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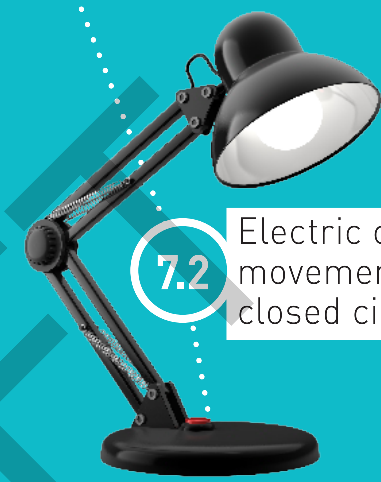
CHAPTER 7

ELECTRICITY

How does electricity light a lamp?

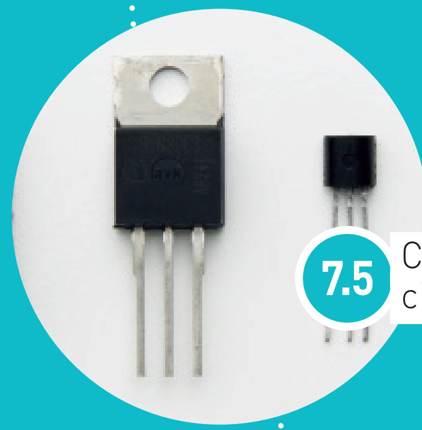
7.1 Electricity is the presence and flow of electric charges



7.2 Electric current results from the movement of charges around a closed circuit

7.3 Current can flow through series and parallel circuits

7.4 Voltage is the difference in energy between two parts of a circuit. Resistance makes it difficult for current to flow in a circuit



7.5 Current and resistance in a circuit can be altered.

What if?

Water magic

What you need:

Running water from tap, wool cloth, plastic rod, puffed rice, small pieces of paper

What to do:

1 Rub the plastic rod with the wool and then place it near the puffed rice.

What if?

» What if you placed the rod near a thin stream of water from a tap?

» What if you placed the rod near small pieces of paper?

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CHALLENGE 7.1B: Separating charges with a Van de Graaff generator
Go to page 190.

7.1 Electricity is the presence and flow of electric charges

In this topic, you will learn that:

- Electrostatic charges occur when electrical charges are unable to move.
- A closed circuit occurs when the positive and negative charges can be separated and reunited.
- A conductor allows the charges to flow easily.
- An insulator restricts the movement of the charges.

'Electricity' is a general term related to the presence and flow of charged particles. An electric charge can be either positive or negative. It is produced by subatomic particles (parts of atoms) such as electrons, which carry a negative charge, or protons, which carry a positive charge.

Electrostatic charge

Objects are normally uncharged – their atoms usually have equal numbers of protons and electrons. But when two objects are rubbed together, some of the electrons may be transferred from one object to the other. This causes the object with fewer electrons to become positively charged and the one with extra electrons to become negatively charged. You can also see this with friction – for example, if you rub a balloon against a woollen jumper, take off synthetic clothing or walk across synthetic carpet. In all these cases, the positive or negative electric charge stays on the charged object without moving. This is called an **electrostatic charge**. When the charges on an object are the same (both positive or both negative), then they are described as 'like charges'. If the charges are different (one positive and one negative), then they are described as 'unlike charges'.

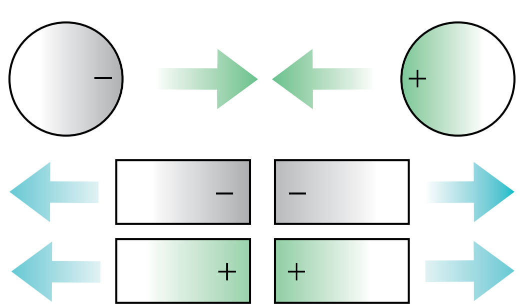

Figure 1 Like charges repel, unlike charges attract.

Important rules to learn about electrostatics:

> Like charges repel.
> Unlike charges attract.
> Charged objects attract neutral objects.

When charged objects are close to each other, the small negative electrons are attracted to the positively charged object (unlike objects attract). If these two objects are brought close enough, the electrons will try to jump across the gap as a spark. This is what happens when the air particles in a cloud rub against each other and become charged. If the charges build up enough, a large spark (lightning) will move between the charges in the clouds or towards the neutral ground (charged particles and neutral objects are attracted to each other).

The **Van de Graaff generator** is a machine that produces an electrostatic charge by rubbing a belt (Figure 2). It is used to accelerate particles in X-ray machines, food sterilisers and process machines, and in nuclear physics demonstrations.

Electrical energy and circuits

When electric charges become separated, they have **electrical energy**. This means they are in a state of excitement and the positive and negative charges try to get back together again. If a closed circuit is provided, the electrons will move along the wire to the positive charges and, as they do so, the electrical energy may transform into some other forms of energy, such as light or thermal energy.

However, it is difficult to continually rub things together to separate charges and give them electrical energy. A **dry cell** (e.g. a torch battery) or a **wet cell** (e.g. a car battery) uses a chemical reaction to continually separate charges and produce current electricity through wires.

Van de Graaff generator
a machine that produces an electrostatic charge

electrostatic charge
an electrical charge that is trapped in an object such as a balloon

electrical energy
energy associated with electric charge, either stationary (static) or moving (current)

dry cell
an object such as a torch battery that uses a chemical reaction to produce electrical energy

wet cell
an object, such as a car battery, that uses a chemical reaction to produce electrical energy

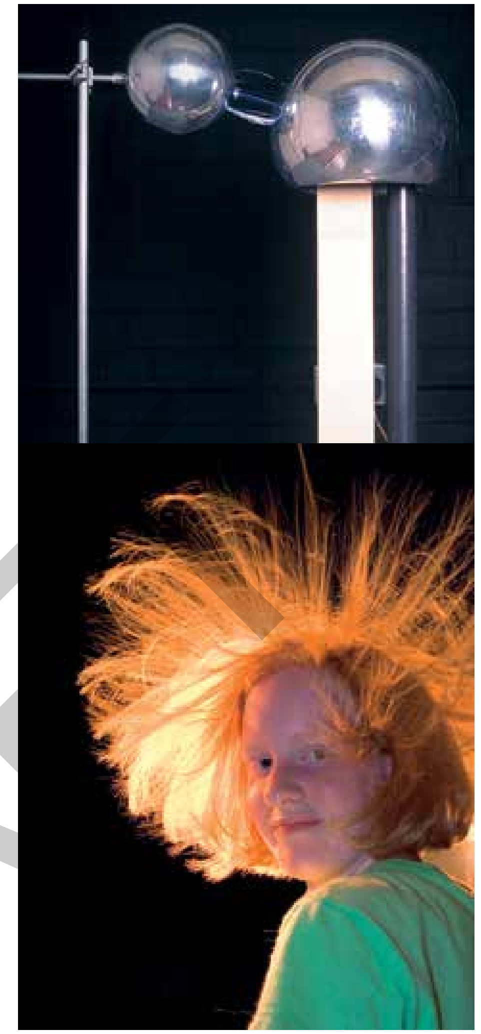

Figure 2 A Van de Graaff generator produces an electrostatic charge by a belt rubbing between rollers. This spreads the charge over the metal dome.

