the poles of the 9V battery.
4. Bring the screw closer to ferromagnetic objects (clips, thumbtacks...): the objects will be attracted to the screw. When you disconnect the battery, the effect disappears.

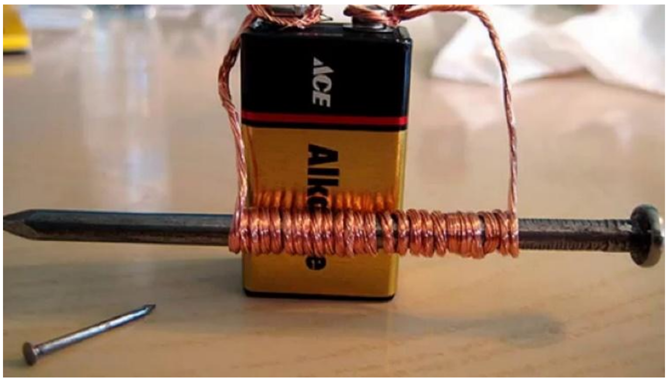

Image 1: *Photograph of the montage*

Scientific explanation

When an electric current flows through a conductor, it **generates a magnetic field around it**, which is known as Biot-Savart's Law.

By winding the wire into a coil, the magnetic fields of each coil add up, **amplifying the effect**. In addition, the iron core of the screw concentrates and strengthens the magnetic field thanks to its high magnetic permeability, which makes the assembly a functional electromagnet.

A more powerful electromagnet can be achieved by increasing the power of the electric field we generate, since the greater the electric field, the greater the magnetic field. This can be achieved, mainly, in 3 different ways.

- **By adding more turns** to the coil (up to a limit, due to the electrical resistance of the cable).
- Using **a higher voltage battery** to increase the current intensity.
- Using a **thicker copper cable**, which reduces resistance and allows more current to circulate.

Tips for dynamization

A good starting point is to ask students if they think electricity and magnetism are related, i.e. that they have the magnet in the fridge and the electricity in a light bulb in common. After the demonstration, the challenge of improving the electromagnet can be raised: what would they change to make it more powerful?

Security

The 9V battery is safe for this type of experiment, but it is worth warning students that the cable can become hot if the connection is maintained for a long time. It is recommended to connect the battery only for the time necessary for demonstrations and not to leave the closed circuit continuously.

Experiment 3 — We build an electric motor!

Topic Electromagnetic Induction and electric motor

Approximate duration: 25–40 minutes

Didactic objective

This experiment allows students to build a functional electric motor with simple materials, directly visualizing how the interaction between an electric current and a magnetic field generates movement. In addition, the electric motor is used in many appliances and machines: fans, washing machines...

Necessary material

- 1 meter of enameled copper wire (galvanized)
- Neodymium Magnet
- 1.5V battery (AA battery or similar)
- 2 large safety pins
- Electrical tape
- Fine sandpaper or knife (to scrape the enamel off the wire)

Procedure

It is recommended that the teacher set up the complete experiment in advance. The success of the engine depends on several technical details that should be mastered before guiding the students.

1. **Fix the two safety pins** in a vertical position on the poles of the battery with electrical tape, one at each end.
2. **Place the neodymium magnet** on top of the battery. If necessary, it can be attached to the battery with electrical tape.
3. **Wrap the copper cable** into a compact circular or rectangular loop, leaving about 3–5 cm free on each side to support it.
4. **Scrape the glaze off the two free ends of** the wire, only on one side. You only have to scrape half of the cable at each end (the part that will be in contact with the safety pin) so that it makes contact and, when turning, disconnects itself.
5. **Rest the ends of the coil** on the upper loops of the safety pins, so that it is suspended and can rotate freely.
6. **Give a small impulse to the coil** to start the movement. If the assembly is correct, the coil will continue to rotate on its own.

