ACTIVITY 1. SOURCES OF ELECTRICAL ENERGY

Energy is ability to do work. It is measured in units called *joules* (symbol J).

In all sources of electricity, some other form of energy is converted into electrical energy.

Complete the list below with three different sources of electrical energy that you can think of. Consider all the energy changes which have taken place in producing each source.

Source	**Energy Changes**
1. Automobile battery	Chemical to electrical
2.	....
3.	....
4.	....

Nature of Electricity:

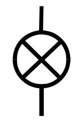
The basic building blocks from which all matter is made are *atoms*. Atoms consist of three main types of particle: *electrons*, *protons*, and *neutrons*. The protons and neutrons make up the core or *nucleus* of the atom, while electrons orbit the nucleus.

If energy is added to an atom, some electrons in outer orbits around its nucleus may leave the atom. Electrons have a small negative charge, so if they leave an atom which has a balanced or neutral charge, the atom which remains will have a positive charge. Similarly, any atom which has gained electrons would then have a negative charge. If one body has a positive charge, then it has a shortage of electrons. If another body has a negative charge, then it has a surplus of electrons.

If a material which permits electrons to flow through it (known as a *conductor*) is connected between these two bodies, surplus electrons will flow from the negatively charged body to the positively charged one until the charge on both substances is the same.

When some other form of energy is changed into electrical energy, *electromotive force* (electron moving force), usually abbreviated to *e.m.f.,* is produced. This is the force which drives electrons from the negative terminal of a source to the positive terminal. The e.m.f. is measured in units called *volts* (symbol V) or *millivolts* (1/1000 part of a volt--symbol mV). An e.m.f. can be measured by a *voltmeter*. It could also be measured by a device called an *oscilloscope*.

ACTIVITY 2. THE SIMPLE CIRCUIT

The lamp holder is indicated by the  symbol .

Set up the circuit shown below.

Connect a d.c. power supply with a 6 volt output and its power switch turned off, or a variable d.c. power supply with its output set to 0 volts, between the points marked +V and -V. The positive (usually red) terminal of the supply should be connected to the point marked +V, and the negative (usually black) terminal to the point marked -V.

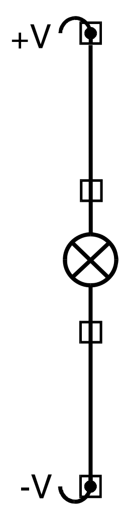
Turn on the 6 volt supply, or slowly increase the output of the variable supply to 6 volts, but be careful not to go beyond 6 volts.

Remove any of the links.

What happened when you removed the link?

....
....

The circuit below shows that a complete path is needed for electrons to travel from the negative terminal to the positive. It is the simplest possible electric circuit.



ACTIVITY 3. ELECTRICAL UNITS

As you already know, each electron carries a tiny negative charge. Charges are measured in units called *coulombs*, and it takes 6,250,000,000,000,000,000 electrons to make a coulomb.

The flow of electrons is called electron *current*, and the rate of flow of charged electrons is measured in units called *amperes* (usually abbreviated to *amps*--symbol A), *milliamps* (1/1000 part of an amp--symbol mA), or *microamps* (1/1,000,000 part of an amp--symbol μA).

One amp is a rate of flow of one coulomb per second.

Set up the same simple circuit you used in Activity 2.

Make sure the 6 volt supply is turned off, or the output of the variable supply is turned to 0 volts. Connect a voltmeter, or multimeter set to a suitable range, between points +V and -V. The +ve (usually red) lead of the meter should be connected to the point marked +V, and the -ve (usually black) lead to the point marked -V. Measure the e.m.f. when you turn on the 6 volt supply or vary the variable supply output control. Be careful not to go beyond 6 volts.

Why should you not go beyond 6 volts?

....
………………………………………………………………………………………

Looking closely at the lamps provided in the kit should provide the answer to this question.

What are the two important details (marked on the neck of the lamp) which are necessary to correctly specify a lamp? (For example, if you were ordering a spare lamp for your torch)

....
........………………………………………………………………………………………

Use a milliammeter, or a multimeter set to a suitable range, to measure the current at any point in the circuit. To do this, remove any one link, and connect the meter to the two pillars between which the link was connected. Make sure that the positive lead on the meter is connected closest to the +V point.

The rate of using energy is called the *power* dissipation of the circuit, and is measured in *watts* (symbol W). The power in watts is equal to the e.m.f. in volts x the current in amps. Try to remember these different units and what they mean.

Q.3.1. Measure the voltage and current in the circuit for six different settings of the power supply output and enter your results in the table below.

Calculate the power in watts for each setting. Remember to use amps in your calculation, not milliamps (1mA = 0.001A).

Substitute the second type of lamp for the one in your circuit, and repeat the measurements.

Lamp Type 6V 40mA:

E.M.F. (VOLTS)	**CURRENT (AMPS)**	**POWER (WATTS)**
1.0		
2.0		
3.0		
4.0		
5.0		
6.0		

ACTIVITY 4. CONVENTIONAL AND ELECTRON CURRENT FLOW

The study of electricity in the form we understand it today began in 1799, when Alessandro Volta made the first simple *cell*. From that time, many famous scientists and researchers studied this new type of electricity, and made numerous important discoveries. During this period the nature of electricity was not properly understood, and electricity was thought to be a kind of fluid which flowed from positive to negative. Many important laws of electrical and magnetic physics which are still used today were discovered at that time, and used the assumption about the flow of a current of electricity described above, which unfortunately turned out to be the wrong direction.

After all the work that has been done using this assumption, it would be very difficult to change things now, so we still use the convention that a current of electricity flows from positive to negative.

Q.4.1. What is the direction of electron current flow?

………………………………………………………………………………………
………………………………………………………………………………………

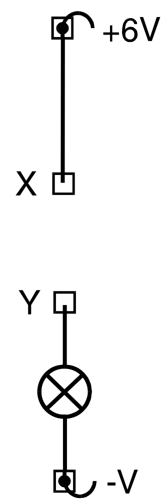
THE DIFFERENCE BETWEEN CONVENTIONAL CURRENT FLOW AND ELECTRON CURRENT FLOW IS IMPORTANT. REMEMBER IT!

ACTIVITY 5. CONDUCTORS AND INSULATORS

Set up the circuit shown, and bridge the pillars X and Y with different materials. Begin with a Locktronics connecting link, which is tin plated phosphor bronze. Then try with other materials you can find around you, such as metals, wood, paper, and so on. If the lamp does not light, the material is a bad conductor. The brighter the light shines, the better the conductor.

Q.5.1. Which materials are usually good conductors?

……………………………………………………………………………………………..



