Electromagnet

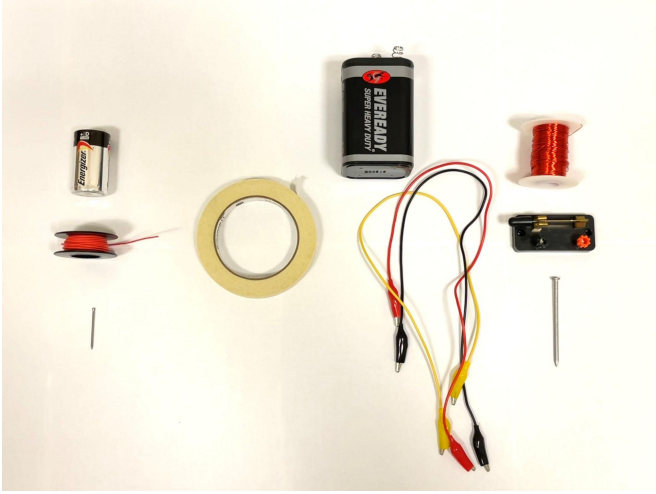
This project demonstrates the components of building an Electromagnet. Participants will learn about electric current and how they generate magnetic fields.

Number of Participants: 1-3

Audience: Elementary (ages 5-10) and older

Duration: 25 minutes

Difficulty: Level 2



Materials Required (*Easy*):

- D Battery
- Insulated Wire
- Nail
- Masking Tape

Materials Required (*Intermediate*):

- 6V Battery
- Insulated wire (24 Gauge or similar)
- Nail
- Masking tape
- 3 Banana Cables
- Switch

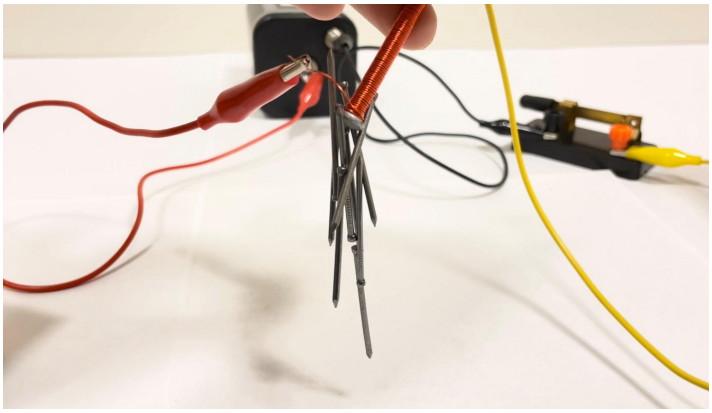
Setup *(Easy)*:

1. Wrap the insulated wire around the nail as many times as possible, the more wire the better the magnet will work so make it tight! Be sure to leave about 5 cm of wire sticking out on both sides of the nail. If the wire is not exposed at the ends, use scissors or sandpaper to strip any coating.
2. Tape one end of the nail wrapped in wire to the top of the D-Battery and the other end to the bottom of the D-Battery.
3. The head or tip of the nail acts as your magnet!

Setup *(Intermediate)*:

1. Wrap the insulated wire around the nail as many times as possible, the more wire wrapped around the nail, the better the magnet will work, so make it tight! Be sure to leave about 5cm of wire sticking out from both sides of the nail. If the wire is not exposed at the ends, use scissors or sandpaper to strip any coating.

2. Connect one end of a banana cable to a 6V battery and the other end of the banana cable to one of the wire ends. Ensure that the connection is stable and has metal touching metal.
3. Connect another end of a banana cable to the other part of the 6V battery and to the switch.
4. Connect another banana cable between the other end of the wire and terminal.
5. The nail is your magnet! *Note that the sharp end will have a stronger magnetic field than the broad end.* Practice grabbing paper clips with the magnet when the switch is up or down to note which is on and which is off.



Warning: The wire and battery will get hot to the touch if "on" for too long. Be sure to take it apart if it is not being used. The addition of the switch can help remedy this.

Presenter Brief:

The presenter should have a basic understanding of electromagnetism and current. The battery introduces the concept that a battery produces a current of charge that flows through the wire wrapped around the nail. Each wrap of wire creates a 'Magnetic Moment'. The strength of the magnet increases with the amount of turns of the wire. It is important to have an iron core and wrap the wire tightly because current through a wire in a loop makes a magnetic field and doubling the wire doubles the strength of the magnetic field if the wires are next to each other. The magnetic field only exists when current is flowing.

Vocabulary:

- Electromagnetism: Interaction of electric and magnetic fields.
- Magnetic field: the region around a magnetic material or a moving electric charge within which the force of magnetism acts
- Current: a flow of electrical charge carriers, usually electrons or electron-deficient atoms
- Voltage: an electromotive force or potential difference expressed in volts
- Faraday's Law: Law of electromagnetism that predicts how a magnetic field will interact with an electric circuit to produce an electromotive force.
- Current: The rate of flow of electric charge
- Solenoid: A device composed of a coil wire often used to transfer electric current.