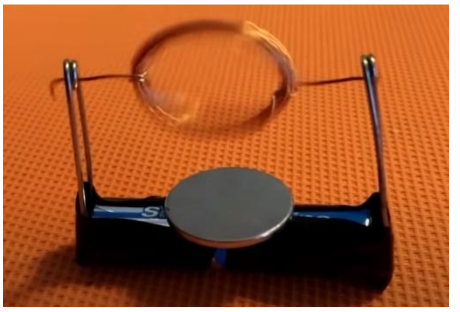

Image 1: *Photograph of the montage*

Scientific explanation

When the electric current from the battery flows through the copper coil, it **generates a magnetic field of its own**, as we discovered in the previous experiment. This field interacts with that of the neodymium magnet: the opposite poles attract and the like poles repel each other, which **produces a force** on the coil that makes it rotate. This force is called the Lorentz force, and it acts on the moving electrons inside the conductor.

The key detail of the design is that the enamel is only scraped off the bottom half of the shafts. This causes **the electrical contact to be interrupted every half turn**, which reverses the effect of the force just when the coil needs an additional boost to continue spinning. If we don't do this, the coil will stop halfway through.

Tips for dynamization

Before we begin, it is helpful to ask students if they know what a fan and a washing machine have in common. The answer: **everyone uses an electric motor.**

If the motor does not start the first time, it is worth reviewing with the students each critical point of the assembly (electrical contact, alignment of safety pins, position of the magnet), to detect (and learn from) the mistakes made.

Security

The 1.5V battery is safe for this type of experiment, but it is worth warning students that the cable can become hot if the connection is maintained for a long time. It is recommended to connect the battery only for the time necessary for demonstrations and not to leave the closed circuit continuously.

Experiment 4 — Electromagnetic Brake

Topic: Electromagnetic Induction

Approximate duration: 15–20 minutes

Didactic objective

This experiment illustrates how a magnet generates currents in metals, and these currents in turn generate a magnetic field. This is known as Lenz's Law, and it's a striking effect because it can appear to defy gravity.

Necessary material

- Copper tube or block with inner hole (the thicker the walls, the greater the braking effect)
- Neodymium magnet slightly smaller than the inside diameter of the tube
- (Optional) A second, thinner-walled tube or plastic tube, to compare the effect
- (Optional) A non-magnetic object of similar weight to the magnet (for initial comparison)

Procedure

1. Drop the magnet from a certain height in free fall (or through a plastic tube, which does not conduct), and **count how long it takes to fall.**
2. Repeat the experiment, but **this time with a copper tube**. The magnet will take much longer to fall than on the first try.
3. (Optional) Repeat with tubes of different thicknesses and compare the time it takes to fall: the more copper, the more it slows down.

Image 1: *Example of copper pipes of different sizes that can be used.*

Scientific explanation

When the magnet falls while inside the copper tube, **Its magnetic field passes through the metal, and because it's in motion, that field is constantly changing. Copper is a good conductor and reacts to this change by generating small electric currents** circular inside,
called eddy currents.

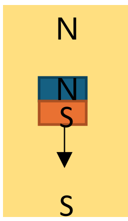

Image 2: *Rendering of the falling magnet. By induction, the tube is like a magnet that has the same poles as the falling magnet, slowing it down.*

These currents **create their own magnetic field**, and this magnetic field goes in the opposite direction to what originated them. In this case, **it pushes the magnet upwards**, slowing it down. The magnet keeps falling because its weight exceeds that braking force, but it does so much slower than normal. If the induced field were strong enough, the magnet would be suspended in the air.

The more copper in the tube (thicker walls), the more currents are generated and the **more you slow down.** That is why the experiment does not work with plastic or wooden tubes: as they are not conductive, no currents are generated and the magnet falls freely.

Tips for dynamization

The brake effect is very counterintuitive, which makes it especially useful for working on hypothesis formulation. Before the demonstration, you may ask, "What will happen if I drop this magnet inside the copper tube? Will it fall as fast as before?"

Security

The experiment does not present electrical hazards. Remember that neodymium magnets are very powerful: handle them with caution to avoid pinching, and keep them away from sensitive electronic devices or cards.

