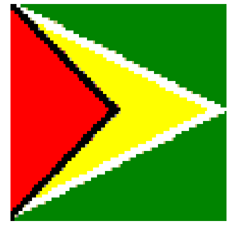
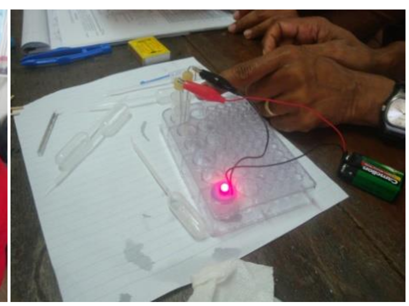


Microscience Manual

Physics Students' Manual

(DRAFT)

First Guyana Version Adaptation of Teaching and Learning Materials on Microscience Experiments



United Nations
Educational, Scientific and
Cultural Organization

Funded by UNESCO in collaboration with the Ministry of Education and the University of Guyana

Contents

The Ministry of Education wishes to acknowledge the team of participants in the consultations for the selection of the Microscience Experiments relevant to the national curriculum for Biology, Chemistry and Physics.

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Introduction to the first Guyana version adaptation of UNESCO teaching and learning materials on micro science experiments

The contents of this document are recommended by the participants of UNESCO/Kingston/Ministry of Education, NCERD consultations on Micro-Science Experiments held in Georgetown (Guyana) on 27-30 June, 2011. The present materials correspond fully to the existing National Curriculum for teaching basic sciences at the different levels. The materials were selected by the participants of the working consultations. The participants worked with teaching and learning packages on microscience experiments which are available on UNESCO's website and are free for all types of adaptations and modifications. The different types of microscience kits donated by UNESCO/Kingston Office to Guyana can be used in practical classes. The experiments are classified according to grades and some were given first priority (refer to appendix 1). The 'priority one' experiments are recommended for the pilot of the microscience experiments. It is very clear that, new experiments can be developed and tested using the same kit, as proposed by the participants of the working consultations which included curriculum development specialists. Developing new materials can be recommended, as a second stage of the project development. It is noted that the microscience experiments, as a new methodology for hands on laboratory work by students, can work in conjunction with macroscience experiments. Furthermore the microscience kits can be used by teachers for demonstration purposes. We hope, that the Science Teachers in Guyana will find the microscience experiments methodology and teaching and learning materials, interesting and of great value for the enhancement of science education.

Participants of the working consultations

May 2012

EXPERIMENT 1 – GET TO KNOW YOUR MICRO-ELECTRICITY KIT

CSEC OBJECTIVE (S): Section E – Objectives 4.1-4.4

Grade Level - 9

Nowadays everything is going "micro", which of course means "small". This micro fever, ranges from computers and Hi-Tech equipment to laboratory equipment. Micro-things become more and more affordable, they are easy to carry and easy to store.

In schools all over the world, micro-equipment invades the classrooms and changes the way of teaching and learning. Work with your micro-electricity kit and you will find out why.

What you need

micro-electricity kit, an A4 sheet of white paper

WHY DO WE USE ELECTRIC CIRCUITS?

1 We use electric circuits to transfer electrical energy to various electrical devices. These devices transform the electrical energy into other forms of energy, which we find useful!

a) a Make a list of five devices which you can find at home, or you see in the shops, which work with electricity.

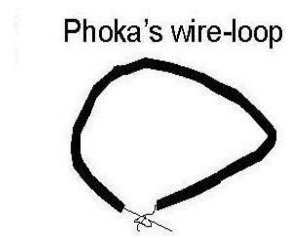
b) What are these devices used for?

c) What energy transformation/s take place in these devices?

WHAT IS AN ELECTRIC CIRCUIT?

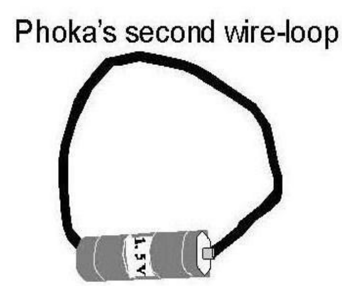
2 An electric circuit is a **closed** path or "loop", made out of materials which are good conductors of electricity.
But this is not enough!

a) Phoka is a learner in your group. He takes a piece of wire. He connects the ends of the wire together. He says: "*This is an electric circuit!*".
Is Phoka right? Is there an electric current in Phoka's wire loop?



b) What must Phoka do to have an electric current in his loop? Explain to him.

c) Phoka connects a 1,5 V cell across his wire.
Did he make an electric circuit?



d) Andile, who is also a learner in your group, has her doubts about Phoka's circuit. She says:
"This is the most useless circuit I have ever seen! It is of no use!"
Is Andile right? Is Phoka's circuit a "useless" circuit? Explain.

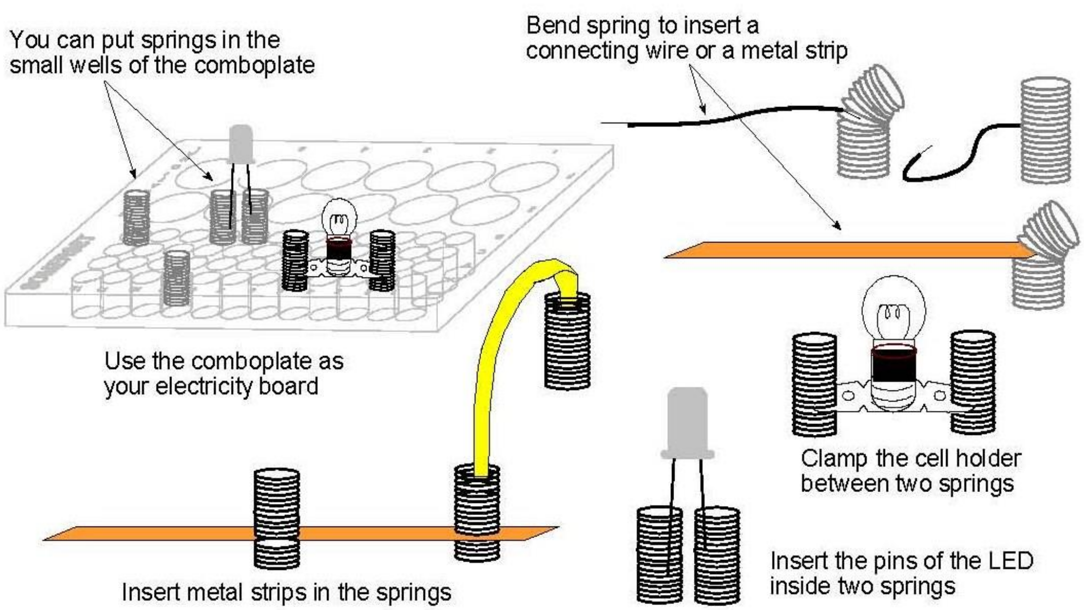
e) So finally, what is an electric circuit and what parts does it need to be made of to make it "useful"?

What to do: Work steps 1 to 4 below, individually.

1. Put the A4 sheet of paper flat on your desk in front of you. Put your micro-electricity kit on the A4 paper.
2. Empty the contents of the kit on the white paper, one by one.
3. Look at the diagram of all the components in the kit. Find the name of each component in the

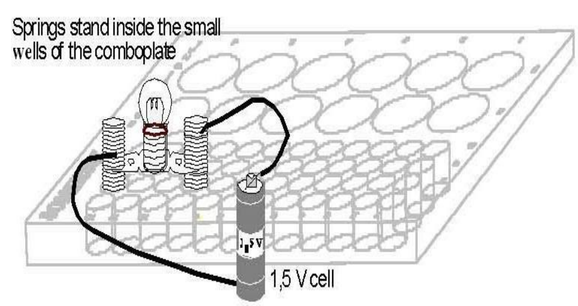
diagram.

4. Divide your components into four parts/categories,
    I. the power sources and any other accessories which you think go with them.
    II. i the electrical devices, which you think "will do something" when you connect them in a circuit.
    III. components which you think you can use for the connections, i.e. which you can use to connect a power source to an electrical device to complete a closed conducting path.
    IV. components which do not belong in any of the above three categories. Think of ways you can use these components with your kit.
5. Look at how the other members of your group have divided their components. Discuss any differences.
   Here are some ideas of how to use some of the components in the kit. But of course, you may have better ones. You must try your ideas!



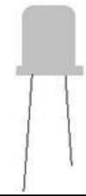
TASK 1 - MAKE YOUR OWN CIRCUIT

6. The following diagram, shows a simple electric circuit - for inspiration!
   Your task is to make a bulb glow, using components from your micro-electricity kit. Each learner in your group must make a **different** circuit. And each circuit must be different from the one shown in the diagram. When you have finished, discuss the circuits you and your group have made. Discuss which connections or components you found the easiest to use. Discuss which type of connection/s you found more firm or sturdy.



TASK 2 - FIND OUT HOW IT WORKS

7. In your micro-electricity kit, you will find a little red bulb, the LED. This is a diode. Diode is a Greek word for “Two-Way”.
   Your task is to find out how it works. How can you make it glow? Why is it called “Two-Way”?



EXPERIMENT 2 – LIGHTEN UP, PREDICT AND EXPLORE

CSEC OBJECTIVE (S): Section E – Objectives 4.1-4.4

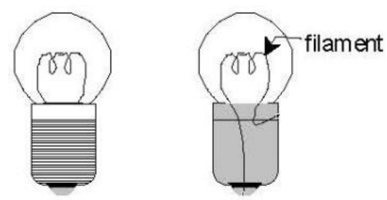
Grade Level - 9

What is electricity? What is an electric current? These are not easy questions, yet electricity is so much part of our lives. The more we learn about it, the more we learn to respect nature and the energy it provides us!
In the past you made simple circuits and you learned how to light up a bulb. This Activity is nothing new, but hopefully it will challenge you to think, and refresh your memory ..... not bad for starters!

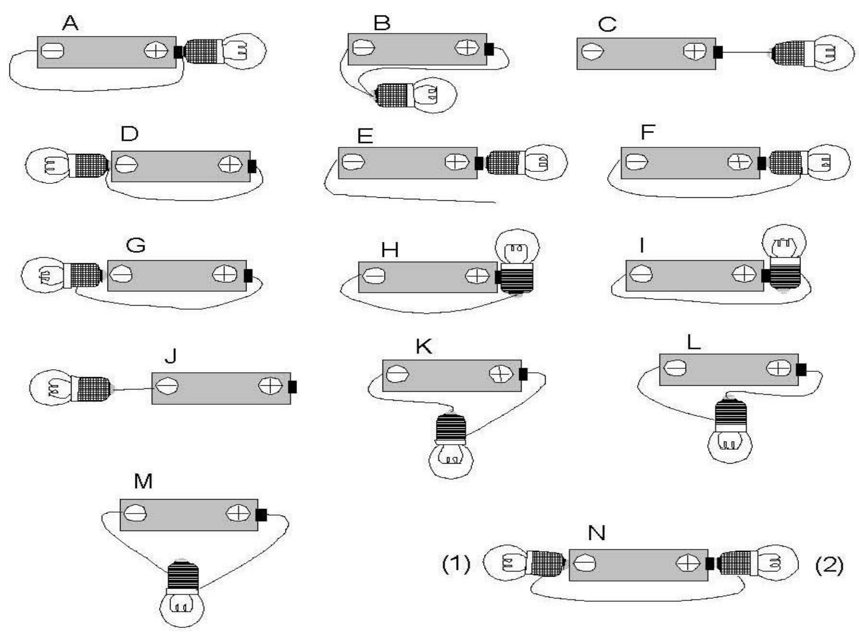
What you need
a micro-electricity kit

PART A

1. The diagram alongside, shows what a bulb looks like inside.
2. Predict which of the bulbs in the following figures will light up. Work on your own.



a) Record your predictions in the table on the next page.



b) Compare your predictions with those of other members of your group. Where you differ explain the reason for your prediction. Make a group prediction and record it in the table on the next page.

PART B

3. Test your group predictions using the micro-electricity kit equipment.
a) Record your observations in the table on the next page.
b) Compare your observations with your predictions. Explain the results you observe. Add your comments in the table on the next page.

4. To conclude, what is necessary to make a bulb light up?

TABLE

Bulb	Your Prediction	Group's Prediction	Observation	Comments
A				
B				
C				
D				
E				
F				
G				
H				
I				
J				
K				
L				
M				
N1				
N2				

EXPERIMENT 3 –CAR HEADLIGHTS

CSEC OBJECTIVE (S): Section E – Objectives 4.1-4.4

Grade Level - 9

To use the electrical energy in cells or batteries to make light bulbs glow we need a closed circuit. There are two common types of circuits, the *series circuits* and the *parallel circuits*. In a series circuit, all the parts of the circuit are connected, one after the other, so there is only one path for the transfer of electrical energy. In a parallel circuit, the parts are connected so that there is more than one path.

Organise yourselves in pairs or groups of three. Select one person to take notes. Discuss the following factors about the main headlights of a car (or taxi):

- during which part of the day are the headlights of a car used?
- the importance of passenger safety when designing car headlights
- what would happen if one of the car headlights was broken for example, by a stone thrown up from another car?
- the electric circuit in a car which connects the car battery to the two headlights.

After you have noted down your answers to the above points, draw a diagram representing an electric circuit which consists of the two headlights of a car, the car battery (source of electrical energy) and the wires that connect the headlights to the car battery.

What you need

a micro-electricity kit

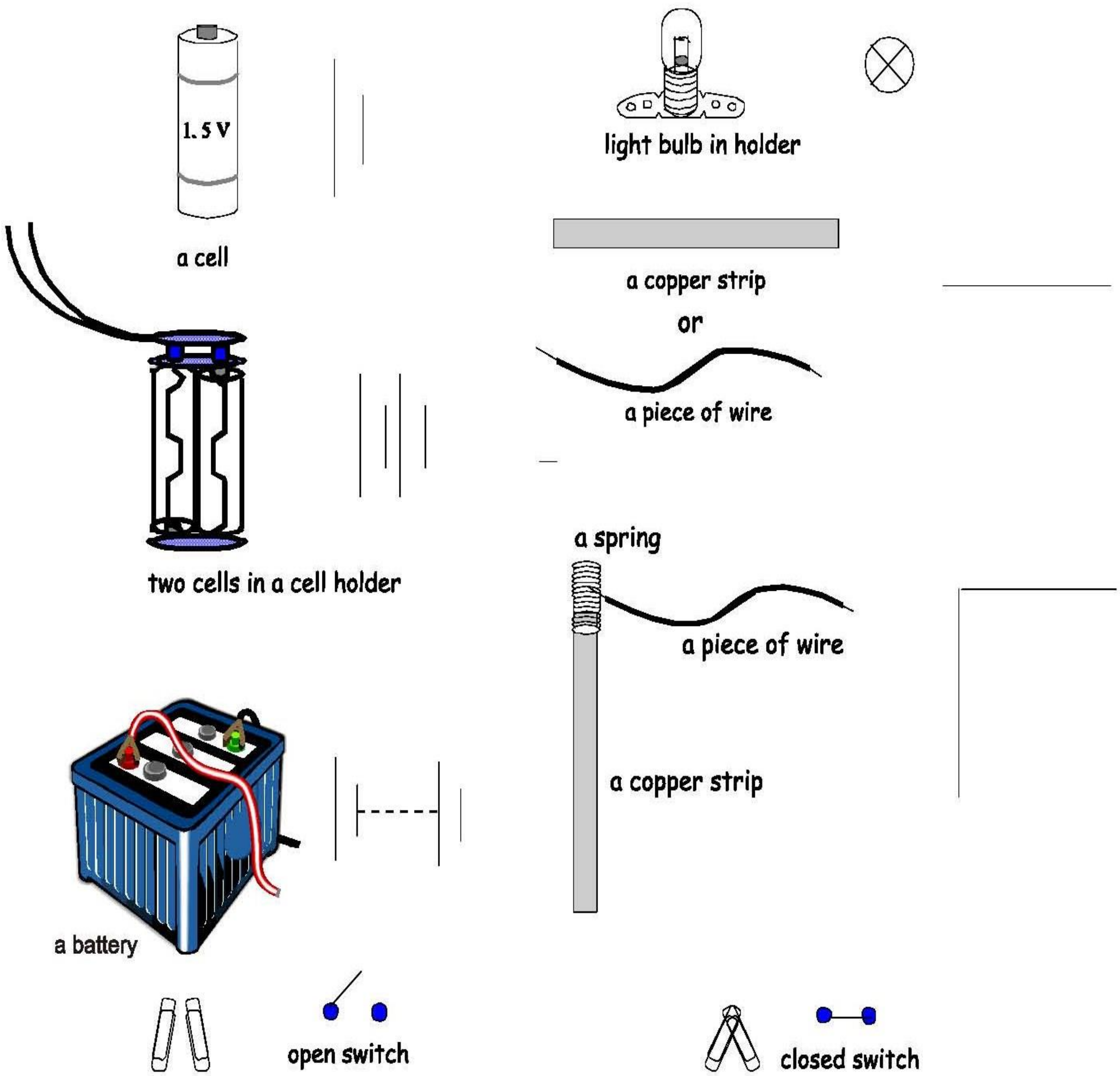
What to do

Select parts of the micro-electricity kit and set up a circuit to represent your circuit drawing of the headlights of a car.