- Magnetic Moment: The measure of the object's tendency to align with a magnetic field.
- Polarity: The property that produces unequal physical effects at different points in a system.

Physics & Explanation:

Elementary (ages 5-10):

- *Magnetic fields are created by electric currents.*

Electromagnets are used daily in speakers, hard drives, motors, etc. They are built using a metal core (most commonly iron), metal wire, and a battery. When current moves through a wire, it creates a magnetic field. When you make a small loop with the wire, it creates a small magnet. When wrapping the iron core with wire and connecting it to a battery, there is a current produced that runs throughout the wire. A magnetic field is produced when the magnet is turned on, and this can be altered (increased or decreased) by altering the current.

- *Permanent magnets cannot be altered while Electromagnets can be.*

Permanent magnets are always "on", making them permanent. These types of magnets are made from hard magnetic material that generates its own magnetic field that cannot be changed to be more or less powerful. The strength on an Electromagnet can be either strengthened or weakened by changing the current.

Middle (ages 11-13) and general public:

- *Magnetic fields are created by electric currents.*

Electromagnets are used daily in speakers, hard drives, motors, MRI scans, etc. An electromagnet is built using a metal core (most commonly iron), metal wire, and a power source. The power source (in this case, the battery) induces a current that flows throughout the wire and causes the electrons to move. This induced current then creates a magnetic field from the electrons' magnetic moment. This magnetic field makes the iron core act as a magnet. Because electromagnets are built with an induced current, the strength of the magnet can be altered by adjusting the strength of the current.

- *Permanent magnets cannot be altered while Electromagnets can be.*

Permanent magnets have a fixed North and South Pole. Thus, they cannot be changed. These are made from hard magnetic material that generate their own magnetic field. The strength on an Electromagnet can be altered either increased or decreased by adjusting current that creates the magnet.

- *Loosely wrapped wire affects the current.*

The magnet's strength can be reduced/increased depending on how tight the solenoid is. With a loosely wrapped wire, the current does not travel far thus creating a weaker magnetic field. With a tightly wrapped wire, the current can travel further–creating a stronger magnetic field. If the wire is wrapped one time, this creates one loop that acts as a magnet. But if the wire is wrapped 10 times, it is 10 times as strong and creates a stronger magnet. Participants can also experiment with this by lifting heavier items with a tight solenoid and a loose solenoid.

- *Electromagnets are used in everyday occurrences.*

Electromagnets are used in MRI machines to scan the human body. The magnets in the MRI machine produce a very strong magnetic field that forces hydrogen protons in the body to align with the magnetic field. Then a radiofrequency current is produced causing the protons to stimulate and spin out of equilibrium. Once this is powered off, the protons begin to realign and the faster this occurs, the brighter the scan can be.

Speakers use electromagnets to produce sound and in large cranes to carry heavy metal.

Highschool (ages 14+):

- *Magnetic fields are created by electric currents.*

Electromagnets are used daily in speakers, hard drives, motors, MRI scans, etc. An electromagnet is built using a metal core (most commonly iron), metal wire, and a power source. The power source (in this case, the battery) induces a current that flows throughout the wire and causes the electrons to move. This induced current through the wire then creates a magnetic field from the electrons' magnetic moment. This magnetic field makes the metal core act as a magnet.

- *The more wire wrapped around the metal core, the stronger the magnet will be.*

Ampere's Law states that the magnetic field created by an electric current on a closed loop path is proportional to the size of the current. Meaning, if the wire is wrapped 10 times around the metal core, it is 10 times as strong. Or if it's wrapped 100 times, the magnet is 100 times as strong. Because electromagnets are built with an induced current, the strength of the magnet can be altered by adjusting the strength of the current.

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- *Loosely wrapped wire affects the current.*

The magnet's strength can be reduced/increased depending on how tight the solenoid is. With a loosely wrapped wire, the current does not travel far thus creating a weaker magnetic field. With a tightly wrapped wire, the current can travel further–creating a stronger magnetic field. This is

also a reflection of Ampere's Law. Participants can experiment with this by lifting heavier items with a tight solenoid and a loose solenoid.

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Additional Resources:

- Video: https://youtu.be/SxAlUkJqgX0

Useful Equations:

Name	Equation
Force of Magnetic Field	F = qv *x* B
Ampere's Law	B = mu*I/2*pi*r

Where:

F = Force

q = Charge

v = Velocity

x = Cross Product

B = Magnetic Field

mu = Permeability of free space (1.26x10^-6)

I = Current

r = Radius