Experiment 5 — The Locomotive battery

Topic: Electromagnetic Induction and Motion

Approximate duration: 20–30 minutes

Didactic objective

This experiment shows how electricity and magnetism work together to produce motion. A battery with two neodymium magnets at its ends runs alone through the inside of a copper solenoid, acting like a miniature train. It is a very visual demonstration of the same principle behind the linear motors used in high-speed trains and on some subway lines.

Necessary material

- Bare copper wire (no enamel coating)
- 1.5V AA battery
- 2 neodymium magnets with a radius of 15 mm radius and 8 mm in height (or spherical magnets of the same radius)
- Tube of the same radius as the magnets, to wind the solenoid (can be a thick cardboard tube, PVC or similar)

Procedure

The critical detail of this experiment is the orientation of the magnets. It is essential to place them with the ***same poles facing the battery*** *(north with north, or south with south): if they are placed with opposite poles, the magnetic fields of both magnets cancel out and the system does not work. It is also important that the diameter of the solenoid is only slightly larger than that of the locomotive, so that the magnets are close to the turns and the electrical contact is good. If the gap is too large, the field generated will be weak and the locomotive will not advance.*

1. **Wrap the copper wire** around the tube compactly and evenly, forming the coil. The length of the coil will determine the train's travel.
2. Attach **a neodymium magnet to each pole** of the AA battery, making sure that both magnets have the same pole facing the battery (N-N or S-S).
3. Insert the "locomotive" (battery + magnets) through one end of the solenoid and watch it advance on its own to the other end.
4. (Optional) Turn the locomotive and insert it again: you will see that it is now moving in the opposite direction.

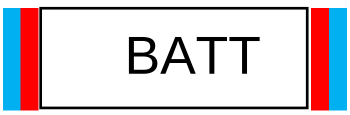

Image 1: *Simple Outline of Stack and Magnets*

Scientific explanation

When the magnets of the locomotive touch the copper wire of the coil, they close the circuit and the current in the battery begins to circulate. As it passes through the coil's turns**, that current generates a magnetic field** right around the locomotive, following the same principle as the electromagnet experiment.

This field interacts with that of neodymium magnets: **the pole of the magnet facing the solenoid field is repelled on one side and attracted on the other**, pushing the stack forward. As the locomotive advances, the magnets come into contact with new coils and the process repeats itself.

Placing the magnets with equal poles touching the stack is essential: it ensures that the field of each magnet points in the same direction and that both contribute to pushing the locomotive in the same direction. With polar opposites, the fields would cancel out and there would be no movement.

Tips for dynamization

The moment of greatest impact is when students see that the battery moves by itself without any visible mechanism. Before the demonstration, you can ask what they think will happen when you insert the battery into the coil and, when you see that it moves, where the energy that moves the battery comes from.

If sufficient material is available, students can be encouraged to experiment with solenoids of different length or coil density, and to observe how it affects the speed of the locomotive.

Security

The 1.5 V battery does not pose any electrical hazards. However, the copper wire can become hot if the locomotive stops inside the solenoid with the closed loop, as the current continues to circulate. It is advisable to ensure that this does not happen for a long time. Also remember the usual precautions with neodymium magnets: avoid pinching and keep them away from electronic devices and magnetic cards.

Experiment 6 — We create a speaker with a plastic cup!

Topic: Electromagnetic Induction and Vibrations

Approximate duration: 30–45 minutes

Didactic objective

This experiment allows students to build a functional speaker with simple materials, understanding first-hand how a device they use daily works. It connects electromagnetism with the phenomenon of sound, showing how a variable electrical signal can be converted into mechanical vibrations and thus into audible sound.

