Magnetism

Name______________________

Date______________________

Period______________________

CONCEPT EXPLORATION

You have already studied electricity and now you will investigate a related topic, magnetism. You will find that moving electric charges generate magnetic fields and that moving electric charges can be influenced by magnetic fields.

Engagement Question

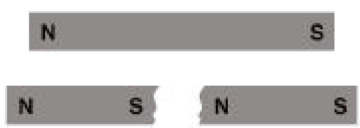
Two magnets are at rest on a table.

1. What do you think would happen to these magnets if they were brought close together?

Your instructor will demonstrate the situation described in the engagement question.

2. Did the same thing always happen when your instructor brought the two magnets close to one another? Describe at least two different things that happened when your instructor brought the two magnets close to one another.

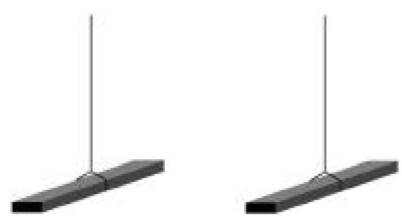
All magnets have a north and south pole. This is due to the alignment of tiny magnetic "domains" within the body of the magnet. If you were to break a magnet in half you would have two smaller magnets, each with their own north and south poles.



3. Why do you think that the ends of a magnet are called north and south poles?

Your instructor will suspend two magnets from strings until they come to rest. If this is done properly, both magnets should "point" in the same direction. Your instructor will indicate the compass directions with respect to your classroom.

The ends of the magnets that point towards geographic north are the "north-seeking" poles of the magnets, otherwise known as the north poles. The opposite end or "south-seeking" end of the magnets are the south poles.



Your instructor will now remove one of the magnets from the string and bring the north end of the magnet close to the north end of the suspended magnet.

4. What did the two north ends of the magnets do to one another? Did they attract or repel one another?

5. Evaluate the following student statement about the questions that you have just answered. Identify ideas that are consistent with your ideas and others that are not consistent with your ideas.

"The two north ends repelled one another. This is kind of like two positive charges repelling one another. Like poles must repel one another and unlike poles must attract one another."

Check your work with your teacher

The Challenge

You will investigate the direction of a magnetic field that exists around a magnetic object.

Your Ideas about the Challenge

6. How can two magnets affect one another if they aren't touching? How did we explain how charged bodies influence one another if they aren't touching?

At each lab station you should find the following:
one bar magnet, one lodestone, a magnetic compass

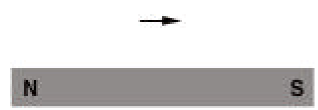
The Investigation

a. Lay the bar magnet in the center of the space on the bottom of this page.

b. Trace around the bar magnet. Label on your outline which end of the magnet is the north pole and which end is the south pole.

c. Place the compass on the paper at a position that is approximately 2 or 3 cm away from the magnet.

d. Remove the compass and draw a short arrow where the compass used to be. Draw this arrow in the direction that the needle of the compass was pointing.



e. Place the compass at a new location close to the magnet and repeat this process. Continue doing this until you have drawn at least 10 small arrows.

The "needle" in the compass that you used is really just a small magnet that is balanced on a pivot so that it is free to rotate. The small magnet in the compass will align itself with magnetic fields that are strong enough to cause the balanced-magnetic needle to rotate. The direction that the compass needle pointed was the direction of the magnetic field created by the permanent magnet.

7. Do you see a pattern to the way the magnetic compass aligned itself with respect to the bar magnet? If so describe the pattern.

8. Did the magnetic field go into or out of the north pole of the bar magnet?

9. Did the magnetic field go into or out of the south pole of the bar magnet?

10. What magnetic field does the magnetic compass usually align itself with when it is not in the presence of any magnetic sources?

11. What geographic direction does the magnetic compass point to when it is not influenced by any magnetic sources?

12. Evaluate the following student statements about the questions that you have just answered. Identify ideas that are consistent with your ideas and others that are not consistent with your ideas.

Student A

"Compasses always point north. The north pole of the earth must be like the north pole of a gigantic magnet."

Student B

"Our magnetic compass pointed into the south pole of our bar magnet. The earth's north pole must act like the south pole of a magnet."