A closed conducting pathway is called an **electric circuit**. As electrically charged particles move around an electric circuit, they carry energy from the energy source (such as a battery) to the device that transforms the energy (such as a light globe, motor or heater). An example of the movement of electrical energy in a simple circuit is shown in Figure 3.

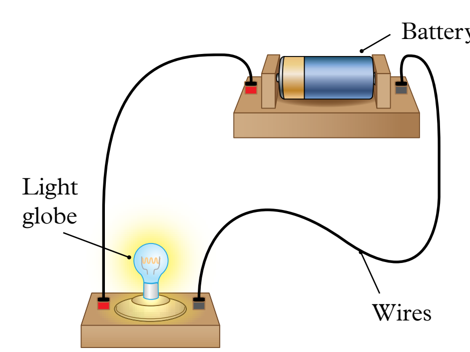

Figure 3 A simple circuit: electric charges move from the battery through the wires to the light globe.

Electrical conductors and insulators

An **electrical conductor** is a material through which charged particles are able to move. An **electrical insulator** is a material that does not allow the movement of charged particles. Most wires are made of copper, a metal, with a plastic coating around the outside. Copper is an electrical conductor – electrons are able to move through it easily. However, plastic is an electrical insulator. The wire is coated in plastic to prevent the charge being 'lost' to the surroundings as it passes through the wire.

Some substances are better **insulators** or better conductors than others. It depends on how easily the substance allows electrons to move through it – that is, it offers less or more resistance to the movement of charges. Air is a good resistor, as it is difficult for charged particles to move freely through it.

Some substances, such as germanium and silicon, are insulators in their pure form but become conductors if they are combined with a small amount of another substance. These materials are called **semiconductors**.

Within a single silicon chip, very thin layers of silicon can be combined with other substances to make that layer a conductor. Complex microcircuits used in computing are made in this way.

electrical conductor
a material through which charged particles are able to move

electrical insulator
a material that does not allow the movement of charged particles

insulator
a substance that prevents the movement of thermal or electrical energy

semiconductor
a material that conducts electricity more than an insulator and less than a conductor; its conductivity can be changed by adding other substances to it

electric circuit
a closed pathway that conducts electrons in the form of electrical energy

7.1 Check your learning

Remember and understand

1 **Identify** the charge on the following particles:
  a protons b electrons.
2 **Describe** how objects can become electrostatically charged.
3 **Describe** an electric circuit.
4 **Identify** the three parts of the electrical circuit shown in Figure 3.
5 **Explain** the purpose of a battery in a circuit.

Apply and analyse

6 **Contrast** a conductor and an insulator.
7 **Describe** how a semiconductor works.
8 If living organisms are good conductors and air is a good resistor, **explain** why it is important not to stand outside in open land during a lightning storm.

7.2 Electric current results from the movement of charges around a closed circuit

In this topic, you will learn that:

- An electric circuit contains an energy source (a battery), a pathway (usually wires) and a load.
- Current can be unidirectional (direct current or DC) or constantly changing direction (alternating current or AC).
- Current (measured in amperes) is a measure of the number of electrons that pass a point each second.
- The pathway of the charges can be represented by a circuit diagram.

Interactive Symbols used in circuit diagrams

Video Building a circuit

Video Using an ammeter and voltmeter

Figure 1 A switch in an electrical device such as this lamp creates a 'gap' in the electric circuit to stop the flow of electricity.

electric current
the flow of electrical charge through a circuit

circuit diagram
a diagrammatic way to represent an electric circuit

positive terminal
the point in the circuit where electrons flow into

negative terminal
the point in the circuit where electrons flow out from

Electric circuits

The pathway travelled by electrical energy is called an electric circuit. Electric circuits must have an energy source, wires to carry the charges, and a 'load', which is any device that converts the electrical energy into heat, light or kinetic energy. Many devices have 'gaps' called switches to control the flow of electricity in a circuit.

Moving charges

An **electric current** results from the movement of negatively charged electrons in an electric circuit. The electrons move, or are conducted, from the negative terminal of the energy source to the positive terminal. For historical reasons, the direction of the current is given as the flow of positive charge from the positive terminal of the energy source to the negative terminal. This imaginary flow of positive charge is referred to as a conventional current (Figure 2). There are two types of current used in electrical circuits. In an alternating current (AC), the flow of electrons reverses direction 50 times every second, in Australia. This type of current is used in electrical power points. In direct current (DC), the electrons flow in one direction only. This current is found in battery-powered circuits.

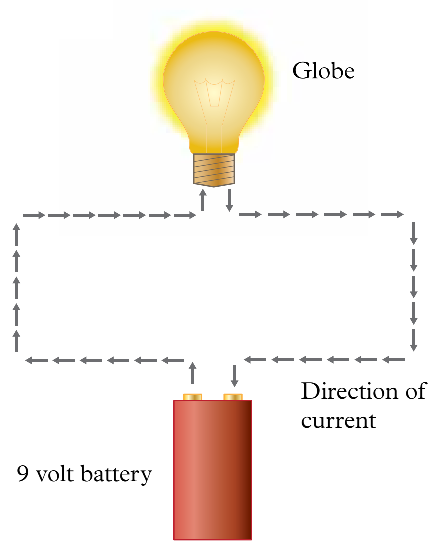

Figure 2 Conventional current in an electric circuit

Circuit diagrams

Circuits are represented by **circuit diagrams**. Each component of a circuit is represented by a symbol (Figure 3). The circuit illustrated in Figure 4a includes a globe, a battery, connecting wires, a switch and a meter, such as an ammeter, to measure the electric current. This circuit is represented in a circuit diagram in Figure 4b. Connecting wires are usually shown as straight lines, and when they meet at junctions they are often (but not always) shown joined at right angles. The longer line on the battery represents the **positive terminal** and the shorter line represents the **negative terminal**. These terminals are where the wires are connected. When drawing a circuit diagram, you should use a ruler and a pencil. All lines should be connected, to indicate that there are no breaks in the circuit. A break in the circuit means the current is not flowing.

CHALLENGE 7.2A: Making a simple torch circuit
Go to page 190.

CHALLENGE 7.2B: Connecting circuits
Go to page 191.