Necessary material

- In-ear headphones with mini-jack connector (not wireless)
- Plastic cup
- Enameled copper wire (galvanized)
- Circular neodymium magnet with a similar radius to the base of the cup
- Electrical tape
- Radius tube similar to the base of the cup
- Scissors and fine sandpaper or knife
- Mobile phone or other device with mini-jack audio output

Procedure

This is the most delicate experiment in the series in terms of editing. It is strongly recommended to complete it in advance to identify possible points of failure before doing it in class. The critical aspects are:

1. **Wrap the copper wire** around the tube to form a coil, slightly smaller than the base of the plastic cup. Leave several centimeters of free wire at each end and scrape the enamel off those ends.
2. **Attach the coil** to the outside of the base of the cup with electrical tape.
3. **Place the neodymium magnet inside the cup**, just in front of the coil. The magnet's own weight can help keep the speaker stable.
4. **Cut the headphone cable** through the connector area, leaving about 10–15 cm of cable. **Peel the cut end** to expose the inner conductors: inside are two thin wires (one back and one back for each channel). **Identify those corresponding to a single channel.**
5. **Connect each end of the coil** to one of the two conductors of the selected channel, closing the circuit.
6. Connect the mini-jack to the device, **play music at high volume** and bring your ear close to the cup. You might need to hold the cup with your fingers.

Scientific explanation

A speaker **converts an electrical signal into sound.** The audio signal sent by the device is an alternating current that continuously changes in intensity and direction in the same way that the voice it sends does.

When that variable current flows through the coil, it **generates a magnetic field** that also varies in strength and direction. The neodymium magnet, fixed, interacts with this changing field: at each moment **the magnet attracts or repels the coil**, which causes it to vibrate at the same frequency as the electrical signal. As the coil is attached to the cup, **the cup vibrates with the coil**, moving air around it in the same way as the original audio.

Tips for dynamization

Before setting up the experiment, students can be asked how they think a speaker works. Most don't have a clear answer, which makes the demo especially revealing.

Security

The experiment does not present significant electrical risks, as it works with the low-power signals of an audio device. Take the usual precautions with neodymium magnets. When cutting and peeling the earbuds, use the scissors carefully.

Supplementary Resource

https://www.youtube.com/watch?v=EYJKlzOun0c

Experiment 7 — Does Water Conduct Electricity as Well as We Think?

Topic: Electrical Conductivity

Approximate duration: 20–30 minutes

Didactic objective

This experiment debunks a widespread misconception: that water is a very good conductor of electricity. In reality, pure water is an insulator and what conducts electricity are the ions dissolved in it. As you add more salt, you'll see how the conductivity increases in real time and the water will go from not conducting electricity to doing so.

Necessary material

- Glass with distilled water
- Table salt (NaCl)
- LED
- DC generator or battery of sufficient voltage (**never the domestic power grid**)
- Connection cables with alligator clips
- Two electrodes (can be aluminum strips or metal clips)

Procedure

1. **Assemble the circuit in series**: power supply → bulb → positive electrode (in water) → negative electrode (in water) → back to the source. The electrodes should be submerged in water without touching each other.
2. Fill the glass with **distilled water** and turn on the fountain. Notice that the bulb remains off: pure water does not conduct.

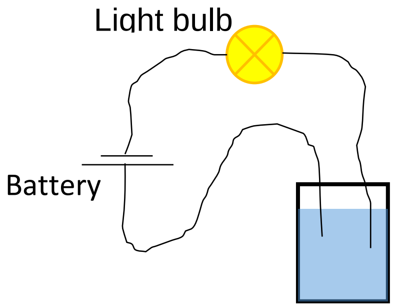

Image 1: *Experiment representation*

3. **Add salt a little at a time**, stirring each time. Observe how the bulb begins to glow softly, and intensifies as the concentration of salt increases.
4. (Optional) Repeat the experiment with tap water instead of distilled water: check that the bulb is already turned on from the beginning, although with less intensity than with added salt.

Scientific explanation

The electrical conductivity of a liquid depends on whether **it has dissolved electrically charged particles** that can move freely. Pure water (H_2O) is an insulator because **its molecules are bound together** and there is no free charged particle that can conduct electricity.

When salt (NaCl) is added, **it dissociates into** Na^+ (positively charged) and Cl^- (negatively charged) ions. These ions are capable of **transporting charges** from one electrode to the other: Na^+ ions migrate to the negative electrode and Cl^- anions to the positive electrode, **allowing current to circulate** and the bulb to turn on. These types of conductors are called **electrolytes**.