All materials offer a certain amount of opposition to the flow of electrons. This opposition is called *resistance*, and is measured in units called *ohms* (symbol Ω), *kilohms* (1,000 ohms--symbol kΩ), and *Megohms* (1,000,000 ohms--symbol MΩ).

The current in any conductor depends on the conductor's resistance, and on the value of the applied e.m.f. The resistance of a pure metallic conductor at constant temperature will also be constant.

Q.5.2. If the e.m.f. across a circuit is increased, what happens to the current?

…………………………………………………………………………………………….

The current rating of a lamp depends on its filament resistance.

Q.5.3. If the resistance of a lamp is low, will more or less current flow through it at its stated voltage rating than through one with higher resistance?

....

Q.5.4. Approximately how many times greater will be current be through a 6.5V / 0.3A lamp than through a 6V / 40mA lamp?

....

The different resistance of materials is a very important concept. Non-conductors are usually called *insulators,* and are very high resistance materials. One of the most important insulators is *air*.

ACTIVITY 6. THE SIMPLE ON/OFF SWITCH

Set up the circuit shown in Activity 5.

Plug in a Locktronics connecting link to bridge the air gap between pillars X and Y. Insert and remove it a number of times.

Q.6.1. What happens when you insert and remove the link?

……………………………………………………………………………………..

……………………………………………………………………………………..

You are using the link as a simple *on/off switch*. An on/off switch is a device which can complete a circuit, or put a break in it. For this reason, it is said to 'make' or 'break' the circuit.

If the e.m.f. across the circuit were large enough, it would overcome the resistance of the air gap between X and Y, and current would jump across the gap in the form of a spark.

Q.6.2. Can you think of an example where a high e.m.f. is used in automobiles to deliberately cause a spark?

……………………………………………………………………………………..

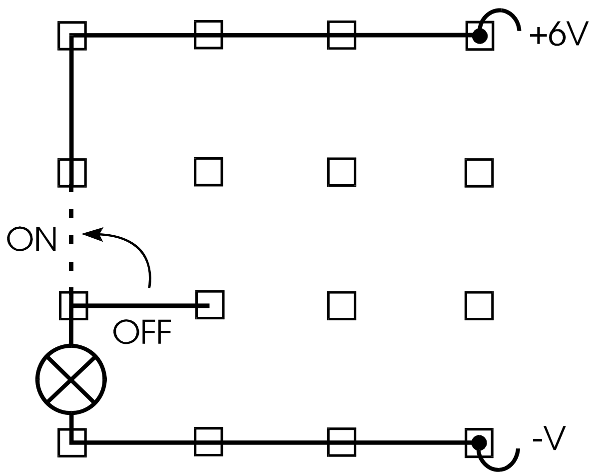
……………………………………………………………………………………..

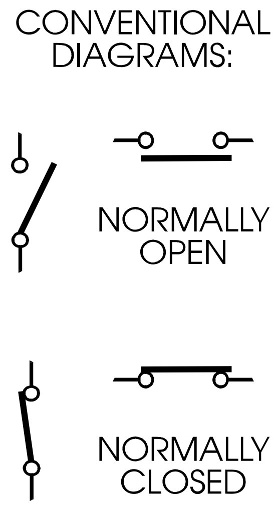
ACTIVITY 7. SWITCHING CIRCUITS

The number of different switch types used in electrical and electronic circuitry is quite surprising.

The operation of a number of different switches can be shown in a Locktronics circuit by using single links in place of the switch.

Set up the simple circuit shown below, and use a single link as you did in Activity 6. This type of switch is often called a *S.P.S.T.* (*single-pole single throw*) or single-pole on/off switch.





ACTIVITY 8. TWO WAY SWITCH

This kind of switch is called a *S.P.D.T.* (*single-pole double throw)* or a single-pole changeover switch.

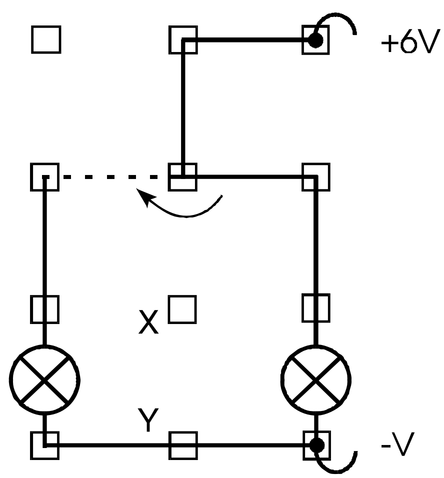
Set up the circuit shown below and verify the operation of the switch.

Add a third lamp between pillars X and Y, and observe the operation of a 3-way switch.

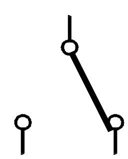
List three applications you can think of for a S.P.D.T. or multi-way switch.

1. ....
2. ....
3. ....

3 (or more) way switches are often made in rotary form.



Conventional
Diagram



ACTIVITY 9. THE D.P.S.T. SWITCH

The two arrows in the diagram below are joined together with dashed lines through the movable links, which indicates that they move together. Switches joined together in this way are said to be '*ganged*'. Switches used in electronic circuits are often ganged, as well as other components.

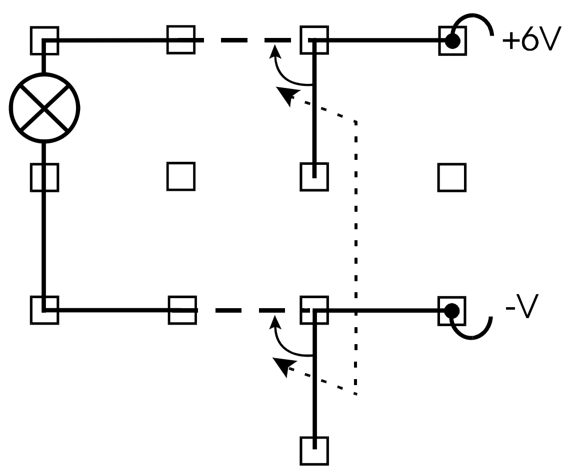
Set up the circuit below, and use both hands to move the two links together to simulate this ganging.

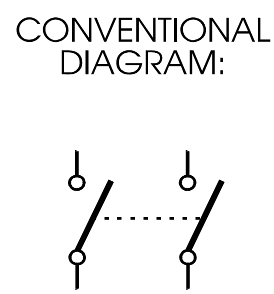
The important feature of this switch is that it breaks **both** poles of the supply (+V and -V) at the same time by a single throw of the switch. This is often used in high voltage switching for improved isolation and safety.

Q.9.1. What does D.P.S.T. stand for?

……………………………………………………………………………………………..

By now, you should find the terminology quite simple.