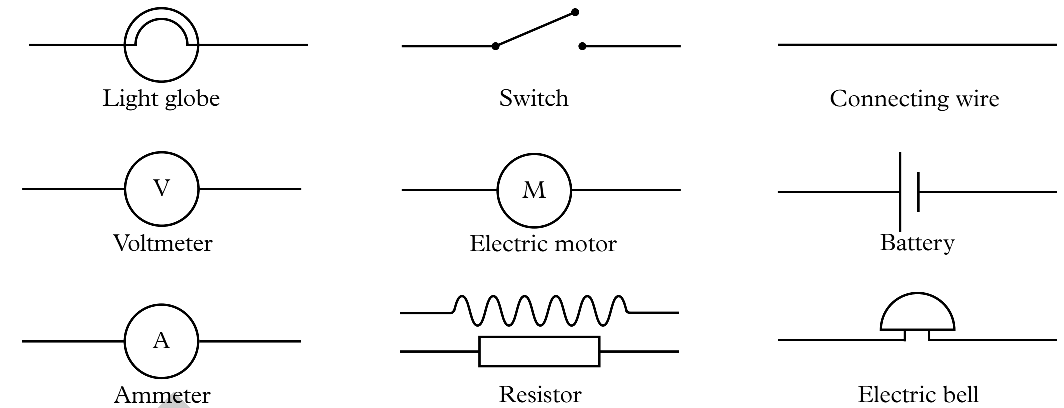

Figure 3 Some symbols used in circuit diagrams

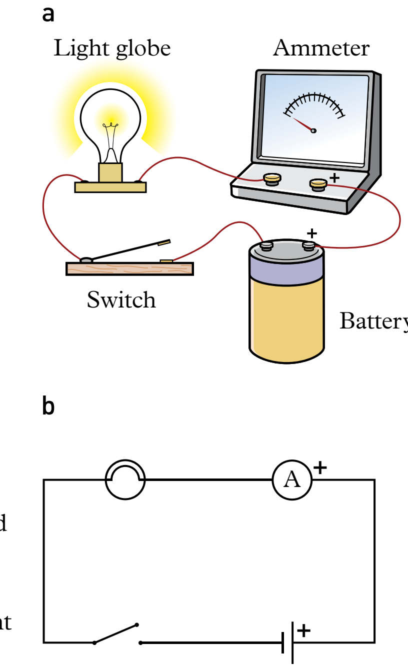

Figure 4 a A simple circuit **b** A circuit diagram of the simple circuit

Measuring electric current

Electric current, or the flow of charge, is measured by counting the number of electrons that go past a point in the circuit in 1 second. The unit of measurement for current is amperes (symbol A). An ampere is a large unit of current, so smaller units such as the milliampere (1000 mA = 1 A) are often used. Traditionally an ammeter (Figure 5a) was used to measure the current passing a particular point in an electric circuit. The ammeter must be connected into the circuit so that the current flows through it. More recently, a multimeter (Figure 5b) is used to measure many different aspects of a circuit, including the current.

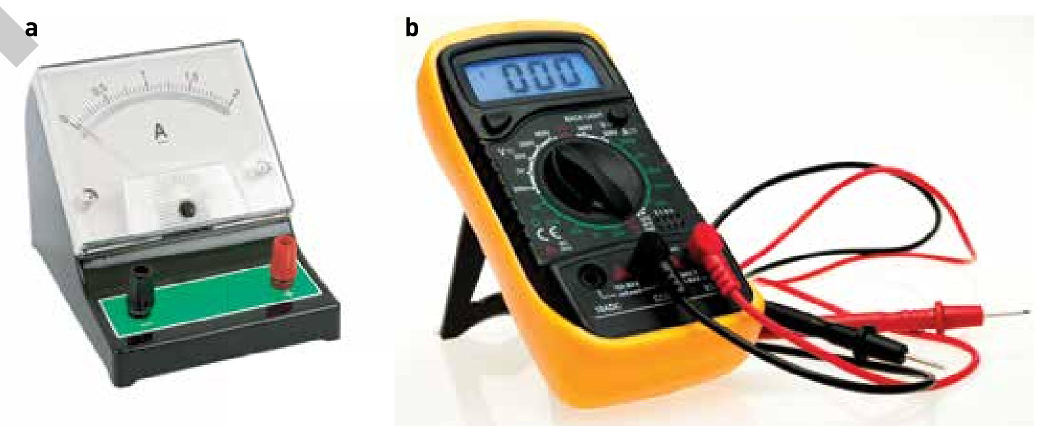

Figure 5 a An ammeter or **b** a multimeter is used to measure electric current.

7.2 Check your learning

Remember and understand

1 **Identify** and **describe** the role of each of the main parts of a circuit.

2 **Identify** the subatomic particle that moves in an electric circuit.

3 **Describe** how you could stop the charged particles flowing in a circuit.

4 **Contrast** AC and DC.

5 **Identify** the direction of:
   a conventional current
   b electrons in a circuit.

6 **Describe** how an ammeter or multimeter must be connected, to measure the current in a circuit.

Apply and analyse

7 **Identify** which of the globes in Figure 6 will transform electrical energy into light energy.

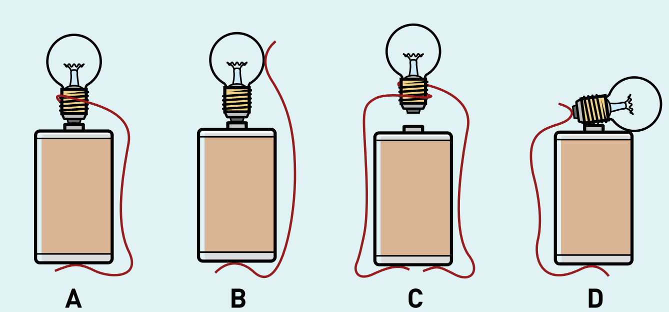

Figure 6

7.3 Current can flow through series and parallel circuits

In this topic, you will learn that:

- In a series circuit, the loads are connected one after the other, and the current is the same throughout the circuit.
- In a parallel circuit, the loads are parallel to each other, and the current is shared between them.
- A short circuit occurs when the electrical energy can move through an easier path with less resistance.

Types of circuit

When two or more globes are connected in a circuit, two different types of connection are possible. In a series circuit, the globes are connected one after the other so that the current goes through one globe and then through the second (Figure 1a). In a parallel circuit, the circuit has two or more branches and the current splits between the branches (Figure 1b) and comes back together afterwards.

parallel
a way of connecting loads (e.g. lights) in an electric circuit so they are all connected to the battery separately; they are in parallel to each other

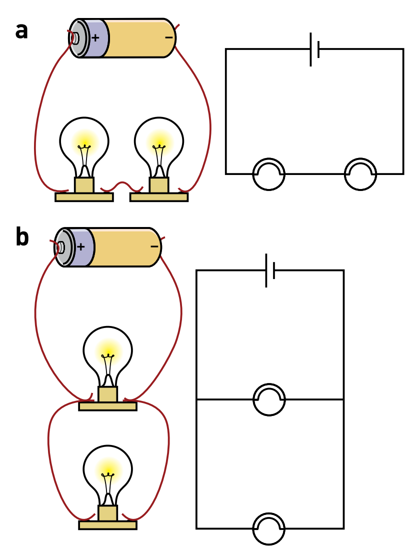

Figure 1 a In a series circuit, the current is the same anywhere in the circuit. **b** In a parallel circuit, the sum of the current going through globe A and globe B is equal to the total current from the battery.

