Physics

In

General Science

Electric Circuits & Using Magnets

Produced by

Vicphysics Teachers' Network Inc.

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Electric Circuits

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Extracts from VELS, Level 6

Learning Focus

"… They investigate how energy may be responsible for the changes observed in … physical processes and applications. Examples include: electromagnetism, the operation of electronic systems, … photonics …"

"… They also explore the ways in which science concepts, language and perspectives can be misunderstood and misrepresented. This involves students applying their conceptual understandings to the consideration of issues significant to themselves as individuals and to the broader society in which we live; for example …, electronic gadgets, …"

Standards

Science knowledge and understanding

"… Students explain change in terms of energy in a range of … physical contexts. …"

Science at work

"… They use …, equipment, electronic components and instruments responsibly and safely. …"

Safety

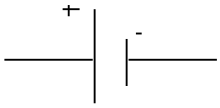
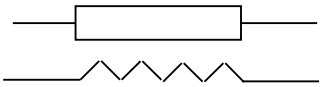
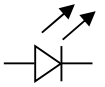
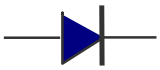
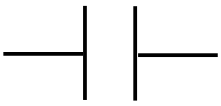
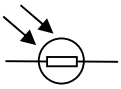
"… As students progress through their schooling they develop skills in the safe use of scientific apparatus, including heating and electrical equipment …"

This material has been produced by the following members of the Vicphysics Teachers' Network: Keith Burrows, Helen Lye and Dan O'Keeffe.

Activity 1
What do electric components looks like?

What are their circuit symbols?

Take the components from your box one at a time and place each component on the word adjacent to its picture.

Component	Picture	Symbol
Battery		
Resistor		
Light Emitting Diode (LED)		
Diode		
Capacitor		
Light Dependent Resistor (LDR)		

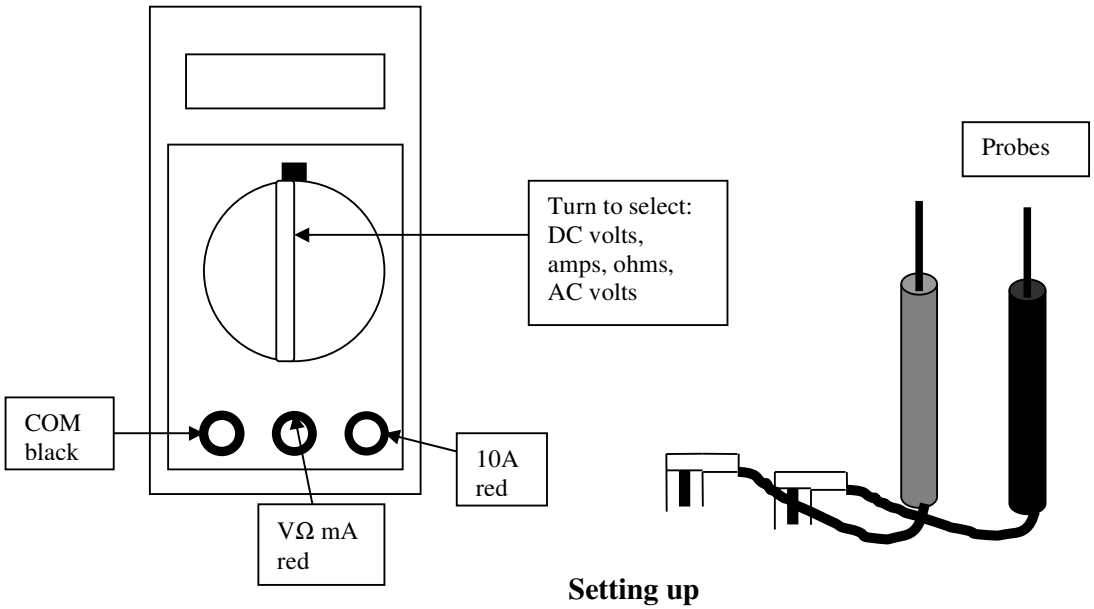
Connecting components

The components have been placed in clear plastic holders and connected to springs. The plastic has the symbol of the component on it.

