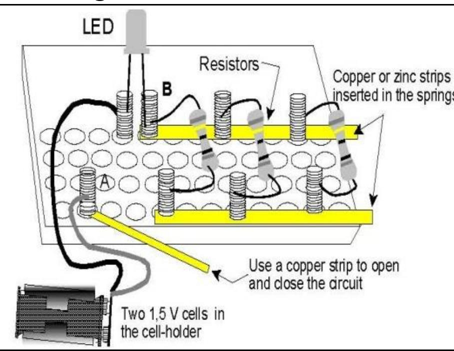
**EXPERIMENT 13 – THE INVESTIGATION**
CSEC OBJECTIVE (S): Section D – Objectives 4.1-4.5

Grade Level - 9

**What you need**
micro-electricity kit, two multimeters

**What to do**
**TO INVESTIGATE**
1. Use components from your microelectricity kit to set up the circuit shown in the diagram on the right.
   You may remove (or add) resistors to this circuit as you work through the tasks.

**Task 1** Investigate what happens to:
a) the total current in the circuit, when a different number of resistors are connected in parallel and
b) the current in each resistor connected in the circuit.




**Task 2** Investigate what happens to:
a) the potential difference supplied by the source of power and
b) the potential difference across each resistor connected in the circuit.

**Task 3** Investigate what happens to the total resistance (V/I), in the circuit, as you add more resistors in parallel.
Record your measurements and observations.

**SUMMARISE**
2. Summarise what have you discovered in this Activity, about
a) the current in a parallel circuit,
b) the potential difference across components in a parallel circuit and
c) the total resistance of a parallel circuit.

**COMPARE SERIES AND PARALLEL CIRCUITS**
3.
a) Compare the current in a parallel and in a series circuit and explain the differences.
b) Compare the potential difference across components in a parallel and in a series circuit.
c) Compare the total resistance in a parallel and in a series circuit.
d) What happens when you remove one component from either a series or a parallel circuit? Explain.

## EXPERIMENT 14 – POTENTIAL DIFFERENCE ACROSS POINTS IN A SERIES CIRCUIT

CSEC OBJECTIVE (S): Section D – Objective3.2

Grade Level – 9

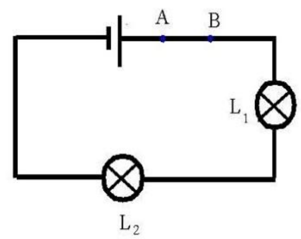
A relationship exists between the potential difference across a series circuit and the potential differences across each of the circuit's components. In this Activity you will use your micro-electricity kits to investigate the relationship between the potential difference across a series circuit and the potential differences across each component of the circuit.

**What you need**

a basic micro-electricity kit, a voltmeter, 3 V battery

**What to do**

1. Use the diagram given and set up the circuit.
2. Connect the voltmeter across the battery and take a reading.
3. Connect the voltmeter across two points A and B in the circuit and take a reading.
4. Connect the voltmeter across light bulb $L_1$ and take a reading, and then across $L_2$ and take a reading. (You will need to work fast because the potential differences can start changing.)
5. Draw up a table and record your results.




**What to discuss**

1. Discuss the voltmeter reading you got across the two points A and B in the circuit.
2. You should be able to recognise a relationship between the potential difference across the circuit which we call $V_{circuit}$, and the potential differences, $V_1$ and $V_2$ across the light bulbs, $L_1$ and $L_2$.
   Write this relationship in words, and then use the potential difference symbols given to write the relationship in an equation form.
3. If the emf of your battery was 3 V explain why the potential difference reading across the battery was less than 3 V.
4. Explain why resistors, in this example, the light bulbs, are sometimes called "potential dividers".
5. The symbols for the current in each of the light bulbs, $L_1$ and $L_2$, are $I_1$ and $I_2$. Give an equation that represents the relationship between the current ($I_{circuit}$) in the circuit and the currents $I_1$ and $I_2$ in the light bulbs.

**PREDICT & EXPLAIN**

6. Predict what will happen to the potential difference of the circuit and the potential difference across $L_1$ and $L_2$, when you connect a third light bulb, $L_3$, in series in the circuit. Give reasons for your prediction.
7. Predict what will happen to the potential difference of the circuit and the potential difference across $L_1$ if you remove $L_2$ from the circuit. Give reasons for your prediction.
8. Set up the new circuits and test your predictions.

## EXPERIMENT 15 – POTENTIAL DIFFERENCE ACROSS POINTS IN A PARALLEL CIRCUIT

CSEC OBJECTIVE (S): Section D – Objective 3.2

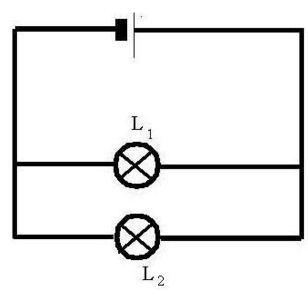
Grade Level – 9

A relationship exists between the potential difference across a parallel circuit and the potential differences across each of the circuit's components which are in parallel.
In this Activity you will use your micro-electricity kits to investigate the relationship between the potential difference across a parallel circuit and the potential differences across the circuit's parallel components.

