SCIENCE NORTH SCIENCE NORD
SUDBURY, ONTARIO, CANADA

Rail Gun **Grade 12 – Electricity and Magnetism**

Lesson Plan

Assessment	AFL, AOL
Cross-curricular	

Big Ideas

- Relationships between electricity and magnetism are predictable.
- Electricity and magnetism have many technological applications.

Learning Goals

- I can use the terms magnet, electromagnet, magnetic field, and motor principle.
- I know the law of magnetic poles.
- I can draw a representation of the magnetic field produced by a bar and a U-shaped permanent magnet.
- I can state Oersted's principle and describe the magnetic field produced by an electric current.
- I can use the right hand rules to determine the direction of the magnetic field around a current-carrying straight conductor and a solenoid.
- I know the Motor Principle and use the right hand rule to explain the direction of the force experienced by a current-carrying conductor in an external magnetic field.

Specific Expectations:

D2. investigate real and simulated mixed direct current circuits and the nature of magnetism and electromagnetism, and analyse related data;
D2.1 use appropriate terminology related to electricity and magnetism, including, but not limited to: direct current, alternating current, electrical potential difference, resistance, power, energy, permanent magnet, electromagnet, magnetic field, motor principle, and electric motor [C]
D3. demonstrate an understanding of the basic principles of electricity and magnetism.
D3.4 describe, with the aid of an illustration, the magnetic field produced by permanent magnets (bar and U-shaped) and electromagnets (straight conductor and solenoid)
D3.5 explain the law of magnetic poles
D3.7 state Oersted's principle, and apply the right-hand rule to explain the direction of the magnetic field produced when electric current flows through a long, straight conductor and through a solenoid
D3.8 state the motor principle, and use the right-hand rule to explain the direction of the force experienced by a conductor

Description:

In this lesson students will investigate the relationship between electricity and magnetism by making an electromagnet and a rail gun. **This lesson is intended for the college level**.

Materials

U.S. Navy Railgun makes public debut video
Navy's New Railgun Can Hurl a Shell Over 5,000 MPH video
Rail Gun Visuals and Information

Demonstration of Magnetic Fields Activity Group Materials:

- 2 bar magnets
- Compass (every iPhone has a compass app)
- 1 sheet of acetate (or transparency)
- Iron filings
- Tray large enough to contain the transparency and iron filings

Electromagnetism Activity Group Materials:

- Compass, 9 V battery, Alligator clips
- Tape, Piece of insulated copper wire,
- Coil of insulated copper wire, Iron nail,
- Paper clips, Iron filings

Construct an Electromagnetic Rail Gun Group Materials

- Cardboard or wood for a base 50 cm by 15 cm
- 2 strips of aluminum foil, 55 cm by 5 cm
- A 5 cm long piece of steel wire (coat hanger). File the ends of the wire flat, perpendicular to the wire.
- 2 disc magnets
- White glue
- 9 V battery
- Alligator Clips

Construct a Rail Gun Handout (Student and Teacher)
Rail Gun Rubric
Rail Gun Assignment (Teacher)

Safety Notes

Students are to be attentive when using and building electrical devices.

Introduction

A powerful new weapon can launch a 23 pound projectile at speeds exceeding Mach 7 (or 8,600 km/h). It is safer, cheaper, and makes use of the principles of electromagnetism to launch its missile further, than an explosives-based weapon.

Begin with the videos of the US Navy's magnetic rail gun.
U.S. Navy Railgun makes public debut
https://www.youtube.com/watch?v=o4ZqfEJTGzw

Navy's New Railgun Can Hurl a Shell Over 5,000 MPH
http://www.wired.com/2014/04/electromagnetic-railgun-launcher/

Electricity and magnetism are actually two sides of the same coin. What we demonstrate as using electrical force – causing current to flow and operating electrical devices -- and as magnetic force -- using a magnetic compass to find magnetic north or even closing the refrigerator door, are two different manifestations of the same ***fundamental force*** of electromagnetism.

Electric fields are created by the relative positions of electric charges, and the movement of electric charges produces magnetic fields.

Watch and complete the handout for the Magnetism and Electromagnetism visuals (See Link) to review some basic concepts of magnetism. We will extend these concepts to include electromagnetism and create our own rail guns.

Action

In pairs complete the following activities:

Demonstration of Magnetic Fields Activity
Group Materials

2 bar magnets
Compass (note: every iPhone has a compass app)
1 sheet of acetate (or transparency)
Iron filings
Tray large enough to contain the transparency and iron filings

Instructions
In this activity, you will draw the magnetic fields surrounding permanent magnets. In between each part of this demonstration, you will carefully pour the iron filings back into their container.
Single Bar Magnet

1. Place one bar magnet under the transparency. Make sure this is on the tray or in a container.
2. Pour the iron filings on top of the transparency.
3. Draw the magnetic field surrounding a single bar magnet.
4. Use your compass to draw the directions of the field lines. Each line should be an arrow, with the tip pointing in the magnetic south direction (i.e. toward the S end of the magnet).

