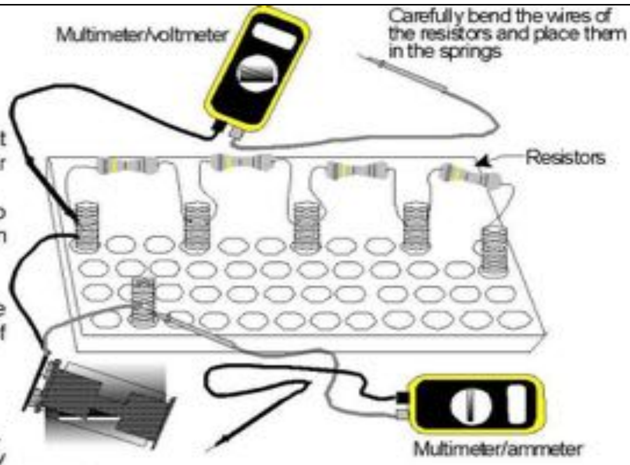
EXPERIMENT 8 – ONE AFTER THE OTHER, CAUSING A GREAT BOTHER
CSEC OBJECTIVE (S): Section D – Objectives 4.12
Grade Level - 9

What you need

micro-electricity kit, two multimeters, graph paper



What to do

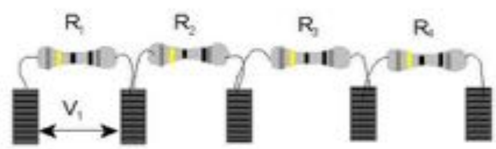
Work in groups of two or three. Set up one circuit per group and combine the components of your kits when necessary.
Use components from the micro-electricity kit, to connect four resistors in series, as in the diagram on the right.

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?

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

EXPERIMENT 9 – FREE ELECTRONS ARE NOT SO FREE!
CSEC OBJECTIVE (S): Section D – Objective 2.2

Grade Level - 9

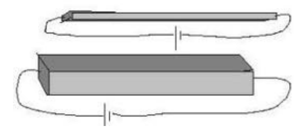
INVESTIGATION No 1 : THE THICKNESS OF A CONDUCTOR

What you need

micro-electricity kit, multimeter

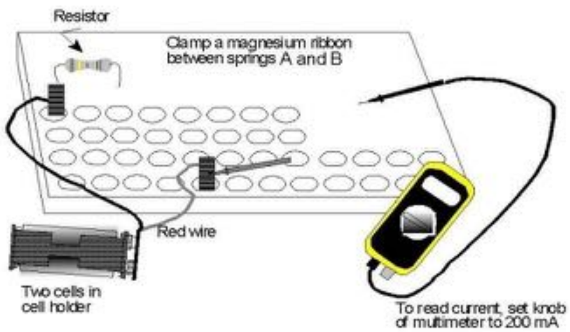
PREDICT

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.

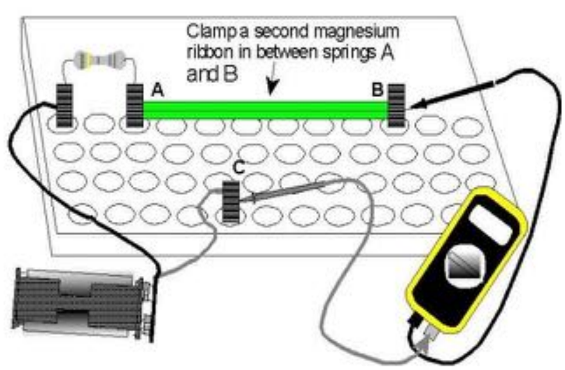


TABLE No 1
The Effect of the Thickness of a Conductor on its Resistance

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.