You can use the short wires to join components together.

Bend the spring back and place the end of the wire in the spring. To place a second wire in the same spring bend the spring in the opposite direction.

Activity 2
Resistance with multimeters
2.1 Using a Multimeter



Setting up

- Put the black probe into the black **com** socket and the red probe into the red **VΩ** socket.
- Use the dial to select the function you need. Ω measures resistance, V… measures voltage or potential difference in a direct current circuit.
- Select the range you need. You would usually start with the highest range and move to a lower range if you need more sensitivity.
- **Measuring resistance**: 1 on the display means that you need a higher range. For example, if you select the 200 scale and connect the probes to a 500 Ω resistance, the display will show 1. If you then move the dial to the 2000 scale, the display will read 500.
- Multimeters are robust in normal usage but care needs to be taken when using them to measure electric current. The VΩ socket has a maximum current of about 200 milliamps. This is only 0.2 amps so it is easy to blow the fuse if the A… scale is mistakenly used when measuring volts or ohms.
- **Measuring current**. Connect the red probe to the red 10A DC socket and select the A… range 10. The values on the display screen will be in ampere (written A or amps). A break in the circuit must be made and the multimeter connected in the gap in the circuit.
- **Reading the scales**
  - On the resistance scale, k means times one thousand. That is the 20k scale reads up to 20000 Ω, and the 2000k scale reads up to 2000000 Ω. A reading of 25.1 could be 25.1 Ω or 25.1kΩ depending on the scale selected. 25.1kΩ can also be written as 25100 Ω or 25100 ohms.
  - On the voltage scale m means milli or divided by 1000. A reading of 10.5 on the display when the 20 volt scale is selected indicates a value of 10.5 volts. When the 200m scale is selected the display would mean a reading of 10.5 mV(millivolts) or 0.0105 volts.
  - On the electric current scale (A…) the symbol m means milli or divided by 1000, while the symbol μ stands for micro and means divided by one million. A display reading of 151.6 when the 200m scale is selected indicates 151.6 milliamps. This can be written 151.6mA or 0.1516A.

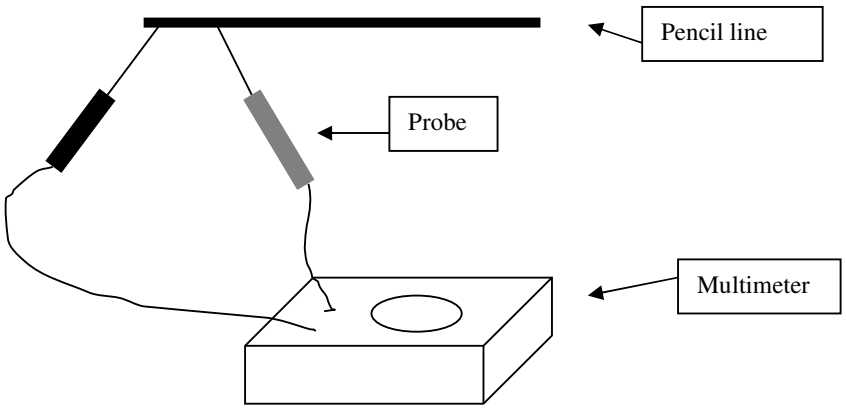
2.2 Making Resistors

Resistors are made of a material with a high resistance to electrical current. They are used to control the size of the electrical current in a circuit.
You can make resistors using the carbon in ordinary grey lead pencils.

Materials
You will need a selection of pencils including 2B, 4B and 6B pencils, paper, ruler and a multimeter

Method
1. Rule a 3 cm pencil line on this paper using the 2B pencil. Go over the line two or three times.