Comparing series and parallel circuits

If two globes are connected in a circuit in **series**, then all the current (the electrons) passes through both globes. This means the current is always the same at all points in a series circuit.

series
describes an electric circuit that is arranged with the loads (e.g. lights) connected in a row, so the electrical energy passes through one load at a time

However, if two globes are connected in **parallel**, the current splits. This means when the electrons reach the point where the wire splits, they will travel along one path or the other. Part of the current passes through each globe, and then joins together again after passing through the globes. This means the currents going through each globe must be added together to determine the total amount of current coming from the battery.

Figure 2 Traditionally, party lights were a series circuit. This meant that when one light broke, all the lights went out. Now, most modern party lights are arranged in a parallel circuit.

In a series circuit, a break at any point in the circuit (e.g. from a switch) affects all the globes in the circuit. In a parallel circuit, a break in one of the branches of the circuit affects only the current (and globe) in that branch.

In a household, lights and appliances are connected in parallel, so that:

> some appliances can be on while others are off (achieved by inserting switches)
> if one appliance fails, the others will still work.

CHALLENGE 7.3A: Making series and parallel circuits Go to page 191.

CHALLENGE 7.3B: Short-circuiting an electric current Go to page 192.

Worked example 7.3: Calculating currents

If the current leaving a battery is 6 amperes (amps), calculate the current travelling through two identical lamps if they are connected (a) in series, or (b) in parallel.

Solution

(a) If the lamps are connected in series, all the electrons flow through each lamp. Therefore, the current in each lamp is 6 amperes.

(b) If the lamps are connected in parallel, the electrons are divided between the wires. This means the current is divided equally between the lamps.

6 amperes ÷ 2 lamps = 3 amperes in each lamp

Batteries in series and in parallel

Batteries may be connected in series or in parallel, in a similar way to globes. When batteries are connected in series, each electron picks up a certain amount of energy as it passes through the first battery and then an additional amount as it passes through the second battery. This arrangement allows electrons to be given larger amounts of energy. For instance, a simple torch normally has two 1.5 V batteries connected in series. As each electron passes through both batteries, it collects a total of 3.0 units of energy to light the torch globe.

When batteries are connected in parallel, each electron passes through either one battery or the other. So each electron collects the same amount of energy as it would from one battery on its own. The advantage of this arrangement is that the two batteries last longer than either one of them would in the same circuit on their own.

Figure 3 A sudden increase in current will cause a fuse or safety switch to break the circuit. This stops the current from flowing and may prevent electrocution.

Short circuit

A **short circuit** occurs when a current (moving electrons) flows along a different path from the one intended. This can be caused by damaged insulation that usually surrounds the wires or by another shorter conductor, such as water, providing an easy path for the electrons. Electric charges will always take the path of least resistance. This means that large currents can flow through any short path or conductor that allows the electrons to move most easily. Short circuits are dangerous because they can also lead to wires heating up from the fast flow of electrons, causing damage or even fire.

short circuit
when electrical current flows along a different path from the one that was intended

Fuse

A **fuse** is a switch or thin piece of wire that burns up quickly when electrons flow too fast in a circuit. This causes a break in the circuit so the electrical energy stops flowing. This is to prevent damage to appliances from the high current, and to prevent loss of life.

fuse
a wire of high resistance; it will melt if too much current flows in the circuit

7.3 Check your learning

Remember and understand

1 **Contrast** the movement of current in a series circuit and a parallel circuit.

2 Look at the party lights in Figure 2.
  a **Describe** how you could determine whether the globes are connected in series or parallel.
  b Draw a circuit diagram showing the possible connection of some of the globes.

3 **Describe** the advantage of having a safety switch or fuse in the electric circuits of your house

Apply and analyse

4 Three lamps were connected in series to a battery that produced a 12 ampere current. **Calculate** the current flowing in each lamp.

5 **Describe** how the household appliances are connected in your house (in series or in parallel). **Justify** your answer (by explaining how series and parallel circuits behave and providing an example that matches your explanation).

6 Double adaptors and power boards enable you to connect additional appliances to a power point. **Explain** whether the double adaptors or power boards are more likely to be series or parallel connections. **Justify** your answer.

Evaluate and create

7 An electrician wanted to connect four identical lamps to a 6 ampere source so that two lamps had a current of 6 amperes and the other two lamps had a current of 3 amperes each. Draw a circuit diagram to show a possible arrangement of the lamps the electrician could use.

SKILLS LAB 7.4A: Using Ohm's law to find resistance
Go to page 192.

SKILLS LAB 7.4B: Understanding resistor colour codes
Go to page 193.

EXPERIMENT 7.4: Investigating Ohm's law
Go to page 194.

7.4 Voltage is the difference in energy between two parts of a circuit. Resistance makes it difficult for current to flow in a circuit

In this topic, you will learn that:

- Voltage is a measure of the difference in electrical potential energy carried by charged particles at different points in a circuit.
- Voltage can be measured using a voltmeter or multimeter in parallel to the circuit.
- Resistance is a measure of how difficult it is for current to flow through part of the circuit.

Voltage

Each charged particle has energy as it moves in an electric circuit. This potential energy can be transformed into sound as it moves through a speaker, or into light and heat if it moves through a globe. This means the charged particle (electron) has different amounts of energy before and after the speaker or globe. This difference in energy is called potential difference or **voltage**.

voltage
potential difference; the difference in the electrical potential energy carried by charged particles at different points in a circuit

Voltage is measured by a voltmeter or a multimeter in the unit volts (symbol V). To measure the potential difference in a circuit, voltmeters are set in parallel across the two points in the circuit that you want to measure (Figure 2).

Figure 1 Each unit of charge in this battery has 1.5 joules of energy.

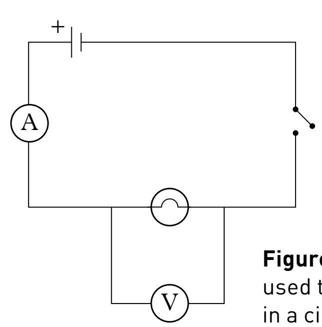

Figure 2 A voltmeter is used to measure voltage in a circuit.

Batteries add energy to the charged particles. The amount of energy added by the battery can be determined by connecting a voltmeter in parallel to the battery. In a 1.5 V battery, each unit of charge (electron) receives 1.5 J of energy as it passes through the battery.

In a series circuit, the potential energy contained by each electron must be divided between the different loads. This means a 12-volt battery connected to two identical globes in series may transfer 6 volts of energy to each globe. If the two globes are connected in parallel, each electron moving in a globe is able to transform all the 12 volts into light and heat.

Worked example 7.4A: Calculating voltage

If a 6-volt battery is connected to two lamps, calculate the voltage that can be transformed in each lamp if they are connected (a) in series, or (b) in parallel.