**What you need**

a basic micro-electricity kit, a voltmeter, 3 V battery

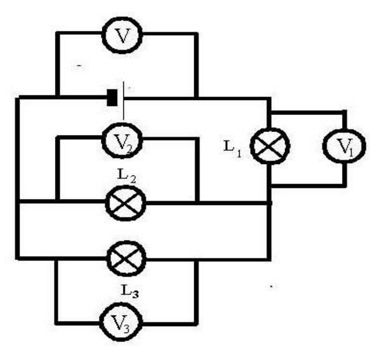
**What to do**




1. Set up a parallel circuit using the given diagram.
2. Connect the voltmeter across the battery and take a reading.
3. Connect the voltmeter across light bulb $L_1$ and take a reading, and then across the other light bulb $L_2$ and take a reading. (You will need to work fast because the potential differences can start changing.)
4. Draw up a table and record your results.
5. The circuit diagram given to you did not include the voltmeter. Draw three circuit diagrams to show the position of the voltmeter when it was connected across the battery, $L_1$ and $L_2$.

**What to discuss**

1. Discuss the relationship between the potential difference across the battery which we call $V_{circuit}$, and the potential differences across each of the two parallel light bulbs, $V_1$ and $V_2$. Write down the relationship in words and then as an equation using the symbols given.
2. The symbols for the current in each of the light bulbs, $L_1$ and $L_2$, are $I_1$ and $I_2$. Give an equation that represents the relationship between the current in the circuit ($I_{circuit}$) and the currents $I_1$ and $I_2$.
3. You were given a warning to work fast during your investigations because the potential difference readings can change. What factor/s could cause the change in the potential difference values?
4. Consider the series-parallel circuit given on the right. Use the V symbols given in the diagram to write an equation which represents the relationship of the potential difference across a series-parallel circuit and the potential differences of the circuit components.
5. The symbols for the current in each of the light bulbs, $L_1$, $L_2$ and $L_3$ are $I_1$, $I_2$ and $I_3$. Give an equation that represents the relationship between the current of the circuit ($I_{circuit}$) and the currents $I_1$, $I_2$ and $I_3$.

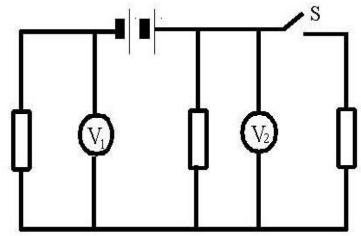



**HOMEWORK**

Here are some multiple choice questions which come from old matric exam papers. Choose a correct answer and then explain why you chose that answer.

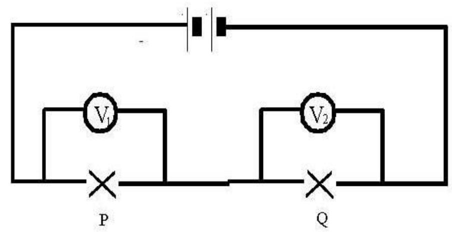
1. The internal resistance of the source of emf in the following circuit is negligible:

| | $V_1$ | $V_2$ |
|---|---|---|
| A | decrease | decrease |
| B | increase | decrease |
| C | decrease | increase |
| D | no change | no change |



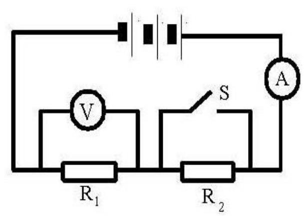

2. Two identical light bulbs, P and Q, are connected in series to a battery of negligible internal resistance. $V_1$ and $V_2$ are identical voltmeters. If bulb P blows (because the filament breaks), how will the readings on $V_1$ and $V_2$ respectively change?

| | $V_1$ | $V_2$ |
|---|---|---|
| A | increases | becomes zero |
| B | becomes zero | increases |
| C | becomes zero | becomes zero |
| D | remains the same | remains the same |




3. In the circuit shown, the internal resistance of the battery is negligible. What will be the effect on the voltmeter reading (V) and on the ammeter reading (A), if switch S is closed?

| | V | A |
|---|---|---|
| A | increases | increases |
| B | increases | stays the same |
| C | stays the same | increases |
| D | stays the same | stays the same |



**EXPERIMENT 16 – OHM'S LAW**

CSEC OBJECTIVE (S): Section D – Objectives 4.7- 4.9

Grade Level – 9

Many years ago a famous German physicist, Georg Simon Ohm (1787-1854), discovered the relationship between the current in a wire and the potential difference across the ends of the wire. When this relationship is expressed as
a ratio,

$$\frac{\text{potential difference}}{\text{current}}$$

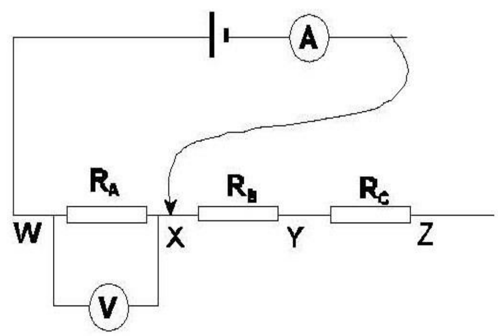
the ratio value is always the same. Because the ratio is constant it can be written as an equation. This constant is equal to the **resistance** (R) of the wire. This is known as **Ohm's law**.