2. Connect the black probe to the black com socket on the multimeter.
3. Connect the red probe to the red VΩ socket.
4. Turn the multimeter dial to the Ω section and select the highest range (probably 2000k)
5. Touch the metal tips of the probes together. The display should read 0.0. Separate the probes. The display should read 1.
6. Place the tips of both probes on your pencil line about 1 cm apart and press down firmly. The reading on the display screen of the multimeter is the resistance of 1 cm of this pencil line.



7. Move the probes so that they are further apart on the pencil line and read the resistance in the new position. What happens to the resistance as the length of the line increases?

_____

_____

_____

8. Use the multimeter to investigate the resistance of pencil lines

You could use the data table on the next page to record your measurements or you could draw up your own data table.

- Decide what length of line you will use if you want to compare the resistance of lines made by different pencils.
- Decide how you will draw your lines so that you can compare the resistance of different lines.
- Does the thickness of the line on the paper change the resistance?
- Does the width of the line change the resistance?
- Do you need to make two or three measurements of the resistance of each line and find an average?

Make notes here about the method you have chosen.

9. Data Table

You can draw the lines you are investigating in the space in the table

Pencil type	Pencil line	Length	Resistance

Questions

10. What conclusions can you make about the type of pencil and the electrical resistance of lines drawn with this pencil?

11. What conclusions can you make about the width or thickness of the lines and the measured resistance?

12. How could the way you drew the lines have affected your results and conclusions?

13. You could investigate the resistance of the leads used in 'Pacer' pencils. You could use the leads themselves as well as the lines you make with them.

2.3 Resistor Colour Code

The resistor colour code can be used to work out the value of many resistors. In this exercise you will use the colour code to find the resistance of small four band resistors.

Materials

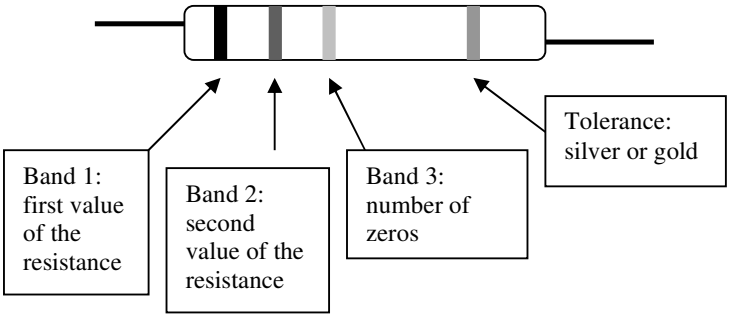
- Card or board with five resistors attached. Resistor colour code chart.
- Multimeter.

Method

1. Use the resistor colour code chart to complete this table

Colour	**Black**	**Brown**		**Orange**		**Green**			**Grey**	
Value	**0**	**1**	**2**		**4**		**6**	**7**		**9**

2. Label this diagram of a 12000Ω resistor by putting in the numbers for each band. The band colours are brown, red, orange.



3. What would be the code for the following resistors? Complete the table.

Resistance	**Colour code**	**Drawing**
25Ω		
200Ω		
33000Ω		
68kΩ		
	Red, red, grey	
	Brown, black, black	
1MΩ		

4. Collect a set of resistors.

- Record the colour code in the table
- Calculate the resistance of each one using the resistor colour code and enter the value in the table.
- Use the multimeter to measure the resistance of each one and complete the table.

Resistor colour code	Calculated value (ohms)	Measured value (ohms)

5. Did your measured values of resistance agree with the calculated values? _____

_____

_____

If the values are different what could be the reasons for these differences?

_____

_____

_____

_____

6. Collect some circuit boards that have been part of electrical or electronic devices. Look for resistors on these boards and calculate and measure the resistance of some of them. What differences do you see when you compare them with the resistances that you used in the previous activity?