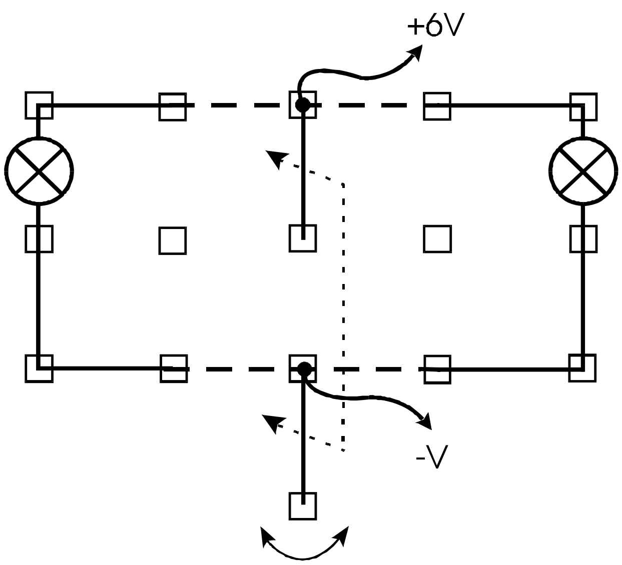


ACTIVITY 10. THE D.P.D.T. SWITCH

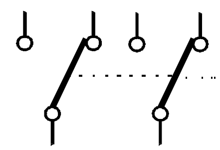
What does *D.P.D.T.* stand for? I am sure that you have the right answer, *double-pole double throw*.

Set up the circuit, and once again use both hands to simulate the switch ganging by moving the two links together.

This type of switch is often used in radios for coil switching. The switch contacts are arranged on wafers in a rotary arrangement, and the number of poles and throws is often greater than two. With multi-pole rotary wafer switches the term 'throw' is usually changed to 'way', for example 6-pole 4 way. Multi-pole, multi-way switches are often miniaturized and can be very small.



CONVENTIONAL DIAGRAM:



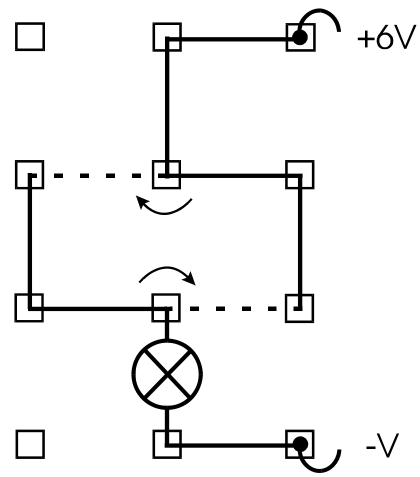
If possible, try to find a multi-way switch to examine.

ACTIVITY 11. STAIRCASE CIRCUIT

Set up the circuit shown.

This arrangement represents two switches, mounted at the top and bottom of a staircase in a house, which allow you to turn the staircase light on and off using either switch.

In this case, two S.P.D.T. switches are used.

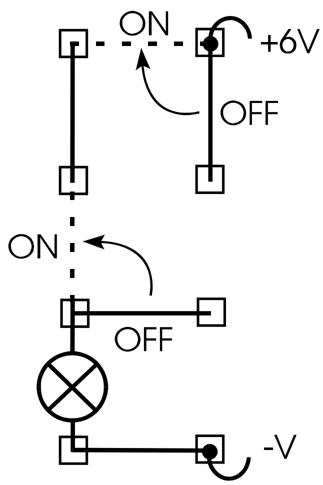


ACTIVITY 12. SWITCHES IN SERIES

Set up the circuit shown.

Here two switches in series are used to control a single lamp.

An example of this arrangement is a switch on a night table lamp connected to an outlet controlled by a wall switch.



ACTIVITY 13. THE SERIES CIRCUIT

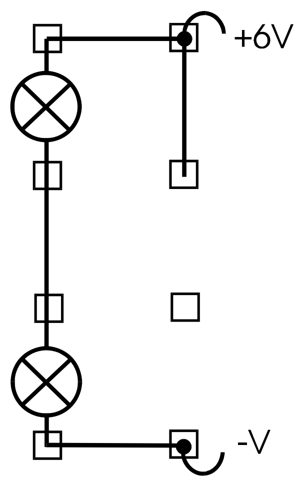
When electricity flows between two points of a conductor, a *potential difference* (*p.d.*) is said to exist between the two points. Like e.m.f., the unit of p.d. is the volt.

To give you a scientific definition: *two points of a conductor are at p.d. of 1 volt if 1 joule of work is done per coulomb of electricity passing the two points.*

$$\text{p.d.} = \frac{\text{Work done (in joules)}}{\text{Charge moved (in coulombs)}}$$

Set up the circuit shown, and measure the p.d. across each lamp using a voltmeter.

p.d. across lamp 1: ....V p.d. across lamp 2: ....V.



Add the two p.d.s you measured across the lamps together: ....V.

Measure the e.m.f. of the supply between the +6V and -V points: ....V.

Q.13.1. What is the relationship between the sum of the lamp p.d.s and the supply e.m.f.?

....

Measure the current around the circuit in as many different places as you can.

Q.13.2. What do you observe about the current in different parts of the series circuit?

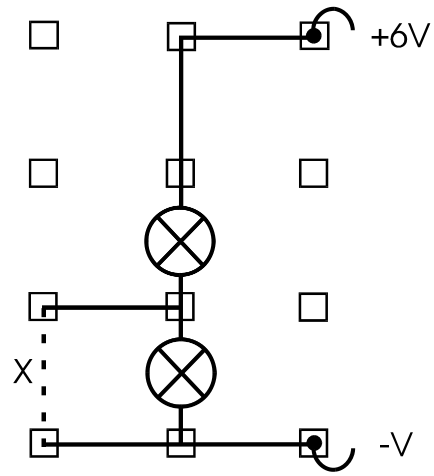
....

ACTIVITY 14. THE SHORT CIRCUIT

Set up the circuit, then insert a link at X.

When link X is inserted, the lamp in parallel with it goes out. This shows that electricity will always 'take the easiest route'. In this case, we have used the second lamp only to avoid short-circuiting the supply.

It is very important to realize that a *short circuit* can easily damage electrical equipment.