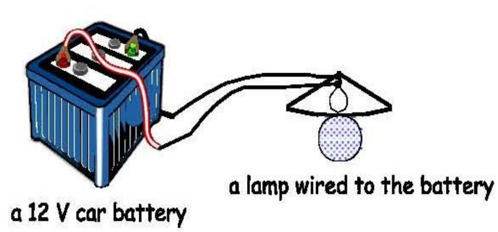
When you have finished the above Activity get together with your group and work through this section.

1. Which circuit, series or parallel, describes the circuit you have constructed? Explain.
2. You can spend a lot of time drawing the real parts (components) of a circuit. It is much easier to use symbols to represent the components of a circuit.

On the next page there are some of the symbols used to draw circuit diagrams.



2.a Use some of the symbols to draw a circuit diagram of the circuit below.



2.b Use the circuit symbols and draw a circuit diagram to represent your circuit of car headlights.

EXPERIMENT 4 – MAKING AN ELECTRIC CURRENT DETECTOR

CSEC OBJECTIVE (S):

Grade Level - 9

In Grade 7 you met the concept of electrical energy and some of its many uses. Think of a torch for example.

Energy stored in the cells of the torch, transfers to the bulb and the bulb glows.

To transfer electrical energy we need an electrical circuit. An electrical current transfers energy in a circuit. There are some substances which allow an electric current in them (conductors) and other substances which do not allow an electric current (insulators).

What you need

a micro-electricity kit

What to do

Work in pairs. Use different parts of the micro-electricity kit to construct a device that can detect the presence of an electric current. The following criteria (things you need to do) must be considered when designing your detector.

- the device must be easy to use
- the device must show whether a current is present or not.

When you have constructed your device, test it on as many objects around you as possible. Before you test an object, predict whether it is a conductor or insulator. Enter your results in the table below.

TABLE

Tested object	Current Prediction Y yes ¥no	Confirmed Prediction Y right ¥ wrong	Explanation
eg. a nail	Y	Y	metals conduct

What to discuss

1. Describe each part of your current detector and how it contributes to the working of the detector.
2. The objects that you tested today were all solids. Discuss whether some gases and liquids can conduct electricity? If they do, could your detector be used to test these substances? Explain.
3. How do conductors and insulators make our day to day living easier and safer? Give at least four examples.

EXPERIMENT 5 – THE CURRENT IN A SERIES CIRCUIT

CSEC OBJECTIVE: Section E – Objectives 4.1-4.4

Grade Level - 9

In a series circuit there is only one closed path for the current. The strength of the current is the same anywhere in the circuit.

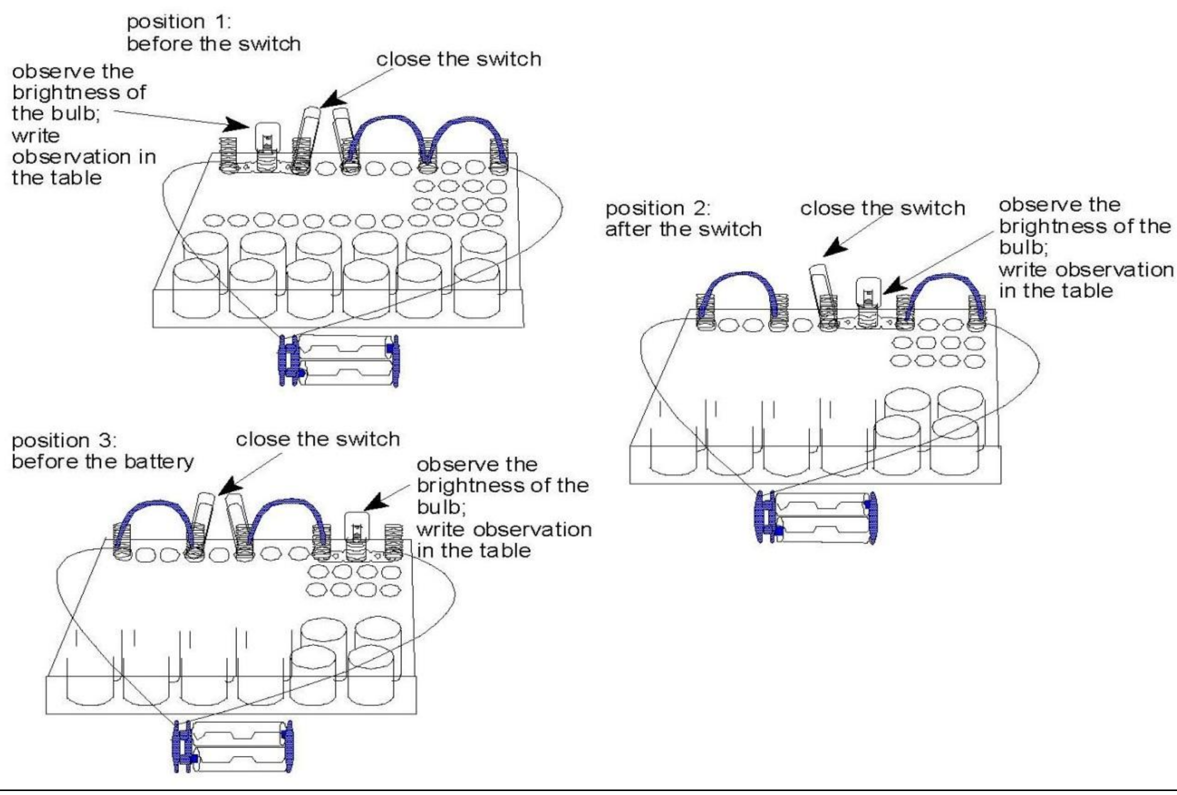
What you need

a micro-electricity kit

What to do

Work in pairs or groups of three. Use the micro-electricity kit to construct the series circuits given in the figures below. Complete the given table. Remember to predict the brightness of the bulb before you close the switch.

Bulb's position	Brightness Prediction	Bulb brightness
Before switch		
After switch		
Before battery		



What to discuss

1. Thando is a Grade 8 learner. When he was asked by his teacher to describe the current in a series circuit he said the following:
   "The strength of the current before the light bulb is bigger. This is because the current goes through the light bulb and gets used up."
   Discuss Thando's statement.
2. In your micro-electricity kit is a part called *a* **resistor**. 

A resistor is a specially designed device to reduce the current in a circuit. Some parts of a circuit cannot work properly if they have large currents in them. If you ever get the chance, look inside a radio or TV. You will see many, many resistors.
Predict the brightness of the light bulb in your series circuit if you were to replace one of the copper strips with a resistor. Set up such a circuit and test your prediction. (You may need to add an LED to your series circuit.)
How accurate was your prediction? Discuss.

EXPERIMENT 6 – LIGHT BULBS IN SERIES

CSEC OBJECTIVE (S): Section E – Objectives 4.1-4.4

Grade Level - 9

In an earlier Activity you designed the circuit of a car's headlights. Let's see what would happen if we connected the following car lights in series: - two car headlights and one other car light, eg, an indicator light.

What you need

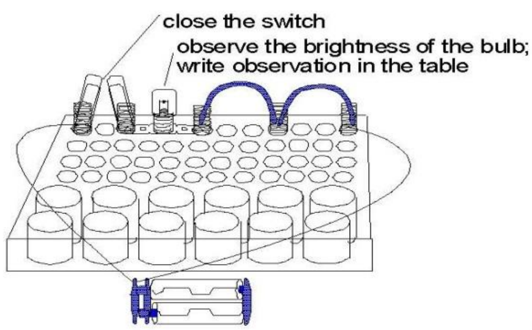
a micro-electricity kit

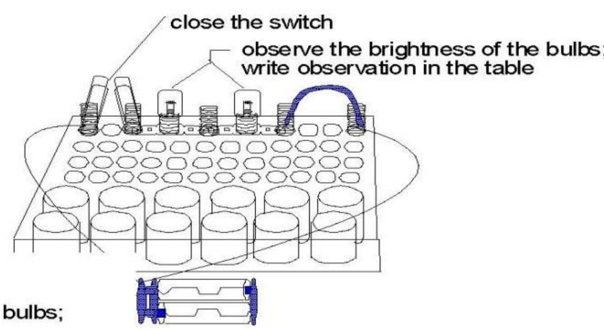
What to do

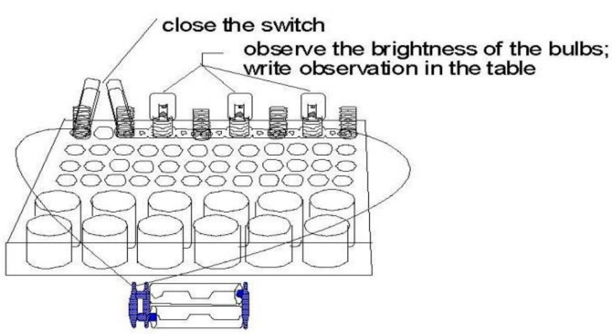
Work in pairs or groups of three. Use the micro-electricity kit to construct the series circuits given in the figures below. Complete the given table. Remember to predict the brightness of the bulb/s before you close the switch.

Note: Only pack away your circuits at the end of the Discussion section.

Bulbs Brightness	Prediction for each bulb	Brightness of each bulb
1		
1 and 2		
1, 2 and 3		







What to discuss

1. Describe the changes of the brightness of the bulbs, in terms of electrical current, each time another bulb is added in series.
2. In an earlier Activity you met an electrical device called a resistor.
   a) What similarities are there between the extra light bulbs added in series and the resistor. We call the property of a substance that reduces current strength, *resistance.*
   b) Each light bulb has a certain resistance. Discuss, in terms of resistance, how the addition of each light bulb affects the current in a series circuit.
3. Predict what will happen if you unscrewed the first light bulb in the last series circuit you set up. Test your prediction. Explain the result.
4. Let's consider the possibility of connecting two car headlights and an indicator light in series. What disadvantages and advantages would there be?

EXPERIMENT 7 – LIGHT BULBS IN PARALLEL

CSEC OBJECTIVE (S): Section E – Objectives 4.1-4.4

Grade Level - 9

In an earlier Activity you met the circuit of car headlights. Car headlights are connected in parallel. Let's look at the advantages of connecting the headlights in parallel.

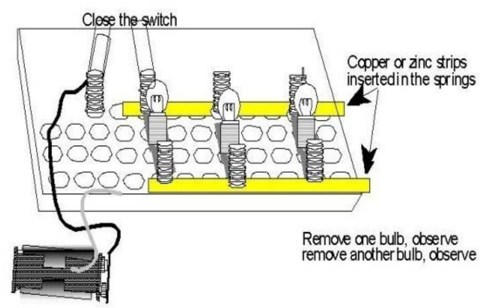
What you need

a micro-electricity kit

What to do

Work in pairs or groups of three.

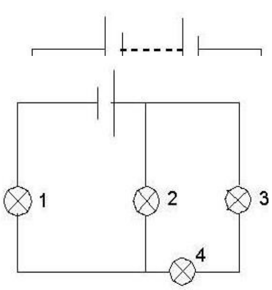
1. Use the micro-electricity kit to construct the parallel circuit as shown on the right.
2. Predict whether the other bulbs will glow if you unscrew one bulb.
3. Test your prediction.
4. Predict whether the other bulbs will glow if you unscrew two bulbs.
5. Test your prediction.
6. Complete the given table.



Bulbs	'Glow' Prediction for each bulb	'Glow' of each bulb
Remove 1 bulb		
Remove 2 bulbs		

What to discuss

1. How do light bulbs connected in parallel differ to light bulbs connected in series?
2. You are given some examples of some common circuits below:
   Christmas tree lights, traffic lights (robots), torch, ceiling lights in the home, street lights;
   a) Which circuits are parallel and which are series?
   b) Give the reasons for your choices.
3. COMPLETE THIS QUESTION ON YOUR OWN. After everyone has finished the questions compare answers. If you disagree set up the circuits to check.
   You are given some circuit diagrams. Chose the correct multiple choice answer for each.
   a) If the light bulb M suddenly "burns out", what happens to light bulb N?
      A. It glows exactly as before
      B. It glows brighter
      C. It glows less bright
      D. It does not glow

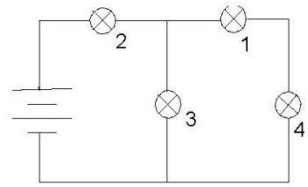


   b) Which bulb/s will glow with the same intensity (same brightness)?

All the bulbs are identical.

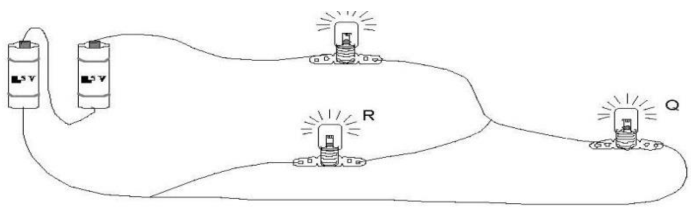
A. 1 and 2
B. 2 and 3
C. 1, 2 and 3
D. 3 and 4

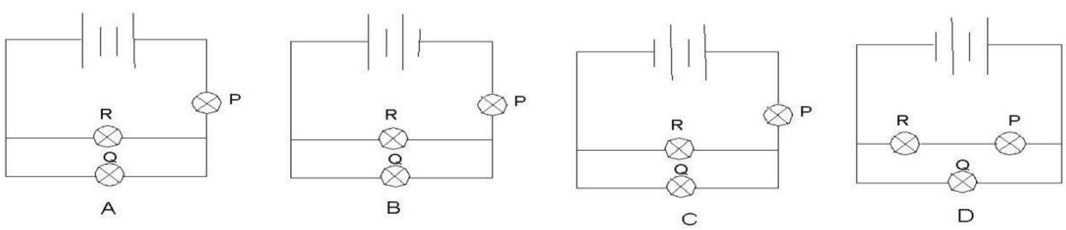
c)Which bulb must be removed from the circuit to make ALL the other bulbs go out?



A. 1
B. 2
C. 3
D. 4

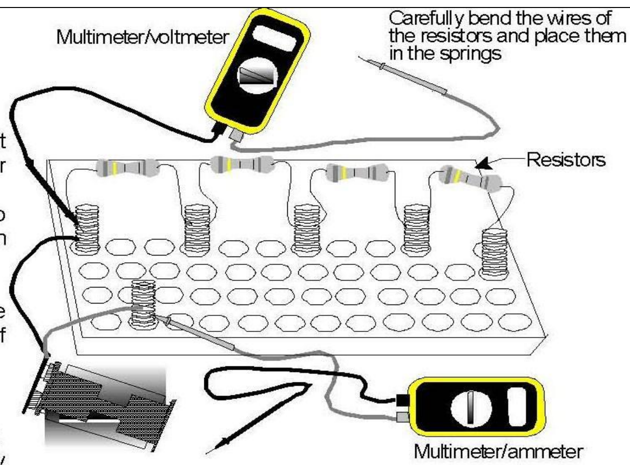
d)Lebala, a Grade 8 learner connects three light bulbs called P, Q and R to two cells. Which circuit diagram corresponds exactly to the circuit she set up.





EXPERIMENT 8 – ONE AFTER THE OTHER, CAUSING A GREAT BOTHER
CSEC OBJECTIVE (S): Section E – Objectives 4.14-4.15
Grade Level - 9

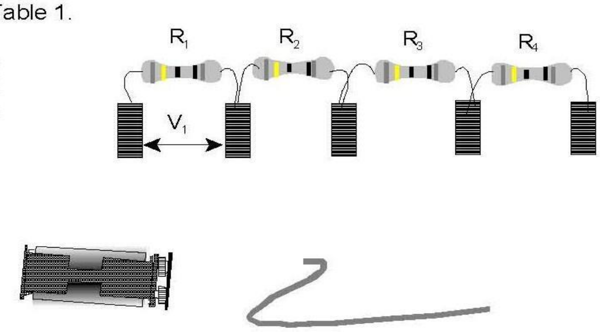
What you need
micro-electricity kit, two multimeters, graph paper



What to do
Work in groups of two or three. Set up one circuit per group and combine the components of your kits when necessary.
Use components from the micro-electricity kit, to connect four resistors in series, as in the diagram on the right.

1 First complete a circuit by including one resistor only (the first resistor on the left of the diagram).
 a Measure:
 X the current in the circuit and
 X the potential difference across the resistor.
 (Decide amongst your group, how to connect the ammeter and the voltmeter.)

 b Record your measurements in Table 1.



2 Complete a circuit by including two resistors (the first two), then three and finally all four resistors. The diagram on the right may help you.
Each time,
 a Measure:
 X the current, (I), in the circuit and
 X the potential difference, (V_x), across each connected resistor.
 X the potential difference, (V), across all the connected resistors.

 b Record your measurements in Table 1.

TABLE 1

Resistors connected in circuit	Current, I (mA)	Voltage across each resistor, V_x (volts)				Voltage across all resistors,	V (Volts)
		V1	V2	V3	V4		
1							
1+2							
1+2+3							
1+2+3+4							

3. On the graph paper, plot the potential difference across the first resistor (V1), versus the current (I) in the circuit. Then, draw a smooth (best fit) line.