**To discuss before you start**

$$\textit{resistance} = \frac{\textit{potential difference}}{\textit{current}} \qquad R = \frac{V}{I}$$

Work with the other members of your group to discuss the following:

1. How are we changing the current in this circuit?
2. Across which points is the potential difference being measured?
3. Ohm's Law applies to a given conductor only when the temperature of the conductor remains constant. How can we keep the temperature of the resistor constant? Is it in fact necessary? Explain.
4. In this Activity, which is the independent variable, the current or the potential difference? Explain.
5. Plan a table in which to record your readings.




**What you need:** a basic micro-electricity kit and 2 multimeters.

**What to do**

1. Set up the circuit using the micro-electricity kit as shown in the diagram..
2. Join W to the positive terminal of your battery.
3. Join the negative terminal of the battery to the ammeter at V.
4. Move the free lead on the ammeter from X to Y to Z in turn. Read the potential difference across $R_A$ and the current in $R_A$ each time.
5. Plot a graph which you can use to find the resistance (in ohms) of $R_A$ between W and X on the graph paper supplied.
6. Use the coloured bands on $R_A$ and the guidelines and the table next page to work out the resistance of $R_A$.
   How does this compare with the resistance you measured from your graph?
7. Use the multimeter as an ohmmeter to measure the resistance of $R_A$. How does this confirm with the resistance you measured from the graph?

## HOW TO USE THE COLOURS ON YOUR RESISTOR TO WORK OUT ITS RESISTANCE (IN OHMS)


Your resistor is likely to show FOUR bands which may or may not be of different colours. The first three bands tell you what the resistance of your resistor is in ohms. The fourth band tells you how accurate this resistance is.

The GOLD or SILVER band tells us the **accuracy** to which the resistor was made.

If the resistor has a **gold** band, the accuracy is 5%. If the resistor has (according to the colours on the first three bands) a resistance of 20 Σ, then, its resistance will vary from 19 Σ, to 21 Σ,. If the resistor's colour code tells us that it has a resistance of 20 Σ with a **silver** band, its resistance will be in the range from 18 Σ to 22 Σ.

The table below shows the numerical values for each of the colours.

| | | | | | |
|---|---|---|---|---|---|
| | 0 | black | 5 | green | |
| | 1 | brown | 6 | blue | |
| | 2 | red | 7 | violet | |
| | 3 | orange | 8 | grey | |
| | 4 | yellow | 9 | white | |

The colour of the FIRST band gives you a number which you can read from the table. The colour of the SECOND band gives you a colour which you can read from the table. The colour of the THIRD band tells you how many zeros (0's) there are after the first two numbers. Use the table to work out the resistance (in ohms) of the resistor in the diagram above. (It is 27 000 Σ.)

## EXPERIMENT 17 – SOLENOIDS & ELECTROMAGNETS

CSEC OBJECTIVE (S): Section D – Objectives 6.5 - 6.7

Grade Level - 10

A long coil of wire, consisting of many loops of wire, is called a **solenoid**. The magnetic field inside the solenoid can be very large, since it is the sum of the fields due to the current in each loop. The solenoid acts like a magnet with north and south poles!

If we put a piece of iron inside the solenoid, the magnetic field increases even more, in fact, a lot more! This is because the piece of iron becomes a magnet itself, and its magnetic field adds to the field of the solenoid. The result? A much stronger magnet, which is called an **electromagnet**.

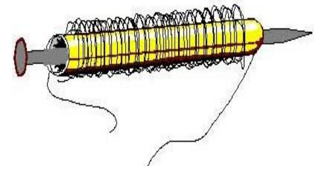
Electromagnets are used widely in industry and in science, when we need strong magnetic fields. They are used in motors (as you will see in a later Activity), in the generators of the power stations, in the scrap-yards to lift up cars, they are even used in simple devices at homes, like in loudspeakers, in electric bells, in some kinds of switches, and in many other practical applications. There are important advantages in using electromagnets instead of permanent magnets. You will discuss some of these advantages, in this Activity

**You need**: micro-electricity kit, a bar magnet (optional), a few steel pins

**JOE'S AUNTY HAS A PROBLEM**

Joe's aunty Lindiwe is a very busy dressmaker. She has lots of magnets. She needs the magnets to pick up her pins off the floor. But all her magnets are covered in pins. It is such a problem removing the pins from the magnets as she keeps on pricking her fingers!

