

Creating Science – Homopolar motors

“Electricity and magnetism may be related, and we’re here to discuss this. Yet as you can see, when I place this magnet near a wire that is carrying an electric current, it doesn’t move.” A possible quote by an about-to-be-astounded Danish Professor Oerstead, around 1820.

How can we get the world simplest electric motor to work? #CreatingScienceHomopolarMotor

Suggested outcomes

(NOTE: This is by no means an exhaustive list of possible outcomes, neither is it intended that ONLY these outcomes can or should be met. Science is a deeply interrelated activity; all outcomes at all levels, when appropriate, should be integrated.)

Science understanding

- Physical sciences F: The way objects move depends on a variety of factors, including their size and shape.
- Physical sciences 2: A push or a pull affects how an object moves or changes shape.
- Physical sciences 3: Heat can be produced in many ways and can move from one object to another.
- Physical sciences 4: Forces can be exerted by one object on another through direct contact or from a distance.
- Physical sciences 6: Electrical circuits provide a means of transferring and transforming electricity.
- Physical sciences 6: Energy from a variety of sources can be used to generate electricity.

Science inquiry skills

- Processing and analysing data and information 5: Compare data with predictions and use as evidence in developing explanations (AC SIS218)
- Evaluating 5: Reflect on and suggest improvements to scientific investigations (AC SIS091)

Science as a human endeavour

- Nature and development of science 5: Science involves testing predictions by gathering data and using evidence to develop explanations of events and phenomena and reflects historical and cultural contributions (AC SHE081)



Science vocabulary words

Tier 1 (Everyday words) – heat, wire, magnets,

Tier 3 (Specialised vocabulary)

- Electricity – a form of energy that results from charged particles. It produces an invisible force that can do work.
- Magnetism – a physical phenomena produced by a moving electrical charge that can result in an attractive or repulsive force.

Warning

- Wires carrying electrical currents get hot – sometimes HOT ENOUGH TO BURN LITTLE FINGERS. Exercise all appropriate caution.
- Wires can be sharp, exercise all appropriate caution.
- Don't swallow anything in this activity.
- Homopolar motors, like many electrical products, require a certain amount of precision to operate properly. They can be a little unforgiving of errors, and so require time and patience to get them working.

Preparation

You'll need:

- Strong magnets, at least one per student. Little cylindrical neodymium are ideal, especially 12mm (circumference) by 5mm (tall). Available online.
- A short length of conducting wire such as copper. Make sure your wire ISN'T made out of steel or iron, as it will get stuck to your magnet and not move at all. About 10cm will do.
- You may need some plyers to move your wire.
- A medium sized steel screw. Nails work, but screws are niftier.

Suggestions for other year levels

As always, more material is presented here than can be used by the average class during the average lesson time. However, since the students' questions can and should guide student learning, more material is presented for your convenience. Remember, it is not uncommon for students to only remember those points which answered their personal questions.

Younger:

Children at this age can have difficulty with small wires and batteries, and may need assistance.

Middle:

This activity is well suited to this age group.

Teen:

You can easily extend this activity by helping students to elaborate the activity (see below).

Engage

- ⇒ Make sure all students write down any questions they may have generated during this phase regarding the topic for today.
- ⇒ Ask students what they think electricity and magnetism are.
- ⇒ Ask students if they think the two forces are related, or independent.



Tell them Orsted's story (see appendix)

What does this story teach us?

- You can learn by accidents.
- Science progresses as people notice important things, and ask about them. However, they are usually LOOKING for the thing they accidentally discover, and so are keyed in and ready to see something others may have seen and ignored for centuries.
- Electricity and magnetism *are* related.

Explore

Ask students to explain how electricity and magnetism are related, in particular, how electricity can turn the compass of a needle or how an electromagnet works.