What to discuss

In the following steps, you will discuss the sort of information you can get from:

i. Table 1, and
ii. the graph of V_1 vs I

4. Lebala, is a learner in your group. She has just drawn a nice, clear graph of V1 vs I.
   Lebala says: "Here is my graph, but so what? Why waste time drawing graphs?"
   The learners in your group must explain to Lebala the role of a graph. What information can she get from her graph of V_1 vs I? How can she use her graph?
   Examples of some points you can include in your discussion are:
   - What does the graph represent?
   - What type of relationship does the graph show?
   - Is it necessary to include the origin? Explain.
   - How can the graph be useful? Give examples.
5. What information can you get from Table 1? Make a list of all information which you consider important.
6. Lebala looks at Table 1. "We can get more information from Table 1, which I cannot see on the graph. See what the text-book says:
   POINT 1: The total voltage supplied by the source, is equal to the sum of the voltages across each resistor, i.e.
   $V_1 + V_2 + V_3 + ... = V$.
   POINT 2: The ratio Vx/I remains constant where, V_x is the voltage across a single resistor and I is the current in the circuit.
   Lebala says, "There was no need to draw a graph after all!"

a) Use your data in Table 1, to see if Points 1 and 2 in Lebala's text-book are verified by your experiment. Record your calculations in a table. Discuss your results with your group.
b) Lebala thinks that in this Activity, there is no need to draw a graph. What do you think? Explain.

7. The ratio of V1/I in Table 1, represents a constant quantity called the **resistance,** (**R**), of the resistor. Every electrical conductor, like the resistors you used in this Activity, has a resistance R. Discuss in your group and write down a few sentences on what you understand by the term "resistance". What does the ratio V/I mean?

$$\mathbf{R = \frac{V}{I}}$$

EXPERIMENT 9 – FREE ELECTRONS ARE NOT SO FREE!

CSEC OBJECTIVE (S): Section E – Objective 2.2

Grade Level - 9

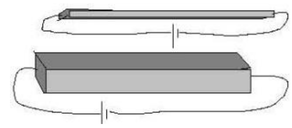
INVESTIGATION No 1 : THE THICKNESS OF A CONDUCTOR

What you need

micro-electricity kit, multimeter

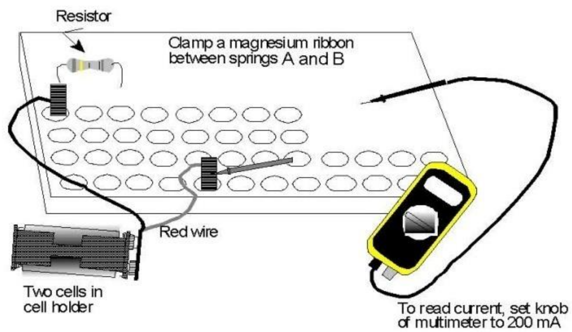
PREDICT

a) The diagram on the right, shows two metallic conductors of the same length and material. Which conductor offers more resistance to an electric current, the thin one or the thick one? Justify your prediction.



What to do

1. Use components from the microelectricity kit, to prepare the circuit shown in the diagram alongside. Connect a magnesium ribbon between springs A and B. The multimeter must be off. (A resistor is included in the circuit to reduce the current, since the multimeter can only read small currents - up to 200 mA.)



a) When you are ready, switch on the multimeter. Record the current measurement in Table No 1 on the next page. Disconnect the multimeter.

b) Use the multimeter to measure the potential difference across the magnesium ribbon. To do this, discuss between your group:

i. What changes you need to do to the circuit? (Hint: where is the closed path?)

ii. How and where will you connect the multimeter?

iii. In which position will you set the knob of the multimeter?

c) Record the potential difference across the magnesium ribbon in Table No 1.

d) Calculate the resistance of the magnesium ribbon (R=V/I) and record the result in Table No 1.

2. Repeat steps 1a to d above, but this time connect a second magnesium ribbon between springs A and B, as shown in the diagram on the right.
   Repeat once more with three magnesium ribbons between springs A and B.
   Each time, record measurements and calculations in Table No 1.

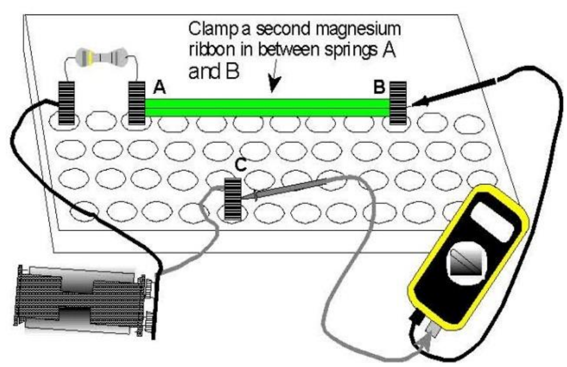


TABLE No 1
The Effect of the Thickness of a Conductor on its Resistance

No of magnesium ribbons	Current (mA)	P. D. across ribbon/s (V)	Resistance of ribbon/s (V/mA)	Resistance of ribbon/s (V/A = ohms)
1				
2				
3				

3. Joe did the same experiment, but instead of magnesium ribbons, he used the copper strips from his microelectricity kit. He measured the current with one, two, three copper strips on top of each other. The following table shows some of his measurements.

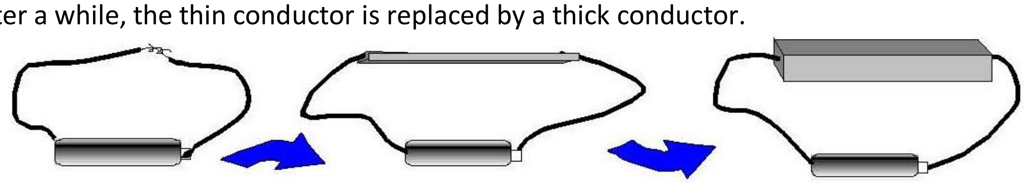
Number of copper strips	Current (mA)	P.D. across copper strips (V)
1	1010	0
2	1019	1
3	1014	0

Joe is worried. He cannot come to any conclusion. Luckily your group is about to help him!

a) Compare Joe's current measurements with your current measurements in Table No 1. List at least two important differences between the two sets of measurements.
b) Compare Joe's and your measurements of the potential difference across the strips. What are your comments?
c) Why are the connecting wires in a circuit mostly made out of copper?

4.
a) What happens to the resistance of a magnesium conductor when you increase its thickness?
b) Do the results of this investigation confirm your prediction at the beginning of the Activity? Explain.

5. Imagine that you are a free electron in an electric circuit.
i. Initially, the circuit is made up of a cell and some copper wire.
ii. Then, somebody connects a thin conductor in the circuit.
iii. After a while, the thin conductor is replaced by a thick conductor.



a) Explain what changes you would experience as you move around the circuit, in each case.
b) In a few sentences, prepare a group report to explain the effect of the thickness of a conductor on its resistance.

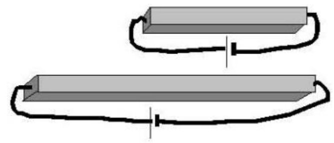
INVESTIGATION No 2 : THE LENGTH OF A CONDUCTOR

What you need

micro-electricity kit, multimeter

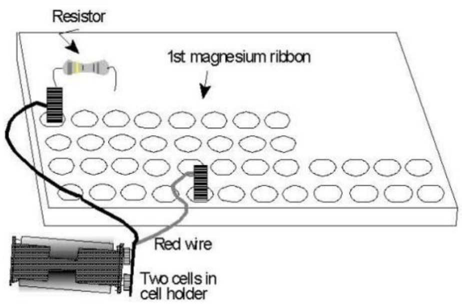
PREDICT

a) The diagram on the right, shows two metallic conductors of the same cross section and material. Which conductor offers more resistance to an electric current, the long one or the short one? Justify your prediction.



What to do

1. Use components from your micro-electricity kit to set up the components as shown in the diagram alongside. The diagram shows three magnesium ribbons connected in a row. Spring D is not clamped onto the comboplate.



a) Your task is to measure the current in the circuit and the potential difference across the magnesium ribbon/s when:
   i. only one magnesium ribbon is included in the circuit
   ii. two magnesium ribbons are included in the circuit
   iii. all three magnesium ribbons are included in the circuit.

b) Record your measurements in Table No 2.

c) In each case, calculate the resistance of the magnesium ribbon/s (R=V/I) and record the result in Table No 2.

TABLE No 2

The Effect of the Length of a Conductor on its Resistance

No of magnesium ribbons	Current (mA)	P. D. across ribbon/s (V)	Resistance of ribbon/s (V/mA)	Resistance of ribbon/s (V/A = ohms)
1				
2				
3				

What to discuss

2. a) What happens to the resistance of a magnesium conductor when you increase its length?
   b) Do the results of this investigation confirm your prediction at the beginning of the Activity? Explain.
   c) In a few sentences, prepare a group report to explain the effect of the length of a conductor on its resistance.
3. What would you expect to observe in this investigation, if instead of magnesium ribbons you used the copper strips from the kit?

INVESTIGATION No 3 : THE MATERIAL OF A CONDUCTOR

What you need

micro-electricity kit, multimeter

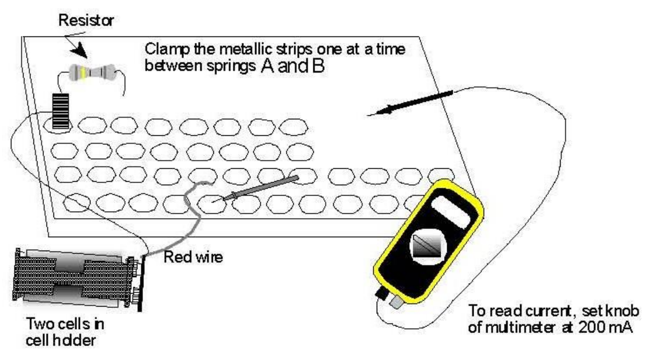
PREDICT

a) The connecting wires of electric circuits are usually made out of copper wire. However, copper is a fairly expensive metal. Why don't we use zinc wires which would be cheaper?

b) In this investigation, you will use roughly similar strips made out of magnesium, copper and zinc. Predict which strip will have the greatest resistance, and list the three materials in order of increasing resistance.
Justify your answer.

What to do

1. Use your microelectricity kit to set up the components as shown in the diagram alongside.



Connect each of the three metallic strips (one at a time) between springs A and B.

a) For each strip, measure the current in the circuit and the potential difference across the strip.
b) Record your measurements in Table No 3 on the next page.
c) In each case, calculate the resistance of the strip (R=V/I) and record the result in Table No 3.

2. Now that you are experts in measuring resistance, why not measure the resistance of some more devices from your micro-electricity kit (bulb, LED, resistors). In this case, bring the springs A and B closer, as in the following diagram.

a) For each device, measure the current in the circuit and the potential difference across the device.
b) Record your measurements in Table No 3.
c) In each case, calculate the resistance of the device (R=V/I). Record the result in Table No 3.

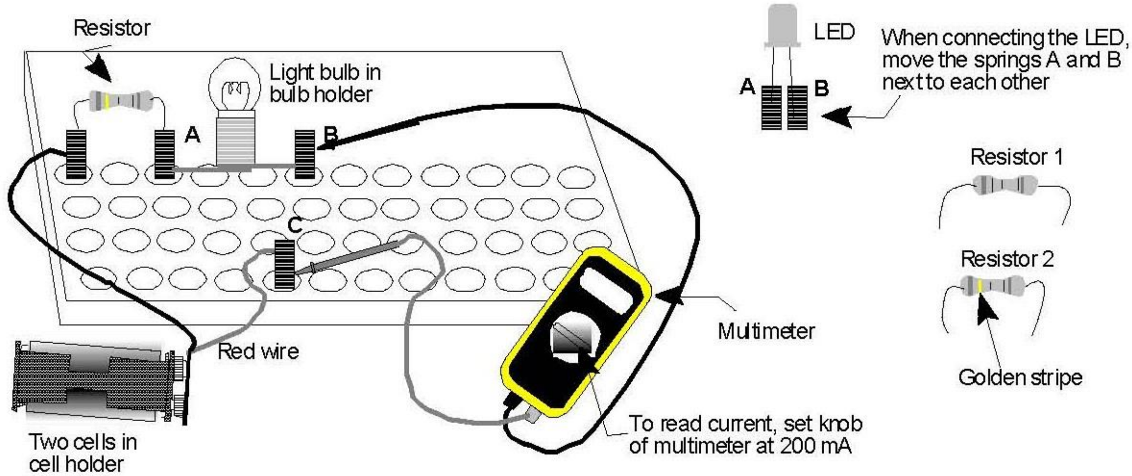
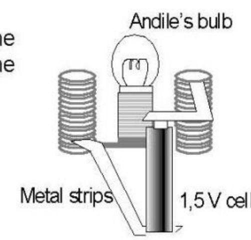


TABLE No 3

The Effect of the Material of a Conductor on its Resistance

Type of Conductor	Current (mA)	P. D. across conductor (V)	Resistance of conductor (V/mA)	Resistance of conductor (V/A = ohms)
Magnesium ribbon				
Copper strip				
Zinc strip				
Bulb in bulb holder				
LED				
Resistor type 1				
Resistor type 2				

3 Andile wants to light up her bulb to be as bright as possible. See the diagram on the right. Which strips should she use for that purpose, the zinc or the magnesium strips? Explain.



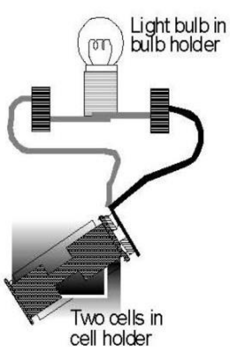


Diagram A

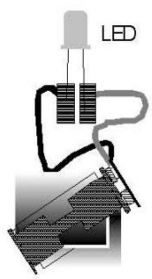


Diagram B

4 a In which one of the circuits on the left, is the potential difference across the two springs greater?

b In which one of the circuits (Diagram A or Diagram B), is the current stronger?

Explain.

INVESTIGATION No 4 : THE TEMPERATURE OF A CONDUCTOR

What you need

micro-electricity kit, multimeter,
hot water, a plastic lid from a coffee jar or similar dish, cold water or ice-blocks (optional)

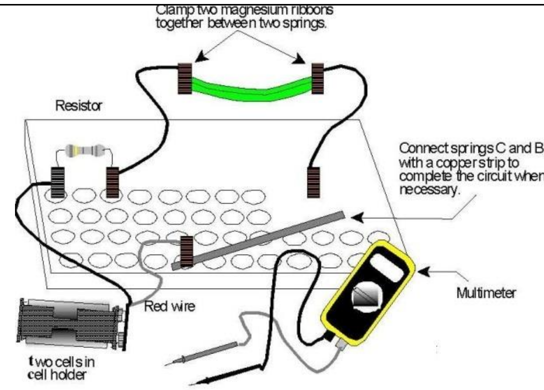
PREDICT

a) What happens to the particles of a material when its temperature rises?
b) Predict which metallic conductor offers more resistance to the flow of electric charge,
   i. a conductor at 20 °C or
   ii. a conductor at 80 °C.
   Justify your answer.

In this investigation, you will calculate and compare the resistance of a conductor at two different temperatures.

What to do

1. Use your micro-electricity kit to set up the components as shown in the diagram on the right.
   a) Measure the current in the circuit and the potential difference across the magnesium strips. Record your measurements in the Table No 4 on the following page.
   b) Calculate the resistance of the strips (R=V/I) and record the result in Table 4.



2. Fill the lid or shallow dish with hot water. Immerse the magnesium ribbons in the hot water, see the following diagram.
   While the ribbons are in the hot water, repeat steps 1a and 1b above.
   Repeat this step with cold water if available.

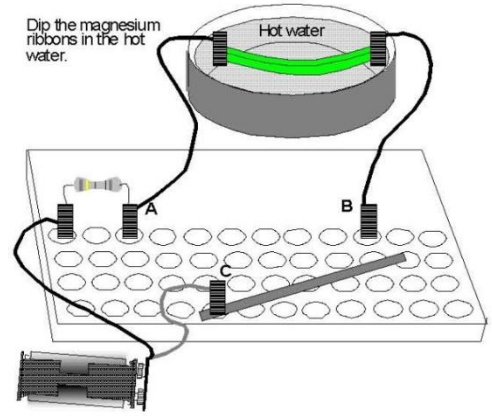


TABLE No 4
The Effect of the Temperature of a Conductor on its Resistance

	Current (mA)	P. D. across ribbons (V)	Resistance of ribbon/s (V/mA)	Resistance of ribbon/s (V/A = ohms)
Conductor in cold water				
Conductor at room temperature				
Conductor in hot water				

3. a) Compare your results with your prediction. What happens to the resistance of the magnesium ribbon as the temperature rises?
   b) What do you expect to happen to the resistance of a material, if its temperature keeps on dropping? Discuss between your group things like:
   Is it possible for the resistance of a material to become exactly zero?
   At which temperature would that be?
   Is there a minimum temperature in nature?

Have you ever heard of superconducting materials, if so what?

EXPERIMENT 10 – WHAT GOES UP MUST FALL DOWN

CSEC OBJECTIVE (S): Section B – Objective 5.1

Grade Level - 9

Why do charges in wires not flow unless the wires are connected to a battery? For the same reason why when we throw a stone out of a window it falls downwards towards the ground! It is a matter of difference in **potential energy**.