Check your work with your teacher

Lodestones are natural magnets. They consist of magnetic iron oxide called magnetite.
Your instructor has suspended a lodestone from the end of a thread in your classroom.
This lodestone has been allowed to come to rest.
One end of lodestone points north.

13. Is the end of the lodestone that points north a north pole or a south pole? Explain how you know.

The Challenge

You will understand that moving electric charges (electric current) are the source of a magnetic field. You will also be able to determine the direction of the magnetic field created by electric current by using the right-hand rule.

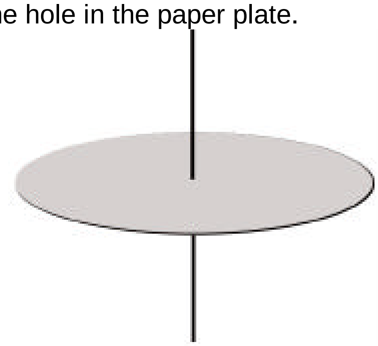
Your Ideas about the Challenge

14. What materials would you need to create electric current?

At each lab station you should find the following materials:
50 cm of wire, four D-cell batteries in series (6 volts), a paper plate with a hole, and four magnetic compasses

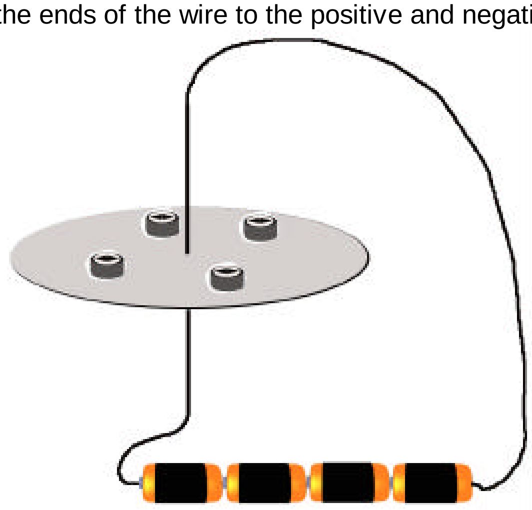
The Investigation

a. The wire should be threaded through the hole in the paper plate.



b. One student should support the plate so that the wire runs perpendicular through the hole of the plate in the vertical direction. The compasses should be placed on the plate so that they are relatively close to the wire, but not so close to each other so that they influence each other with their magnetism.

c. Another student should connect the ends of the wire to the positive and negative terminals of the batteries.

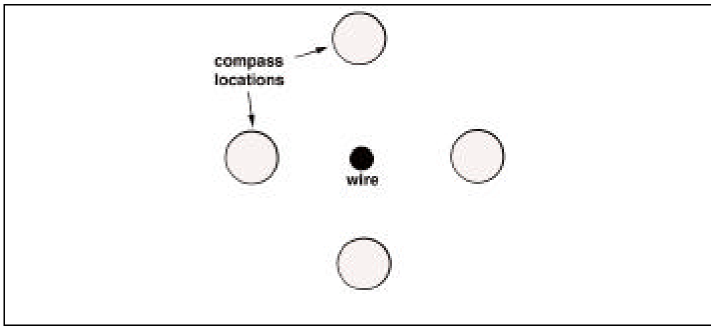


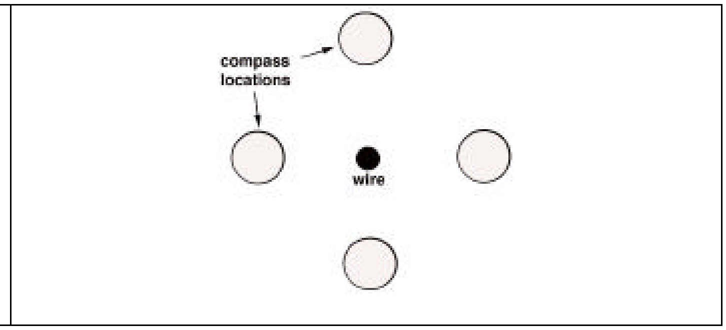
d. In the space that follows, draw an arrow in the direction that the compasses were pointing while current was flowing through the wire. The dot in the center of the diagram represents a cross section of the wire coming out of the paper.

e. Take note of which way the current was moving in the circuit that you created.

f. Reverse the direction of the current by switching the terminals of the battery. Draw an arrow in the direction that the compasses were pointing when you switched the direction of the current.