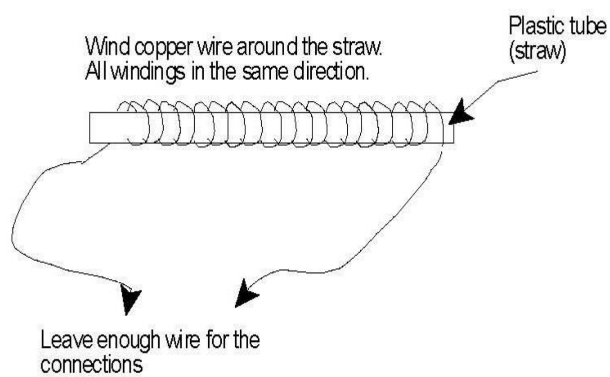
Joe tries to help her to do something about it. He shows her an electromagnet a friend of his made at school with his micro-electricity equipment. "Aunty you need something like this! This is a revolutionary device my friend has made. Once you try it you will never look back!"



But his aunty cannot believe that this device is a magnet. "My dear, this is not a magnet! Look, it doesn't stick on the fridge! You've been fooled!" she tells Joe. And Joe does not know what to say, surely his friend was not lying!

**THE INVESTIGATION**

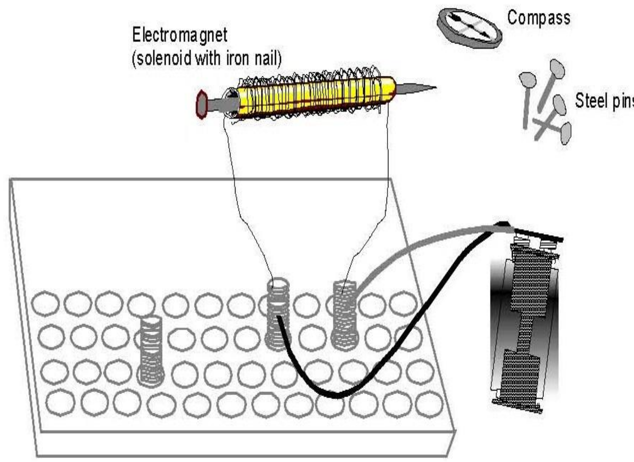
Joe wants to convince his aunty Lindiwe, that the electromagnet is indeed a magnet. The truth is, that he does not really know how, because he does not know how an electromagnet works. Your task is to explain to Joe how an electromagnet works, and why it is a magnet. You will use your micro-electricity kits to aid you in your explanation. At the end of this Activity, your report back to the class will be in the form of a role play. One of the learners in your group will be Joe. Joe is full of questions and wants to understand everything. He asks questions, like, "how do you know this?" and "can you prove this to me?" and "why does this and that happen?", etc. The rest of the group will take turns to answer Joe's questions, using the micro-kit equipment or diagrams.



**Remember: Close your circuit only when you want to observe something, or else you will "run down" your cells!**

Here are some steps you could include in your investigation:

X Start by making an electromagnet using components from your microelectricity kit, like the one shown in the text. (Remember to always coil the wire in the same direction.)




- Find and identify the poles of your electromagnet.
- Compare the magnetic field of your electromagnet with that of a permanent bar magnet.
- Investigate the role of the iron nail, the core of your electromagnet.
- Investigate ways to change the "strength" of your electromagnet.
- Think of the advantages and disadvantages of your electromagnet in comparison to a bar magnet.
- Are there any major differences between a permanent bar magnet and an electromagnet?

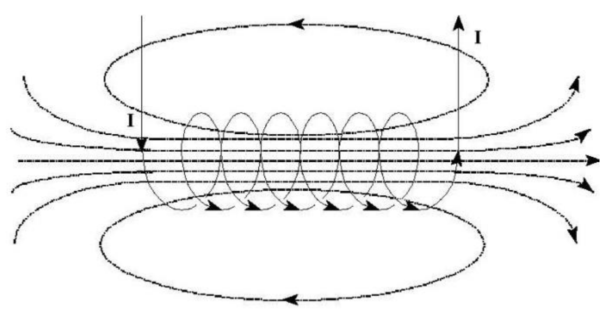
You must be prepared to explain the steps of your investigation to Joe. Explain what you do in each step. Is it true that Joe's aunty will stop pricking her fingers, if she uses an electromagnet? You must be able to explain the reason why. In conclusion, what must Joe do to make an electromagnet that will pick up lots of pins? Suggest the right materials he must use.

**EXTENSION QUESTIONS**

1. Suppose you have three iron rods, two of which are magnetised but the third is not. How would you determine which two are the magnets without using any additional objects?
2. What do you understand by the terms:

a) Coil b) solenoid c) electromagnet d) soft iron

3. Explain how the presence of a soft iron core affects the resulting magnetic field.
4. The figure alongside shows the magnetic field around a solenoid.




a) Find the north and south poles of the solenoid.

b) There is another hand rule to determine the location of the north pole of a solenoid (or electromagnet) in general cases. See if you can make it up yourselves.

5. Solenoids and electromagnets are widely used. You may go to the library to find some applications in which solenoids or electromagnets are used.

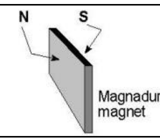
Each group chooses a device to study and describes to the other groups in class how this device works.