DIFFERENCES IN HEIGHT

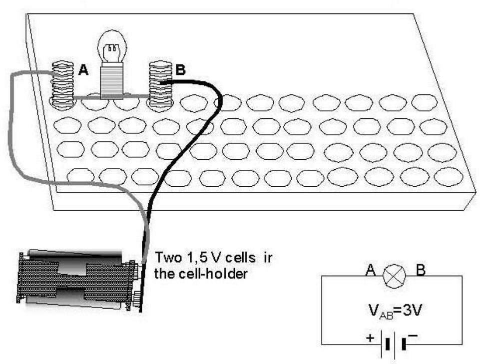
Alex is a primary school boy, who is often up to mischief. This morning, he dropped a stone out of a third floor window. The roof of his mother's car now has a great dent in it! "Mom, it was a small stone!" Alex said.

"Yes, but a small stone from a big height causes lots of damage, it has lots of energy!"

Consider a stone of mass *m* on the ground. The stone has no potential energy in respect to the ground. You lift the stone from the ground up to a height *h*. To overcome the force of gravity you exert an upward force on the stone.

That is, you do work on the stone, you transfer energy to the stone (remember, when you do work you transfer energy). The stone now has **gravitational potential energy** in respect to the ground. You know this because if you let the stone free, something happens. The stone starts moving - it falls, and when it hits the ground it can cause damage.

DIFFERENCES IN ELECTRIC POTENTIAL



Much the same way, if you want to move an electric charge from one point to another, you must apply a potential difference between these two points. This is what a power source does.

In an electric circuit, we consider the movement of the positive charge, the conventional current. Consider the simple circuit shown in the diagram. For simplicity, we assume that cells, springs and connecting wires have no resistance.

In the diagram, spring A is connected to the positive terminal, and spring B is connected to the negative terminal of the cells. The positive terminal is at high potential (3 V), the negative terminal is at low potential (0 V). The difference in potential between the positive and negative terminals is 3 V. Therefore, the difference in potential between points A and B (across the bulb) is also 3 V. Positive charge that moves from A to B, "falls" from 3 to 0 volts, i.e. moves from a higher to a lower potential. The charge loses its potential energy! This lost potential energy transfers to the bulb (so it's not really lost!) And the bulb glows!

A charge of one coulomb, can transfer one joule of energy to a device, for each volt of potential difference across the device. In the case of the diagram above, the potential difference across the device (the bulb) is 3 V, therefore, one coulomb of charge transfers 3 joules of energy to the bulb.

We can say the same thing in different words:

There is a potential difference of 3 V across the bulb, if each coulomb of charge loses 3 joules of electrical potential energy as it passes through the bulb.

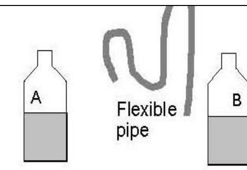
And because there are more ways to say the same thing, we use an equation to summarise it all!

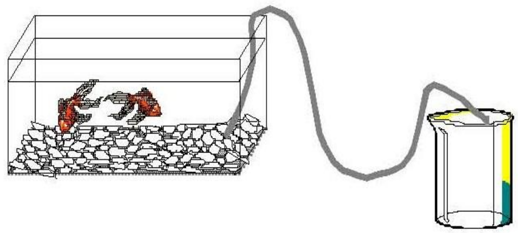
Potential difference = Energy transferred / Charge

$$V = \frac{W}{Q}$$

What you need

Micro-electricity kit, two 2 litre plastic bottles, tap water, flexible pipe/tubing, about 1 m long, like a hose pipe. A silicon pipe would be the best, as it is transparent





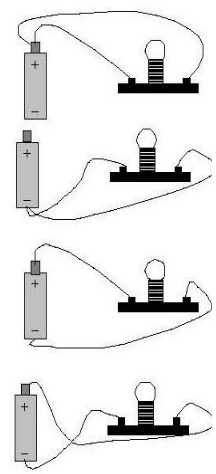
THE SIPHON

Alex loves his goldfish.

He wants to clean the dirt from the gravel in their fish-tank. He decides to siphon the dirt out. Alex brings a bucket and a long flexible pipe, as he saw in a book. He puts one end of the pipe in the tank, the other end inside the bucket. He waits.... nothing happens. The bucket is still empty and the dirt still in the gravel!!!

What to do

1 Help Alex to clean the fish-tank. Show him what to do.
Use a flexible pipe and the two 2 litre plastic bottles to represent the fish-tank and bucket.
See if you can get water flowing between the two bottles through the pipe.
Record all observations.
Under which conditions will water flow inside the pipe? In which direction?
How can you make the water flow faster or slower?
How would you explain to Alex in scientific terms, what is happening?
Prepare to report back your conclusions.



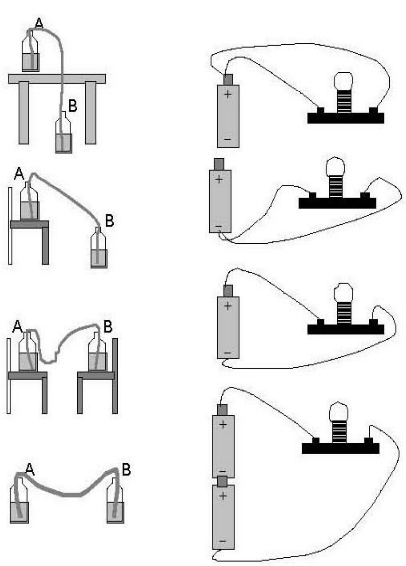
THE CHARGE AND ITS FLOW

2 The diagram on the right, shows a bulb and a cell connected in four different ways.

a In each case, predict if the bulb glows or not and why. Explain in terms of potential energy.

b Use components from your micro-electricity kit to test your predictions.

c Use your equipment to increase the flow of charge through the bulb. Explain in terms of energy, how this change affects the performance of the bulb.



FIND THE ANALOGIES

3 In the diagram on the left, draw a line to connect each circuit diagram to the corresponding water flow diagram. In each case, give reasons why you think there is an analogy between each pair of diagrams.

COMPARE

4.There are many similarities in the way masses with gravitational potential energy, and electric charges with electrical potential energy behave.

Use what you have discovered in this Activity, and what you already know, to compare masses falling in a gravitational field with charges “falling” in an electric field.

Think of analogies, similarities, and differences. You may use examples, like what you did with the bottles, or consider a falling stone, and compare it with the movement of charge in a simple electric circuit. Discuss between your group and record your conclusions in a table.

EXPERIMENT 11 – THE CURRENT IN A SERIES CIRCUIT

CSEC OBJECTIVE (S): Section E – Objective 4.5

Grade Level - 9

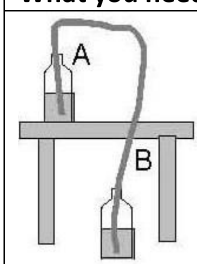
Nature is governed by laws. These laws are the same in all parts of the world. Many important laws, concern the conservation of certain quantities. You are already familiar with the law of conservation of energy, this very important concept in science. Another important conservation law, is the law of **conservation of charge**. This law states that: **"the net amount of electric charge produced in any process is zero"**.

For example, when you rub a plastic ruler with a cloth, the plastic acquires a negative charge and the cloth is left with an equal amount of positive charge. The charge is separated, but the sum of the two is zero. Charge cannot be created or destroyed!

The same applies to an electric circuit. The charge is not created by any component of the circuit. The charge is there in the wires, in the electrical devices, in the cells. When we complete the circuit, the free electrons at one end of the wires are attracted into the positive terminal of the power source. At the same time, electrons leave the negative terminal of the source and enter the wires at the other end. This way, there is a continuous flow of electrons through the wires, which begins as soon as the wires are connected to **both** terminals. Remember however, that when we talk about current, we mean conventional current, which is the flow of positive charge. But this is exactly equivalent to negative charge flowing in the opposite direction. (Also see Activity 3, grade 9).

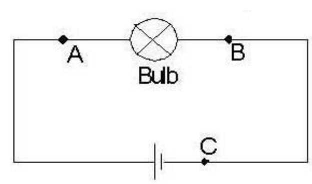
This means that the source of power does not create new charges (electrons), nor does it destroy old ones! The source simply supplies the charge with energy. The source of course as one of the components in the circuit, has its own charges. Bulbs or other resistors in the circuit, do not use up or destroy charge. The charges move with the same overall speed through all components. So the current is the same in all parts of the same circuit loop. The charges do not accumulate at any point!

What you need: micro-electricity kit, multimeter



What to do:

1. In the previous Activity, you worked with the flow of water, through a pipe, between bottles. In the diagram on the right, consider the water flowing inside the pipe. Discuss with your group, and chose the best answer:
   a) The water in the pipe flows faster at point A than at point B, because point A is higher.
   b) The water in the pipe flows slower at point A than at point B, because at point A the flow is upward, while at B is downward.
   c) The water in the pipe flows at the same rate at points A and B, because water is incompressible.



2. Is there any analogy between the water-flow model above and the current in the circuit alongside? Explain.
   Compare the electric current at points A, B and C. Explain.
3. Mantombi brought a book called "Exploring Electricity". Mantombi reads some text from the book, which is accompanied by a diagram to make the text more vivid.

Mantombi says: "When I look at this page, I think there are some serious mistakes. Is it possible or is it that I don't understand a thing?"

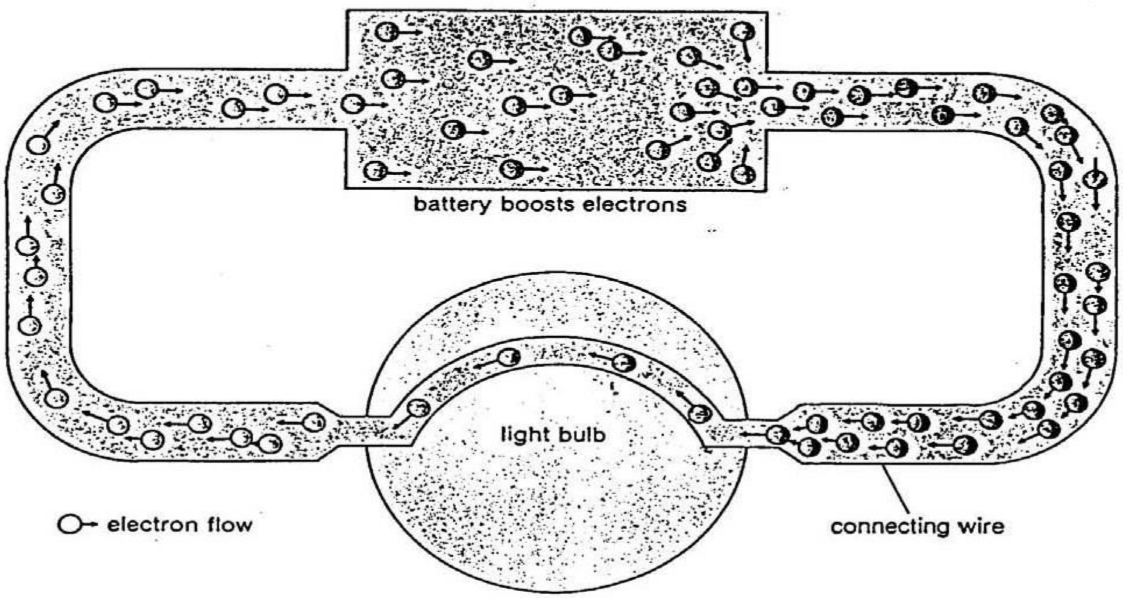
You can see Mantombi's text on the next page. Read the text and study the diagram on your own.

Underline the sentences you disagree with. Then try to explain what is wrong. Explain if there is anything wrong with the diagram. When you have finished, discuss your findings with your group to come up with a common conclusion. Prepare a group report of your findings.

Suggestion: In your report, mention what the text is all about, then proceed with the mistakes you found and your explanations/corrections. You may also mention any models used in the text or diagram, and if these models are successful or not.

4. Use your micro-electricity kit, to test if your corrections to Mantombi's book are correct! Explain how you are going to prove your points, what measurements you will take and why.

THIS IS THE TEXT & DIAGRAM FROM MANTOMBI'S BOOK



When an electric circuit is made, electrons flow from the negative terminal of the battery to the positive terminal. In order to see that the electric current is flowing, a bulb can be put in the circuit. Electrical energy is converted into light energy in the bulb.

A bulb is rather like a narrow bridge. The electrons are slowed down as they jostle to cross the bridge. This means that they have less energy to complete the circuit, when they are boosted again by the battery. We could put a second bulb in the circuit after the first bulb. The bulbs are placed one after another in a series. This is called a series circuit. The electrons now have two bridges to cross. They have twice the work to do. There are not enough electrons crossing both bridges to light both bulbs strongly, so the bulbs are dimmer than before.

Electron flow in a circuit containing a battery and a light bulb. The wire in the light is like a narrow bridge. The electrons lose energy as they cross this bridge.

You can now add a third bulb in series. The electrons have to pass through three lamps, so they are dimmer still. More electrons could be added by adding more batteries to the circuit. The batteries must be connected positive to negative terminal to complete the circuit. Now the bulbs have more electrons and should be brighter.

Remember: there must be a complete circuit for the electrons to flow. Any break in the circuit will prevent the flow of electricity and the bulbs will go out. If a bulb is removed from a series circuit, the other bulbs will fail. Christmas tree lights often work like this.

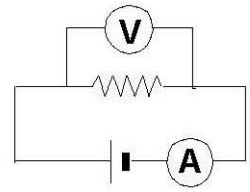
EXPERIMENT 12 – THE REAL & THE IDEAL WORLD

CSEC OBJECTIVE (S): Section E – Objective 4.5

Grade Level - 9

In science we often simplify the way we see the world. This is a valuable technique but it is not so easy! We try to imagine what would happen in idealised cases. Galileo was the first to introduce this technique, when he analysed the laws governing the "falling bodies". He ignored the air. He imagined that objects fall in a vacuum. He came to the conclusion that all falling objects dropped from the same height, land at the same time. But when we drop a marble and a feather from the same height, we see the marble landing first far ahead of the feather! This is the real world with air and friction!!!

Look at the circuit diagram alongside. When we study what type of relationship exists between the current in the circuit and the potential difference across a resistor, we make all sorts of assumptions. We assume that all connecting wires have no resistance. We assume that the source of power has no resistance. We assume that the voltmeter and ammeter do not interfere with the circuit, as if they were not there. But all these happen in an ideal world, the world of simplification (and abstraction)!



In electricity, the equipment we use is real. And connecting wires, meters, cells, ... they all interfere with the current in our circuit. The result? It reflects in our measurements! What sort of discrepancies can we expect between reality and theory? Let us take a look in this Activity.

What you need

micro-electricity kit, two multimeters

What to do

REFRESH UP YOUR MEMORY

1. We say (and we want) that meters for measuring current and voltage, must not interfere with our circuit.
   a) Comment on the resistance of a good ammeter.
   b) Comment on the resistance of a good voltmeter.

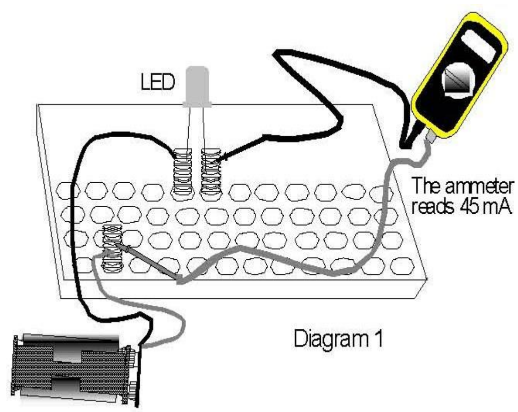


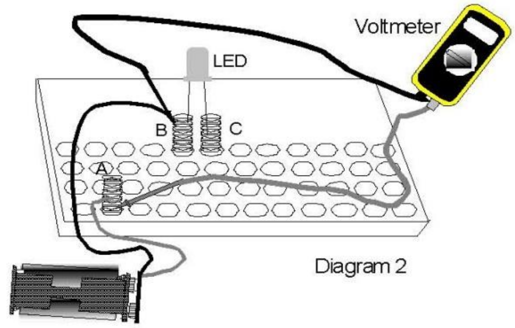
Diagram 1

TEST YOUR AMMETER

2. In diagram 1, the ammeter reads 45 mA.
   a) How will you know if this is the correct reading of the current in the circuit? What can you do to test if the ammeter changes the current in the circuit?
   b) If you connect a second ammeter in the same circuit, what do you expect both ammeters to read?
   c) Try it with your equipment. What do both ammeters actually read? What does this tell you?