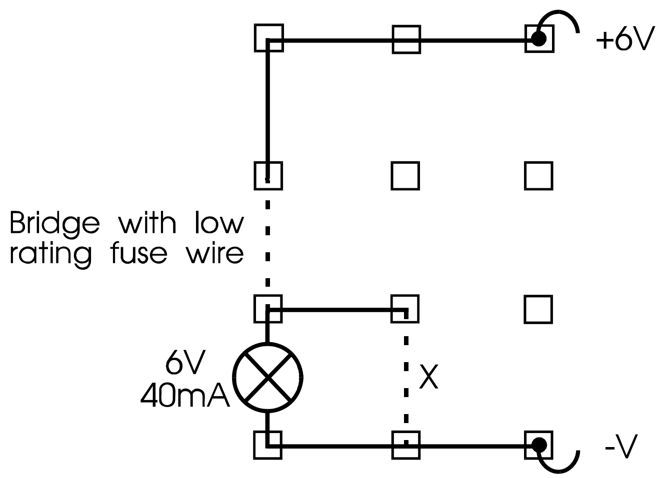


ACTIVITY 15. OVERLOAD PROTECTION

Set up the circuit shown. If possible, obtain a piece of fuse wire with a rating of approximately 50 mA from your instructor. If not, use a single strand of wire wool (Grade 00). **Be careful not to touch the fuse, as it may become very hot**.

Insert a link at X and observe the result.

Fuses are widely used to protect electrical circuits from overload. Circuit breakers are sometimes used in place of fuses in industrial and household electrical circuits, as they can easily be reset, and do not require replacement.



ACTIVITY 16. THE PARALLEL CIRCUIT

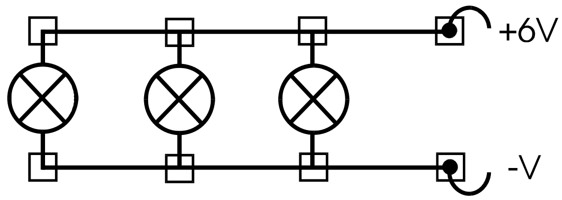
Voltage measurement:

Set up the circuit, and measure the voltage across each lamp.

Lamp 1 voltage : ....V Lamp 2 voltage: ....V Lamp 3 voltage: V

Q.16.1. In a parallel circuit, what have you observed about the voltage across its individual components?

....



ACTIVITY 17. THE PARALLEL CIRCUIT

Set up the circuit and measure the current in each of its branches. To do this, first remove link A, and connect the current meter to the pillars across which the link was connected. Then replace link A and repeat the procedure with link B.

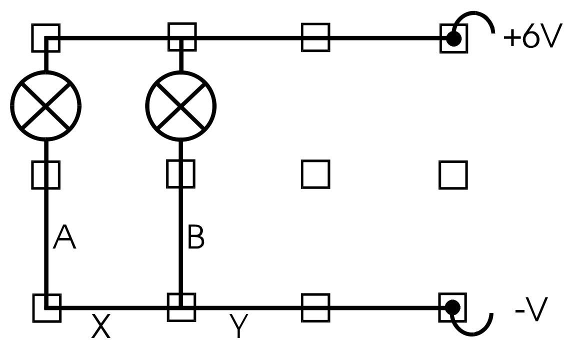
Current at A: ....mA Current at B: ....mA

Once you have carried out these measurements, repeat the procedure with link Y to measure the total current in the circuit.

Total current at Y: ....mA

Q.17.1. What is the relationship between the total current and the current in each branch of the circuit?

....



ACTIVITY 18. EFFECT OF RESISTANCE

Set up a simple circuit with links and a lamp.

Measure the current in the circuit: ....mA.

Replace the link next to the lamp with a 180Ω resistor.

Measure the current again: ....mA

Replace the 180Ω resistor with resistor Rx.

Measure the current: ....mA.

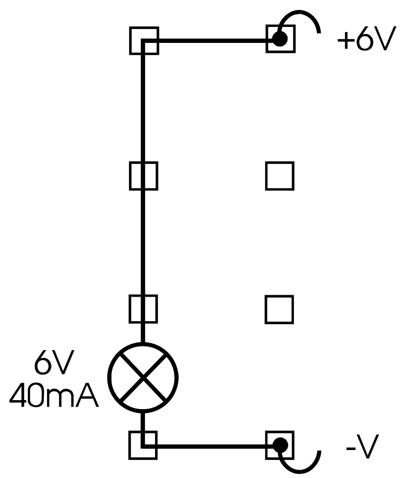
Replace resistor Rx with a 1kΩ resistor.

Measure the current: ....mA.

What do you observe? Current is still flowing, but not enough to light the lamp.

Q.18.1. What is the relationship between the resistance in ohms and the current?

....



ACTIVITY 19. RESISTORS IN SERIES

Set up the circuit shown using a single 180Ω resistor.

Measure the current at any point in the circuit: ....mA.

Remove any link and replace it with a second 180Ω resistor.

Measure the current again: ....mA.

Compare this with your first measurement above.

What has happened?
………………...

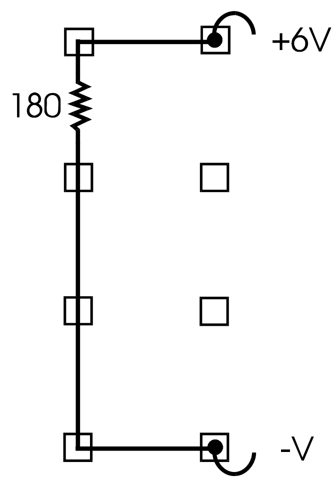
Now borrow a third resistor from another kit if possible. Put the three 180Ω resistors in series.

Measure the current: ....mA.

Q.19.1. What is the total resistance of resistors in series equal to?

....

To put it in mathematical terms, $R_{Total} = R_1 + R_2 + R_3$ and so on.



ACTIVITY 20. RESISTORS IN PARALLEL

Set up the circuit shown using a single 180Ω resistor.

Measure the current at any point in the circuit: ....mA.

Insert resistor Rx in the position indicated by the dashed line.

What happens to the lamp brightness?
……………………………………………...

Repeat using resistor Rx on its own first, then add the 180Ω resistor.

Measure the current in each branch of the circuit and through the lamp:

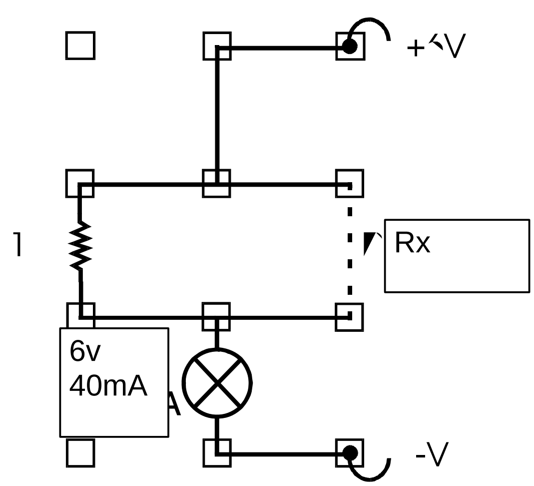
Current in 180Ω resistor: ....mA   Current in Rx: ....mA

Current in lamp: ....mA.