**EXPERIMENT 18 – FEDERAL BUREAU of INVESTIGATIONS, FBI**
CSEC OBJECTIVE (S): Section D – Objectives 7.4 -7.7

Grade Level - 10

Only a magnetic field can deflect a magnetic compass needle. You saw earlier, that a compass deflects when placed near a current carrying wire. This proves that electric currents produce magnetic fields.
In nature, forces come in pairs. We call the one force the force of action, and the other force, the force of reaction (action - reaction pair). If an electric current can exert a force on a compass needle, could the opposite be true?
Could a magnetic field exert a force on a current carrying wire? This is what you are going to investigate in this Activity.

**What you need**
micro-electricity kit, steel-wool, two magnadur magnets



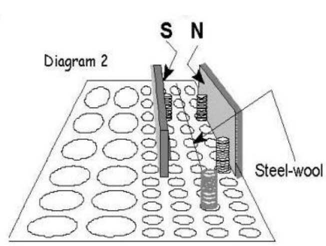

**What to do**
Work as a group. Prepare one set-up per group, and combine your components when necessary.

1. One face of a magnadur magnet is a north pole, the other face is a south. Discuss with your group, and find a way to identify the north and south poles of your magnets. Mark their faces with N or S symbols. Explain how you will identify the poles.
2. Pull about five strands (about 10 cm long) from the steel-wool. Twist this piece, as if it was a piece of wool, to make it as thin as a connecting wire.
3. Connect the steel-wool between the springs marked A and B, see diagram 1.

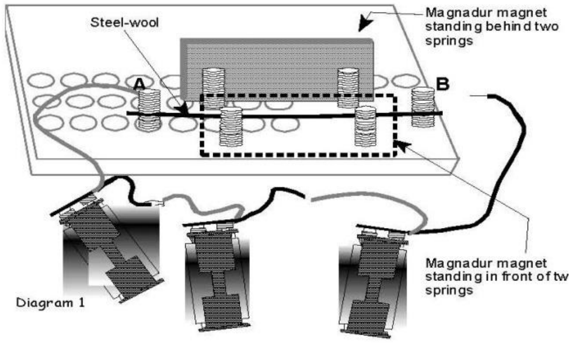


4. Use two magnadur magnets and micro-electricity equipment to set up the rest of the components, as shown in diagram 1.

Place the two magnets on the comboplate, as shown in diagram 2.
Do not complete the circuit yet! (i.e. do not touch spring B with the black wire.)




NOTE 1: The magnets are placed so that opposite poles face each other.

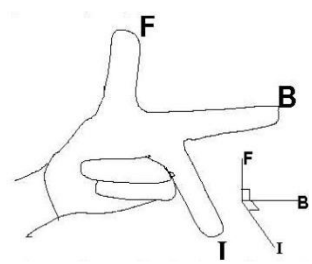



**PREDICT**

5. Draw a circuit diagram of the circuit shown in diagram 1.
a) On the circuit diagram, indicate the direction of the electric current in the steel-wool wire, when the circuit is complete.
b) On the circuit diagram, indicate the direction of the magnetic field produced by the magnets.
c) Compare the directions of the electric current and magnetic field.
6. Predict what will happen, if you complete the circuit in diagram 1. Explain what and why.
If you reverse the current in the steel-wool wire, what do you expect to change?

**WHAT HAPPENS?**

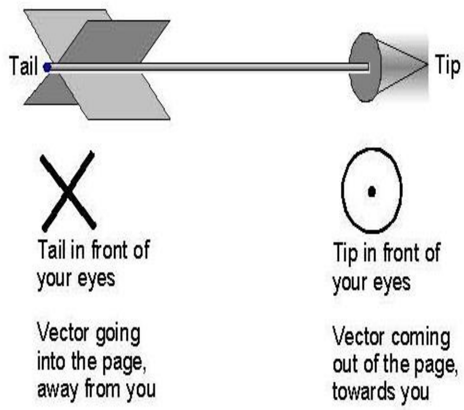
7. Complete the circuit in diagram 1, by touching the black wire on spring B for a second. Look carefully at the steel-wool wire. Repeat if necessary, always touching spring B for no more than a second.
Repeat by reversing the current in the steel-wool wire. How will you do this?
Repeat by reversing the magnetic field. How will you do this?
Each time, record the direction of the magnetic field B, the direction of the current I, and the behaviour of the steel-wool wire.
Note 1: If the cells become warm, let them cool down for a couple of minutes before you continue.
Note 2: If you touch the connecting wire to the steel-wool, there will be sparks. Not really dangerous, but better play it safe! If you insist on seeing sparks, touch the protruding piece of steel-wool on the right of spring B.
8. Because the three quantities you are dealing with, i.e. force on wire, F, magnetic field, B, electric current in the wire, I , have all a direction, it is wise to apply a "trick" to make your lives easier. The "trick" is called **The Left Hand Rule**, also known as the **FBI rule**. This is the FBI rule, shown on the right:




Apply the FBI rule in what you did in this experiment. Do your observations agree with this rule? Explain.
9. Prepare a group report to summarise what you did in this Activity, what you have investigated and what you have discovered.