Solution

(a) If the lamps are connected in series, the electrons must divide the voltage (potential energy) between the lamps. Therefore, the voltage transformed in each lamp will be 3 volts.

6 volts ÷ 2 lamps = 3 volts in each lamp

(b) If the lamps are connected in parallel, the electrons will separate at the fork in the wires and carry all the energy to each lamp. This means the voltage (potential difference) transformed will be 6 volts in each lamp.

Resistance

The amount of current flowing in a circuit is determined by the **resistance** of the circuit. The electrical resistance of a material is a measure of how difficult it is for charged particles to move through. Electrons collide with the atoms in the wires and the various other components of a circuit, and some of their electrical energy is converted or transformed into heat. Most connecting wires are thick and made of good conductors. This means they have very low resistance, and so hardly any energy is lost by the electrons. However, the wires in a toaster are designed so that a lot of the electrons' energy is transformed into heat – so much that the wires glow red-hot and brown our toast.

Resistors are devices that are placed deliberately in circuits to control or reduce the size of the current. Resistance is measured by a multimeter in units called ohms (symbol Ω).

A potentiometer is another type of variable resistor with a dial that rotates. A light dimmer is a potentiometer, as is the temperature control on an oven.

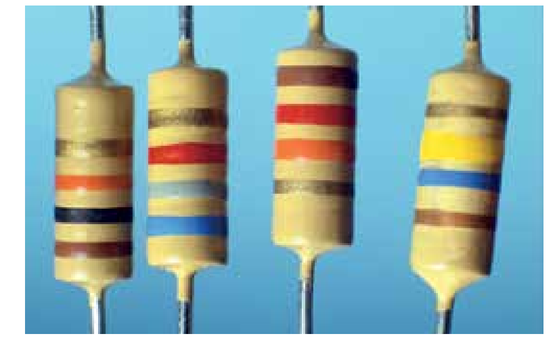

Figure 3 Many types of resistor are available. The resistance of carbon resistors is indicated by the coloured bands on their plastic case.

resistance
a measure of how difficult it is for the charged particles in an electric circuit to move

Ohm's law

Georg Ohm, a German physicist, discovered the relationship between voltage, current and resistance. Ohm found that the voltage drop across a fixed-value resistor is always directly proportional to the current through the resistor. This means that as the voltage goes down, the current will also go down. This relationship is known as Ohm's law and is written as:

$$V = IR$$

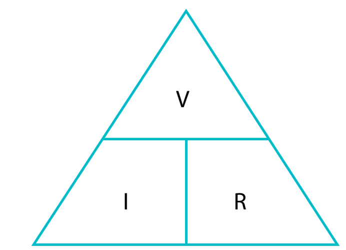

Figure 4 The Ohm's law triangle can be used to remember the equations for Ohm's law. To find resistance, cover the *R* – the other two letters show you the formula to use. The *V* is over the *I*, so *R* = *V*/*I*.

Worked example 7.4B: Calculating resistance

If a 9 volt battery produces 6 amps of current, calculate the resistance of the circuit.

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

Solution

If V = 9 volts, and I = 6 amperes, then

$$R = \frac{9 \text{ volts}}{6 \text{ amperes}} = 1.5 \text{ ohms}$$

Therefore, the resistance in the circuit is 1.5 ohms.

7.4 Check your learning

Remember and understand

1. **Define** the term 'voltage'.
2. **Describe** the voltage across two lamps when they are connected:
   a in series
   b in parallel.

Apply and analyse

3. **Identify** the three equations that can be obtained by rearranging Ohm's law triangle.
4. **Calculate** the current flowing through a 44 Ω resistor when it has a voltage drop of 11 V across it.
5. **Calculate** the change in voltage across a 25 Ω resistor when a current of 50 mA (0.05 amps) flows through it.
6. **Calculate** the value of a resistor that has a 'voltage drop' of 8 V across it when a current of 0.4 A flows through it.
7. Use Table 1 on page XXX to find the value of a resistor that has three coloured bands of:
   a red, white, black
   b yellow, green, red
   c brown, blue, orange.

CHALLENGE
7.5A: Investigating with a remote control
Go to page 195.

CHALLENGE
7.5B: Lighting up LEDS
Go to page 195.

CHALLENGE
7.5C: Wiring a house
Go to page 196.

7.5 Current and resistance in a circuit can be altered

In this topic, you will learn that:

- Diodes allow current to flow in one direction only.
- Rectifiers are a type of diode that convert alternating current to direct current.
- LEDs are diodes that emit light.
- Photoresistors alter their ability to conduct electricity according to the amount of light they are exposed to.
- Some thermistors reduce their resistance as they are heated.

Diodes

Many materials can alter their ability to conduct electricity. A diode is a semiconductor device that allows current to flow in one direction only. Most diodes are made of specially treated silicon. The symbol for a diode in a circuit diagram is shown in Figure 1. You can think of the triangle as an arrow that shows the direction that the diode allows the conventional current (from positive to negative) to flow.

rectifier
a device that coverts AC to DC, commonly composed of diodes

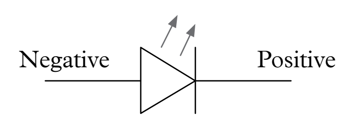

Figure 1 Think of the triangle as an arrow that shows the direction that the diode allows the conventional current (from positive to negative) to flow.

When the diode is connected correctly, and the voltage is above the minimum threshold, current will flow through the circuit. If the diode is reversed, the current will try to travel in the opposite direction, but the diode will resist the current (Figure 3). This will stop the flow of all charges in the circuit.

light-emitting diode (LED)
a type of diode that emits light of a particular colour

Some diodes can only carry small currents, of much less than 1 amp. Bigger currents produce too much heat, which would destroy the diode. Most diodes are connected in series with a resistor so that the current is below the maximum allowed by the diode.

Figure 2 Diodes come in all shapes and sizes depending on their role in the circuit.

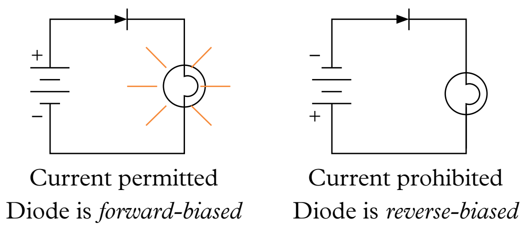

Figure 3 The diode allows current to flow in one direction only.

Silicon diodes are useful for converting AC to DC. Such a device is called a **rectifier**. A lot of electrical equipment operates on DC instead of AC, but it is convenient to plug them into AC power points. For example, a hair dryer plugs into an AC power point, but most hair dryers contain a rectifier circuit that converts the AC to DC before it flows to the heating elements and the fan motor.

Light-emitting diodes

A **light-emitting diode (LED)** is a special type of diode that not only restricts current flow to one direction only, but also emits light of a particular colour (Figure 4) when a current flows through it. Typically, the light from LEDs is one of the visible colours (commonly red, yellow or green), infrared (IR) light or ultraviolet (UV) light. The remote controls of televisions and DVD players send their messages via infrared LEDs. Red LEDs are also widely used on electrical equipment to show that the power is on or to indicate a particular setting. They are also used in torches, and garden and vehicle lights. LEDs are replacing incandescent globes in traffic lights, where they appear as dots of coloured light.

