Do You Read Me? Radio Waves, Magnets and Information Transfer	
Grade Level	Content Standards for 6-8th
Subjects	Physical Science, Earth, and Space Science
Duration	Preparation: (minimum <15 min) Activity: 3 hours class time
Setting	Classroom with internet, video software and PowerPoint

Objectives:

In this lesson students will

1. Be able to define, describe and draw magnetic field lines around a single magnet
2. Describe the interaction between like and unlike magnetic poles
3. Be able to understand waves in various forms
4. Understand how radio waves are used to transmit information

Activity Summary

In this lesson, student will explore magnetic forces, be introduced to radio waves and concepts involving the electronic transfer of information. The students will have an opportunity to work with magnets, engage in on-line simulations and in a physical activity to demonstrate how radio waves work.

Materials

- PowerPoint Presentation
- Video: Earth's Magnetic Shield - click here to watch
- Activity: Magnetic fields
    - Bar magnets (2 for each group of 2-3 students)
    - Salt shakers of iron filings
    - Wax paper
    - Manila file folders
    - Notebooks
- Activity: Morse Code
    - Handouts
    - Jump ropes
- Video: Radio Waves - click here to watch

Activity Procedure

Engage – Defending our Planet through Magnetism [Slides 1-4]

In our previous lesson, we discussed the use of the compass and the fact that it points north.

- Can someone explain why a compass points to the north?
  Answer: magnetic fields in the poles

- Ask students, who has a smartphone?
    a. When you make a call, how does the sound of your voice get from your phone to someone else's phone? How do your text messages and Facebook posts travel instantly to other people's devices?
    b. Have you ever had trouble using your phone inside a large building or underground? What causes this problem? What do you think could be done to fix the problem?

Exploration – Magnets and Magnetism

The Earth is electrically charged and is actually a magnet. A magnet is a piece of iron (or other metallic alloy) that is attracted to other iron-containing objects. Earth has an iron core in the middle that creates electrical forces within Earth and extends through the middle of Earth from the North Pole to the South Pole. It turns the center of Earth into a giant bar magnet. So the magnet within a compass is drawn toward Earth's magnetic north pole and therefore it points in that direction. The magnet inside of the compass is reacting to the magnetism of the planet.

Meanwhile, the sun is sending radiation and electrical waves into space which could be harmful to life on Earth. However, the magnetic activity within Earth's center that forms these magnet poles creates a huge magnetic field that surrounds Earth and provides a protective shield for us. We are going to watch a video that talks about this phenomena and explains why this matters for our future.

- Show video on magnetism and Earth
- Follow up with a discussion and questions on the film to ensure that students understand the concepts of magnetic fields, their protection of Earth, the impact that magnetic fields have on animals and humans to find locations on Earth, the Aurora Borealis and research on magnetism and space that may impact the future of humankind.

Demonstrate How Magnets Work

Split the class so that students are working in groups of 2 or 3. Pass out a manila folder, 2 bar magnets, salt shaker of iron filings and wax paper to each group. Make sure each group has paper of notebooks to record findings.

Step 1. Have students place a manila file folder on their desk or table, then place one bar magnet in the center of the file folder.

Step 2. Place a piece of wax paper on top of the magnet.

Step 3. Have students sprinkle iron filings all around the bar magnet (they may need to gently tap the wax paper with their finger to get the best view of the magnetic field lines).

Step 4. Have students draw what they see on the notepaper.

Step 5. Ask students the following questions: Are your lines of force greater at the ends or in the middle of the bar magnet? (Answer: at the ends) What assumption can you make about the strength of the magnetic field at that location? (Answer: The magnetic field is strongest at the ends or at the poles. This is where the lines are concentrated and closer together.)

Step 6. Have the students place the used iron filings back in the saltshaker or in a location specified by you.

Step 7. Have the students now place two bar magnets onto the manila file folder so that north poles are facing each other and are about an inch apart. Place the wax paper on top of the magnets.

Step 8. Have students sprinkle iron filings around the north poles of the magnets (they may need to gently tap the wax paper win their finger to get the best view of the magnetic field lines).