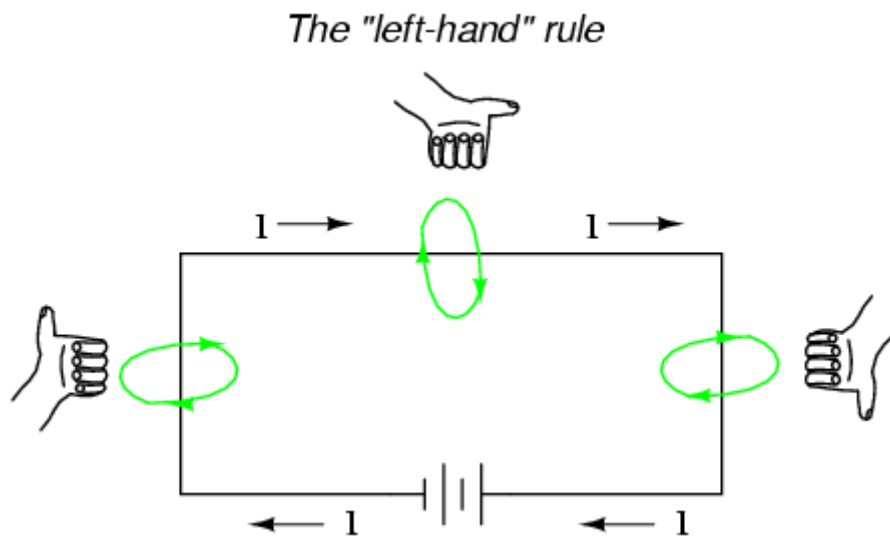
- ⇒ Encourage and validate student explanations of this phenomenon. You may like to ask students to write or draw their explanation personally to avoid embarrassment to students unfamiliar with this material. Remember, 'I don't know' is a valid explanation in science - it is the beginning of learning new things!

Basically, a flow of electricity creates a magnetic field around it. Even normal wires produce magnetic fields, and high tension power lines create such a powerful magnetic field people are worried about the effect they have on nature. So far, science in general finds such magnetic fields safe for human use.

Explain

The 'left hand rule' explained with a little help from <http://www.allaboutcircuits.com/textbook/direct-current/chpt-14/electromagnetism/> taken 10th july 2015

"Detailed experiments showed that the magnetic field produced by an electric current is always oriented perpendicular to the direction of flow. A simple method of showing this relationship is called the *left-hand rule*. Simply stated, the left-hand rule says that the magnetic flux lines produced by a current-carrying wire will be oriented the same direction as the curled fingers of a person's left hand (in the "hitchhiking" position), with the thumb pointing in the direction of electron flow:



"The magnetic field encircles this straight piece of current-carrying wire, the magnetic flux lines having no definite "north" or "south" poles."

So the idea is as the electricity flows along the wire, it creates a magnetic field around the wire.

If this magnetic field around the wire comes into contact with a magnetic field, they can push each other away.

We can use this push to make motion: i.e., to make the motor spin.

Once this was realised, a whole new field of science and technology opened up: the ability to move things using electricity. We realised we could invent doors that opened at the push of a button, maybe even cars that moved one day using their own electricity. This was exciting stuff!!!

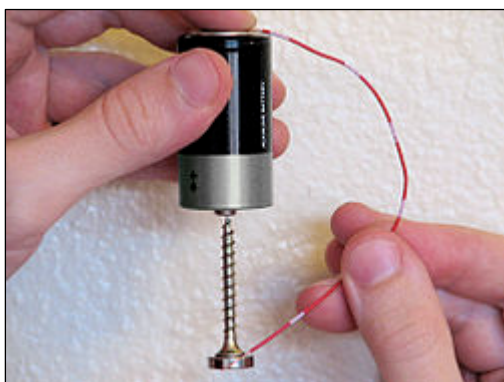
It still took many years before the first practical electrical motor was invented. It was used to push a car by two Dutchmen - Sibrandus Stratingh and Christopher Becker (<http://www.eti.kit.edu/english/1376.php> 10th july 2015).

Homopolar motors

We can use this to create something useful and fun: a homopolar motor.

'Homopolar' indicates that the electrical polarity of the conductor and the magnetic field poles do not change, ie, the electricity is flowing in the same direction all the time.

A simple version of the homopolar motor - almost guaranteed to work, comes from https://en.wikipedia.org/wiki/Homopolar_motor taken 10th July 2015.



“DIY simple homopolar motor made with a drywall screw, a battery cell, a wire, and a disk magnet. The magnet is on top of the screw head. The screw and magnet make contact with the bottom of the battery cell and are held together by the magnet's attraction. The screw and magnet spin, with the screw tip acting as a bearing.”

See my youtube channel “Dr Joe Science” for a live action version.