First compass pattern	**Second compass pattern (switched terminals)**





15. Was the current going up or down when you first created the electric current? Remember, current goes from the positive terminal of the batteries to the negative terminal.

16. Did the magnetic needles in the compasses move when the circuit was completed? If so, what do think was creating the magnetic field that made the compasses react as they did?

17. What happened to the direction of the compasses when you switched the current? Did they point in the same direction or did they point in a different direction?

18. Evaluate the following student statements about the questions that you have just answered. Identify ideas that are consistent with your ideas and others that are not consistent with your ideas.

<u>Student A</u>
"The copper wire must have acted like a magnet. I bet if we held a compass close to any copper wire that the compass would point at the wire."

<u>Student B</u>
"The compasses didn't move until we completed the electric circuit with the wire and the batteries. Also, the compasses didn't point towards or away from the wire. I think that it must be the electric current in the wire that creates the magnetic field."

19. Was there a pattern for the way that the compasses pointed when the current was flowing through the wire each time? If so, describe this pattern by drawing a picture.

20. Evaluate the following student statements about the questions that you have just answered. Identify ideas that are consistent with your ideas and others that are not consistent with your ideas.

<u>Student A</u>

"The compasses that were around the wire all seemed to point in a direction that was perpendicular to the wire. Magnetic fields around wires must form a square pattern."

Student B

"I think that if we had enough compasses around the wire we would have seen them pointing in a kind of circular pattern. I bet that magnetic fields form circles around electric current flowing through a wire."

Check your work with your teacher

Magnetism

***Name*______________________**

***Date*_______________________**

***Period*_____________________**

CONCEPT DEVELOPMENT

Moving electric charges create magnetic fields. Permanent magnets are made of substances that have atoms whose electrons orbit their nuclei in a particular way. In a permanent magnet the synchronized movement of these orbiting electrons generates a resulting magnetic field. The molecules of a permanent magnet also have their molecules (or atoms) aligned in such a way that their magnetic fields all add together.

Engagement Question

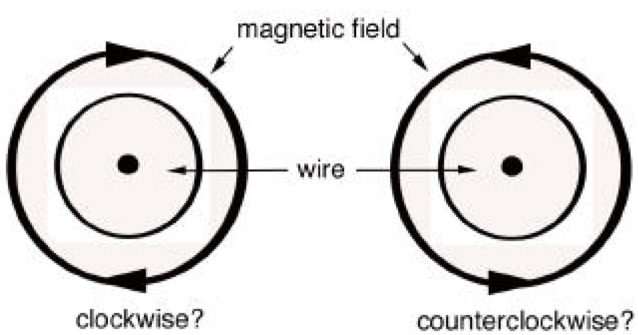
1. What is "flowing" in an electric current?

The electron "drift" that makes an electric current creates a magnetic field. Each electron is a moving charge that generates its own magnetic field. Since the electrons all move roughly in the same direction, their individual magnetic fields add together to create a detectable magnetic field.

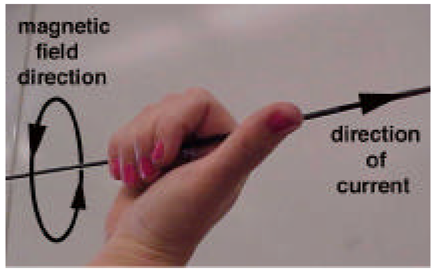
The diagrams shown below represent cross sections of two wires. The cross section on the left (with the dot in the center) represents a wire that has electric current that is flowing towards you out of the page. The cross section on the right (with the "x" in the center) represents a wire that has electric current that is flowing away from you (into the page). Remember that the direction for electric current is the opposite as the flow of the electrons. The electrons would actually be moving in the opposite direction as the electric current.

The magnetic field generated by electric current in a wire forms loops around the wire.

2. Do you think the magnetic field goes clockwise or counter-clockwise around the wire with the current coming out of the paper? Explain how you know.