LED televisions use the light from the LEDs behind a screen of liquid crystals. The LEDs produce a light that shines through the pixels to create an image. Because LEDs are more energy efficient, LED TVs are thinner than normal liquid crystal display (LCD) televisions.

Figure 4 Robot vacuum cleaners send infrared beams around a room to tell the robot the size of the room and if there are any drop offs like stairs.

Figure 5 Light-emitting diodes (LEDs) are more efficient, longer lasting and use less power than light globes, making them useful for a wide range of applications.

Light-dependent resistors

Light-dependent resistors (LDR) (or photoresistors) use light to change the amount of electric current that moves through the circuit. The more light that shines on a photoresistor, the less it resists the movement of electrons and the more the current is allowed to flow through the circuit. This property is called **photoconductivity**. In the dark, a photoresistor has a very high resistance (thousands of ohms), while light can reduce the resistance to a few hundred ohms. This means more light causes more current.

Photoresistors are used in camera light meters, night lights and solar street lamps. When light falls on the photoresistor in a street lamp, it turns the lamp off.

light-dependent resistor (LDR)
a resistor that changes its resistance according to the amount of light it is exposed to

photoconductivity
a property of light-dependent resistors, where the amount of electricity passing through the resistor is dependent on the amount of light it is exposed to

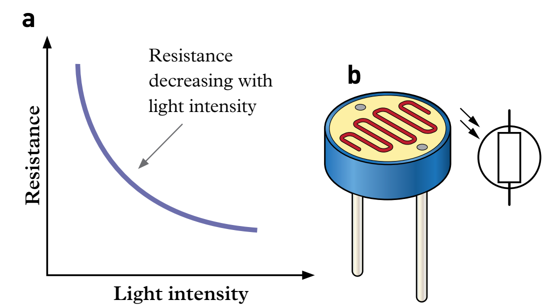

Figure 3 a The resistance of an LDR decreases when more light shines on it. **b** An LDR and its circuit symbol

Temperature-dependent resistors

Temperature-dependent resistors (or **thermistors**) are devices that change their resistance when the temperature varies. This affects the amount of current that can flow through the circuit. Most commonly, the higher the temperature, the lower the resistance. Thermistors are often included in programmable circuits that detect the amount of current flowing and use it to display the temperature (as in thermometers) or to turn an object on or off.

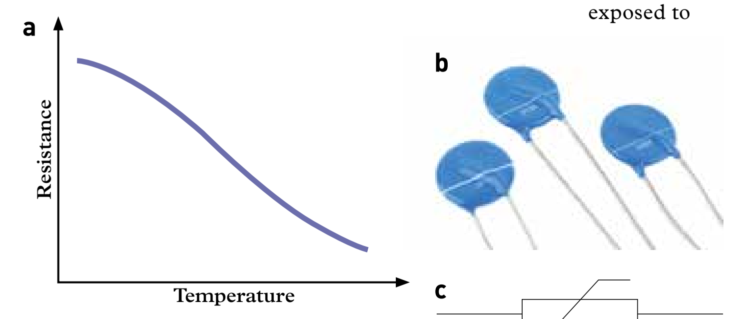

Figure 6 a The resistance of a thermistor changes with temperature. **b** Thermistors **c** Thermistor circuit symbol

7.5 Check your learning

Remember and understand

1 **Describe** the role of the following devices in a circuit.
  a LED
  b photoresistor
  c thermistor

2 **Describe** the role of a resistor that is connected in series with a diode. Draw a circuit using circuit symbols showing the correct arrangement of these components.

Apply and analyse

3 **Compare** a photoresistor and a thermistor.

4 **Explain** why an electrical device such as a toaster would need a rectifier.

5 A television remote control usually has an infrared LED that converts electrical energy into infrared energy. **Identify** the device the television must have to communicate with the remote.

temperature-dependent resistor
a resistor that varies the flow of current according to the temperature it is exposed to

thermistor
a temperature-dependent resister that varies the flow of current according to the temperature it is exposed to; commonly used for temperature control

Multiple choice questions

1 The units of voltage, current and resistance, respectively, are
- **A** amps, ohms, volts.
- **B** ohms, volts, amps.
- **C** volts, amps, ohms.
- **D** volts, ohms, amps.

2 The potential energy that can be transformed in a lamp is also known as
- **A** current.
- **B** voltage.
- **C** resistance.
- **D** load.

3 A 50 ohm resistor is connected to a 10 volt battery. The current flowing through it is _________ amps. If the voltage is doubled, then the current will be _________ amps.
- **A** 5 A, 2.5 A
- **B** 0.2 A, 0.1 A
- **C** 5 A, 10 A
- **D** 0.2 A, 0.4 A

Short answer

Remember and understand

4 Draw a circuit diagram for a circuit containing a battery, globe and switch. **Identify** the direction of electron flow and the direction of conventional current.

5 Match each circuit symbol shown in Figure 1 with its name.

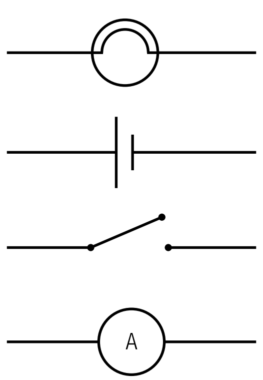

Figure 1 Circuit symbols

ammeter   battery   globe   switch

6 **Describe** the role of an ammeter.

7 If you don't connect the conducting wires to a globe correctly, the globe doesn't light up. Use the terms 'insulators' and 'conductors' to **explain** this observation.

8 **Define**:
- **a** LED
- **b** rectifier.

9 **Compare** current and voltage.

10 **Describe** how current moves in a parallel circuit.

11 **Contrast** a voltmeter with a multimeter.

12 **Describe** the relationship between current, voltage and resistance.

13 **Describe** how voltage changes through a series circuit.

14 **Identify** the circuit in Figure 2 as either a parallel circuit or a series circuit.

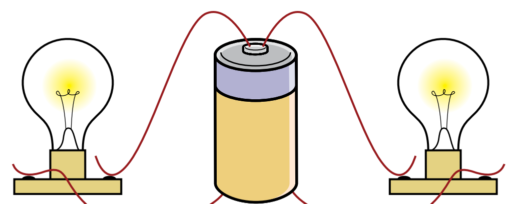

Figure 2 Identify the circuit.

Apply and analyse

15 Draw a circuit diagram that shows a battery and a switch, with a globe on either side of the switch.
- **a** **Describe** if/how the circuit will be affected if the switch is placed before both globes.
- **b** **Identify** the direction of electron flow and the direction of conventional current in the circuit.