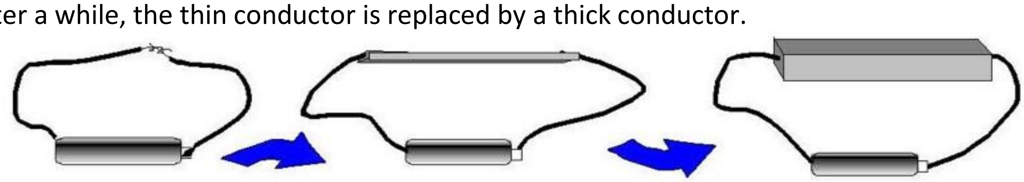
Number of copper strips	Current (mA)	P.D. across copper strips (V)
1	1010	0
2	1019	1
3	1014	0

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.

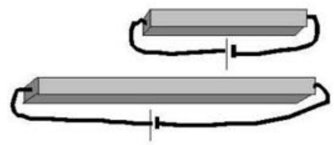
INVESTIGATION No 2 : THE LENGTH OF A CONDUCTOR

What you need

micro-electricity kit, multimeter

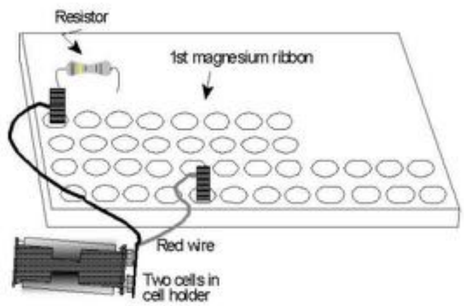
PREDICT

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

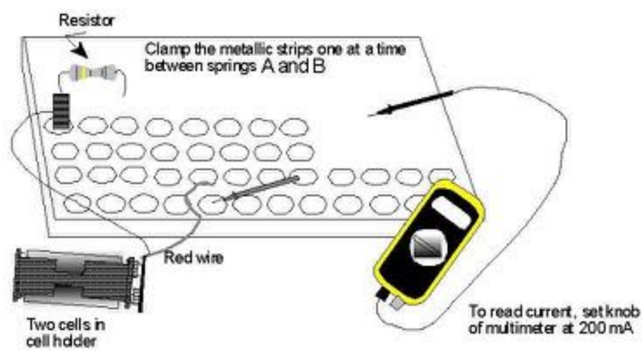
PREDICT

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 more 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.

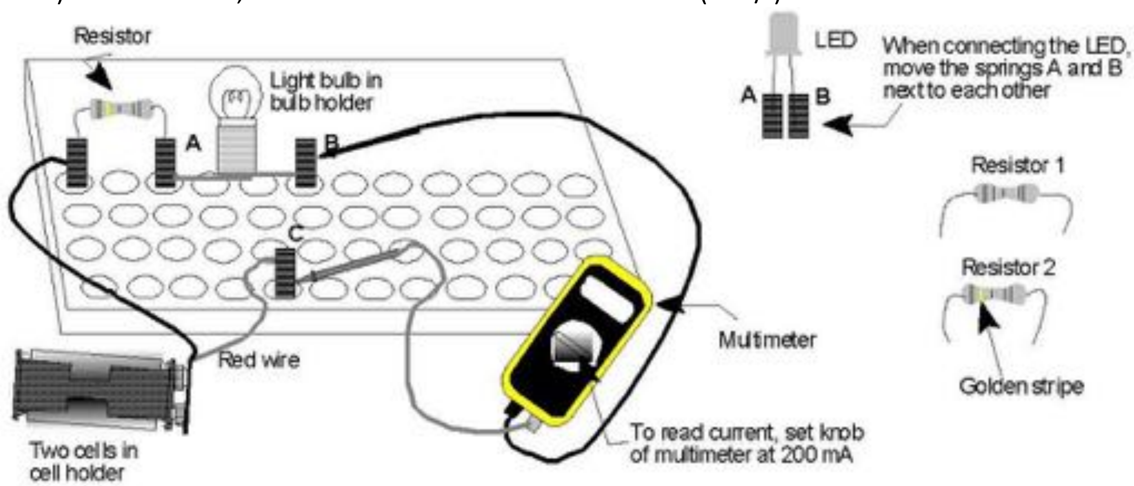


TABLE No 3
The Effect of the Material of a Conductor on its Resistance

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.