**EXTENSION QUESTIONS - THE CHALLENGE!**

We represent a quantity which has a direction, with an arrow, to show its direction. (Such quantities are called "vectors").
The diagram on the left shows an arrow complete with tip and tail.

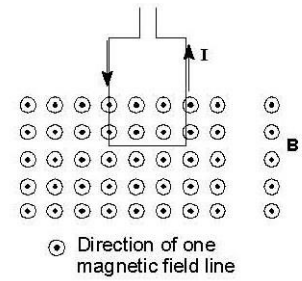



When you hold the tip of the arrow straight in front of your eyes, you only see a circle with a dot in the middle.

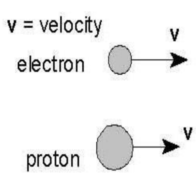
When you hold the tail of the arrow in front of your eyes, you only see an "X".

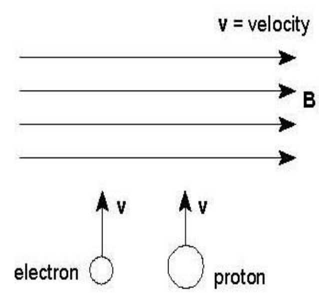
The symbols shown in the left diagram, are very useful when we draw vectors in three dimensions, like in some of the following examples.

1. A horseshoe magnet is held vertically with the north pole on the left and south pole on the right. A wire passing perpendicularly between the poles carries a current directly away from you.
   a) In what direction is the force on the wire?
   b) Draw a diagram to show directions of magnetic field, electric current and force on wire.




2. The figure alongside shows a current carrying rectangular loop of wire. The loop is suspended vertically by a spring and is partially inserted in the region of a uniform magnetic field.
   Find the direction of the force acting on each side of the loop. How will the loop behave?
3. How about freely moving electric charges? Are they electric currents? A proton has a positive electric charge. An electron has a negative electric charge. When we say "electric current", we mean the conventional current, which is the flow rate of positive charge.
   a) In the left diagram, draw the directions of the electric current of the moving electron and of the moving proton.
   b) The diagram on the right, shows an electron and a proton moving in the region of a magnetic field, at right angles to the field.




Are they going to experience a force as they enter the field? If yes, use the FBI rule to find the direction of this force in each case.

## EXPERIMENT 19 – COMING ATTRACTION

CSEC OBJECTIVE (S): Section D – Objective 7.4

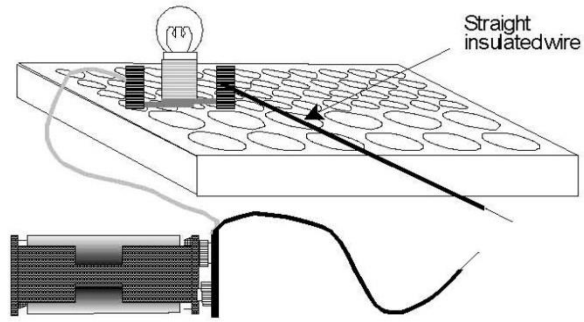
Grade Level - 10

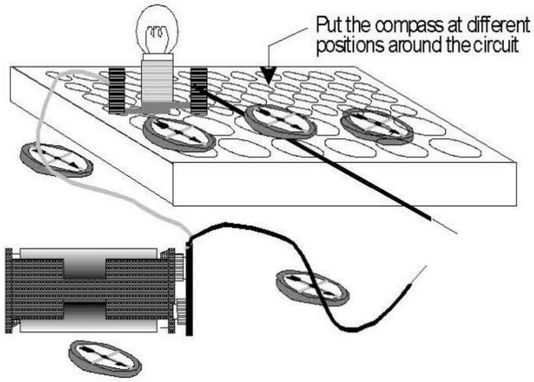
**What you need**

your micro-electricity kit

**What to do**

1. Prepare a circuit, as shown in the diagram on the right. Use a 3 V battery. Do not connect the bare ends of the insulated wires yet!
2. Put the magnetic compass at different positions around the wires and the other components of the circuit. The diagram below gives some examples of where to put the compass.



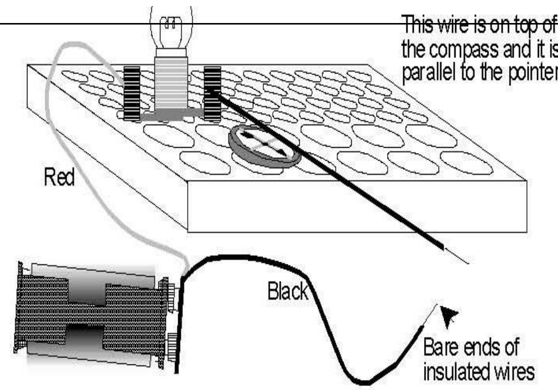



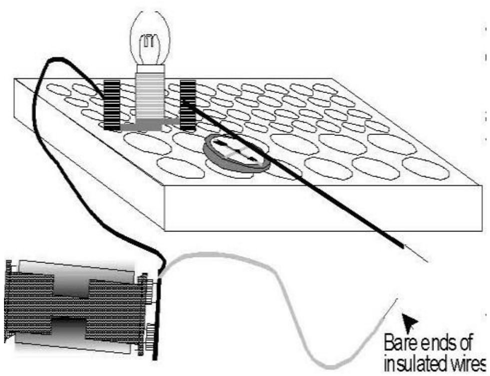

At each new position of the compass, wait until the pointer stops shaking, and then touch the bare ends of the insulated wires. Complete the table below with your observations.