_____

_____

_____

_____

_____

_____

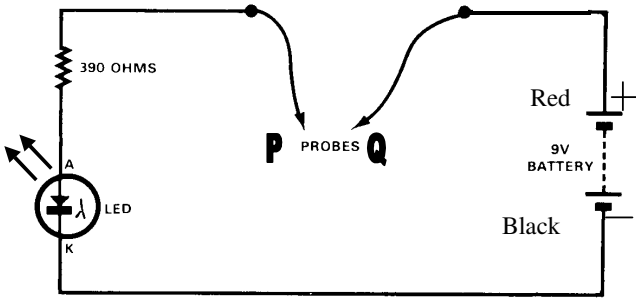
_____

Activity 3
What do Electric Components do in a Circuit?

Basic Testing Circuit

Circuit Diagram

The circuit diagram gives a simple description of the layout of the circuit, using component symbols and connections. Your first circuit, shown below, is used to test the operation of other electronics components. When the probes are connected, the LED lights up.



Circuit Diagram

a. Construct the circuit as shown in the circuit diagram. Connect to the 9 Volt battery.

b. Join leads P and Q. If the circuit is connected correctly, the Light Emitting Diode (LED) should light up.

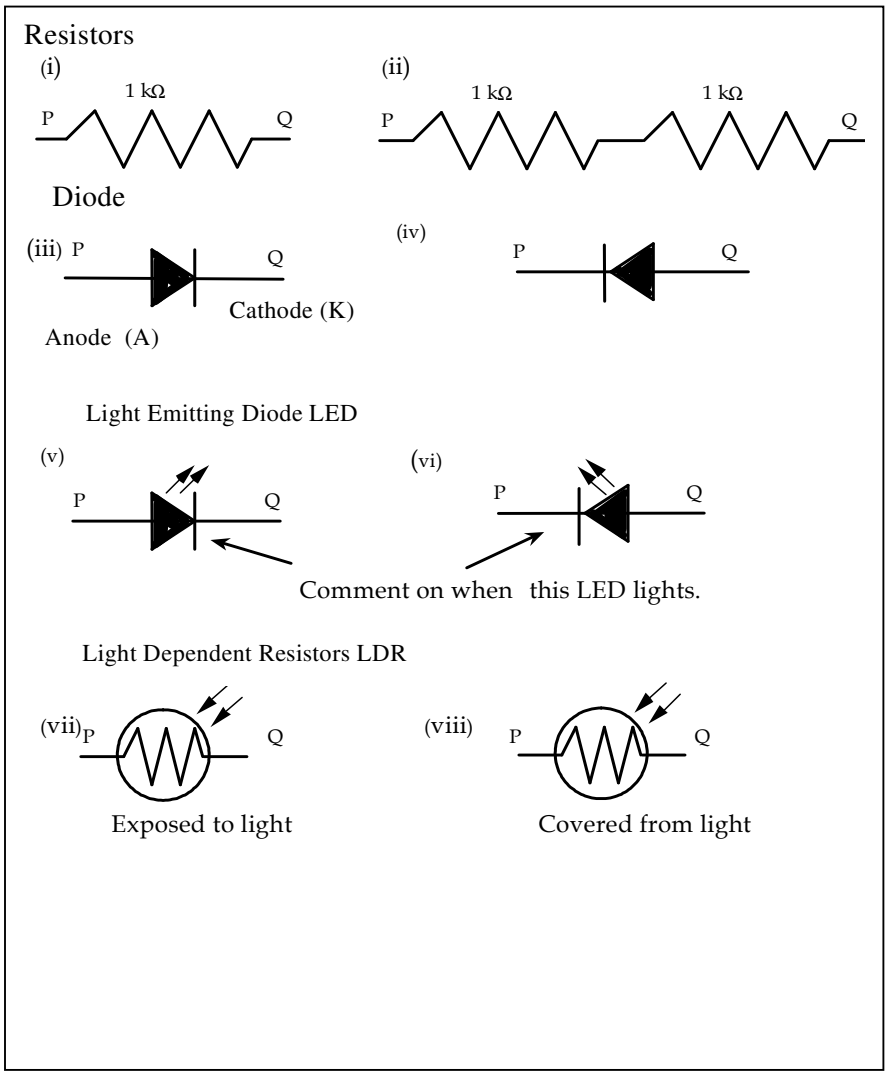
c. Write a few lines describing how this circuit works.
Begin with *"Current flows from the positive terminal of the battery, then* _____

_____

_____

d. Place (one at a time) each of the components shown overleaf across points P and Q. Describe how the brightness of the LED changes compared to the original brightness in 'b.' above. Write logical statements.