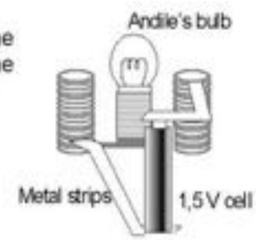


Diagram A

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 oC or
   ii. a conductor at 80 oC.
   Justify your answer.

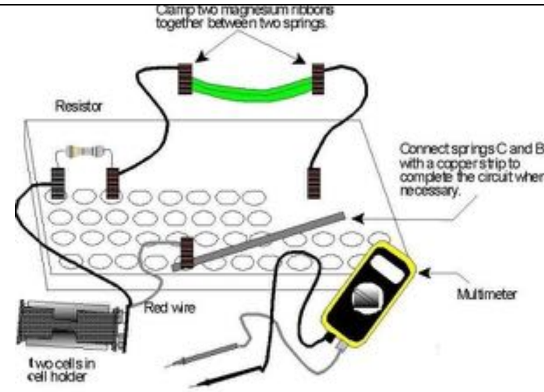
In this investigation, you will calculate and compare the resistance of a conductor at two different temperatures.

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.

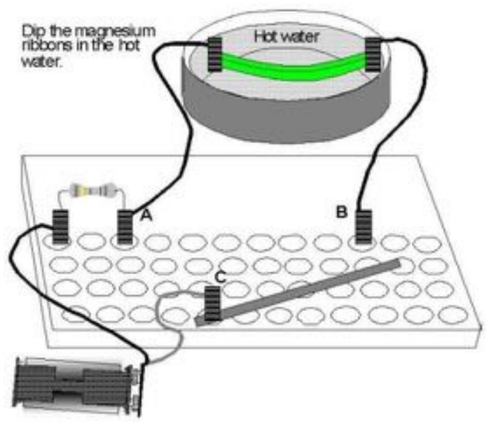


TABLE No 4
The Effect of the Temperature of a Conductor on its Resistance

	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 A – Objective 5.2

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!"

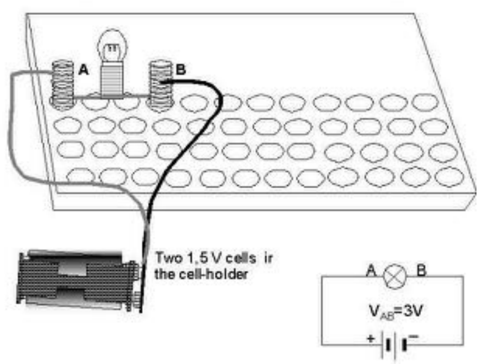
Consider a stone of mass *m* on the ground. The stone has no potential energy in respect to the ground. You lift the stone from the ground up to a height *h*. To overcome the force of gravity you exert an upward force on the stone.

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.

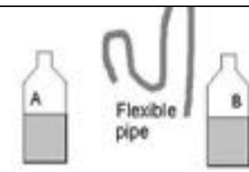
And because there are more ways to say the same thing, we use an equation to summarise it all!

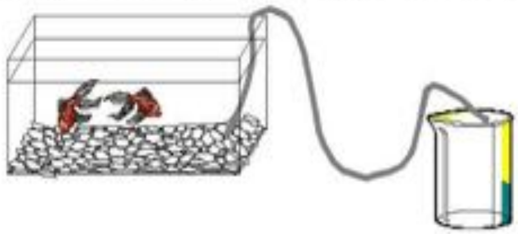
Potential difference = Energy transferred / Charge

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

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





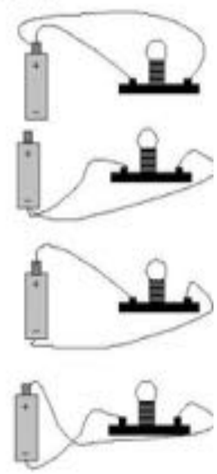
THE SIPHON

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.