| Position of magnetic compass | Observations |
|---|---|
| On top of (black) negative wire | |
| Under negative wire | |
| Next to negative wire | |
| On top of (red) positive wire | |
| Under positive wire | |
| Next to positive wire | |
| On top of the bulb | |

| | |
|---|---|
| Next to bulb | |
| On top of the battery | |
| Next to battery | |
| Other (specify) | |

3. Put the magnetic compass under the straight black insulated wire, as in the diagram on the right.
   Note that the straight black insulated wire is on top and parallel to the pointer of the compass. (You might have to turn the whole comboplate until you achieve this orientation.)




Connect the bare ends of the insulated wires and look at the pointer of the compass. Record what happens.

4. Now reverse the wires from the battery as in the diagram on the left.
   a) Before you close the circuit, predict which one of the following will happen to the pointer. Explain your prediction to the others in the group.
      I. the pointer will not deflect this time
      II. the pointer will deflect the same as in 3
      III. the pointer will deflect in the opposite direction of that in 3
   b) Connect the bare ends of the insulated wires and look at the pointer of the compass. Record what happens.
      Compare your observations with 3.

**What to discuss**

1. a) In which positions around the circuit did the pointer of the magnetic compass deflect the most?
   b) In which positions did you not notice a deflection?
   c) When the circuit was incomplete, that is, when you did not touch the bare ends of the wires, did you see any deflection of the compass pointer at any position?
2. What would be the difference in your observations, if you were to use the 9 V battery instead of the 3V battery? You may try it.
3. In general, what deflects a magnetic compass?
4. What causes the magnetic compass to deflect in this Activity?
5. In conclusion, as far as you saw in this Activity, what is the connection between an electric current and magnetism? Discuss with your group and write it down. The spokesperson of your group will present it to the rest of the class.

**EXPERIMENT 20 – FIELDING**

CSEC OBJECTIVE (S): Section D – Objective 7.5

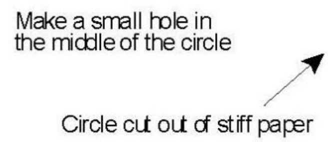
Grade Level - 10

**What you need**

your micro-electricity kit

stiff paper, toilet paper roll, a pair of scissors,

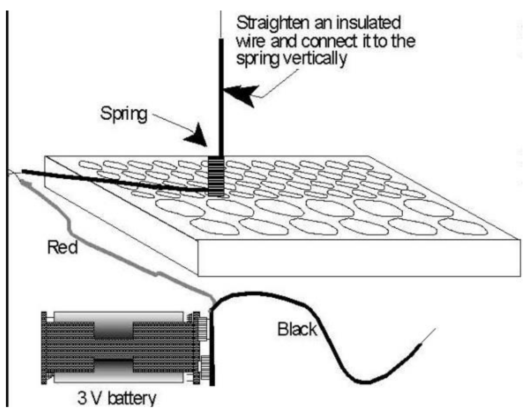
two different colour pens (for example blue and red)



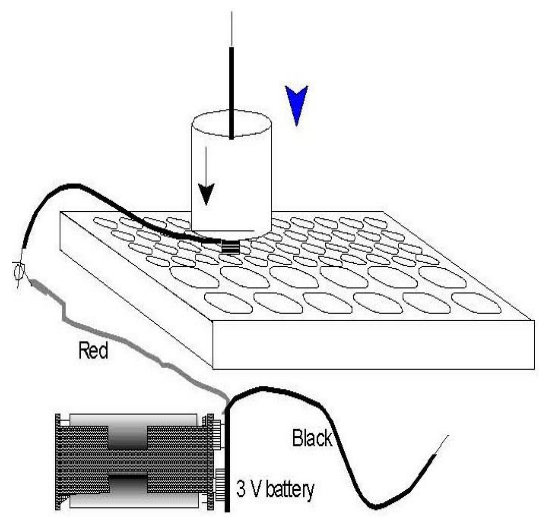

**What to do**

Work in pairs.

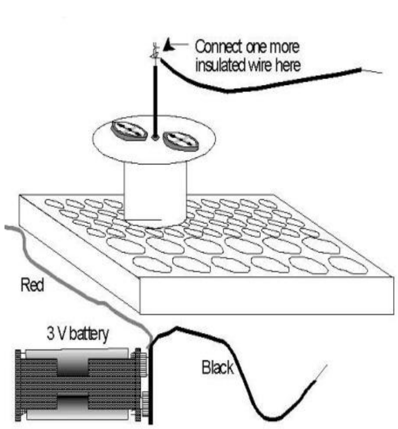
1. Cut a circle out of stiff paper. Cut the toilet paper roll in half (see diagram above right.)