Two Bar Magnets

1. Place two bar magnets end to end – approximately 3 cm apart – under the transparency.
2. Pour the iron filings on top of the transparency.
3. Draw the magnetic field surrounding both bar magnets.
4. Use your compass to draw the directions of the field lines.
5. Carefully turn one bar magnet 180° under the transparency and repeat steps 3 and 4.

During this activity, the teacher should circulate and ensure that students understand that the compass points to the South side of the magnet. The students should also see that the field lines are closer together near the poles of the magnets. As the presentation continues, students will learn that magnetic field lines always form closed loops and start and end at infinity.

Electromagnetism Activity
Group Materials

Compass
9 V battery
Alligator clips
Tape

Piece of insulated copper wire
Coil of insulated copper wire
Iron nail
Paper clips
Iron filings

Part A: Demonstration of Oersted's Law

Instructions

Draw a diagram of your setup before and after you connect the conducting wire to the 9 V battery. Divide your blank page into "Before" and "After" and draw the compass at two different locations; one, 2 cm from the wire, and one 5 cm from the wire.

1. Put the compass near the copper wire.
2. Now attach the wire to the 9 V battery using alligator clips.
3. Put the compass near the wire that has now been connected in series.

Discussion

A. What happens to the compass near the un-electrified wire?
B. What happens to the compass near the electrified wire?
C. What happens to the compass when it is further away from the electrified wire?
D. Try to pick up the iron filings and paper clips with the connected copper wire. What do you notice?
E. Now attach the coil of copper wire to the battery and try to pick up the iron filings and paper clips. What do you notice?

Part B: Making an Electromagnet

Instructions

Draw a diagram of your setup after you connect the conducting wire to the 9 V battery.

A. Coil the copper wire around an iron nail.
B. Tape the wire in place.
C. Attach the wire to the 9 V battery using alligator clips.
D. Put the compass near the coil that has now been connected in series.

Discussion

E. What happens to the compass near the two ends of the nail? Indicate the North and South of the nail on your diagram.
F. Try to pick up the iron filings and paper clips with the connected coil. What do you notice? Why do you think this is the case?
G. Now increase the number of coils around the nail and try to pick up the iron filing and paper clips. What do you notice?

During this activity students should observe that a magnetic field is set up around the conducting wire, but it is not very strong. Once they run current through the wire coil, students can see that the magnetic field is much stronger. Students should use their compass to determine the North and South poles of the electromagnet. They should also observe that increasing the number of coils on the nail increases the strength of the magnetic field. The teacher may also have students connect more than one battery in series to show that increasing the current through the wire will increase the magnetic field strength as well.

Construct an Electromagnetic Rail Gun (Student and Teacher-See Link)
Finally, students will learn about electromagnetic induction and then create their own electric rail gun.

The teacher should note that the permanent magnets enhance the magnetic field. They should be facing with like poles away from each other and should repel but still stick to the steel wire.

Group Materials

Cardboard or wood for a base 50 cm by 15 cm
2 strips of aluminum foil, 55 cm by 5 cm
A 5 cm long piece of steel wire (coat hanger). File the ends of the wire flat, perpendicular to the wire.
2 disc magnets (http://www.homedepot.com/p/MASTER-MAGNETICS-0-7-in-Neodymium-Rare-Earth-Magnet-Discs-3-per-Pack-07047HD/202526369?MERCH=REC-_-PIPHorizontal1_rr-_-202526367-_-202526369-_-N)
White glue
9 V battery
Alligator Clips

Instructions

1. Apply glue to the base to paste down the aluminum foil "rails" approximately 1.5 cm apart. Leave 5 cm of foil hanging off the end of the base upon which to attach the alligator clips.
2. Attach the rails to the battery in series, using the alligator clips.
3. Stick the neodymium magnets to opposite ends of the steel wire. They should be placed with the poles facing in opposite directions.
4. Drop the axle with wheels on the two rails. If it does not accelerate, flip one of the magnets.
5. Discussion.
6. How does the rail gun work?
7. Why will the projectile only accelerate if the magnets are in a certain configuration?

Consolidation/Extension

Electromagnetic Rail Gun Assignment:
There are actually many challenges to using electromagnetic principles to create a rail gun weapon. In a 1-2 paragraph response, identify some of the benefits and problems with this technology. Is this technology of overall net benefit or detriment to society? Can you think of other applications for this technology?

Rail Gun Assignment (Teacher)-See Link