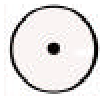


One way to determine the direction of the magnetic field that surrounds a current-carrying wire is to use the "right-hand rule". When you use the right-hand rule you should grab the wire (or imagine that you grab the wire) with your right hand so that your thumb points in the direction of the current. The direction that your fingers curl around the wire is the direction that the magnetic field lines go.



Another way to visualize this is to imagine that you are grabbing a wire that has electric current flowing out of this piece of paper.

3. If you grab the wire with your right hand, which way does the magnetic field circle the wire? Does it circle the wire in the clockwise direction or in the counterclockwise direction?



4. Evaluate the following student statements about the questions that you have just answered. Identify ideas that are consistent with your ideas and others that are not consistent with your ideas.

<u>Student A</u>

"When I imagined that I grabbed onto this wire with my thumb pointed out of the paper, my fingers curled around in the clockwise direction. The magnetic field lines must go clockwise around this wire."

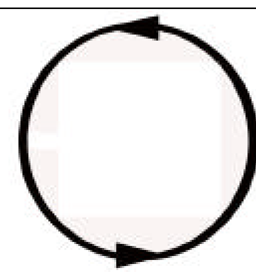
<u>Student B</u>

"When I imagined that I grabbed the wire, my fingers curled around counter-clockwise. I bet you "grabbed" the wire with your left hand. You're supposed to use your right hand. I bet that you could use your left hand if you're talking about the direction of electron flow."

Check your work with your teacher

A strong magnetic field can be created by bending a wire around in a spiral coil. When current flows through this coil the magnetic field of each loop of the coil will add together. To understand how this works we will first look at a single "loop" of wire.

Imagine that there is a loop of wire in which there is electric current flowing in the counter-clockwise direction. Also imagine that you were to "grab" this wire with your right hand so that your thumb pointed in the direction of the electric current.

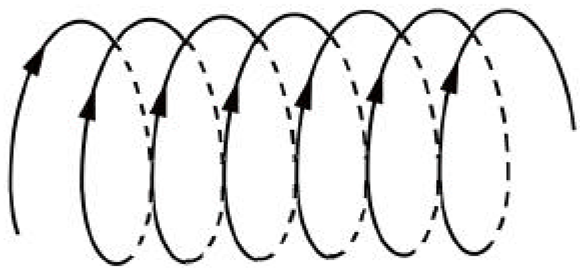
5. As your fingers "curled" around this wire, would they point into or out of this piece of paper at the point where they would intersect the plane of this piece of paper?	 counter-clockwise current

6. Does it matter where you grab the wire? Does the magnetic field point out of the paper at some locations and into the paper at others?

The magnetic field for each loop has the greatest intensity at the center of each loop. The magnetic fields of all the loops add together to create a strong magnetic field running through the center of the coil.

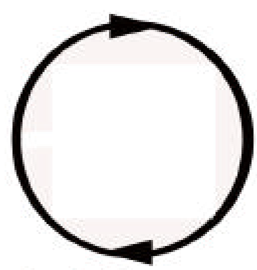
7. How would the number of loops in a coil be related to the strength of the magnetic field at the center of the coil? Would the strength of the magnetic field be directly proportional or inversely proportional to the number of loops in the coil? Explain your answer.

8. What do you think is the direction for the magnetic field at the center of the current-carrying coil pictured below? Is the magnetic field directed to the right or the left?



You can use another version of the right-hand rule to determine the direction of the magnetic field at the center of a coil. Imagine curling your fingers in the direction of the current (clockwise or counter-clockwise). The direction that your thumb points in is the direction of the magnetic field at the center of the coil.

Curl the fingers of your right hand in the direction of the current shown in the loop below.



clockwise current

9. Does your thumb point into or out of this piece of paper?

The Challenge

You will investigate how a changing magnetic field can generate electric current.

Your Ideas about the Challenge

10. How does your electrical "power" company generate electricity? Do they use giant batteries?

At each lab station you should find the following:
one bar magnet, one micro-ammeter, one coil, and two wires

The Investigation

a. Connect each end of the coil to one side of the micro-ammeter with the two wires as shown below.

b. Quickly insert the north pole of the bar magnet into one end of the coil and just as quickly pull it back out again.

c. Observe how the micro-ammeter behaves when you do this. Answer question 11 below.

d. Quickly insert the south pole of the bar magnet into one end of the coil and just as quickly pull it back out again.

e. Observe how the micro-ammeter behaves when you do this. Answer question 12 below.