⇒ Have students explain how the motor works. If you think it helps, have students draw in the magnetic fields and electrical currents on the handout sheet.

Elaborate

⇒ Ask students if they can design new ways to test this explanation, is it really sufficient? Can they think of further or better explanations, and the experiments needed to test them?

There are loads of other kinds of set ups for making a homopolar motor

- Build a standard homopolar motor using the rectangle piece of wire.
- Build an elaborate homopolar motor, such as the tiny dancer (see appendix)

What other uses are there for homopolar motors and the Lorentz force?

- Research rail guns, with the potential to fire projectiles at twice the current speed of chemical based ballistics.
- How about at fun parks? What technology does the ‘tower of terror’ at Dreamworld use?

What happens when you run the homopolar motor in reverse? I.e., move the wire yourself? How can this be used to *generate* electrical energy?

Evaluate

- ⇒ Review with students what they felt they learnt from this lesson. Did they have any questions at the start that they feel were answered?

- Have students engage in extra research (suggested in elaborate above) in order to expand their understanding of electricity and homopolar motors.
- Make a photo journal of students building their own homopolar motors.

Success criteria

- ⇒ Review the Learning Intentions of this lesson with students. Was it met?

At the end of each class, review the learning objective and see how we did. Ask:

- ⇒ Did you achieve your learning goal?
- ⇒ What did You learn?
- ⇒ What worked to help you achieve it?
- ⇒ What might you do better next time?
- ⇒ (If needed) where can you go for extra help or information?

Assessment

Prior learning:

- Ask students what they think electricity and magnetism are.
- Ask students if they think the two forces are related, or independent.

Formative:

- Take time to focus on planned content material during the engage phase, for example, asking students what they think the electricity is doing in the wires where it cannot be seen.

Summative:

- Help students consider ways they can communicate their new understanding to others, just as scientists need to do.

So what

- Electricity and magnetism are closely interrelated forces.
- Sometimes random chance can help us do science.

Creating Science

Science understanding

As we learnt about electromagnetism and made our homopolar motors, we learnt about;

- Physical sciences F - 6: etc.

Science inquiry skills

As we saw that sometimes happy accidents, or 'serendipity', can cause scientific breakthroughs (For example, Oersted was lecturing at the time he made his breakthrough), we experienced;

- Processing and analysing data and information 5: Compare data with predictions and use as evidence in developing explanations (AC SIS218)
- Evaluating 5: Reflect on and suggest improvements to scientific investigations (AC SIS091)

Science as a human endeavour

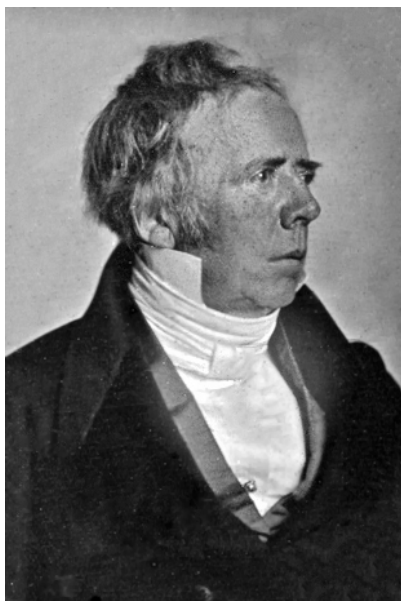
As we learnt about the people who contributed to this important scientific and technological breakthrough, such as People from different cultures and countries contribute to science (ie, Oersted and Gian Domenico Romagnosi), we learnt that;

- Nature and development of science 5: Science involves testing predictions by gathering data and using evidence to develop explanations of events and phenomena and reflects historical and cultural contributions (AC SHE081)

Appendix – Hans Orsted

On 21 April 1820, during a lecture, Ørsted noticed a [compass](#) needle deflected from magnetic north when an electric current from a battery was switched on and off, confirming a direct relationship between electricity and magnetism.^[6] His initial interpretation was that magnetic effects radiate from all sides of a wire carrying an electric current, as do light and heat. Three months later he began more intensive investigations and soon thereafter published his findings, showing that an electric current produces a circular magnetic field as it flows through a wire. This discovery was not due to mere chance, since Ørsted had been looking for a relation between electricity and magnetism for several years. The special symmetry of the phenomenon was possibly one of the difficulties that retarded the discovery.^[6]