Step 9. Have students draw what they see. Ask the students if the magnets are attracting or repelling? (Answer: Repelling) How do you know? (Answer: The magnetic field lines are bending away from each other.)

Step 10. Have the students place the used iron filings back in the salt shaker or in a location specified by you.

Step 11. Repeat steps 7, 8, and 9 with a north pole of one magnet facing the south pole of a second magnet.

Step 12. Ask students if these magnets are attracting or repelling? (Answer: attracting) How can you tell? (Answer: The magnetic field lines are connecting the two poles together.)

Step 13. Have the students clean up per your directions.

[POTENTIAL BREAKPOINT FOR CLASS SESSION DEPENDING ON THE LENGTH OF YOUR CLASSROOM PERIOD]

Engage - Radio Waves and Information Transfer [Slides 5-7]

- Ask students, who has a cell phone?
- When you make a call, how does the sound of your voice get from your phone to someone else's phone? How do your text messages and Facebook posts travel instantly to other people's devices?
    - Have you ever had trouble using your phone inside a large building or underground? What causes this problem? What do you think could be done to fix the problem?

Exploration – Radio Waves:

After this brainstorming discussion, note the following:

- Cellular, cable TV and internet technology transmit our communications based on the use or radio waves.
    - What is a Radio Wave? It is an electromagnetic wave with radio frequency. It is an electromagnetic radiation (as are microwaves, infrared radiation, X-rays and gamma rays).

Electromagnetic waves are waves which can travel through the vacuum of outer space. They are created by the vibration of an electric charge.

- Radio waves are a series of repeating peaks and valleys and are used for wireless transmission of sound messages, or for passing information.
- The entire pattern of a wave, before it repeats itself, is called a cycle. The wavelength is the distance a wave takes to complete one cycle. Radio waves have long wavelengths. Visible light has wavelengths between 400 and 700 nanometers (10^{-9} m), that is 0.0000004 and 0.0000007 meters. Radio waves are a form of light that have much longer wavelengths: in the order of meters.
- The number of cycles of a wavelength is called a frequency. Frequency is measure in the unit of hertz (Hz), referring to a number of cycles per second. One thousand hertz is referred to as a kilohertz (KHz)
- The height of a radio wave is called its amplitude.
- Generally, waves keep the same amplitude or frequency all the time.

Demonstrate Radio Waves:

Step 1: Use a jump rope and explain how radio waves move. Radio or light waves are perpendicular to the direction of the waves. This is called a transverse wave.

Step 2: Have two students hold the jump rope between them. One student moves his/her arm up and down until waves are formed in the rope. Have the students try to get the wave as flat as possible for longer waves. Then have them try to get the waves as short as possible. This will demonstrate the look of different frequencies or amplitudes.

Exploration – Information Transfer

So how is information transferred through these radio waves?

- There are two common ways to put information in a radio wave: AM and FM [amplitude modulation and frequency modulation]. The information is put into a radio wave by varying the amplitude or frequency.
- So how do you make a radio wave? When a direct electrical current is applied to a wire the current flow builds an electromagnetic field around the wire. This field sends a wave outward from the wire. When the current is removed, the field collapses which again sends a wave. If the current is applied and removed over and over for a period of time, a series of waves is propagated at a discrete frequency.
- Ok, but how is information carried on these waves?
  - Modulation: A radio wave is generated by a transmitter and then detected by a receiver. The radio wave is the carrier signal – transmitter - and is changed by the signal we want to send to the receiver. This change of the carrier signal is called modulation. The receiver of such a modulated signal must know the type of modulation that was used to change the carrier signal. With the knowledge the receiver will be able to demodulate (or understand) the received signal.