The more salt it dissolves, the more ions there are and the better it conducts electricity, so the bulb shines brighter and brighter. **Tap water has mineral salts** in small amounts and therefore also conducts electricity and it is dangerous to mix water and electrical appliances.

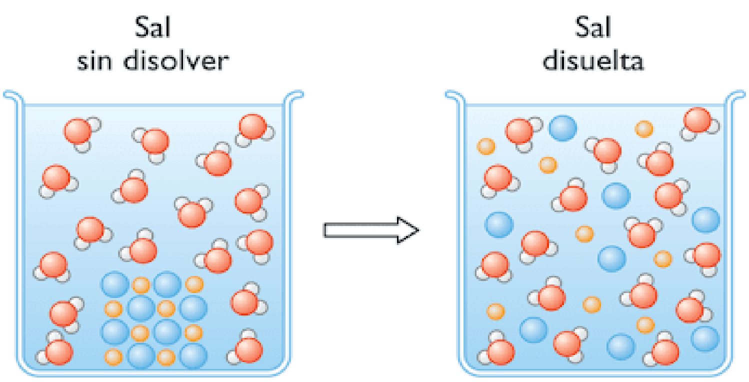

Image 2: *Representation of how the added salt dissolves, and the free ions remain in the liquid.*

Tips for dynamization

The ideal starting point is the question in the title: "Does water conduct electricity?" Most students will answer yes, and will be surprised by the light bulb connected to the generator, but not working.

It is recommended to spend a few minutes reflecting on the danger of common water with the students at the end of the demonstration to reinforce learning.

Security

Use only low-voltage sources (laboratory generator or batteries). Under no circumstances should the circuit be connected to the domestic electrical network. Make sure students do not touch the electrodes or water while the circuit is connected. Disconnect the source before any manipulation of the assembly.

Experiment 8 — Building a potato lamp

Topic: Redox reactions

Approximate duration: 20–30 minutes

Didactic objective

This experiment introduces the concept of electrochemical battery and redox reaction in a very accessible way: students generate enough electricity to light an LED using only a potato or lemon, a coin and a nail. It is a direct demonstration of how a chemical reaction can be converted into electrical energy, and lays the foundation for understanding how conventional batteries work.

Necessary material

For each cell (lemon or potato):

- 1 lemon or 1 potato (lemon gives more voltage: ~0.8 V; potato, ~0.5 V)
- 1 copper coin (or copper foil)
- 1 zinc galvanized nail (or zinc sheet)
- Connection cables with alligator clips

For the experiment:

- 1 LED (red is recommended, as it has the lowest voltage threshold, ~1.8 V)
- With lemon, build at least 3 cells in series, with potatoes at least 4

Procedure

Image 1: *Example of assembly with 6 lemons*

1. **Place the copper coin and zinc cloves in the lemon or potato**, separated from each other without touching. The nail must be made of galvanized zinc, not steel or painted, and the coin must be clean, without rust.
2. Connect one wire to the coin and another to the nail.
3. To connect multiple cells in series: **Bonding the wire of the zinc nail of a cell with the copper coin** of the next. Repeat until you have the necessary number of cells. The total voltage will be **the sum of the individual voltages** (V = n × v).
4. Connect the long LED leg (positive) **to the copper coin wire** of the last cell, and the short leg (negative) **to the zinc nail** of the first cell.
5. Observe how the LED lights up **powered only by the chemical reaction.**

Scientific explanation

We have built a handmade **electrochemical battery**, with the same operating principle as a conventional battery. The system has three essential components:

- The anode (zinc nail): zinc oxidizes and **gives up electrons** (negative pole)
- The cathode (copper coin): The surface of the copper coin **receives the electrons**, which is known as "reduction".
- The electrolyte (the acidic juice of the lemon or potato): allows **the passage of ions** between the two electrodes, completing the internal circuit.

The electrons released by the zinc **travel through the external circuit** (the wires and the LED) from the anode to the cathode, and that current is what powers the LED. The more cells that are connected in series, the higher the total voltage.

Tips for dynamization

A good entry question is, "What's inside a stack?" Few students know that there is a chemical reaction going on, so seeing that a lemon can do the same thing as a battery can be shocking.