It is sometimes claimed that Italian [Gian Domenico Romagnosi](#) was the first person who found a relationship between electricity and magnetism, about two decades before Ørsted's 1820 discovery of electromagnetism. Romagnosi's experiments showed that an electric current from a voltaic pile could deflect a magnetic needle.^[7] His researches were published in two Italian newspapers and were largely overlooked by the scientific community.^[8]

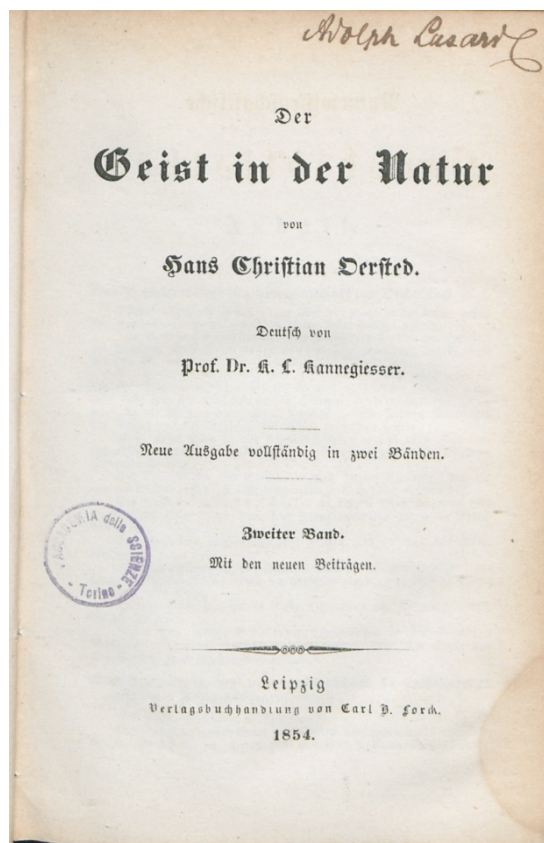


Ørsted's findings stirred much research into electrodynamics throughout the scientific community, influencing French physicist [André-Marie Ampère](#)'s developments of a single mathematical formula to represent the magnetic forces between current-carrying conductors. Ørsted's work also represented a major step toward a unified concept of energy.

In 1822, he was elected a foreign member of the [Royal Swedish Academy of Sciences](#).

Courtesy of https://en.wikipedia.org/wiki/Hans_Christian_%C3%98rsted

10th July 2015

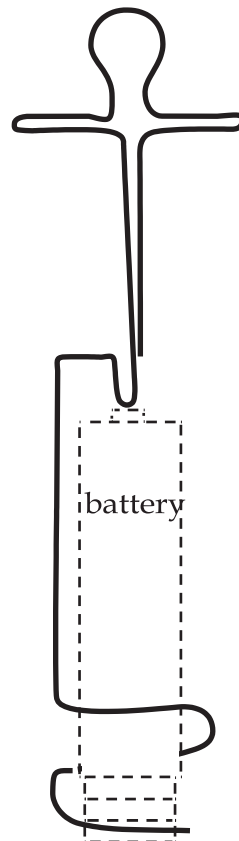


"Ørsted - ger, 1854 - 682714 F" by Ørsted, Hans Christian - Available in the digital library of the European Library of Information and Culture and uploaded in partnership (ID:). Licensed under Public Domain via Wikimedia Commons - https://commons.wikimedia.org/wiki/File:%C3%98rsted_-_ger,_1854_-_682714_F.tif#/media/File:%C3%98rsted_-_ger,_1854_-_682714_F.tif

Tiny dancers

Tiny dancers adapted 10th july 2015 from <http://babbledabbledo.com/wp-content/uploads/2015/03/Homopolar-Motor-Templates.pdf>