Note that when the LED is bright, there is little resistance in the circuit. When the LED is dim, the resistance of the circuit is high.



Resistors
i) _____

_____

ii) _____

_____

Diode
iii) _____

_____

iv) _____

_____

LED
v) _____

_____

vi) _____

_____

LDR
vii) _____

_____

viii) _____

_____

e Complete the following statements:

* The LED becomes (dimmer/brighter) as the resistance in the circuit increases.
* Diodes must be placed in the circuit so that their [anode (A) /cathode (K)] is nearest the positive terminal of the battery.
* The resistance of an LDR is large when it is (exposed to/covered from) a light source.

Activity 4
Using a capacitor - Delay circuits
Yet to be developed

What is a capacitor?
How is it made?
Why does it take time to be charged?
How can it be charged more quicky?
What can you use it for?
Design a circuit using a battery, switch, resistors, a capacitor and one or two LEDs so that the light goes on very quickly when the switch is closed, but goes off slowly when the switch is opened.

Charging the capacitor

Connect up the circuit below with the only one of the two wires to the battery connected.
(Battery, capacitor, LED and resistor plus wires).

i) Connect the last wire and describe what happens.

The LED shows whether there is a current, that is, charge moving in the circuit.

ii) Suggest an explanation for your observations

iii) Now disconnect one of the wires connected to the battery and connect it to the other wire. This takes the battery out of the circuit, which is now only the capacitor, the LED and the resistor) Describe what happens.

Discharging the capacitor

Investigating a capacitor resistor circuit.

Applications of capacitor resistor circuits.

Electrical Terminology

Amplifier	An electronic circuit that increases the amplitude of the input signal.
Alternating Current(AC)	The current type in which electricity moves back and forth rapidly. Australian household electricity alternates at 50 Hz (Hertz-times per second). Measured in Amps.
Battery	Often the terms battery and cell are confused. A battery is actually a group of cells connected together. In electric circuits, the red lead is positive (+), the black lead is negative (-). In the circuit diagram the longer line is the positive.
Capacitor	Components that store electric charge. The larger the capacitor, the more charge that can be stored. Capacitance is measured in Farads, but unit such as microfarads and picofarads are commonly used.
Cell	A container with substances that react to produce a chemical reaction. Chemical energy is converted into electrical energy.
Conductor	A substance that conducts electricity, with a very low resistance.
Current	The movement of electrons along a wire or other conductor. By convention, current always flows from the positive, through the circuit, and back to the negative terminal of the battery. It is likened to water flowing through pipes. The unit of current is the Amp (A).
Diode	Components which allow current to flow in one direction only. In resistance terms, they have a very high resistance when connected in one way, and a very low resistance in the other. They must be placed carefully in circuits, facing the correct way.
Direct Current (DC)	The current type in which electricity flows in one direction only. Produced by batteries. Used by electronic circuits. Measured in Amps.
LED	Light Emitting Diode. When connected correctly, they glow brightly. Used in many electronic displays.
LDR	Light Dependent Resistor. In darkness, they have a very high resistance (millions of Ohms). In light they have a low resistance. (hundreds of Ohms)
Microphone	A device able to convert sound energy into electrical energy.
Resistance	The ability of a component to oppose the flow of current. The higher the value, the less current allowed to flow. Measured in Ohms (□). It is likened to friction caused by water as it flows along a pipe.
Semiconductor	Neither a conductor nor insulator. Often it has the property to be able to change its resistance by various means.
Switch	A device for connecting and disconnecting power.
Speaker	A device for converting electrical current into sound energy.
Voltage	Described as the ‘pressure’ exerted by the power supply on a circuit. The higher the voltage, the more current that will flow through a circuit. Measured in Volts (V).