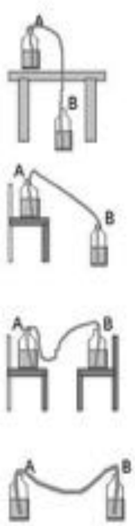
THE CHARGE AND ITS FLOW

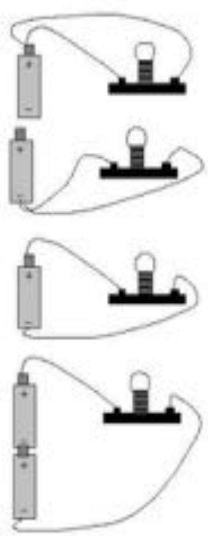
2 The diagram on the right, shows a bulb and a cell connected in four different ways.

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 D – Objective 4.6

Grade Level - 9

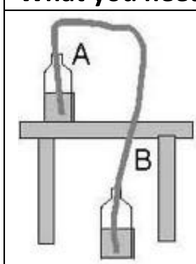
Nature is governed by laws. These laws are the same in all parts of the world. Many important laws, concern the conservation of certain quantities. You are already familiar with the law of conservation of energy, this very important concept in science. Another important conservation law, is the law of **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).

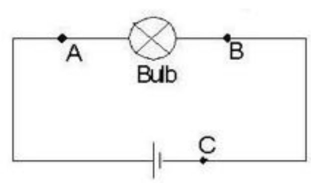
This means that the source of power does not create new charges (electrons), nor does it destroy old ones! The source simply supplies the charge with energy. The source of course as one of the components in the circuit, has its own charges. Bulbs or other resistors in the circuit, do not use up or destroy 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?"

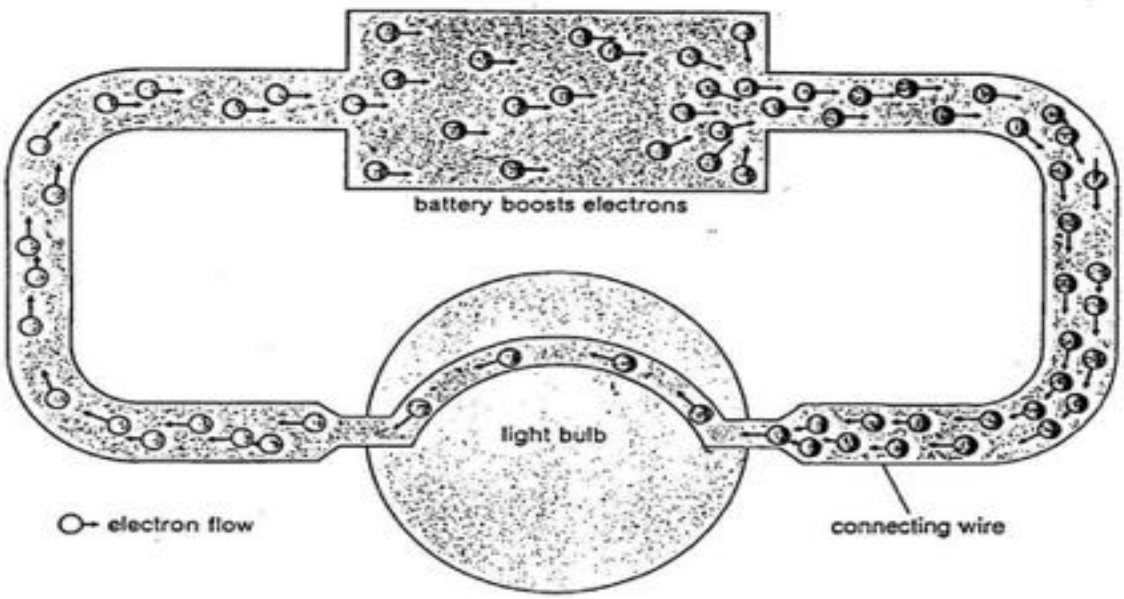
You can see Mantombi's text on the next page. Read the text and study the diagram on your own.