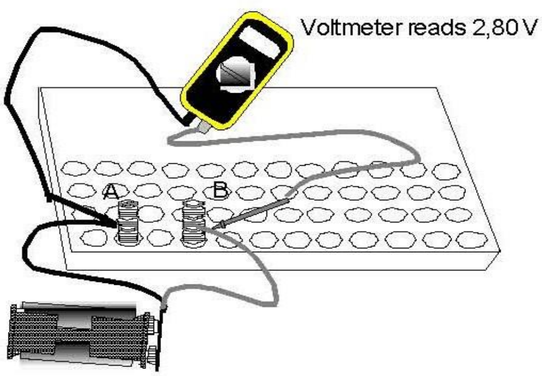
TEST YOUR VOLTMETER

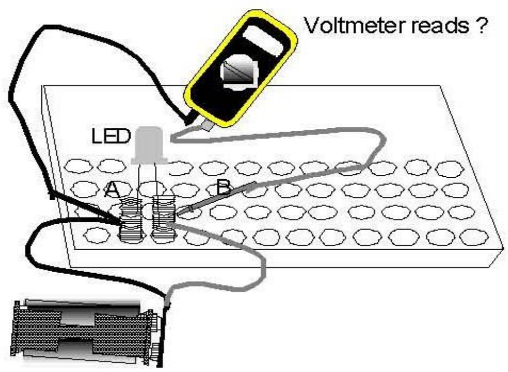
3. In diagram 2, the voltmeter reads 2,85 V across the springs A and B.
   a) What do you expect the voltmeter to read across the springs A and C?
   b) Try this with your equipment. What does it read? What does this tell you about your voltmeter?



TEST YOUR CELLS

4. In the figure below, the voltmeter reads 2,80 V when nothing is connected between springs A and B.
   a) What should the voltmeter read when an LED is connected between springs A and B?
   b) Try this with your equipment. What does the voltmeter read? What does this tell you about the resistance and the current in your circuit?



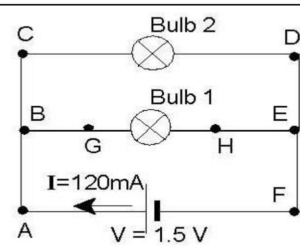


PREDICT

5. In the diagram on the right, the two bulbs are identical.
   a) a Predict the current value in bulb 1 and bulb 2.
   b) b What is the potential difference value between:

Points C and D	Points B and E
Points A and F	Points G and H
Points B and C	Points C and H

   c) c What is the potential difference across any of the points A, B, C,G?
   d) d What is the potential difference across any of the points D, E, F, H?



TEST YOUR PREDICTIONS

6. Use components from the micro-electricity kit to test your predictions in question 5. Take your measurements quickly. Remember to switch the meters off between measurements. Compare your predictions with your measurements. Discuss any discrepancies with your group.

EXPERIMENT 13 – THE INVESTIGATION

CSEC OBJECTIVE (S): Section E – Objectives 4.1-4.4

Grade Level - 9

What you need

micro-electricity kit, two multimeters

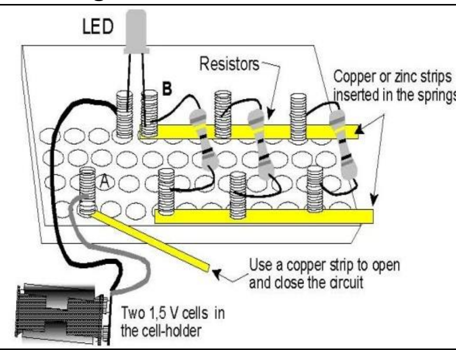
What to do

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 E – Objective3.2

Grade Level – 9

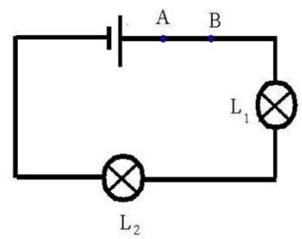
A relationship exists between the potential difference across a series circuit and the potential differences across each of the circuit's components. In this Activity you will use your micro-electricity kits to investigate the relationship between the potential difference across a series circuit and 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 E – Objective 3.2

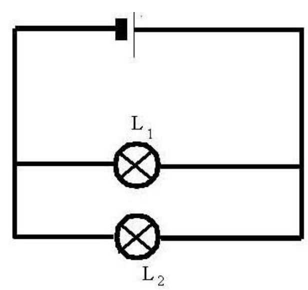
Grade Level – 9

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

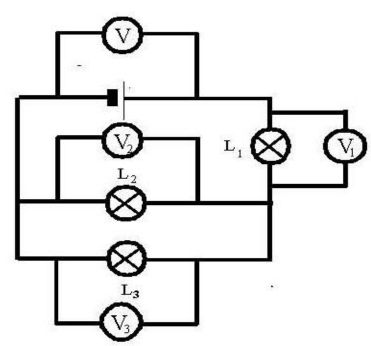
What to do



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.



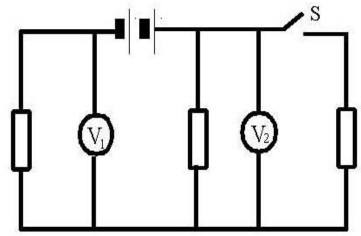
3. You were given a warning to work fast during your investigations because the potential difference readings can change. What factor/s could cause the change in the potential difference values?
4. Consider the series-parallel circuit given on the right. Use the V symbols given in the diagram to write 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.

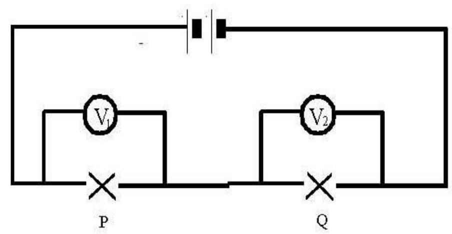
1. The internal resistance of the source of emf in the following circuit is negligible:

	V_1	V_2
A	decrease	decrease
B	increase	decrease
C	decrease	increase
D	no change	no change



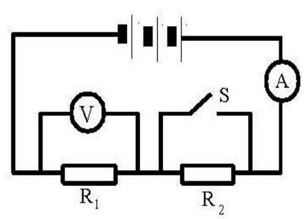
2. Two identical light bulbs, P and Q, are connected in series to a battery of negligible internal resistance. V_1 and V_2 are identical voltmeters. If bulb P blows (because the filament breaks), how will the readings on V_1 and V_2 respectively change?

	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 E – Objectives 4.6-4.8

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,

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

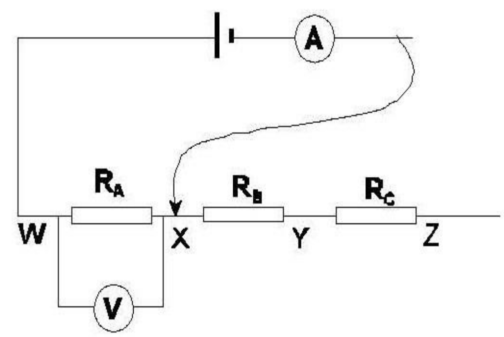
the ratio value is always the same. Because the ratio is constant it can be written as an equation. This constant is equal to the **resistance** (R) of the wire. This is known as **Ohm's law**.

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 E – Objectives 6.8-6.10

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**.

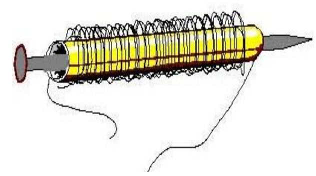
Electromagnets are used widely in industry and in science, when we need strong magnetic fields. They are used in motors (as you will see in a later Activity), in the generators of the power stations, in the scrap-yards to lift up cars, they are even used in simple devices at homes, like in loudspeakers, 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!

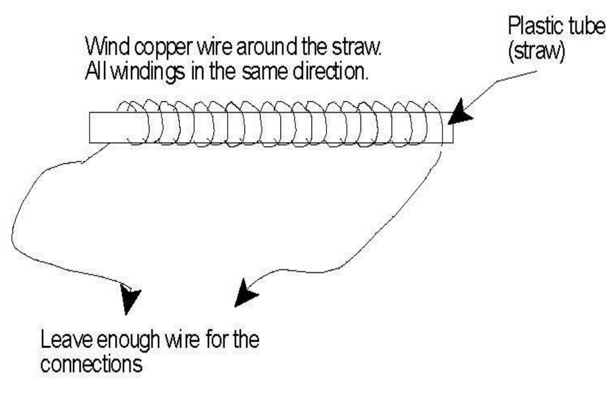
Joe tries to help her to do something about it. He shows her an electromagnet a friend of his made at school with his micro-electricity equipment. "Aunty you need something like this! This is a revolutionary device my friend has made. Once you try it you will never look back!"



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

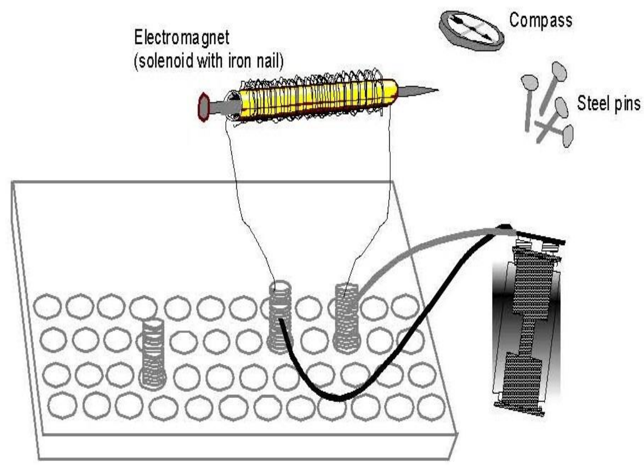
Joe wants to convince his aunty Lindiwe, that the electromagnet is indeed a magnet. The truth is, that he does not really know how, because he does not know how an electromagnet works. Your task is to explain to Joe how an electromagnet works, and why it is a magnet. You will use your micro-electricity 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.)

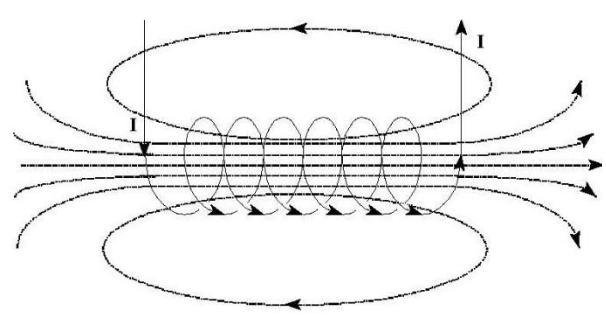


- Find and identify the poles of your electromagnet.
- Compare the magnetic field of your electromagnet with that of a permanent bar magnet.
- Investigate the role of the iron nail, the core of your electromagnet.
- Investigate ways to change the "strength" of your electromagnet.
- Think of the advantages 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 E – Objectives 7.5-7.8

Grade Level - 10

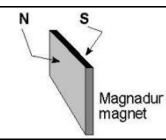
Only a magnetic field can deflect a magnetic compass needle. You saw earlier, that a compass deflects when placed near a current carrying wire. This proves that electric currents produce magnetic fields.

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.

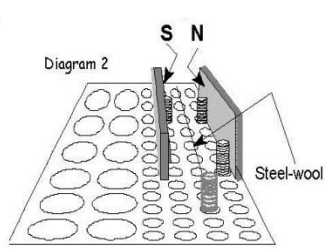
1. One face of a magnadur magnet is a north pole, the other face is a south. Discuss with your group, and find a way to identify the north and south poles of your magnets. Mark their faces with N or S symbols. Explain how you will identify the poles.
2. Pull about five strands (about 10 cm long) from 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.

Twist the strands of the steel-wool

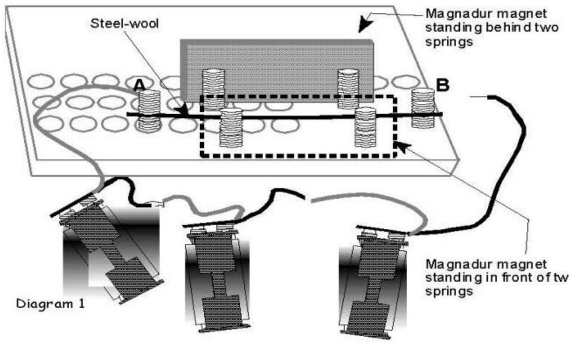
4. Use two magnadur magnets and micro-electricity equipment to set up the rest of the components, as shown in diagram 1.

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.

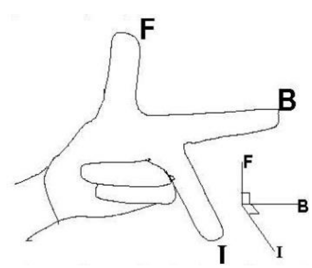


PREDICT

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?

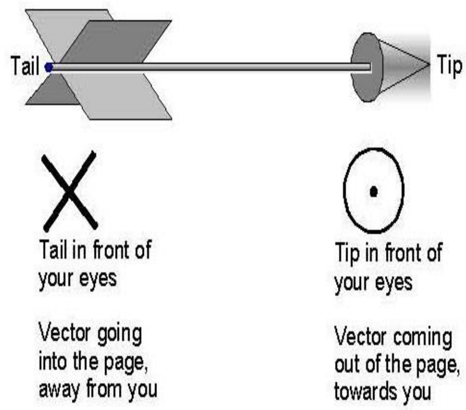
7. Complete the circuit in diagram 1, by touching the black wire on spring B for a second. Look carefully at the steel-wool wire. Repeat if necessary, always touching spring B for no more than a second.
   Repeat by reversing the current in the steel-wool wire. How will you do this?
   Repeat by reversing 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.

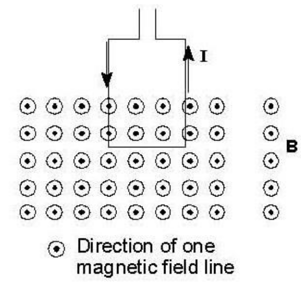
EXTENSION QUESTIONS - THE CHALLENGE!

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.

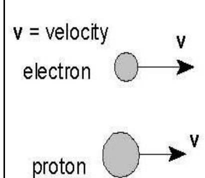


When you hold the tip of the arrow straight in front of your eyes, you only see a circle with a dot in the middle.
When you hold the tail of the arrow in front of your eyes, you only see an "X".
The symbols shown in the left diagram, are very useful when we draw vectors in three dimensions, like in some of the following examples.

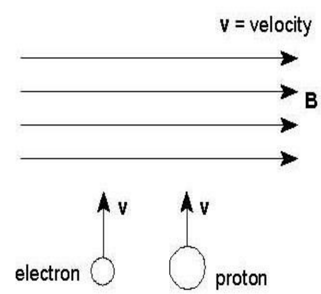
1. A horseshoe magnet is held vertically with the north pole on the left and south pole on the right. A wire passing perpendicularly between the poles carries a current directly away from you.
   a) In what direction is the force on the wire?
   b) Draw a diagram to show directions of magnetic field,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



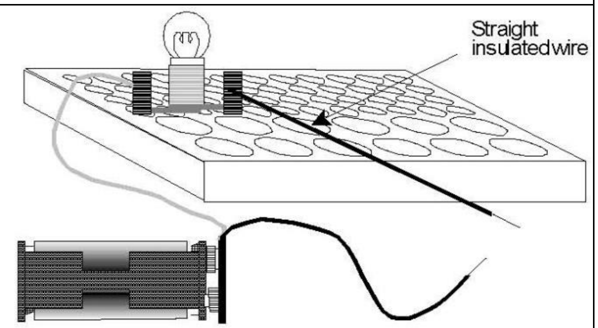
Are they going to experience a force as they enter the field? If yes, use the FBI rule to find the direction of this force in each case.

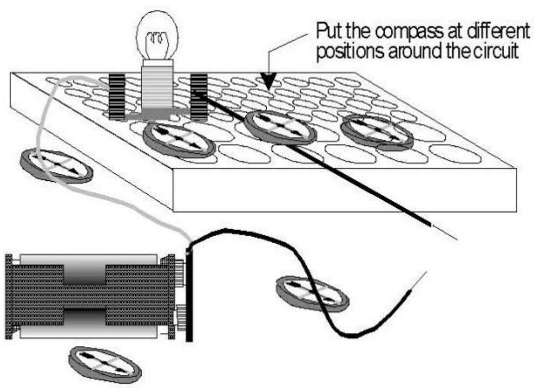
EXPERIMENT 19 – COMING ATTRACTION
CSEC OBJECTIVE (S): Section E – Objective 7.5
Grade Level - 10

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.

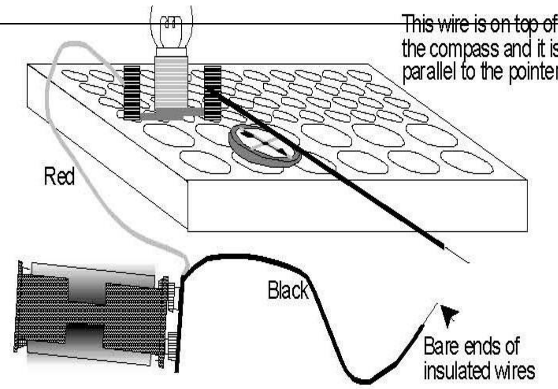




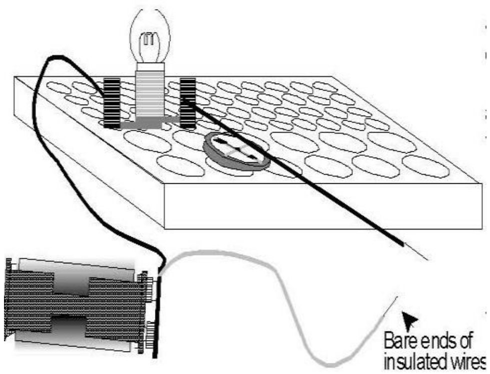
At each new position of the compass, wait until the pointer stops shaking, and then touch the bare ends of the insulated wires. Complete the table below with your observations.