11. Describe what the micro-ammeter did when you quickly pushed the north pole of the bar magnet into and out of the coil.

12. Describe what the micro-ammeter did when you quickly pushed the south pole of the bar magnet into and out of the coil. How did this differ from the behavior of the micro-ammeter when you inserted the north pole of the magnet into the coil?

13. Why do you think the needle on the micro-ammeter deflected as it did when you quickly pushed the bar magnet into and out of the coil?

14. Evaluate the following student statements about the questions that you have just answered. Identify ideas that are consistent with your ideas and others that are not consistent with your ideas.

<u>Student A</u>
"The magnet must have attracted and repelled the needle inside of the micro-ammeter due to magnetic attraction and repulsion."

<u>Student B</u>
"I think that you created a moving magnetic field which acted on the charges inside of the copper wire of the coil. This caused the charges to begin to move and it was this electric current that was detected by the micro-ammeter."

Check your work with your teacher

Magnetism **Name**____________________

Date____________________

Period____________________

CONCEPT REFINEMENT

It has been observed through experimentation that a moving electric charge will experience a force when it moves in a particular direction in the presence of a magnetic field.
The magnitude (size) of this force is directly proportional to the size of the charge (q), the velocity of the charge (v), and the strength of the magnetic field (B).

$$F\ ?\ qvB$$

The upper case letter "B" is the symbol that is traditionally used for the size of a magnetic field.

The size of the force due to the magnetic field is also directly proportional to sin ?, where ? is the angle between the velocity of the moving charge and the direction of the magnetic field.

1. At what angle, ?, would the force acting on a moving electric charge in a magnetic field be a maximum?

2. At what angle, ?, would the force acting on a moving electric charge in a magnetic field be a minimum?

One form of the equation that can be used to calculate the magnitude of the force experienced by a moving electric charge in a magnetic field is:

$$\mathbf{F = qvB\ sin\ ?}$$

?
We will only consider situations where the velocity of the moving charge is perpendicular (90^o) to the direction of the magnetic field. Since sin 90^o is equal to 1 our equation will reduce to the form:

$$\mathbf{F = qvB}$$

One unit that can be used to express the size of a magnetic field is called a Tesla (T). This unit was named in honor of Nikola Tesla who, among other things, was partially responsible for the use of alternating current for electrical power delivery systems.

3. Solve the abbreviated magnetic force equation (F = qvB) for the magnetic field (B).

4. Show the unit "breakdown" for a Tesla by substituting the units for the other concepts shown in the rearranged equation that you wrote above.

1 T =

The denominator in your unit breakdown expression can be rearranged $\frac{C}{s}\ ?\,m$. Since a Coulomb per second ($\frac{C}{s}$) is an Ampere (A) the denominator is usually expressed as A · m. Therefore a Tesla (T) is usually expressed as $1\frac{N}{A\,?\,m}$.

A +2C charged sphere is moving at 8 m/s towards the east in a uniform 6-T magnetic field that points straight up. The direction of the magnetic field is indicated by the dots in the diagram shown below. This indicates that the magnetic field is directed out of this piece of paper. The direction up would be coming out of this page.

5. Calculate the magnitude of the force that acts on the moving +2C charge as it moves at 8 m/s in the 6-T magnetic field. Be sure to show your calculations and to label your answer with appropriate units.

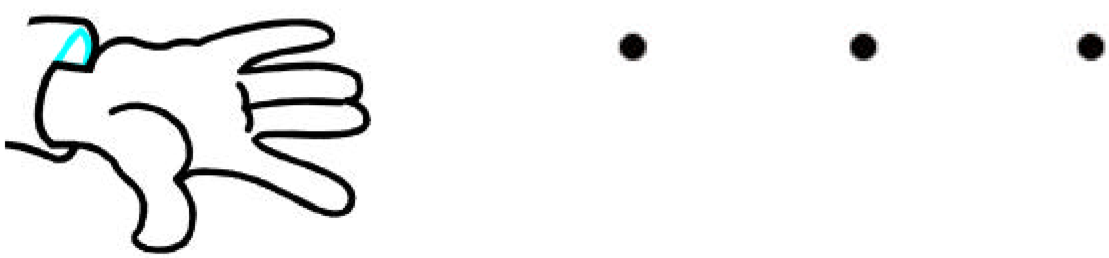
6. What do you think is the direction for the force that acts on the moving charge described in this problem?