Activity 5: Making a DC Electric Motor

Principle of a DC Motor

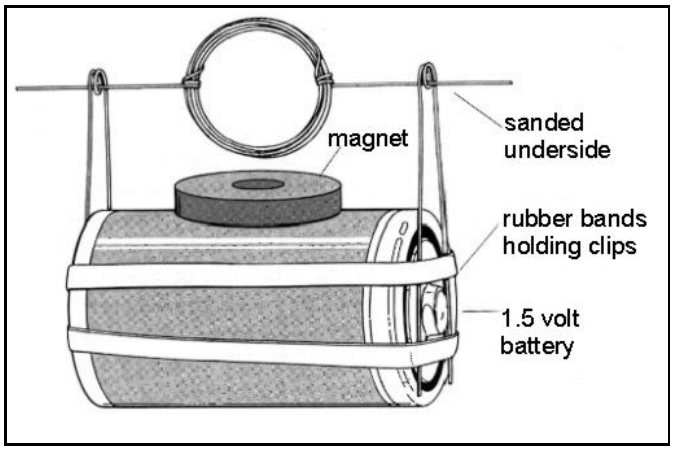
An electric motor works because of the **magnetic force** on current carrying wires. In most motors, the **magnetic field** is created by either **permanent magnets** or **electromagnets** which are held stationary, and hence called the **stator**. The current carrying wires are formed into a coil which is made to rotate by this magnetic force. This coil is normally wound on an iron core and is called the **armature**.

How it works

Here is a picture of our simple motor. The magnetic field is supplied by the disc magnet shown on top of the battery. Our "armature" is a simple coil of copper wire but has no iron core. You will realise that another important part of an electric motor is the **commutator**. This is the part that carries the current to the rotating coil and switches direction every half turn. The commutator in this motor is very simple; it consists of the wire extending from the coil, sitting on the bent paper clips that both hold it up and connect it to the battery. The current is not reversed every half turn, it is simply switched off for half of each turn.

Equipment Needed

One D size 1.5 volt battery
One magnet
One thick rubber band
One test tube
Two 50mm paper clips
90 cm of enamelled 22 gauge copper wire
One piece of sand paper or steel wool
One pencil or biro



Steps in making a DC Motor

Making the Copper Coil

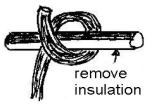
1. Wind about 5 or 6 turns of insulated copper wire (22 gauge or thereabouts) around a piece of dowel (or a test tube) about 2 cm in diameter.
2. Leave about 4 cm of wire at either end. Tie the ends around the loop as shown and straighten the bits that stick out so that the coil is balanced and turns freely. You may find it best to loop the wire around itself where it goes around the coil so that the wire sticking out is directly in line with the centre of the coil.

Bending the Paper Clips

3. Straighten out two paper clips.
4. To make the loop place the middle of each straightened paper clip across the pen and wrap the wire around the pen. The ends of the paper clips do not need to be even.
5. Attach the bent paper clips to the battery by a rubber band as shown. Ensure the band is tight and the paper clips are in contact with the metal ends of the battery.

Assembling the components

6. The next bit needs to be done carefully. Arrange the coil in the loops in the paper clips and see how it swings. Bend the wires, if necessary, until it is well balanced and rotates fairly freely.
7. Now take the coil out and sand off the insulation from **half** the circumference of the wire along the **section that was resting on the support when the coil is in the vertical position as in the diagram on the previous page**. Do this for each end. Ensure that the bared halves are on the same side of the wire as you look at it. Sand the wire right up to the coil.



8. Now put the coil back in the support.
9. Place the magnet on the battery and see if it runs! If it doesn't, give it a little flick. If it still doesn't, try switching the coil around or taking it out and re-balancing it. Experiment with the position of the coil relative to the magnet. Also, check to see that the area you sanded is quite free of insulation and that the supports are in contact with that area. Also check that the paper clips are in contact with the terminals of the battery.