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.

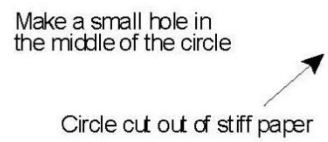
EXPERIMENT 20 – FIELDING

CSEC OBJECTIVE (S): Section E – Objective 7.6

Grade Level - 10

What you need

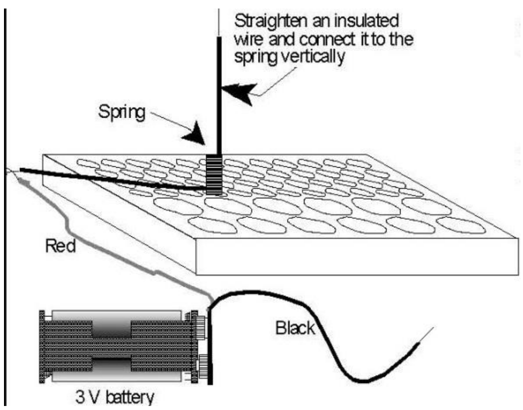
your micro-electricity kit
stiff paper, toilet paper roll, a pair of scissors,
two different colour pens (for example blue and red)



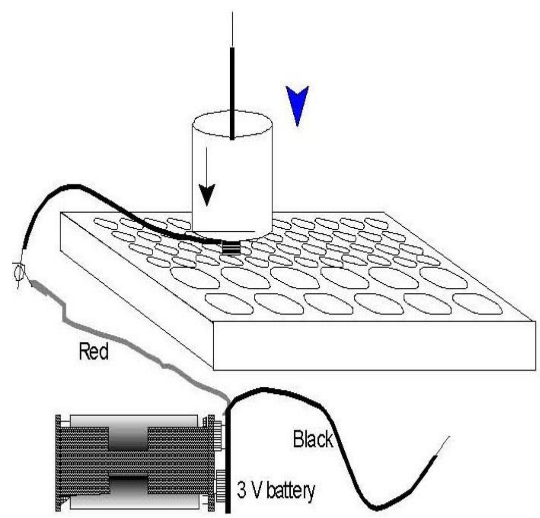
What to do

Work in pairs.

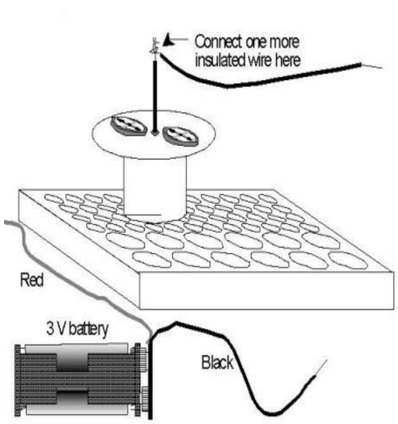
1. Cut a circle out of stiff paper. Cut the toilet paper roll in half (see diagram above right.)



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.

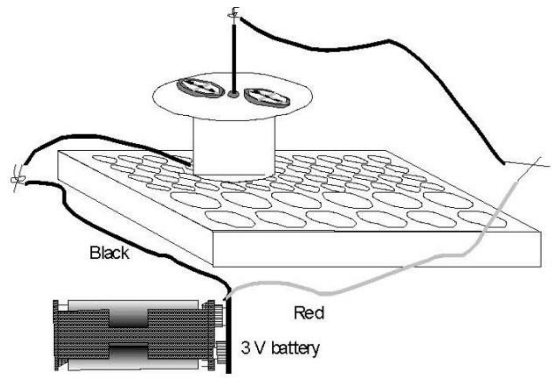


4. Connect another insulated wire to the top of the vertical wire.
   Rest two magnetic compasses on the circle of stiff paper on opposite sides of the vertical wire, as in the d diagram below.
   Where do the pointers of the compasses point to?



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.

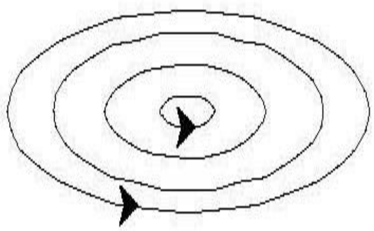


What to discuss

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.

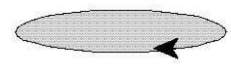


1. From what you saw in this Activity, is this diagram correct? Explain to the others in your group.

Maria's textbook also says that:

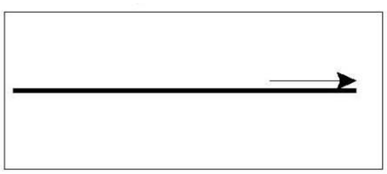
"If you hold the current carrying wire with your right hand, with your thumb pointing in the direction of the current, then the rest of your fingers show the direction of the magnetic field."

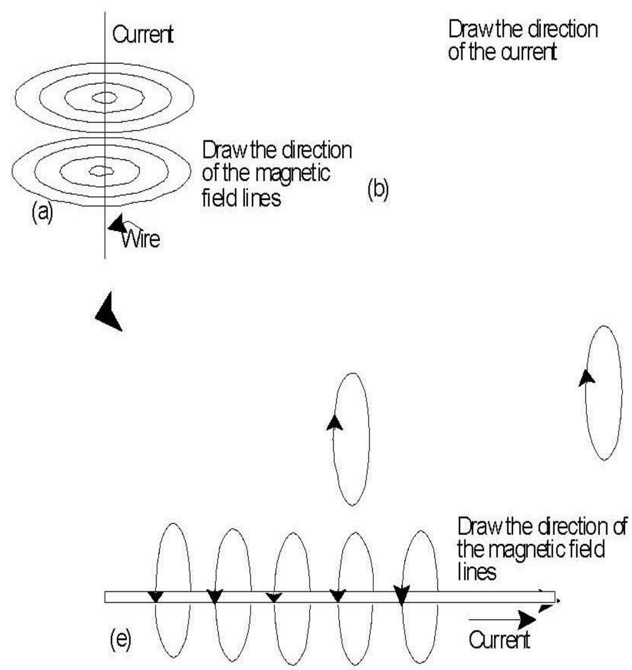
This is called the **right hand rule**.



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?

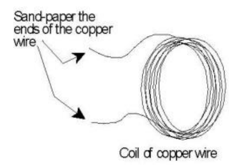
EXPERIMENT 21 – THE STRONGEST OF THEM ALL!

CSEC OBJECTIVE (S): Section E – Objectives 7.1-7.3

Grade Level - 10

What you need

your micro-electricity kit, steel nail or steel paper clips, small steel pins or iron filings, prestik/plasticine



What to do

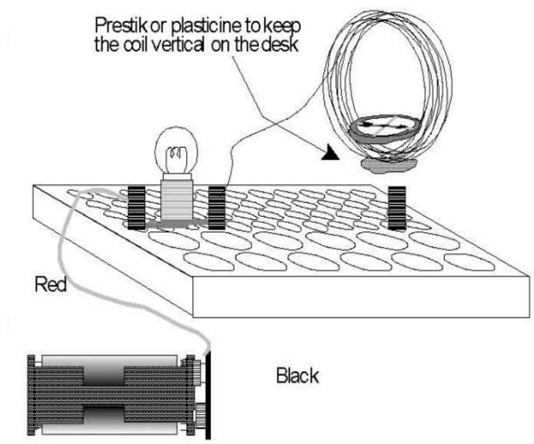
Note: In your micro-electricity kit you will find a coil of copper wire. This copper wire is coated. You must remove the coating from both ends of the wire. You do this by rubbing the ends with the sand paper.

1. Prepare the set up shown in the diagram on the right. Stand the coil vertically on the desk. Place the compass inside the coil.

a) Where does the pointer of the compass point to?

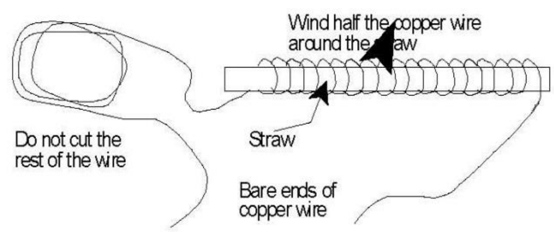
b) Connect the free end of the coil, to the right (as in diagram) spring.
Where does the pointer of the compass point to this time?

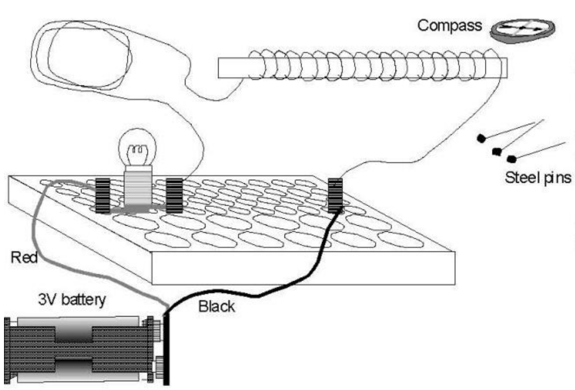
c) Disconnect the ends of the coil from the springs, and connect them the other way round. Where does the pointer of the compass point to this time?



2. In your micro-electricity kit, you have a piece of plastic straw. Wind about half the length of the copper wire around the straw.
Do not cut the rest of the copper wire! Lie the straw on your desk.

Note: The windings must be in the same direction!



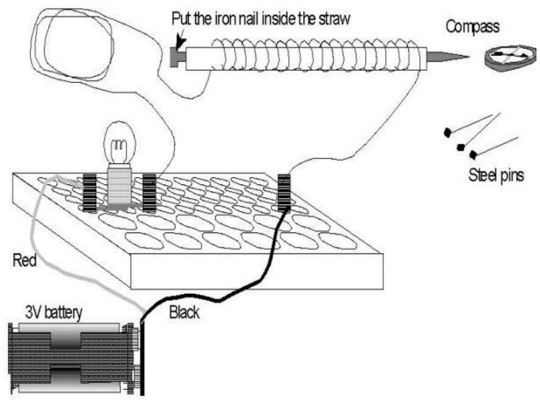


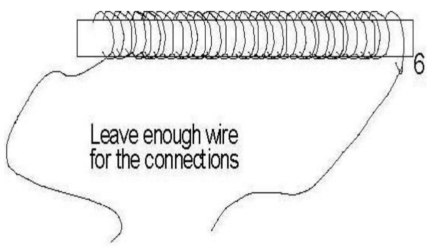
3. Connect the ends of the copper wire to your circuit, as in the diagram on the left.

a) Bring the compass close to the straw at different positions.
What happens?

b) Move one the end of the straw close to the pins. What happens?

4. Now, insert the iron nail inside the straw, as shown in the diagram on the right.
   a) Bring the compass close to the straw. What happens?
   b) Move one end of the straw close to the pins. What happens?
5. Disconnect the copper wire from the springs. Wind some more wire around the straw. Repeat steps 3 and 4.



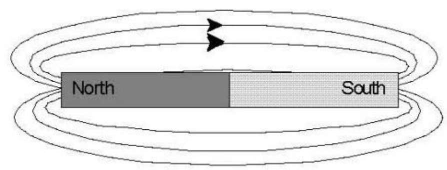


6. Replace the iron nail with the steel nail or straightened paper clips.
   Repeat steps 3 and 4. If you have steel paper clips, straighten up two of them and insert them in the straw. You may also try the same thing with some of the strips in your kit. Record your observations in a table.

What to discuss

A coil of wire, like the copper wire wound around an empty straw, is called a **solenoid**. The word “solenoid” is a Greek word meaning “hollow pipe”. If you put an iron bar inside the solenoid, you have an **electromagnet**.

1. In this Activity, you inserted an iron nail inside your solenoid. The solenoid with the nail is an electromagnet.
   a) Do you think this name is suitable? Explain.
   b) Does a solenoid connected to a battery produce a magnetic field around it? Explain.
   c) In this Activity, how did you make a stronger electromagnet?
2. If you were to use the 9 V battery instead of the 3 V battery you used in this Activity, how do you think this change would affect your electromagnet?
3. Sibongile reads in her text book : “**An electromagnet is similar to a bar magnet.**”
   Sibongile asks: “Then where is the south and north pole of the electromagnet?”
   a) Explain to Sibongile how to find the north and south pole of an electromagnet.
   b) How can you change the north and south poles of your electromagnet?
4. Diagram A, shows the magnetic field lines around a bar magnet. Their direction outside the magnet, is always due south.
   With the help of diagram A, find the north and south poles of the electromagnet shown in the diagram B. (Hint: Use the right hand rule).



5. In conclusion, which factors affect the strength of your electromagnet?

EXPERIMENT 22 – AMMETER, TO BE AND NOT TO BE

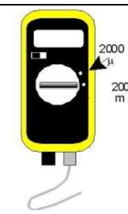
CSEC OBJECTIVE (S): Section E – Objective 4.5

Grade Level - 10

What you need

micro-electricity kit, multimeter

YOUR MULTIMETER - MAKE GOOD USE OF IT!



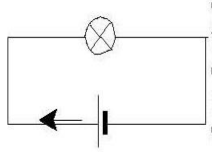
1. The diagram on the right shows roughly what your multimeter looks like. The multimeter becomes an ammeter, when the pointer points at either of the two dots shown in the diagram.

i. In the diagram, the pointer points at the dot marked 200 m. It stands for 200 milli-amperes (or mA). At this position, you can measure currents up to 200 mA.

ii. The dot marked 2000 m, stands for 2000 micro-amperes (or mA). When the pointer points at this dot, you can measure currents up to 2000 mA.

SOME MATHS NOW

2. What is “milli-” and what is “micro-”?
   a) Surely you have heard of millilitres (ml). You have also heard of millimetres (mm). What then is a milli-ampere (mA)?
   b) When do we use the prefix “micro”?
   c) The micro-ampere (µA) is a millionth of an ampere. How many µA make an ampere? How many µA make 1 mA?
3. You want to know the current in your circuit, so you must connect an ammeter in the circuit.



On the one hand, you want the charge to pass through the ammeter, so that it can measure the current.

ii. On the other hand, you do not want the ammeter to interfere in anyway with the current.

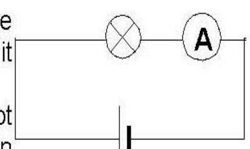


Diagram (a)

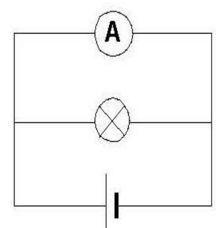
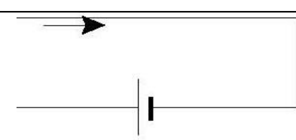


Diagram (b)

a How does one deal with these two points?

b You want to measure the current in the diagram on the left. Which diagram on the right shows the correct way to connect the ammeter and why?

MAKE SOME PREDICTIONS

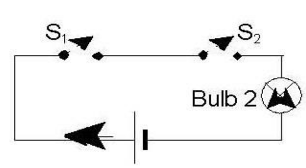


4. You connect an ammeter at point B of the circuit on the right. The ammeter reads 130 mA. What will the ammeter read if you connect it at:

a) point C?

b) point D?

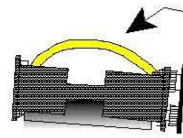
c) Compare the current at points C and D with the current at point B.



5. The diagram on the right shows a circuit with two identical bulbs and two switches S1 and S2 connected as shown.

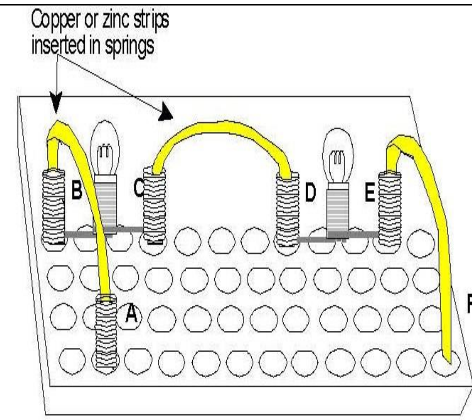
a) Which switch/es must you close to make bulb 2 glow?

b) If you close switch S1 while S2 stays open, what will happen to bulb 1?

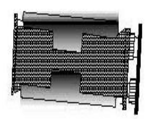


TEST YOUR PREDICTIONS

A USEFUL TIP: The cell holder is designed to hold two 1,5 V cells. If you want to use one cell only, you can still use the cell holder. The diagram on the right shows one way.
Of course you may have better ideas....