Now replace Rx with a second 180Ω resistor and repeat the current measurements.

Current in 180Ω resistor: ....mA   Current in 180Ω resistor: ....mA

Current in lamp: ....mA.



Q.20.1. What is the relationship between the total current flowing through the lamp and the currents which flow through each resistor?

....
.

Q.20.2. What is the total resistance of two **equal** resistors in parallel equal to?

....

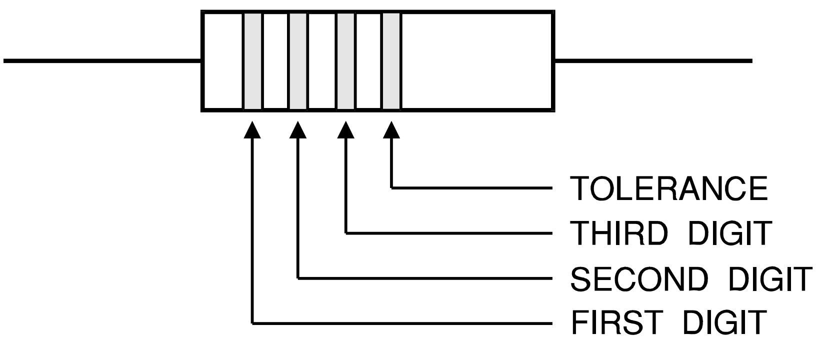
It is important to realize that putting any resistor in parallel with another will produce a total resistance which is lower than that of the lowest resistor.

For resistors in parallel it is easier to use the following formula:

ACTIVITY 21. RESISTOR IDENTIFICATION AND COLOR CODE

Examine one of the resistors under its carrier, and note the colored bands.

The bands indicate the value of the resistor. The first band indicates the first digit of the value of the resistor, the second band indicates the second digit, and the third band indicates the number of 0s which follow the second digit. An additional gold or silver band indicates the tolerance of the resistor: gold = 5%, silver = 10%, or no band = 20%.



COLOR	VALUE
Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Gray	8
White	9

For example, a resistor with the following colored bands: brown, gray, brown, and gold would have a value of 180Ω, and a tolerance of 5%. Check under the 180Ω resistor carrier in the kit to verify this.

Q.21.1. What value and tolerance does a resistor with colored bands green, blue, red, and gold have?

....

It is important to realize that manufacturers do not make every possible value of resistor. They normally list certain 'preferred' values. For example, if you wanted a 3 kΩ resistor the two nearest preferred values are 2.7 kΩ and 3.3 kΩ.

The 10% tolerance E12 range of preferred values is 10,12, 15,18, 22, 27, 33, 39, 47, 56, 68, 82, and multiples of 10, 100, 1000 and so on times these numbers.

The 5% tolerance E24 range of preferred values has twice as many resistor values in it.

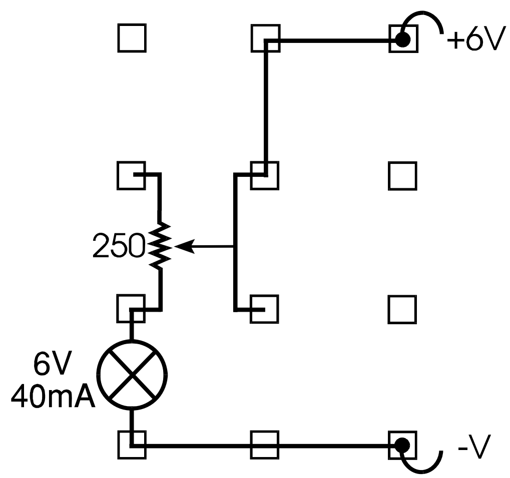
Many different kind of resistors are manufactured. General purpose resistors are generally carbon composition, but others include high stability carbon film, metal film, wire-wound, precision wire-wound, and vitreous or flameproof wire-wound. They are available in different watt ratings from 1/8 watt, 1/4 watt, 1/2 watt, 1 watt and so on to 50 watts or higher.

ACTIVITY 22. THE VARIABLE RESISTOR (POTENTIOMETER)

This activity is designed to show the applications of this device, which is normally a carbon track or wire wound resistor with a moving slider. As the slider is rotated it 'taps' varying lengths of the resistor track. You are probably familiar with examples of *variable resistors* or *potentiometers*, for example they are used as volume controls in radios and televisions.

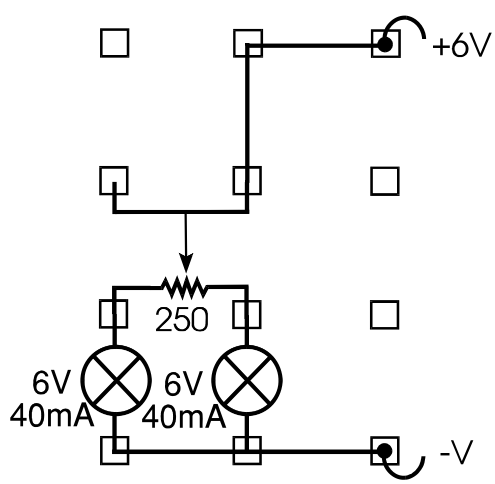
The variable resistor supplied in the kit is a *linear* component, meaning that equal lengths of track have equal amounts of resistance. From this it follows that equal degrees of rotation cause equal changes in the resistance value. There is also another type of variable resistor in which the resistance of the track is not linear, but varies *logarithmically*.

Set up the circuit shown and rotate the control knob clockwise and counterclockwise. You should notice the lamp becoming brighter and dimmer as you vary the resistance.



Now turn the variable resistor carrier through 90° and repeat.

Set up an arrangement with two lamps as shown on the next page.



What do you observe about the behavior of the two lamps?

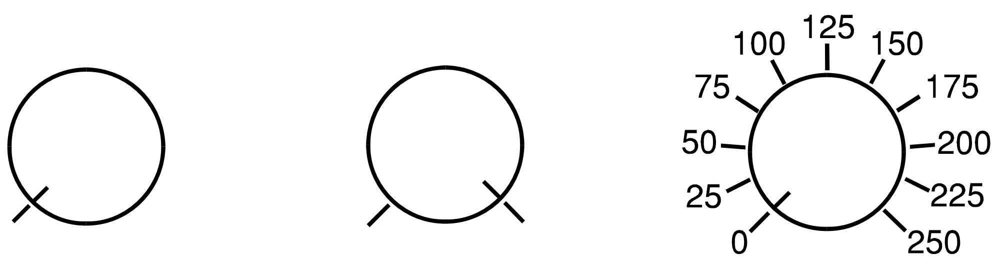
....