16 Two identical bulbs are set up in a parallel circuit. **Describe** what would happen if a third identical bulb is connected in parallel.

17 Use Table 1 on page **XXX** to **calculate** the value of a resistor with the following coloured bands (in order):
- **a** green, brown, black
- **b** brown, yellow, red.

18 Use Table 1 on page **XXX** to **calculate** the coloured bands on a 7.9 MΩ resistor.

19 The lights in Figure 3 are connected in series. **Describe** what will happen if one globe fails.

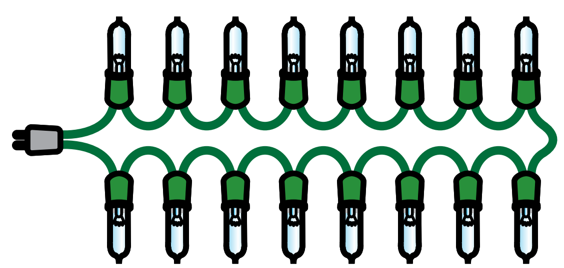

Figure 3 Lights connected in series

20 **Calculate** the current flowing through a 30 Ω resistor when it has a voltage drop of 12 V across it.

21 **Calculate** the voltage drop across a 50 Ω resistor when a current of 25 mA flows through it.

22 **Calculate** the value of a resistor that has a voltage drop of 18 V across it when a current of 0.3 A flows through it.

23 Explain why electrical current flows more easily in conductors.

Evaluate and create

24 Power lines carry electricity from power stations to cities and towns. They experience a voltage loss due to the high resistance along the lines according to Ohm's law. **Describe** how the current in power lines could be changed to minimise this voltage loss due to resistance.

25 **Explain** why a voltmeter is connected in parallel and an ammeter is connected in series in a circuit.

26 Use the correct symbols to draw a circuit consisting of a 6 V DC supply, an LED and a 100 Ω resistor connected in series. Add a voltmeter to measure the voltage drop across the LED.

27 **Evaluate** the claim: 'Resistance increases as voltage decreases.'

Critical thinking

28 In a storm, a tree has been blown over onto the main power line to your neighbourhood. The electricity supply is cut. **Describe** your day without electricity.

29 **Use** your understanding of current and voltage to model the flow of electricity through a circuit. You might use people or even an animation as your model.

Social and ethical thinking

30 LEDs are gradually replacing incandescent street lights and traffic lights because they are more energy efficient. Unfortunately, this makes the lights much brighter, which can interrupt the sleep or migration patterns of local wildlife, including the bogong moth.

The bogong moth is a major food source of the pygmy possum. When the moths are attracted to the LED lights in the city, this diverts them away from the pygmy possum's habitat, and so the possums fail to get the food they need to survive.

Discuss the ethical dilemma caused by use of LED lights by:
- describing the advantages of using LED lights
- describing the disadvantages of using LED lights
- deciding whether the advantages are more important than the disadvantages (consequentialism) or whether some rules should not be broken (deontology).

31 Less than 3% of batteries that are purchased in Australia are recycled. This means 97% of batteries get sent to landfill, where they contaminate soil and water with toxic matter. Lithium batteries can also cause fires and explosions if they are inappropriately stored, damaging native habitats and homes. Evaluate the importance of recycling batteries and using rechargeable batteries to avoid damaging the environment.

Research

32 Choose one of the following topics for a research project. A few guiding questions have been provided, but you should add more questions that you wish to investigate. Present your report in a format of your own choosing.

» Seeing the light

Research incandescent light globes. **Identify** what is meant by 'incandescent'. **Describe** the materials that these globes are made of. **Explain** why the filament must contain an inert gas like argon. **Describe** the temperature the filament needs to be heated to so that it gives off light. **Describe** the efficiency of incandescent light globes.

Figure 4 Incandescent light globes

» Light-emitting diodes

Describe diodes and how they work. **Describe** light-emitting diodes (LEDs) and **explain** why they are used in traffic lights. **Evaluate** the benefits of using LEDs. **Identify** other applications of LEDs. **Compare** their longevity to that of compact fluorescent globes and incandescent globes.

Figure 5 LED are used in traffic lights

» Energy-efficient housing

In previous societies, energy efficiency was important because people had limited access to the types of energy supplies and their applications that we have today. Research how civilisations in tropical areas designed their homes to keep them cool and damp-free. **Describe** the different types of energy-efficiency practices that humans have used through the ages.

Figure 6 Solar panels improve energy efficiency.

Reflect

The table below outlines criteria for successfully understanding Chapter 7 Electricity. Once you have completed this chapter, reflect on your ability to do the following:

	I can do this.	I cannot do this yet.
Describe the difference between static electricity and electric current. Identify the key components of an electric circuit.	☐	☐ Go back to Topic 7.1 Electricity is the presence and flow of electric charges. Page XX
Describe why circuit diagrams are used to represent circuits and draw appropriate circuit diagrams. Explain how an ammeter measures current.	☐	☐ Go back to Topic 7.2 Electric current results from the movement of charges around a closed circuit. Page XX
Describe the differences in arrangement of series and parallel circuits. Measure current using an ammeter.	☐	☐ Go back to Topic 7.3 Current can flow through series and parallel circuits. Page XX
Describe how voltage is shared in series circuits and the same in parallel circuits. Measure voltage using a voltmeter.	☐	☐ Go back to Topic 7.4 Voltage is the difference in energy between two parts of a circuit. Resistance makes it difficult for current to flow in a circuit. Page XX
Describe how a diode restricts current to one direction. Describe how resistance can be altered by light or temperature.	☐	☐ Go back to Topic 7.5 Current and resistance in a circuit can be altered. Page XX

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EXPERIMENTS

CHAPTER
9

7.1B Separating charges with a van de Graaff generator

CHALLENGE

What you need

- Van de Graaff generator
- Smaller sphere connected to discharge wand
- Paper streamers
- Small pieces of paper
- Aluminium plates
- Paper cup with Rice Bubbles

What to do

1. Observe what happens to objects that have been charged by a van de Graaff generator. Record your observations in a table.
2. Your teacher may demonstrate any of the following:
   a. a smaller sphere held near a larger sphere
   b. paper streamers attached to the top
   c. paper streamers held nearby
   d. long dry hair nearby
   e. small pieces of paper thrown on top
   f. aluminium plates placed on top
   g. paper cup with Rice Bubbles inside.

Discussion

1. **Describe** the three rules of electrostatic charges.
2. **Explain** what happens in each example, using your knowledge of electric charge.

Figure 1 What happens to paper streamers?

7.2A Making a simple torch circuit

CHALLENGE

What you need

- Pieces of insulated electrical wire with the ends stripped bare
- 1.5 V battery
- 1.2 V torch globe
- Hand lens

What to do

1. Try different arrangements of the wires, battery and torch globe to make the globe light up. Draw each arrangement that you tried.
2. Use circuit diagrams to record some of the arrangements that work and some that do not.
3. Use the hand lens to look carefully at the filament in the globe. The filament is the tiny wire inside the glass of the globe – the part that glows brightly when the globe lights up. Draw what you see.
4. Use the hand lens to look at how a globe holder (the base of a globe) is constructed.