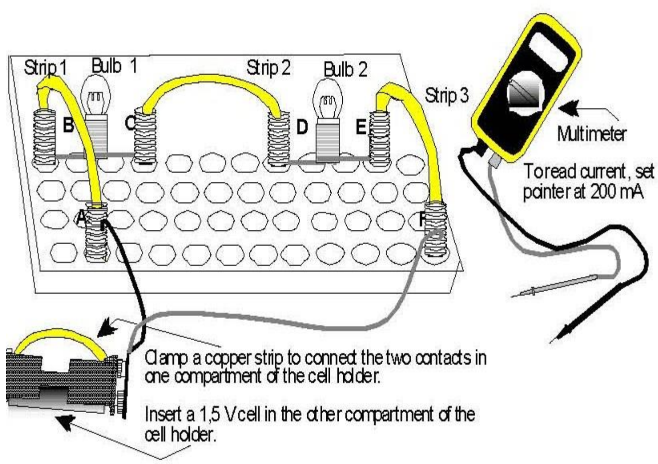


6. In question 4, you compared the current at points C and D with the current at point B. Test this prediction using components from the micro-electricity kit. Use only one 1,5 V cell.
7. Use components from your microelectricity kit to prepare the circuit shown in the diagram on the right.



a) Use this circuit to test your predictions in question 5. How will you simulate the action of the switches S1 and S2?
b) Compare your observations with your predictions. If there is conflict, explain.
c) Remove one bulb (or just unscrew it) from the circuit. What happens to the other bulb? Explain.

8 Work with the circuit you have just made, but use only one 1,5 V cell.



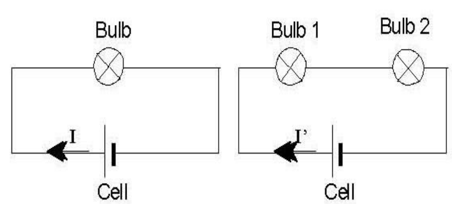
a Use the multimeter to measure the current:
- i on the left of bulb 1
- ii between bulbs 1 and 2
- iii on the right of bulb 2

In between measurements switch the ammeter off.
Record your measurements in a table.
When you finish, don't forget to disconnect the cell.

b Compare the three currents you have just measured. What is your conclusion?

9 The diagrams on the right, represent the circuits you set up in question 6 and in question 8 respectively.

Compare these two circuits. Compare what you have measured and observed. What conclusions can you draw from the information?



EXPERIMENT 23 – ELECTRIC MOTOR 1

CSEC OBJECTIVE (S): Section E – Objective 7.9

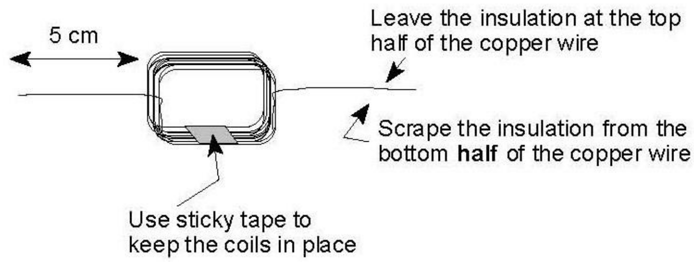
Grade Level - 10

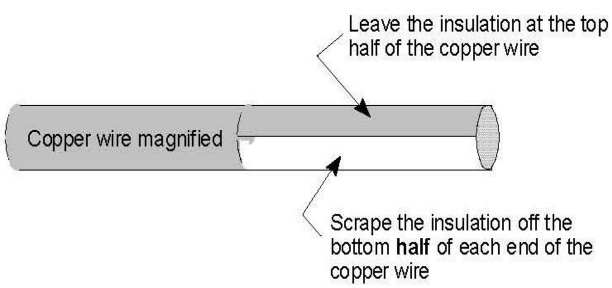
What you need

micro-electricity kit, two magnadur magnets, sticky tape, a pair of scissors

What to do

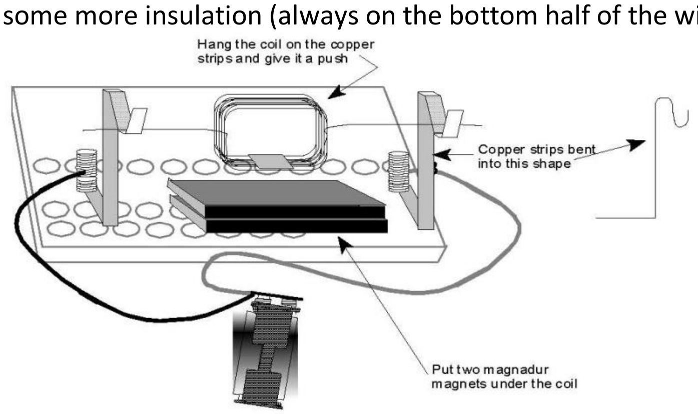
1. Use wire from the copper coil in the micro-electricity kit. Use this wire to make a coil of about 10 to 15 windings. You may use the 9 V batteries and wind the wire around it to make a coil. Leave about 5 cm wire free from both ends of the coil.





2. Scrape the insulation from only the bottom half of both the ends of the wire. See diagrams.
3. The diagram below, shows how to set up the coil and the magnets on the c omboplate.
   Connect the cell only when you are ready to test your motor.

The ends of the coil where you scrapped off the insulation, must touch the copper strips.
When your motor is ready and the cells connected, give the coil an initial push with your finger to get it started. If the coil does not turn, check that the contacts between copper strips and coil are good. You may have to scrape off some more insulation (always on the bottom half of the wire).



4. This is the complete motor. You must be prepared to identify the direction of the current in the coil and the polarity of the magnets. You must give the initial push in the right direction!
5. You must also be prepared to explain to the other learners in your group, why you only scrape the insulation from the bottom half of the wire. What would happen if you were to scrape the insulation off all around the wire?

What to discuss

1. List five things that run with a motor. Things you can find at home or at school. Why do these things need a motor? (Which part of each device does the motor turn?)
   For example: The electric fan has a motor. The motor turns the blades.
2. In the following figure, what happens to each straight current carrying wire

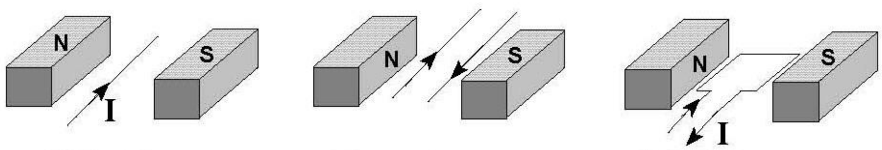


Diagram a Diagram b Diagram c

a) in diagram a?
b) in diagram b?
c) in diagram c?
d) On all three diagrams draw any forces acting on the wires.

YOUR MOTOR

3. Study the motor you made in this Activity and briefly explain how it works. Mention the following:

a) is the magnetic field produced by a permanent magnet or by an electromagnet?
b) the direction of current in the coils, does the current alternate?
c) are there any commutators and brushes?
d) does the motor turn continuously in one direction? What keeps the motor turning in the same direction?
e) ways to make the motor “stronger”.

EXPERIMENT 24 – ELECTRIC MOTOR 2

CSEC OBJECTIVE (S): Section E – Objective 7.9

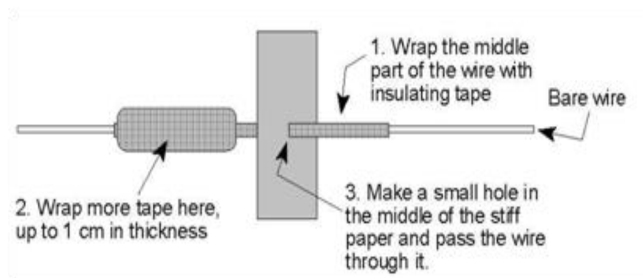
Grade Level – 10

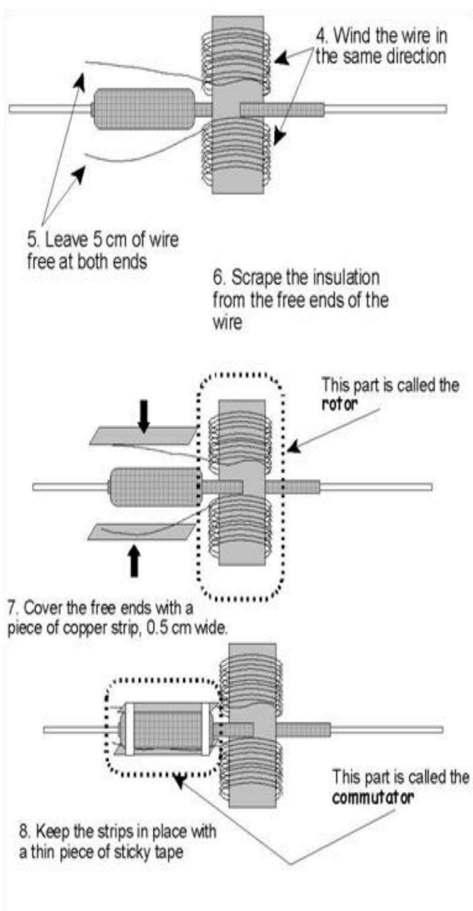
What you need

a micro-electricity kit, straight wire about 15 cm long (eg. a large paper clip), two magnadur magnets, sticky tape, like insulating tape, a pair of scissors, a piece of stiff paper or other light material (eg. polystyrene), 4 cm x 1 cm.

What to do

1. Make this motor, following the steps in the diagrams.
2. To make the windings of this motor, use the wire from the copper coil in the micro-electricity kit. If you need two coils, remember to scrape the insulation from both the ends to be connected.





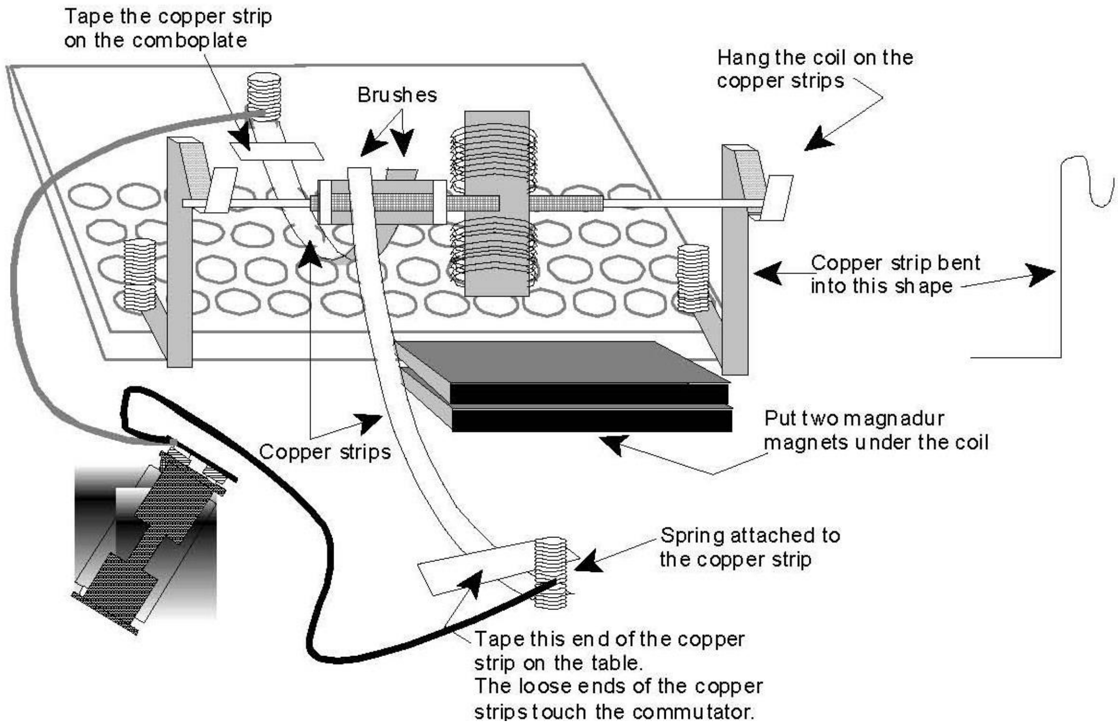
Leave 5 cm of wire free and start winding the rest onto the piece of stiff paper. *Start at the centre and wind evenly towards one end of the paper, in a clockwise direction. When you reach the end, work back towards the centre. **Without** breaking the wire, do the same thing on the other side of the stiff paper.

Repeat from the asterisk until you wind all the wire.

At the end leave a 5 cm piece of wire free.

Be careful that the windings are made in the same direction and be careful to wind the same number of layers on both sides of the stiff paper.

3. The diagram on the next page shows what to do next. The long copper strips that touch the commutator (see diagram), are called "brushes". Make sure that the brushes touch the conducting parts of the commutator at the same time. The motor is ready!



What to discuss

YOUR OWN MOTORS

1. Compare the motors in Activities 5 and 6. Briefly explain how each one works. Mention the following:

a) how the magnetic field is produced, by a permanent magnet or by an electromagnet?
b) the direction of current in the coils, does the current alternate?
c) are there any commutators and brushes?
d) does the motor turn continuously in one direction, and if so, what keeps the motor turning in the same direction?
e) ways to make the motors "stronger".

2. Explain the major difference in the way the two motors work.

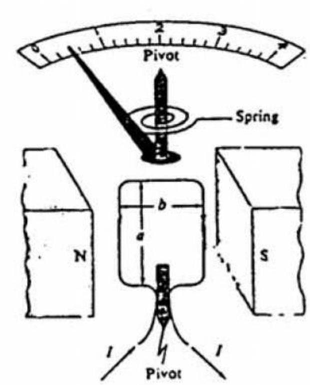
AND THERE IS MORE!

There are more important and practical devices, which also take advantage of the force between a current and a magnetic field, other than the motors! Such devices are the galvanometers, the loudspeakers, the chart recorders, and many more!

3. The diagram shows the principle workings of a galvanometer, the basic component of many meters (ammeters, voltmeters, ohmmeters.....)

a) Use the hand rule to find the force acting on each side of the rectangular loop.
b) Briefly explain how the pointer moves.

4. What energy transformations take place in an electric motor?



EXPERIMENT 25 – CAN MAGNETISM PRODUCE ELECTRICITY?

CSEC OBJECTIVE (S): Section E – Objective 7.5

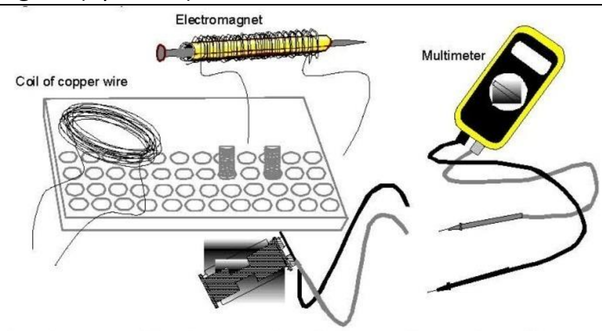
Grade Level – 10

Electricity produces magnetism. An electric current produces a magnetic field. Is the opposite true? Can magnetism produce electricity? Can a magnetic field produce an electric current?

What you need

micro-electricity kit, multimeter, magnadur magnet (optional)

To discuss before you start



Rashay, Nicolas and Alex are all grade 10 learners. In their group they discuss the question: **Can magnetism produce electricity?**

Rashay all excited, says: "If electricity produces magnetism, then I am absolutely certain that magnetism can produce electricity. In nature, everything happens in pairs .... positive and negative, north and south, action and reaction.... you name it!"

Nicolas is even more excited. He says: "And what is even better, having a strong magnet at home, will produce all the electricity we need! No more electricity bills! Electrical energy for free with a magnet!"

Alex is not very excited! He says: "Nicolas, I wonder why nobody has thought of this before! We also know that we can't get something out of nothing! Can a magnet, even a strong one, provide us with free energy?

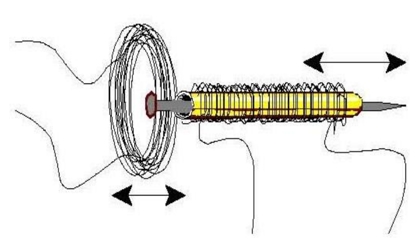
I find it hard to believe, it is against the laws of nature!"

So what do you think the answer is? Discuss the above comments with your group and add your own views. You can discuss this question again at the end of the Activity.

What to do

THE INVESTIGATION

1. Use a coil, an electromagnet (or a magnadur magnet), your multimeter, and any other component from your micro-electricity kit which you might think would be of some use. Your task is to investigate if there is a way to produce (induce) an electric current in the coil.

   Hint: Compare what happens when:
   - the electromagnet is stationary inside the coil
   - the electromagnet moves inside the coil
   - the coil moves along the length of the electromagnet

   Explain how you will produce a magnetic field.
   Explain how you will know if a current is induced in the coil.
   Something to consider in your group: If you manage to induce a current in the coil, do you expect this current to be large or small? On which scale would you set your multimeter?
   Try your plan out using your components.
2. If you do not have a multimeter, is there any other way to test if a current is induced in the coil? (using equipment from your micro-electricity kit.) If you think yes, test this new way.

3. Summarise your conclusions and prepare a report back. In your report, mention ways (and test these ways if possible), to increase the induced current in the coil.
4. It took more than 10 years after Oersted's discovery, before two other scientists eventually succeeded to induce an electric current this way. These scientists were the American Joseph Henry and the Englishman Michael Faraday. Working independently, they both found that it was possible to produce an electric current from a magnetic field.
   This phenomenon is called electromagnetic induction.
   Why do you think it took them so long?
5. When Henry and Faraday made this discovery, many people were not impressed! "So what!" they said.
   Today, our electricity supply relies on electromagnetic induction!
   Most of the electricity we use at home, comes to us in wires. We know by the monthly bill we pay, that there is an electrical company at the other end of the wires. How does the electric company produce electricity? With "giant batteries"? Surely not! Electricity is produced in power stations.

a) From which power station does your community get its electrical supply of energy?
b) Discuss in your group, how electrical energy comes from the power station to your homes or school? (As far as you know).