Security

The experiment does not present significant risks. The voltages generated are very low (less than 5 V even with several cells in series). Remember that the materials used (lemon, coin, cloves) are not suitable for consumption/use after the experiment.

Experiment 9 — Separation of water into hydrogen and oxygen

Topic: Water Electrolysis

Approximate duration: 30–45 minutes

Didactic objective

This experiment allows students to experimentally verify that water is composed of hydrogen and oxygen. An electric current is capable of breaking water molecules, converting them into these two elements that form it, through a process called electrolysis.

Necessary material

- Plastic Tuper
- Distilled water
- Common salt (NaCl)
- 2 stainless steel screws (a must: other metals corrode quickly and contaminate the experiment)
- 2 test tubes
- Connection cables with alligator clips
- 9V battery
- Lighter or match
- Silicone Gun

Procedure

This experiment requires some precision in assembly for the gas collection to work properly. It is recommended to assemble it in advance:

1. **Make two holes** in the lid of the container, several centimeters apart, and insert a stainless steel screw into each one. **Seal** tightly around the screws with silicone.
2. Connect **a wire to each screw** on the outside of the lid.
3. Fill the container with **distilled water** and dissolve a tablespoon of salt. **Also fill the test tubes** with the solution.
4. Invert each test tube onto its corresponding screw**, upside down**, so that the gases we generate are trapped inside.
5. Connect **each wire to a pole** of the 9 V battery. Watch as bubbles begin to form on the electrodes and as water is displaced by the gas in the tubes.

6. Wait for an appreciable amount of gas to accumulate in both tubes. Note that the cathode tube (negative) accumulates approximately **twice as much gas as the anode tube.**
7. (Teacher only) To confirm the nature of the gases: carefully remove the hydrogen tube and bring a flame closer. It will occur **A small explosion**. For oxygen, bring a burning wood chip closer: **The flame will be fanned** visibly.

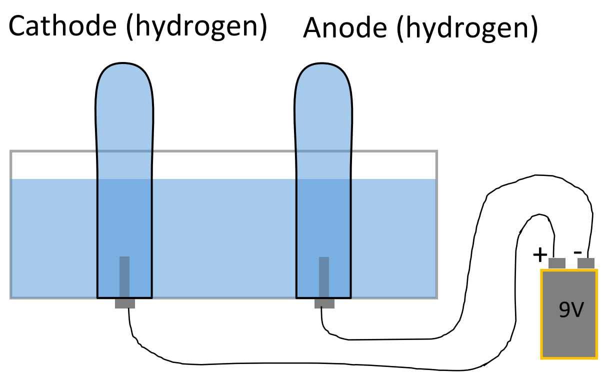

Image 1*: Diagram of the experiment setup. The tubes are filled with the salted water.*

Scientific explanation

Electrolysis is the process by which **an electric current forces a chemical reaction.** In this case, the electrical energy from the battery **breaks the bonds** of the water molecules and gives us **oxygen and hydrogen.**

The function of salt is to make water conductive, as we saw in the previous experiment, allowing the current to circulate with sufficient intensity. You can see that there is twice as much hydrogen as oxygen, since a water molecule is made up **of 2 hydrogen atoms and 1 oxygen atom (H_2O).**

Tips for dynamization

The trial by fire is the moment of greatest impact of the experiment. The little "pop" of hydrogen and the fanning of the flame with oxygen are unmistakable results that students remember. Before doing it, it is useful to ask students to predict what will happen in each tube.

The difference in volume between the two tubes (2:1) is another very productive moment of discussion: why is there twice as much hydrogen as oxygen? The answer leads directly to the chemical formula of water.

Security

The 9 V battery does not pose an electrical hazard. The critical safety point is the fire test that should only be carried out by the teacher and never by the students. This test must be done in a ventilated space and with the students at a certain safety distance.

Experiment 10 — How to make a flashlight with a pencil?

Topic: Joule Effect and Incandescence

Approximate duration: 15–20 minutes

Didactic objective

This experiment illustrates how, due to the effect of heat, a graphite mine connected to a 12 V battery is heated until it emits light in a few seconds. This is known as the Joule effect.