The direction of the force that acts on a moving charge in a perpendicular magnetic field is perpendicular to both the velocity of the charge as well as the magnetic field.

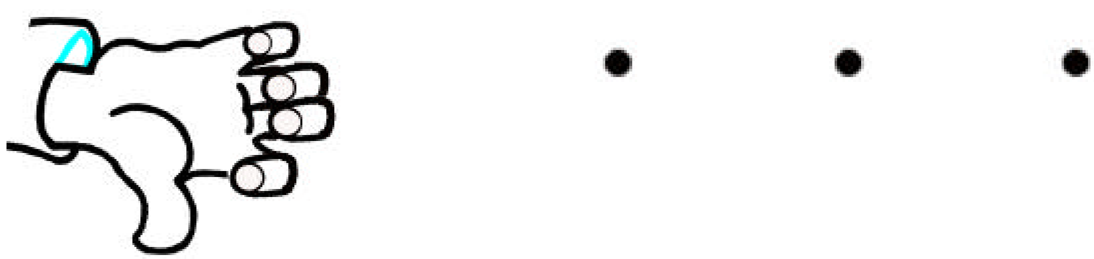
7. What is the maximum number of lines that can be drawn through a single point that are all perpendicular to one another?

You can use another variation of the right-hand rule to determine the direction of the force that acts on a moving charge in a perpendicular magnetic field.

You should begin by pointing the fingers of your right hand in the direction of the velocity of the moving positive charge. If the charge is negative you could use your left hand.



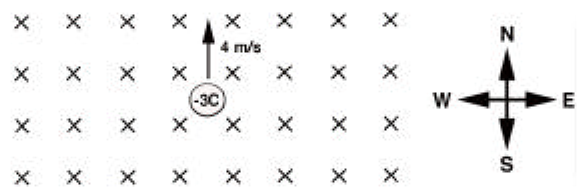
You should then rotate your hand so that you can "curl" your fingers in the direction of the magnetic field. You will have to orient your right hand as you see in the diagram above in order to do this.



The direction that your thumb points in is the direction of the force.

8. What must be the direction of the force acting on the moving charge described in the preceding problems?

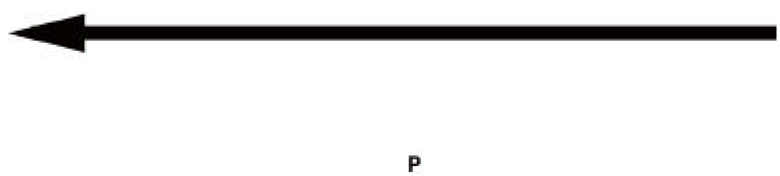
A –3 C charged sphere is moving directly north at 4 m/s in a uniform 5-T magnetic field that is directed straight down. The direction of the magnetic field is indicated by the x's in the diagram seen below.



9. Calculate the magnitude of the force that acts upon the negative charge as it moves at 4 m/s in the 5-T magnetic field. Hint: don't use the polarity of the charge (negative) in your calculations. You should express your answer as a positive force. Be sure to show all of your calculations and to label your answer with appropriate units.

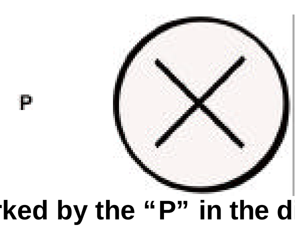
10. What is the direction of the force that you calculated in the previous problem? Hint: should you use your right hand or your left hand to determine the direction of this force acting on the negative charge?

A horizontal wire has electric current flowing to the left.



11. What is the direction of the magnetic field at the position marked by an "P" in the diagram above?

A wire that is perpendicular to this piece of paper has electric current flowing into the page.



12. What is the direction of the magnetic field at the position marked by the "P" in the diagram above?