- For radio, the modulation are relatively simple forms of modulation. For wireless communication like the internet, routers and network cards use far more complicated forms of modulation

- Radio wave communication signals travel through the air in a straight line. Imagine that you are talking to someone in the next room through an open door. They can hear you because the sound is going through a straight line; there is nothing blocking the sound. The further you are away from the door, the harder it is to hear. Now if we close the door, what do you think will happen to the sound? What if the other person goes to a room downstairs or across the street? Can you still hear them? Is the sound the same?
- Early scientists developed a way to send pulses of electric current along wires which controlled an electromagnet located at the receiving end; this became a telegraph system. A code was developed to be able to transmit and then translate the messages from these pulses. What was this called? (answer – Morse Code after Samuel F.B. Morse who was attributed with developing the telegraph system in 1836)

[POTENTIAL BREAKPOINT FOR CLASS SESSION DEPENDING ON THE LENGTH OF YOUR CLASSROOM PERIOD]

Demonstrate Information Transfer by Morse Code [Slide 8]

Step 1: Have students now try to communicate through the jump rope signals using the Morse code exercise worksheet.

Step 2: Ask students to identify some factors that need to be taken into account when considering radio waves signals as they are transmitted and intercepted. These should include things such as weather in space and on Earth, solar flares, the curve of Earth, interference by objects such as power lines, radio stations, mountains and trees, buildings etc.

Step 3: Have students model how these interferences might look in a simple example with the jump ropes. Students can hang items on the jump ropes. Have students run through the path of the waves. See what other ways they could model the interference brainstormed by the class. See if they can still send signals across the jump rope successfully.

Exploration - Show NASA's Radio Waves video here [Slide 9]

Satellites use radio waves for their various communication duties.

Engage students by asking, "If you had to design a satellite and you wanted to make sure that its radio wave signals did not send out the same type of signals (radio frequency or radio codes) as radios, or airport traffic control tower signals, how would you do this?"

Prodding ideas to promote critical thinking:

- We know waves have different frequencies and therefore wavelengths
- We know that pulses are used to transmit information
- We know waves can be interfered with by the environment and other waves...

The answer is that satellites have a very specific signal structure. They transmit Pseudo Random Noise (PRN) Code, which is digital code that acts like an "ID" for the satellites. The PRN is formed with pulses of electrical "noise" in a seemingly random pattern on their own unique frequency. This frequency, complexity, and randomness keep the signals from being in sync with other sources and can't be mistaken for anything else. Each satellite has its own PRN code so a receiver can't receive another satellite's signal by mistake.

Key Terms for Students

Magnetism: A physical phenomenon produced by the motion of electric charge, resulting in attractive and repulsive forces between objects.

Aurora Borealis: A display of lights in the sky seen around the magnetic north pole. This light display is caused by collisions between electrically charged particles released from the sun that enter the earth's Earth's atmosphere and collide with gases such as oxygen and nitrogen.

Radio Waves: a series of repeating peaks and valleys that are the building block of radio communications. The wave length is the distance a wave takes to complete one cycle

Frequency: The number of cycles or times that a wave repeats in a second. Frequencies are measured in the unit hertz (Hz) referring to a number of cycles per second.

Amplitude: The maximum extent of a vibration. As applied to radio waves it is measured perpendicular to the time axis and includes volume level, strength of signal.

Background for Educator

This is the second lesson from a 12-lesson curriculum introducing STEM topics through the lens of GPS and many uses in our lives. The lessons include discussion of various STEM careers related to GPS, and the activities provide practical applications that may be used in various career fields. Module 1 of the STEM curriculum includes this introduction to radio waves plus two more lessons on mapping and the Global Positioning System (GPS).

Here are some common misconceptions about GPS to remember:

- Radio waves (the GPS signal) are sound waves
  - Truth: Radio waves are transverse waves similar to light. Sound waves are longitudinal waves or compression waves. Sound waves need a medium like air or water to travel through. There cannot be sound in space since there is no medium in a vacuum. Radio waves do not need a medium but cannot always travel through walls. This is why GPS requires line of sight with the sky and does not work well indoors.

Next General Science Standards

MS-ESS2-A Earth's Materials and Systems

MS-PS4-A Wave Properties

- Crosscutting concepts of patterns

MS-PS4-B Electromagnetic Radiation

References

- www.nasa.gov
- Wave on a String
- Radio Waves & Electromagnetic Fields
- https://www.education.com/activity/article/Morse_Code/