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.

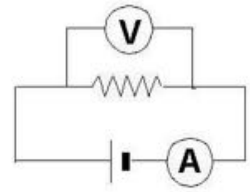
EXPERIMENT 12 – THE REAL & THE IDEAL WORLD

CSEC OBJECTIVE (S): Section D – Objective 4.6

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.

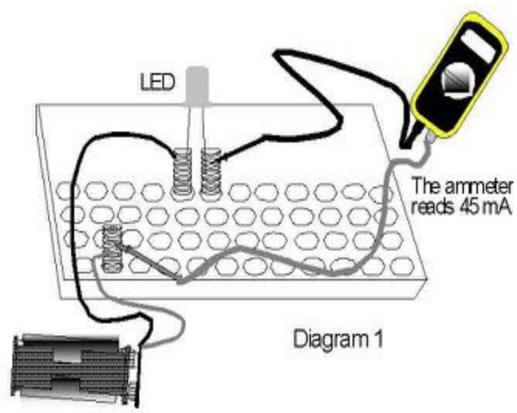


Diagram 1

TEST YOUR AMMETER

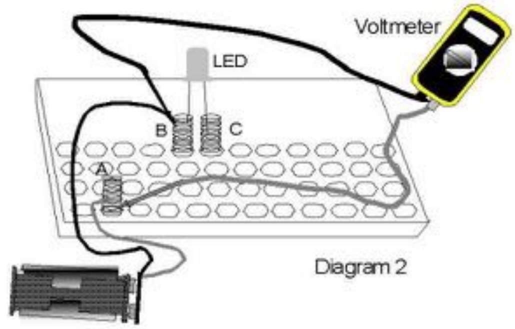
2. In diagram 1, the ammeter reads 45 mA.
   a) How will you know if this is the correct reading of the current in the circuit? What can you do to test if the ammeter changes the current in the circuit?
   b) If you connect a second ammeter in the same circuit, what do you expect both ammeters to read?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

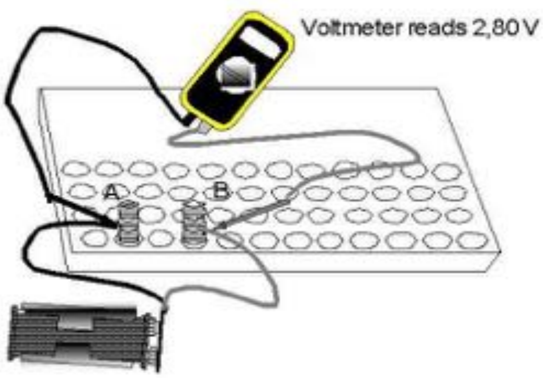


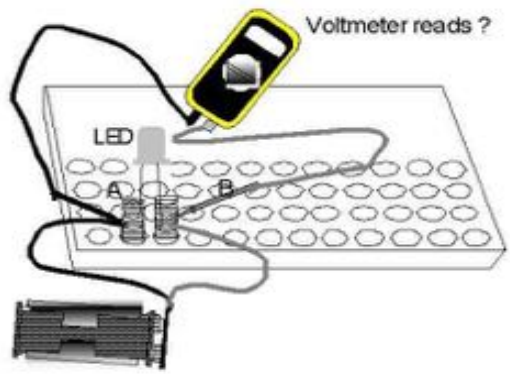
TEST YOUR CELLS

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.

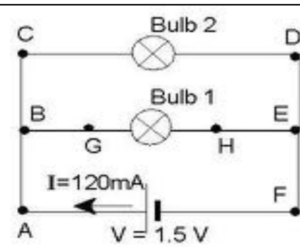
a) a Predict the current value in bulb 1 and bulb 2.

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.