ACTIVITY 23. CALIBRATING YOUR VARIABLE RESISTOR

Since the variable resistor supplied in the kit is linear, it is easy to calibrate.

Use a point on the control knob as a reference, and turn the control knob fully counterclockwise. Make a pencil mark on the carrier, as shown in the left hand diagram below.

Turn the knob fully clockwise, and repeat the pencil mark as shown in the middle diagram.



Divide the distance rotated between the two pencil marks into equal divisions and draw a scale as shown in the right and diagram. Any small errors you may make will easily be absorbed by components tolerances.

ACTIVITY 24. CHECKING THE CALIBRATION

Set up the circuit shown below.

Adjust the control knob until the lamps are equally bright.

Read off the approximate resistance from your scale: ....Ω.

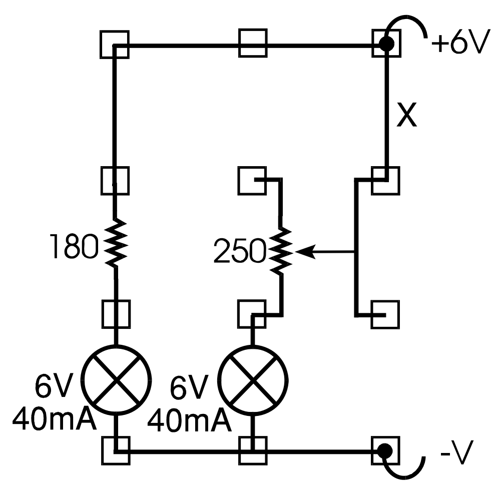
As you might expect, it should read about 180Ω.

Move the link X one row of pillars to the left, so that it is at the end of the variable resistor track, and move the right hand lamp one row of pillars to the right, so that is at the bottom of the slider.

Once again adjust the knob until the lamps are equally bright.

Read off the approximate resistance from your scale: ....Ω.

This time the scale should read about 70Ω (250 - 70 = 180Ω).



ACTIVITY 25. THE SERIES-PARALLEL CIRCUIT

Set up the circuit shown. Measure the p.d. between points A and B, and between points B and C.

p.d. between A and B: ....V p.d. between B and C: V

Now add a third lamp in the position shown by the dashed lines. This has the effect of reducing the resistance of the lower half of the circuit, and causes the potential difference across the upper and lower halves to change.

Measure the p.d. between A and B and between B and C again.

p.d. between A and B: ....V p.d. between B and C: V

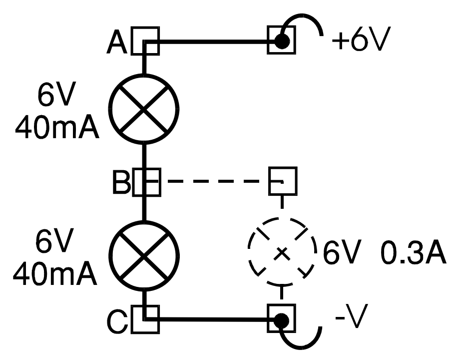
Remove the left (40mA) lower lamp and replace it with the right (0.3A) lamp. Repeat the measurements.

p.d. between A and B: ....V p.d. between B and C: V

Replace the 40mA lamp in the right position and repeat the measurements.

p.d. between A and B: ....V p.d. between B and C: V

Experiment with using different values of resistor in place of the third lamp.



ACTIVITY 26. THE POTENTIAL DIVIDER

A resistor network can be used to divide the voltage of its source and give a different output voltage.

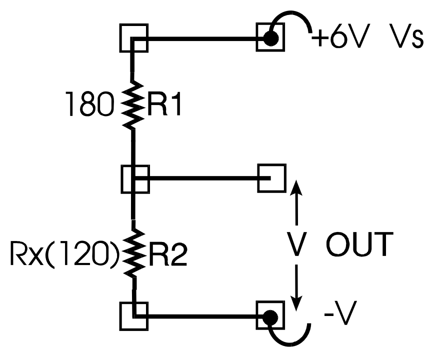
Set up the circuit shown, and measure the value of V_{out}: ....V.

Now change the positions of the two resistors and repeat your measurement:

..........V.

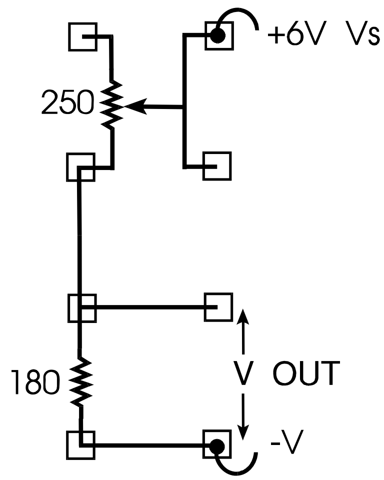
In a potential divider the output voltage V_{out}:

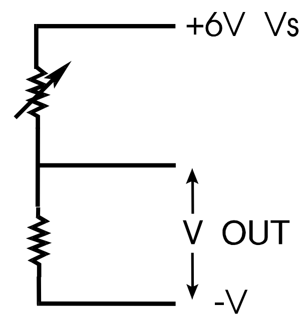
$$= V_S \times \frac{R_2}{R_1 + R_2}$$



ACTIVITY 27. THE VARIABLE RESISTOR USED IN A POTENTIAL DIVIDER

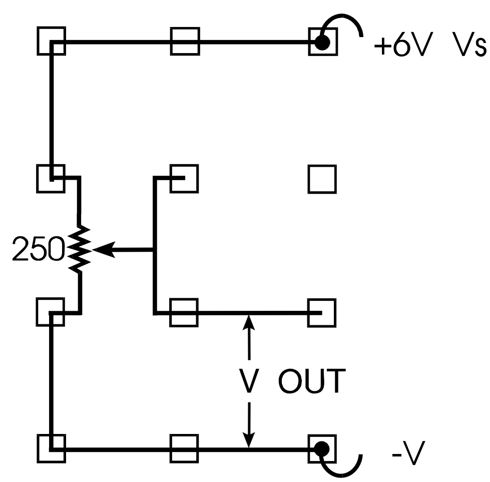
The *potential divider* is a very important circuit, with many applications in electronics. The right diagram below is equivalent to the one on the left. Set up the circuit shown in the diagram on the left and measure V_{out} as you vary the control.





Now change the circuit to the one shown. This is an even simpler potential divider circuit.

This activity should help you to understand the series-parallel circuit.



ACTIVITY 28. OHM'S LAW

It should now be possible for you to understand *Ohm's Law*, one of the most important relationships in electricity and electronics. Ohm's Law is basically a mathematical statement of the facts that:

1. current through a conductor increases if the voltage across it increases.