Necessary material

- Graphite pencil (preferably hardness B or 2B)
- 12V battery or power supply
- Connection cables with alligator clips
- Heat-resistant surface on which to rest the mount
- Thermal tweezers or gloves

Procedure

This experiment should be carried out only by the teacher, as a demonstration. The temperatures reached by the graphite mine are sufficient to cause severe burns on contact.

1. **Cut the lead into 2–3 cm segments**, carefully, as graphite is brittle and can splinter.
2. Connect an alligator clip to each end of the lead, and each wire to the corresponding pole of the 12V battery.
3. Close the circuit briefly and observe **How the mine begins to emit light** orange-white in a few seconds. Disconnect the circuit **after a few seconds** to prevent the mine from breaking or burning.
4. Open the circuit by disconnecting one of the wires. Do not touch the mine until it has cooled completely.

Image 1: *Graphite bar emitting light when the electric current passes.*

Scientific explanation

When an electric current passes through a conductive material, **some of the electrical energy is converted into heat**. The reason is that the material has a resistance to the passage of electrons, which is known as Joule's Law

Graphite has a very high electrical resistance (more than 1000 times that of copper) and **dissipates a lot of energy in the form of heat**. When the temperature of the bar reaches about 700–800 °C, the material begins to emit visible light, which is known as incandescence.

The main problem with incandescence is that it is **very inefficient** and most of the energy is dissipated as heat and not as light.

Tips for dynamization

Before the demonstration, students can be asked what they think will happen if we run electricity through this graphite bar (the inside of a pencil). In this way they will formulate hypotheses and, generally, they will be surprised to discover that this pencil emits light.

Security

This is the experiment with the highest thermal risk in the series. Graphite lead reaches temperatures of several hundred degrees and can cause severe burns on contact or ignite nearby materials.

For this reason, this experiment has to be done by the teacher as a demonstration, and with the students at a safe distance.

The experiment should be performed on a non-flammable surface such as ceramic or stone, and the closed loop should not be left in place for more than a few seconds.

At the end of the experiment, do not touch the mine with your hands and use tweezers or thermal gloves to handle it.

Experiment 11 — How does a mobile screen work?

Topic: Capacitors

Approximate duration: 15–20 minutes

Didactic objective

This experiment debunks a widely held intuitive idea: that touch screens detect finger pressure or heat. In reality, modern displays detect changes in an electric field, and any conductive material can trigger them. From a very simple demonstration, students will understand the physical principle behind one of the devices they use the most.

Necessary material

- A mobile phone with a capacitive screen (any current smartphone)
- Non-sharply conductive objects: coin, aluminum foil, etc.
- Non-conductive objects: plastic pen, eraser, wood, cloth glove...

Procedure

This experiment works very well in a guided exploration format: the teacher raises hypotheses and the students check them directly with their own mobile phones or with the teacher's.

1. Touch the screen **with your bare finger**, as usual, and notice that it works as usual.
2. Try it **with a cloth glove** and check that the screen does not respond.
3. Try **non-conductive objects** (plastic pen, rubber...)
4. Test with **conductive objects** (coin, aluminum foil): The screen responds.
5. (Optional) Test with the glove on, but holding a conductive object (coin, aluminum foil) **between the finger and the screen**. The screen will respond normally again as it detects the conductive object, and not the finger itself.

Scientific explanation

A mobile phone screen is made up of **a grid of transparent electrodes** that maintain a uniform electric field on the surface. The electrodes have two conductive surfaces, and between them there is an insulator capable of storing electrical charge. That is, these electrodes are **electrical capacitors.**

When we bring a conductive material close to the surface of the **electrode, it alters this electric field**, and the mobile phone is able to detect this alteration. In fact, the detection system **measures these changes in the entire grid** of electrodes on the screen, to detect precisely where we have touched.

And why does the finger work? Because **Human skin conducts electricity**. That's why, when we put on a cloth glove (which is not conductive) the screen stops detecting our finger. The screen **only detects conductive materials**, but she has no idea if a coin is touching her finger.