Tiny Dancer



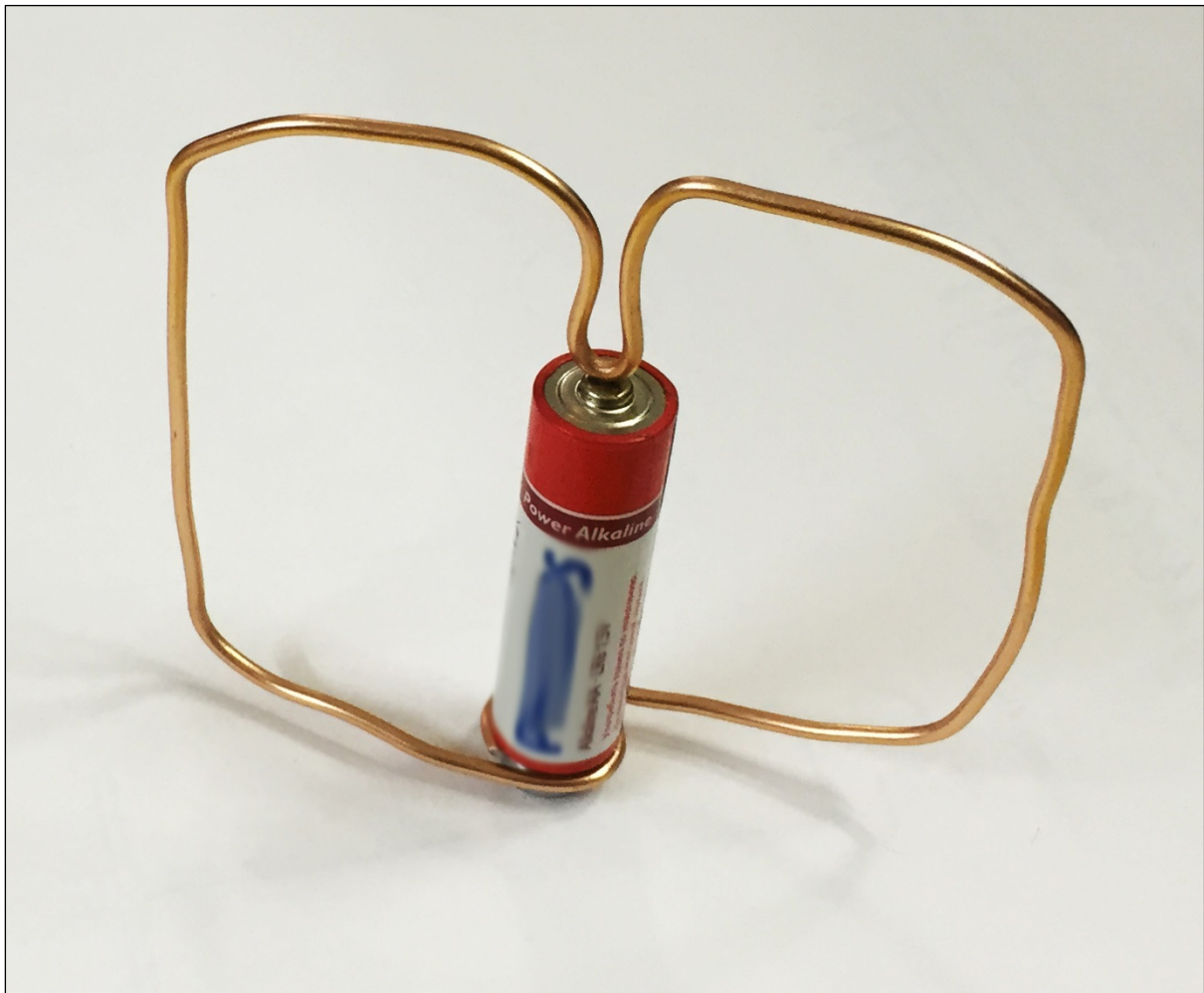
Side View

Instructions:

1. Print out this page
2. Place the neodymium battery/s under the -ve terminal of the battery, standing upright.
3. Bend copper wire using this page as a guide. Make sure it twists smoothly around the neodymium batteries, and dips down to balance on the top of +ive terminal of the battery.
4. Place wire on battery as indicated. It should start spinning on its own. If it's having trouble be sure to not make your wire too loose (to break the circuit) or too tight (and get stuck by friction) anywhere.

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Tips from the Masters



Another simple homopolar motor based off the 'tiny dancer'. Note the wire wraps around the neodymium super magnets very gently, and not around the battery. They must also go in an anticlockwise (from above) direction to maximise push.



**BE CAREFUL TO NOT LET
YOUR LITTLE MOTOR RUN FOR
TOO LONG, IT WILL GET HOT!**