2. Set up your components, as shown in the diagram on the left. Use a 3 V battery.
Do not connect the bare ends of the insulated wires yet!
3. Put the toilet paper roll and paper circle over the vertical wire, as shown in the diagram below right.

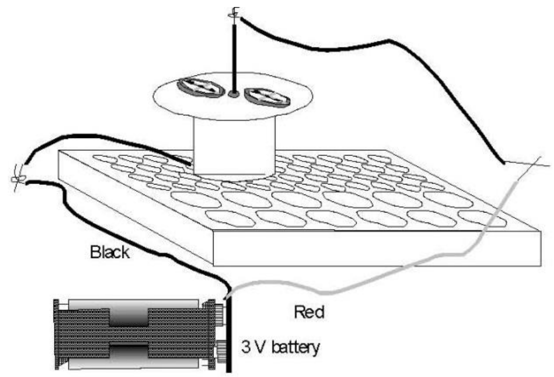



4. Connect another insulated wire to the top of the vertical wire.
Rest two magnetic compasses on the circle of stiff paper on opposite sides of the vertical wire, as in the d diagram below.
Where do the pointers of the compasses point to?




5. Now touch the free bare ends of the insulated wires for two seconds. Look at the compass pointers.
   a) What do you see?
   b) Use the blue pen to draw an arrow on the circle, to show the direction in which the tips of the pointers move.
6. Change the position of the compasses on the circle to another position. For each new position, repeat step 5.
7. Record the direction of the current in the vertical wire.

8. What do you expect to happen if you swop the red and black wires of the battery, as in the diagram alongside?
9. Now connect the battery as in the diagram. Repeat steps 5, 6 and 7. Use a different colour pen to mark the arrows on the circle.

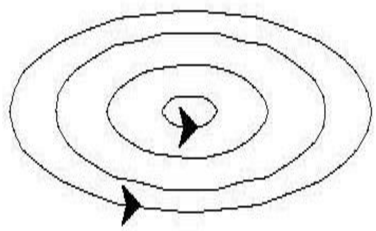


**What to discuss**

Maria reads in her textbook, that:

"The magnetic field around a current carrying wire is "pictured" with concentric circles (i.e. with a common centre), around the wire. These circles are closed loops."

The textbook shows this diagram on the left.

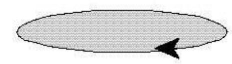


1. From what you saw in this Activity, is this diagram correct? Explain to the others in your group.

Maria's textbook also says that:

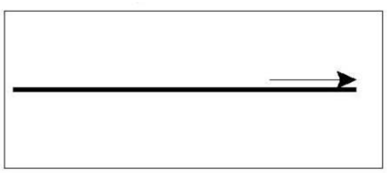
"If you hold the current carrying wire with your right hand, with your thumb pointing in the direction of the current, then the rest of your fingers show the direction of the magnetic field."

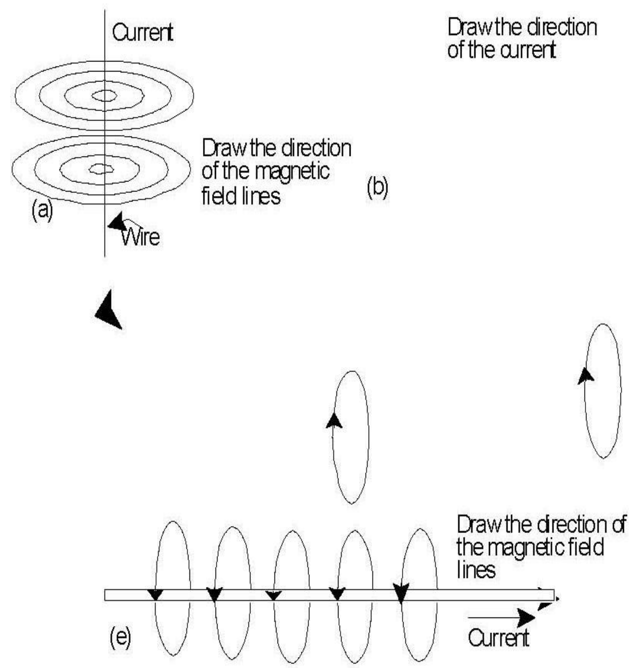
This is called the **right hand rule**.



The diagram on the right shows how this rule works.

2. Use the right hand rule, and complete the diagrams shown below right.
3. The diagram below, shows a current carrying wire. Sipho puts a paper under the wire. He then puts a magnetic compass next to the wire, as shown on the diagram. What will the direction of the pointer be?






4. In the last two Activities, you saw that an electric current has a magnetic effect.
   a) What is this effect?
   b) Do you think that this effect is important, or that it could be of any use?