It is not necessary to put the magnet on the battery as shown. It may be easier to simply place the magnet on the table and hold the battery and coil above the magnet. A disc magnet is shown but almost any magnet will do if you experiment with the position.

NOTE: The resistance of the coil is fairly low and so a fair bit of current will flow. For this reason don't leave your motor going for too long at one time. You could try finding ways to reduce the current flow!

Activities

1. Which way does the coil turn?

   _____

2. Turn the magnet over and try again. Which way does the coil turn now?

   _____

3. Now take the coil out of the supports and put it back in the opposite way. Which way does the coil turn now?

   _____

4. Nudge the coil across the magnet from one end to the other. How does the spin rate change?

   _____

5. Other things to try:

Put the magnet on its edge	Try a bar magnet
Use a shorter piece of copper	Clean the enamel off all way round the ends of the wire

Teacher Notes

Using a Multimeter

1. The probes can be used by touching the tips to the part of a circuit or component to be tested or jumper leads can be used to connect the probes to a component.
2. Care must be taken to connect each probe to the correct socket on the multimeter. For measurement of voltage and resistance the black probe is connected to the black **com** socket on the front of the multimeter and the red probe to the red **VΩ** socket. The appropriate section of the multimeter is then selected using the dial.
3. Multimeters can be used as ammeters, AC or DC voltmeters or ohm meters and have other functions such as continuity test and transistor test.
4. A basic digital multimeter costs $10-$12.

Making resistors

1. Pencil leads contain a mixture of graphite and clay. The softer pencils (B, 2B and so on) have more graphite. Graphite is a form of the element carbon that conducts electricity although carbon is a non-metal element. Connecting a pencil sharpened at both ends in a circuit will allow an electric current to flow in the circuit. Making pencil lines on paper forms a thin layer of graphite with a measurable resistance.
2. Any pencils can be used but generally anything harder than HB has too little graphite in it to give a measurable resistance.
3. The question in method 7. Generally the resistance increases as the length of the line between the multimeter probes increases.
4. The pencil lines can be drawn in the data table and the resistance of different lengths of each line recorded.
5. Question 10. Students should be encouraged to make inferences and draw conclusions consistent with their data. In general softer pencils with a greater proportion of graphite would have lower resistance and shorter lines have lower resistance.
6. Question 11. Generally wider lines would be expected to have lower resistance.
7. Question 12. You may want to ask students to discuss differences between the data and /or conclusions of different groups in the class.
8. 13 is offered as an extension.

Resistor colour code

1. **Resistor types**:
   Fixed resistors have a particular value of resistance which is taken as constant. They may be constructed from wire (wire wound), carbon or metal oxide.
   Variable resistors can supply a changing resistance. Potentiometers have a resistance that depends on the length of the wire selected, light dependent resistors (LDRs) have a resistance that changes under different light levels, thermistors have a resistance that changes with temperature.
2. **Resistor use**. Resistors are used to limit electric currents in circuits in ways that help the circuit to function as intended.
3. Small carbon resistors covered with a protective coating and connected to a wire at each end have a colour code on the outside of each resistor. Various forms of this colour code are available in text books, from electronics suppliers and on the internet. The activities aim to familiarise students with the use of the resistor colour code. There is no need for them to memorise it.
4. **The colour code chart**. In this exercise the resistor colour code chart will be used for four band resistors with a gold or silver tolerance band at one end and three coloured bands at the other end. The chart may also be used for more accurate 5 band resistors and may have up to 7 colours for tolerance levels.