2. the ratio of voltage (V) to current (I) is called resistance (R).

If the resistance is constant, the conductor is said to obey Ohm's Law.

So the formula is:

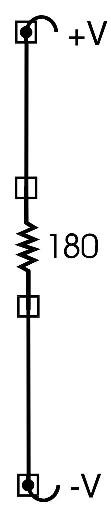
$$R = \frac{V}{I}$$

where I is the current in amps, V is the p.d. in volts, and R is the resistance in ohms.

Form this we get:

$$V = IR \text{ and } I = \frac{V}{R}$$

Set up the circuit shown, and use any source voltage you choose between 0 and 15V.



Measure the voltage V: ....V.

Since R is 180Ω, you should be able to calculate the current I: ....A.
Check your result by measuring the current and comparing the results.
There may be some difference between your calculated and measured values of current. Most of this difference is due to the tolerance of the resistor value,

which can cause it to vary slightly from its stated value of 180Ω. The tolerance of the component supplied is 5%.

ACTIVITY 29. OHM'S LAW

Set up the circuit shown.

Measure the current I: ....A.

Calculate the voltage V across the 180Ω resistor: ....V.

Measure the voltage between point A and B: ....V.

Q.29.1. How do the two voltages compare?

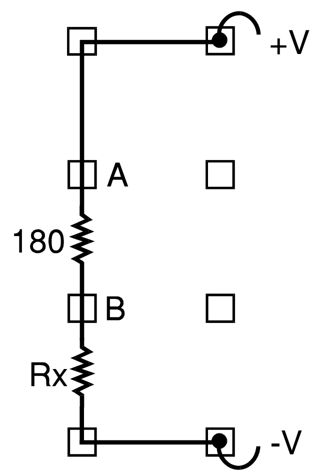
....

Subtract the measured value of V from the supply voltage: ....V.

This is the voltage across Rx.

Q.29.2. What is the value of Rx?

....



ACTIVITY 30. OHM'S LAW

In this Activity, we will calculate the value of Rx again, but this time using a parallel circuit.

Set up the circuit shown.

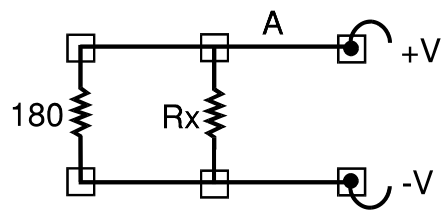
Measure the total current I at point A: ....A.

Measure the supply voltage V: ....V.

Calculate the current through the 180Ω resistor: ....A.

Subtract this current from the total current I: ....A.

Calculate the value of Rx: ....Ω.



ACTIVITY 31. OHM'S LAW

Set up the circuit shown.

Measure the supply voltage V: ....V.

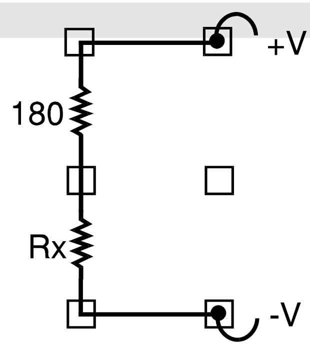
Measure the current I: ....A.

Calculate the total resistance: ....Ω.

Subtract 180Ω from this value: ....Ω. This is the value of Rx.

Does this value approximately agree with those you obtained from the two previous Activities?

....



ACTIVITY 32. EFFECT OF TEMPERATURE ON THE RESISTANCE OF A METAL

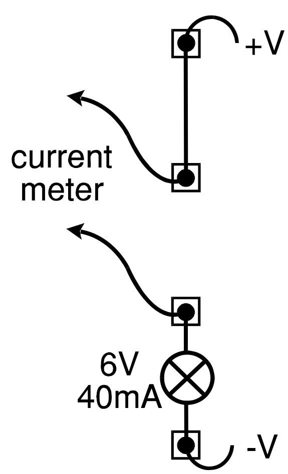
This activity requires a supply with a variable output.

Set up the circuit shown. Start with the supply output set to 0V, and increase the voltage in 1V increments up to 6V, recording the current at each step in the table below.

Use Ohm's Law to calculate the resistance R at each step.

V	I	R
1		
2		
3		
4		
5		
6		

You can relate your results to the *color temperature* of the lamp. It will glow dull red at about 1100°F, it will be bright red at about 1300°F, and it will be yellow at 1800°F at 6V.



ACTIVITY 33. WHEATSTONE'S BRIDGE (TWO UNEQUAL RESISTORS)

Set up the circuit shown, which will be used to determine the value of an unknown resistor Rx.

Measure the current in milliamps between points B and D: ....mA.

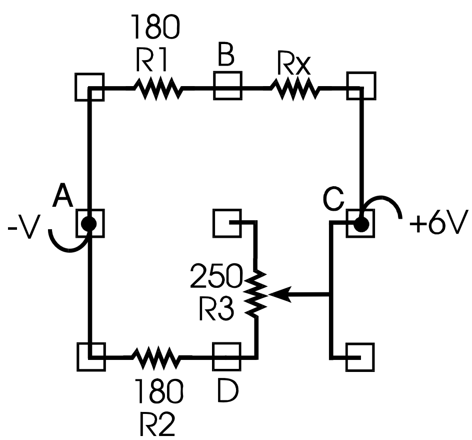
Use the variable resistor you calibrated in Activity 23. Adjust it until the meter is indicating zero current. This is called the null point. At this point, equal current must be flowing in both branches of the circuit--ABC and ADC.

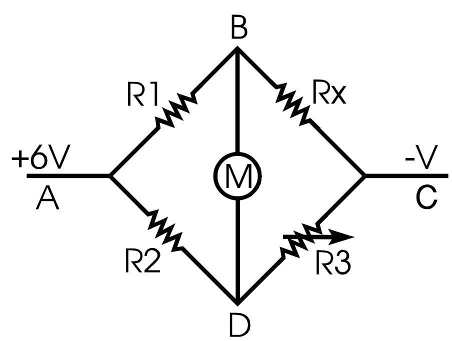
As R_1 and R_2 are equal, this condition will only occur when Rx and the value to which the variable resistor is set are equal.

You can therefore read the value of Rx directly from the scale of your calibrated variable resistor.

Value of Rx: ....Ω.

This should correspond to the value of Rx you have found in earlier Activities.





CONVENTIONAL DIAGRAM

ACTIVITY 34. WHEATSTONE'S BRIDGE (TWO UNEQUAL RESISTORS)

Set up the circuit as used in Activity 33, but this time use Rx (120Ω) as R_1 and use a lamp as the unknown resistor. We will call the lamp R_4.

Again connect a current meter between point B and D and find the null point.