***Image 1**: Representation of a telephone screen. The copper grids are the electrodes, and in between is the insulator.*

Tips for dynamization

Start the experiment by asking the students why they think the mobile screen knows where we are touching it. Students are likely to give ideas such as finger pressure (or strength), or finger heat. It is a good way for them to generate hypotheses that can later (or may not) be dismantled.

The optional step with the glove and coin is particularly didactic: it shows that it is not the finger that detects the screen, but the conductivity of the material in contact with it. It is a good example of how understanding how it works allows the system to be "tricked".

Security

The experiment does not present any risk. Use only non-sharp objects to avoid scratching the phone screen.

Experiment 12 — The Plasma Ball

Topic: Plasma, Ionization, and High Voltage Electric Discharge

Approximate duration: 20–30 minutes

Didactic objective

The plasma ball is one of the most visually striking experiments in the series. It allows us to introduce concepts such as the fourth state of matter (plasma), the ionization of air, the relationship between voltage and intensity, and the principle by which electricity always follows the path of least resistance.

Necessary material

- Plasma Ball
- Aluminum foil
- Plain paper
- Fork
- Fluorescent or small neon tube (optional)

Procedure

It is recommended to perform the experiment in a dimly lit room so that the plasma filaments are well visible and increase the visual impact.

Demonstration 1: The finger conducts electricity

1. Light the ball and observe the plasma filaments evenly distributed inside.
2. Bring one finger close to the ball: **all the filaments will go towards the finger**.
3. Repeat with a non-conductive object (rubber, plastic): **the filaments do not move.**

Demonstration 2: Cordless fluorescent (optional)

4. Bring a fluorescent or neon tube close to the ball **without connecting it to any wires**. Watch how it lights up only thanks to the electric field generated by the ball.

Demonstration 3: Spark Writing (Teacher Only)

5. Place **aluminum foil** on the ball and a sheet of plain paper on top.
6. **Slowly bring the fork closer** to the sheet of paper. The flying sparks will burn the paper at the discharge points, allowing you to "write" with electricity.

Scientific explanation

Inside the ball is a noble gas (very little reactive) at low pressure, and in the center an electrode connected to a high-frequency, high-voltage generator. This voltage is so high that it ionizes the gas, that is, **it stripes electrons from atoms,** and in the process emits light. The result of stripping electrons from a gas is a plasma **,** and the filaments are the path that the current follows to the glass.

Electricity **always looks for the "easiest" path to ground**, the one with the least resistance. When we bring a conductor closer to the surface, it becomes this path, and all the filaments go towards it.

Touching the ball is not dangerous because, although it uses a very high voltage, **The intensity is very, very small**. The total power is calculated by multiplying intensity by voltage, so the result is still low and the ball safe.

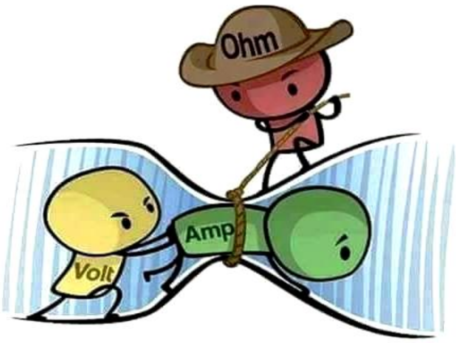

Image 1: *Analogy of how voltage, current, and resistance work.*

Tips for dynamization

The plasma ball has an instant surprise effect that makes it a good closure for the whole series of electricity experiments. Before the demonstration, you can ask what lightning is, and use the answer as a common thread to explain everything that happens in the ball.

It is also a good time to recap **the concepts worked on throughout the series**: conductors and insulators, magnetic field, resistance, Joule effect, voltage and intensity. The plasma ball brings almost all of them together in a single experiment.

Security

Direct contact with the ball is safe for healthy people without electrical implants or pacemakers. Keep the ball away from all electronic devices. It is recommended that the demonstration of sparks on the aluminum foil be made only by the teacher, or in any case by a single student chosen and controlled by the teacher.