Discussion

1. Select one of the arrangements that did not allow the globe to light up. **Explain** why this arrangement did not allow electricity to pass through the circuit.
2. **Describe** how the filament in the light globe is able to transform electricity into light and heat.
3. **Describe** how the globe holder connects the light globe to the circuit.

Figure 1 How does a torch work?

7.4B Understanding resistor colour codes

SKILLS LAB

Carbon resistors typically have four colour-coded bands on their case (Figure 1). These bands are part of a code that allows you to work out their approximate value and tolerance. The fourth band is the tolerance band, which indicates the amount that the resistance may vary (the relative accuracy of the resistor). Gold means 5% tolerance, silver means 10% tolerance, and no fourth band means 20% tolerance. The lower the percentage tolerance, the more accurate (or closer to the true value) the resistor is.

Figure 1 A resistor with colour-coded bands

To read the three other bands, put the tolerance band on the right and start at the other end. The first two bands form a two-digit number according to their colour (see Table 1). The third band tells you how many zeros to put after the number.

Look at the resistor in Figure 1. What does its code mean?

1. The tolerance band is gold, so the resistor has 5% tolerance.
2. The first band is blue, so it has a value of 6.
3. The second band is red, so it has a value of 2. The number is 62.
4. The third band is also red, so this means 2 zeros need to be added to the number. The number is now 6200.
5. Resistor values are always coded in ohms, so the value of this resistor is 6200 ohms or 6.2 kilo-ohms.

Table 1 Resistor colour codes

Colour	Value
Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Grey	8
White	9

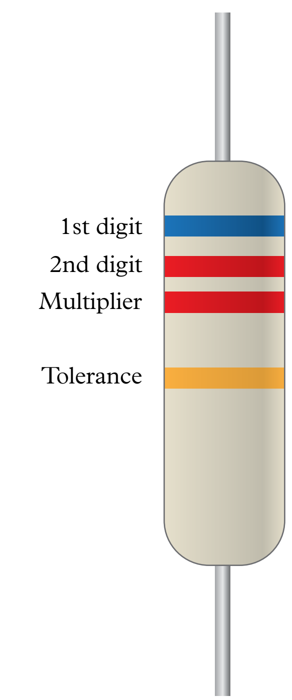

Figure 2 Calculate the value of this resistor.

Discussion

1. **Define** the electrical term 'resistance'.
2. **Explain** why different resistors may need to be used in different circuits.
3. **Explain** what is meant by the term 'tolerance'.

7.4 Investigating Ohm's law

EXPERIMENT

Aim

To investigate the voltage drop across and the current flow through a resistor, and to calculate an average value of the resistance

Materials

- Power supply
- Ammeter
- Voltmeter
- 10 Ω resistor
- 3 other resistors with masking tape over their coloured bands
- Connecting wires

Method

1 Identify the 10 Ω resistor. It should be colour-coded brown, black, black.

2 Connect the circuit as shown in Figure 1. Use the DC terminals of the power supply and start with the dial on 2 V.

3 Switch on the power supply, take the readings on the ammeter and voltmeter, and switch the power off again straight away (so you don't overheat the resistor).

4 Change the dial on the power supply to 4 V and repeat Step 3. Then change the dial to 6 V and repeat.

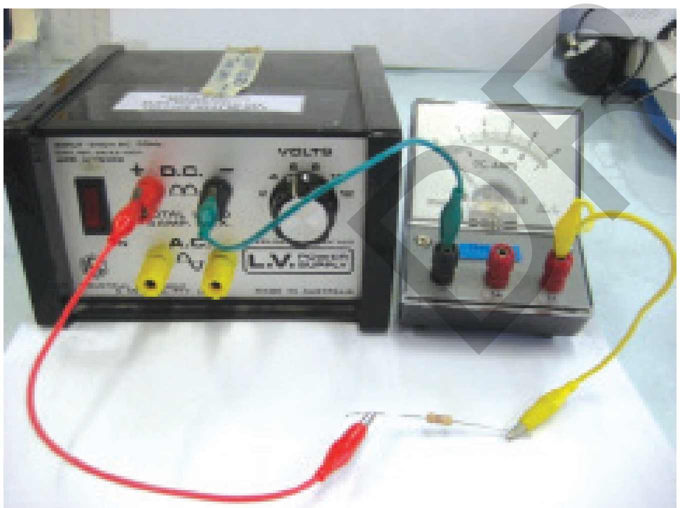

Figure 1 Circuit set-up

5 Record your results in the following results table.

Resistor	Voltage (V)	Current (mA)	Volts ÷ amps

6 Repeat the experiment for the other three resistors, without reading their coloured bands.

7 Complete the results table for each of the three masked resistors and calculate their resistance.

8 Remove the masking tape and determine the resistance values from the coloured bands of the resistors.

Results

Include your results table.

Discussion

1 From your results table, **identify** what the values in the last column calculate.

2 For the three masked resistors, **compare** the accuracy of the values you obtained to the values indicated by their coloured bands.

3 Use the formula below to **calculate** the difference (error) between the two values as a percentage of the marked value.

$$\%\ \text{error} = \frac{\text{marked value} - \text{average calculated value}}{\text{marked value}} \times 100$$

4 **Identify** which value – the one obtained by reading the coloured bands or the one obtained from your calculations – provides the most useful measure of a resistor's resistance. **Justify** your answer (by **explaining** how each value is obtained, **describing** which value is most relevant to use in a circuit and **deciding** which value provides the most useful measure).

Conclusion

Describe what you know about Ohm's law.

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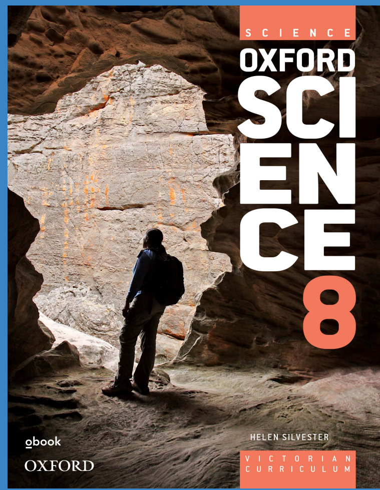

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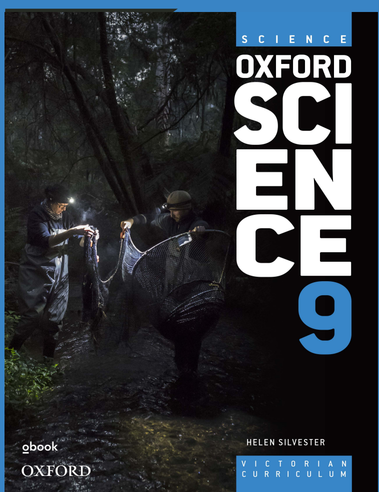

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