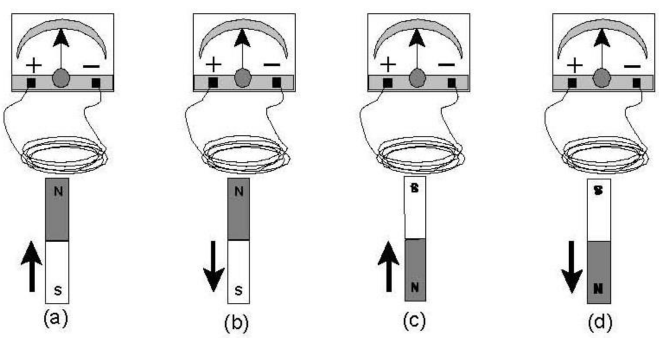
THE CHALLENGE!

How do we find the direction of the induced current in the coil?

Lenz's law: The induced current in a coil has such a direction, so that its magnetic field opposes the change brought about by the external magnetic field.

The diagrams below, show a coil connected to a galvanometer and a bar magnet in the vicinity of the coil. The bar magnet moves, its movement is indicated by an arrow.

A galvanometer is an instrument that detects small currents and their direction. When the needle is in the middle, it means that there is no current in the circuit.



Use Lenz's law to find the direction of the induced current in each diagram.

a) What will be the deflection of the galvanometer in each diagram?
b) What does this indicate?
c) Explain how you find the direction of the induced current.

EXPERIMENT 26 – ON, OFF-OFF, ON

CSEC OBJECTIVE (S): Section E – Objectives 4.1-4.4

Grade Level – 10

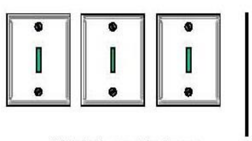
This Activity is to refresh your memories about electrical circuits. You will think about the differences between light bulbs when they joined in series and when they are joined in parallel. You will also use circuit diagrams to represent light bulbs in series and in parallel.

What you need

a basic micro-electricity kit

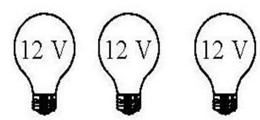
MR DHLAMINI'S ON, OFF - OFF, ON PROBLEM

Mr Dhlamini is quite an impatient man. He has been waiting for two years for electricity to be brought to his community, as promised by the government. He finally decides to try and light up his home on his own. He wants lights in three rooms of his house. He knows that the headlights of a car run off a car battery so he decides to use a 12 V car battery as his energy source. He buys three wall switches, three light fittings, three 12 V light globes and metres and metres of single stranded electrical wire.



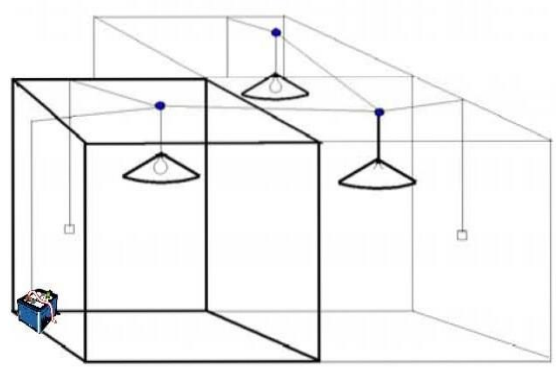
`light switches

12 V battery



light bulbs

He very proudly connects up the lights and switches in the three rooms to the car battery, as shown in the figure. However, he is so disappointed when none of them work. He finally discovers that only when the three switches are 'on' do his lights work. He is unable to turn any one of the lights on or off individually. They either all stay on or all go off. To say that he is disappointed is an understatement. He knows very little about electrical circuits and does not know how to solve this problem. How can you help him?



Note: The figure does not accurately show how the lights are connected.

PART A

What to do

1. Chose someone from your group to reads Mr Dhlamini's problem out aloud.
2. As a group you will discuss what Mr Dhlamini did wrong, and why he was unable to switch the lights on and off separately.
3. Each of you will sketch a circuit diagram of Mr Dhlamini's lights set up. You will then compare and discuss your circuits.
4. Select one of the circuit diagrams to use for the next step.
5. Use the chosen circuit diagram and the micro-electricity kit to build a model of the circuit.

What to discuss

1. Why is Mr Dhlamini having such problems with his lights?

2. Why do you need to have a switch in a circuit?
3. As there are no switches in your micro-electricity kits how are you going to show that there is a switch in your circuits?
4. How do the bulbs compare in brightness? What does this tell us about the current in the bulbs and the circuit? What instrument can you use, and how will you connect it in a circuit, to measure current at different points in a circuit?
5. If you remove one of the light bulbs so that there are only two in the circuit, what is the brightness of the remaining two light bulbs compared to when there were three bulbs? Try this out with your set up.
   Describe why there is a difference?
6. In your discussions you will have used the words, 'electricity', 'current' and may be even 'charges' several times, perhaps now is the time to discuss with each other what the terms actually mean. Choose someone from your group to write the meanings of the three words on a piece of flipchart paper. Your teacher will later ask someone from each group to stick the explanations (definitions) on the wall.

PART B

What to do

Your next task is to solve Mr Dhlamini's problem.

1. First as a group, discuss how Mr Dhlamini should connect his lights so that he can switch them on and off separately.
2. Draw a circuit diagram which Mr Dhlamini can use to solve his problem.
3. Use the micro-electricity kit to make a model of your proposed circuit.

What to discuss

1. What are the differences between Mr Dhlamini's circuit and your circuit, and what are the advantages of your circuit? Are there any advantages of Mr Dhlamini's circuit?
2. How do the bulbs compare in brightness? What does this tell us about the current in the bulbs and the circuit?
3. If you remove one of the light bulbs so that there are only two in the circuit, what will the brightness of the remaining two light bulbs be compared to when there were three bulbs? Once you have made your prediction make changes to your circuit to test your prediction.
4. How will the brightness of three light bulbs compare when one of the bulbs is connected in series and the other two are connected in parallel? Once you have made your prediction change your circuit to test your prediction. Explain.
5. A battery is a source of energy. Discuss the following energy transfers;

a) from the battery to the electrons of the connecting wires;
b) from the connecting wires to the filament (tungsten) inside each of the light bulbs;
c) from the light bulbs to the surrounding environment.

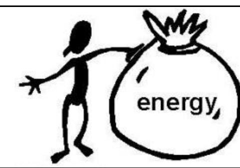
6. When we talk about current we need to give it a direction. What is the conventional direction of an electrical current?
7. Something Mr Dhlamini has not thought of is that his battery does not have an ever-ending source of energy and will go 'flat' after a few hours. One nice feature of a car battery is that it can be recharged.
   Discuss possible ways in which Mr Dhlamini could recharge his battery.

EXPERIMENT 27 – WHAT IS ELECTRICAL POTENTIAL DIFFERENCE?

CSEC OBJECTIVE (S): Section E – Objective 3.2

Grade Level – 10

Electrical potential difference means the difference in electrical potential energy per coulomb (unit charge) between two points. In this activity you will consolidate your understanding of the concept of electrical potential difference.

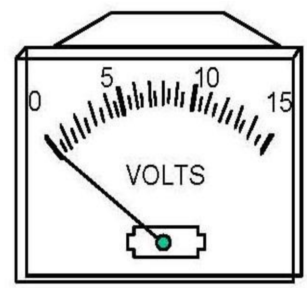


PART A

In this Activity, you will work in small groups. You will again be answering some of Mr Dhlamini's questions.

Mr DLAMINI'S CAR BATTERY IS FLAT!

Mr Dhlamini takes his car battery to the local store to recharge it. He sees that Mpho, who works at the store, uses a 'little machine' to check the battery. After he has recharged the battery the reading on the 'little machine' is 12 V. He learns that the 'little machine' is called a voltmeter. He asks Mpho if he can borrow the voltmeter for a few days to check the battery. Mpho tells him that he must be very careful when he connects the voltmeter, otherwise he could damage it. He shows him how to connect the voltmeter to the one terminal of the battery and then the other.



Mr Dhlamini has also taken your advice, given in an earlier activity. He has connected his three light bulbs in parallel and is very pleased with them. On his way home he thinks about the voltmeter and asks himself these two questions:

a) How does a voltmeter work, and what does it measure when it is connected across a battery?
b) What does the word "volts" on the voltmeter mean?

You are going use your prior knowledge of voltmeters and potential difference to answer Mr Dhlamini's questions.

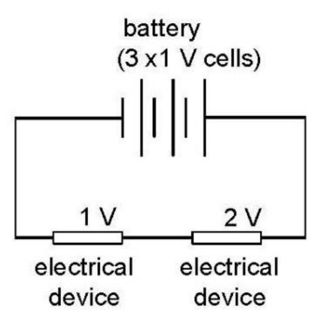
Support your answers with labelled drawings of circuit symbols. Put your answers and drawings onto flip chart paper or big pieces of plain paper.

PART B

The whole class will do a role play of voltage, energy and current. You will act out what happens in the series circuit given on the right.

This is a fun activity but it is important because it will help make some of the following concepts clearer and easier to understand;

- differences in potential energy,
- a current is composed of moving charges,
- charges do not get used up, only the potential energy of the charges is used up as they move in the circuit,
- charges leaving the battery have high potential energies and charges entering the battery have no potential energy.



What you need

1. 3 buckets or any other large containers. One bucket is the battery. The other two buckets are

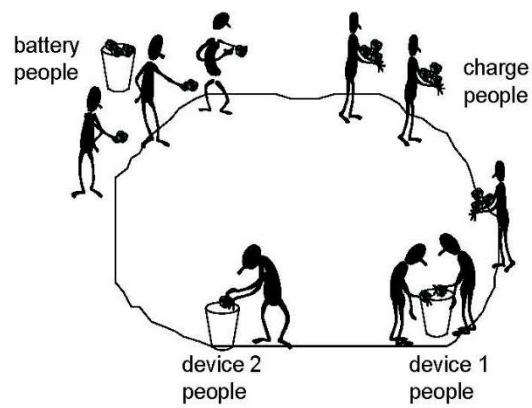
the electrical devices.

2. Mark out the circuit with string or rope, or else use chalk. You can also do this outside and draw the circuit in the sand.
3. Crumpled pieces of paper, or stones, or any other small objects, that can represent "bundles of energy".

   Fill the battery bucket with the "bundles of energy".

What to do

1. Choose one person or two people (not your teacher) to be the director(s), who will be in charge of the "circuit". Your teacher is the assistant director who gives help and guidance. The director will decide who is doing what, make sure all the instructions are clear, decide when the role play stops etc.
2. Choose three people to be "battery people". The "battery people" give the "charge people" "bundles of energy" from the battery bucket.
3. Choose two people to be the two electrical devices, the "device people". The devices are not identical. One device must have a voltage of 1 volt across it, and the other 2 volts across it.
4. The rest of the class are the "charge people" travelling around the circuit. As each "charge person" travels through the battery they get a "bundle of energy" from each "battery person". This means each "charge person" will have three "bundles of energy".The "charge person" gives each "device person" the correct number of "bundles of energy" as he/she travels through the device. The "charge person" then continues travelling around the circuit and returns to the "battery people" to get more "bundles of energy".



What to discuss

1. The following terms, "volts" and "battery" were mentioned briefly, and the terms "coulombs", "cells", "current" and "potential difference" were purposely left out in your role play instructions. Use these terms and write a paragraph explaining the whole process of what happens when charges move in a series circuit.
2. The SI unit for potential difference is 'the volt' represented by the symbol 'V', however there is another unit which can be more meaningful. In Grade 10 you met the following equation:-

   potential difference = energy transferred/coulomb of charge

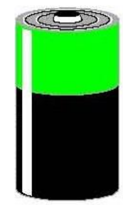
$$V = \frac{W}{Q}$$

   Discuss this equation and then derive the second unit, and explain why it is more meaningful.

EXPERIMENT 28 – THE MAXIMUM POTENTIAL ENERGY OUTPUT OF A BATTERY

CSEC OBJECTIVE (S): Section e – Objective 3.2

Grade Level – 10



If we measure the potential difference across the terminals of a cell or battery when it is not supplying a current, we measure the maximum electrical potential energy which the cell or battery can deliver to a coulomb of charge. We call this maximum electrical potential the emf of the cell. It was originally thought that an electromotive force (abbreviated emf) caused charges to move. We don't think of it that way anymore, we think instead in terms of energy transferred.

In this Activity you will again be meeting Mr Dhlamini and his excitement about the voltmeter. Soon after Mr Dhlamini gets home from seeing Mpho at the store he connects his car battery to the light circuit of his house. He follows Mpho's careful instructions and he connects the voltmeter in parallel with the car battery. To his surprise, the reading on the voltmeter is less than 12 volts. His first response is that the voltmeter is not working properly.

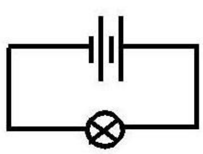
Then he thinks maybe his battery is leaking "energy". He then starts to worry. How can the newly recharged car battery have less volts and it hasn't even being used.

What you need

a basic micro-electricity kit, a voltmeter

What to do

1. Make a battery with the two 1.5 V cells and the cell holder. Connect the voltmeter across the terminals of the 3 V battery. Note the voltmeter reading.
2. Draw a diagram of the voltmeter connected across the battery.



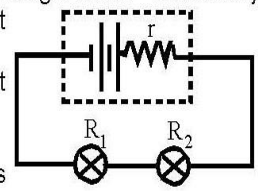
3. Set up the simple series circuit given on the left.
4. Connect the voltmeter across the battery and take a reading.
5. Connect the voltmeter across the light bulb and take a reading.
6. Draw up a table to record the three readings.

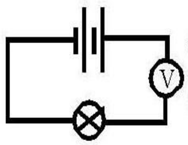
What to discuss

1. What was the emf of your battery? Use the values that you measured to describe the emf value in terms of joules and coulombs.
2. This is part of a conversation between Lebala and Phoka when they set up a similar circuit. The only difference between the circuits is that they used a 9 V battery.
   Lebala: "You know Phoka, I am confused! When we measured the potential difference of the battery before we put it in the circuit it was 9 V. But when we measured it when it was in the circuit it was only 7 V. Where have the other 2 V gone?"
   Phoka: "I think they are 'lost'."
   Lebala: "Phoka, how can you just lose some volts, eh?"
   Phoka: "You know, the battery was quite hot after we finished taking our measurements. Maybe it has something to do with the battery."
   Consider the above conversation. Did any of you observe the same thing as Lebala? Try and explain what happened to the 'lost volts'.
3. One of the important features of a voltmeter is that it is designed so that it has a very high resistance.

Why is it designed in this way?

4 The diagram alongside represents a series circuit of a battery and two light bulbs. The battery symbol includes the two cell symbols and the resistance offered to a current by the battery. Use the symbols r, R_1 and R_2 given in the diagram, to represent the total resistance of the circuit as an equation.





5 The circuit on the left shows a voltmeter that is connected in series with a light bulb. The voltage of the battery is 3 V.

Consider the following questions about the circuit.

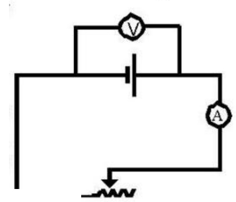
a) Will there be a reading on the voltmeter? If there is a reading on the voltmeter, will it be the same as the emf reading of the battery or will it be the same as the reading across the light bulb?
b) Will the light bulb glow? In other words will there be a current in the circuit?

Answer the questions and give a reason for each of your answers.
compare your actual observations of the circuit with your predictions.
Where your answers do not agree with your observations, explain why that is so.

TO THINK ABOUT

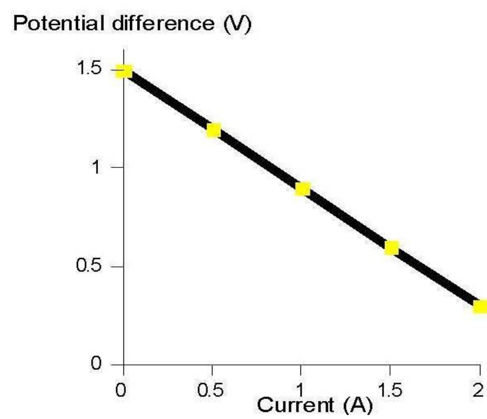
1. A range of results were obtained from the circuit on the right. The rheostat (variable resistor) is connected in the circuit to vary the current.

Set up the circuit and then Reassess your answers.



The table and the graph below show the relationship between the potential difference across a cell and the current that flows from it.

Current (A)	Potential difference across cell (V)	"Lost voltage" (V)
0	1.5	0
0.5	1.2	0.3
1	0.9	0.6
1.5	0.6	0.9
2	0.3	1.2



Answer the following questions.

a) What is the meaning of the term, "lost voltage"?
b) Explain why the "lost voltage" value is zero when the potential difference value across the cell is 1.5 V.
c) Describe how an increase in current will have an effect on the potential difference values.

2. A current of 5 A in the resistance-wire of a hot-plate transfers 66 000 joules of heat in 1 minute. What is the potential difference between the terminals of the hot-plate?