5. **Remembering the code** If you want students to remember the colour code as well as being able to use it when given a chart, you could ask them to make up a sentence with the colours in order. There are several around eg:
   Barney Bull Runs Over Your Garden, Blue Violets Gone West.
   Big Brown Rabbits Often Yield Great Big Vocal Groans When Gingerly Slapped.
   Bad Beer Rots Our Young Guts But Vodka Goes Well.
6. Method 3. You may find drawing the coloured bands on the diagram in the table helps some students or helps all focus on the task.
7. Method 4. Loose resistors can be used but mounting them in some way makes measurements easier and keeps them from being lost. The measured values should be close to the calculated values but do not have to be exactly the same.
8. Method 5. Students could consider the 5% or 10% tolerance and the possibility of damage to the resistor.
9. Method 6 can be used as application or extension. Circuit boards from old clock radios, tape players, phones etc and toys and novelties will often have identifiable resistors, transistors, capacitors and diodes. Some boards are helpfully numbered R6, D2, C12 where R is resistor, D is diode, C is capacitor and so on. Increasingly ICs (integrated circuits or chips) with only a few other components carry out all the functions.

Activity 3: What do the Components do in a Circuit?

Basic Testing Circuit

Comments of the basic circuit:

- What does the 390 ohm resistor do?
  It limits the size of the current through the Light Emitting Diode (LED),and so protects it.
- If the LED does not light up, it is probably connected in the wrong way round.

Answers:

c. *Current flows from the positive terminal of the battery, then through the 390 ohm resistor. It then passes through the LED, lighting it up, and then on to the negative terminal of the battery.*

d. (i) When the 1 kilohm resistor is placed in the circuit, the brightness of the LED reduces.
   (ii) With two 1 kilohm resistors the brightness is even less.
   (iii) The LED does not go on.
   (iv) The LED does light up as bright as if there was nothing between P and Q.
   (v) Neither LED lights up.
   (vi) Both LEDs light up as bright as if there was nothing between P and Q.
   (vii) The LED lights up, but not very brightly
   (viii) The LED is very dim.

e. Conclusions
   * The LED becomes **dimmer** as the resistance in the circuit increases.
   * Diodes must be placed in the circuit so that their **anode (A)** is nearest the positive terminal of the battery.
   * The resistance of an LDR is large when it is **covered from** a light source.

Electronics References

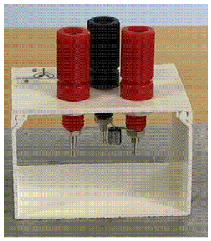
Kit List

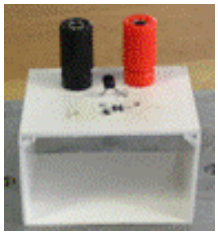
1. Resistor Colour Code

- Six resistors
- Multimeter

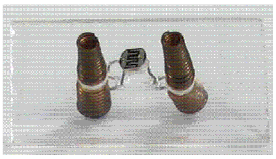
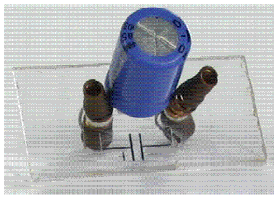
2. What does this component do?

- 9V battery and clip
- 390 ohm resistor
- LED
- Two 1k ohm resistors, diode, LDR, LED, transistor
- Two wires





Duct, non metallic PVC
($35 for 4m)
Electrical & data supplies
Rose Street, Doncaster
(03) 9848 9122

Conical compression springs(phosphor bronze)
($0.65 each based on an order of 300)
Bell Springs Pty Ltd.
P.O Box 344 Reservoir (03) 9464 6611

Overall

- 9V battery and battery holder (S6100 $2.28 pack of 5)
- 390 ohm resistor (R1064)
- 2 LEDs (Z4084, $14.50 pack of 100)
- One 1k ohm (R1074 $0.04 each), 1.2k ohm (R1076), 10k ohm (R1098), 100k ohm (R1124) resistors
- Six resistors (Mixed values)
- LDR (Z4801 $2.50 each)
- 10 µF (R4315 $0.25 each), 100 µF (R4360, $0.32 each), 1000 µF (R4440 $0.70 each) capacitors
- Three wires
- One wire with alligator clips
- Multimeter
- Component holders (conduit with banana sockets (red P1730 and black P1732 $1.40 each or cheaper (P1720 and P1726 $0.50 each) or thick plastic sheet with springs