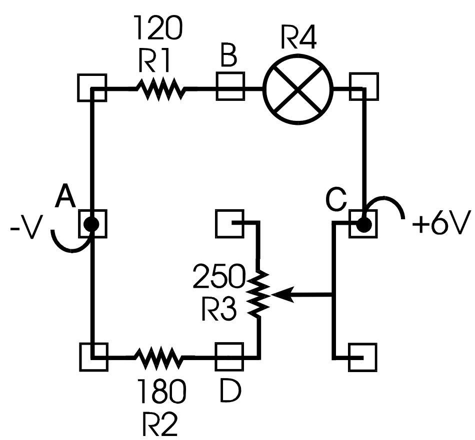
If we call the part of the variable resistor in the circuit R_3, if no current is flowing through the meter, the ratio R_4/R_3 must be the same as the ratio R_1/R_2.

So if

bce2f9bfb742f6bf0008000001000000e8d4620001000000ded4620018000201f0d46200c501

then $R_4 = \dfrac{R_1 \times R_3}{R_2}$

Using the formula above, calculate the value of R_4: ....Ω.



ACTIVITY 35. SEMICONDUCTORS

In Activity 5, you tried to find out which materials were good conductors, poor conductors or insulators. You should have discovered that metals are good conductors. However, some non-metals such as carbon are poor conductors, and these are used to make resistors. Insulators, of course, do not conduct any significant current under normal conditions.

There is a fourth group of materials called *semiconductors*, which are exceptional materials. The two most often used in electronics are silicon and germanium.

Semiconductors, as the name implies, are materials whose conductive properties fall between those of conductors and insulators.

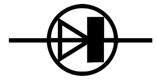
To produce usable semiconductor devices, small amounts of impurities are added to pure silicon or germanium. This will result in the material having an excess of electrons (called *N-type)* compared with the base semiconductor, or a deficiency of electrons (called *P-type*). Both P- and N-type semiconductor materials are electrically neutral.

If pieces of P-type and N-type semiconductor material are joined together, a *P-N junction* results. A voltage barrier forms at the junction between the two kinds of material, which prevents electrons in the N-type material from moving over to the P-type material.

However, when a voltage is applied with the correct polarity, the barrier is overcome, and electrons flow from the N-type to the P-type material. If the applied voltage polarity is reversed, little or no current will flow through the P-N junction.

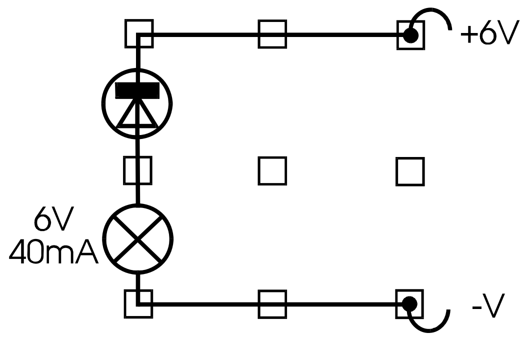
This is the principle of a *semiconductor diode*.

ACTIVITY 36. THE PROPERTIES OF A SEMICONDUCTOR DIODE

The diode symbol is: 

The diode included in your kit is a special type of diode called a light emitting diode.

Setup the circuit shown.

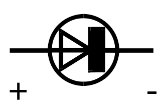


Turn on the supply to the circuit, then reverse the diode.

What happens?

………..

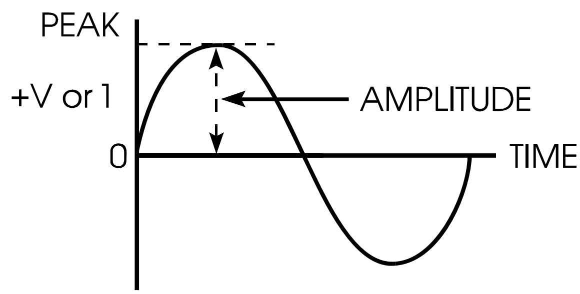
The basic property of a diode is that it will permit current to pass in one direction only. In practice, a small leakage current will flow in the other direction. When the diode conducts, it is said to be *forward biased*. A forward biased diode has the negative potential connected to the bar (which is the negative symbol) portion of the diode symbol, and the head of the arrow is pointing in the direction of conventional current flow. The diode in the Locktronics circuit shown above is said to be *reverse biased*.



It is important to understand that any semiconductor diode can only pass a limited amount of forward current, or stand a limited amount of reverse voltage without being damaged.

ACTIVITY 37. ALTERNATING CURRENT (A. C.)

An *alternating current (a.c.)* is one in which the flow of electrons is constantly reversing. If the instantaneous (immediate) values of an alternating current or alternating e.m.f. were plotted over a short period of time, the result would be a graph similar to the one below, with the current or e.m.f. changing in a *sinusoidal* way. The graph shows one complete cycle of change.



The number of complete cycles per second is called the *frequency* of the a.c. and is measured in units called *hertz* (symbol Hz). The frequency of the public electricity supply in the U.S. and Canada is 60 Hz. The time taken for one complete cycle is called the *period* of the a.c.

$$\text{Period} = \frac{1}{\text{Frequency}}$$

The amplitude is normally called the peak voltage. An instrument called an oscilloscope could be used to measure the peak voltage of an a.c. waveform.

In electronics, the frequency of an a.c. waveform is an important quantity, and is often in the order of thousands or millions of hertz.

1,000 hertz = 1 kHz (kilohertz)

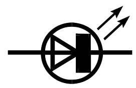
1,000,000 hertz = 1 MHz (Megahertz)

The voltage of the U.S. and Canadian public electricity supply is 110V r.m.s.

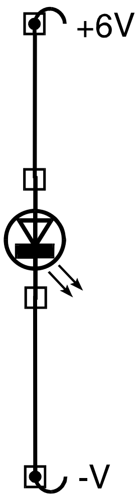
The r.m.s. value of an a.c. waveform is $\frac{\text{peak value}}{\sqrt{2}}$, approximately 0.7 x peak value.

R.M.S. Stands for *root mean square*, and is the voltage indicated by a moving coil a.c. Voltmeter.

ACTIVITY 38. THE LIGHT EMITTING DIODE (LED)

The symbol for an  *LED* is .

Set up the circuit shown.



Note the operation of the circuit, then reverse the LED.

Notice that it emits light when forward biased, and that it acts like any other semiconductor diode when reverse biased.

Remove the LED from the circuit and examine its carrier. Note that a resistor is fitted to limit the current through the LED.

There are many different varieties of LED manufactured, including some that flash. They are most commonly available in red, green and yellow, and some packages are available which can include two or three different colors in one package.

The semiconductor material from which LEDs are made is usually *gallium phosphide* or *gallium arsenide*.