DEPARTMENT OF EDUCATION

GRADE 9

SCIENCE

UNIT 5

ELECTRICITY

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GRADE 9

SCIENCE

UNIT 5

ELECTRICITY

IN THIS UNIT YOU WILL LEARN ABOUT:

TOPIC 1: TYPES OF ELECTRICITY

TOPIC 2: ELECTRIC CIRCUITS

TOPIC 3: USES OF ELECTRICITY

TOPIC 4: GENERATING ELECTRICITY

Acknowledgement

We acknowledge the contributions of all Secondary Teachers who in one way or another have helped to develop this Course.

Our profound gratitude goes to the former Principal of FODE, Mr. Demas Tongogo for leading FODE team towards this great achievement.

Special thanks to the Staff of the Science Department of FODE who played active roles in coordinating writing workshops, outsourcing lesson writing and editing processes, involving selected teachers of Central Province and NCD.

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DIANA TEIT AKIS
PRINCIPAL

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SECRETARY'S MESSAGE

Achieving a better future by individual students and their families, communities or the nation as a whole, depends on the kind of curriculum and the way it is delivered.

This course is a part of the new Flexible, Open and Distance Education curriculum. The learning outcomes are student-centred and allows for them to be demonstrated and assessed.

It maintains the rationale, goals, aims and principles of the national curriculum and identifies the knowledge, skills, attitudes and values that students should achieve.

This is a provision by Flexible, Open and Distance Education as an alternative pathway of formal education.

The course promotes Papua New Guinea values and beliefs which are found in our Constitution, Government Policies and Reports. It is developed in line with the National Education Plan (2005 -2014) and addresses an increase in the number of school leavers affected by the lack of access into secondary and higher educational institutions.

Flexible, Open and Distance Education curriculum is guided by the Department of Education's Mission which is fivefold:

- To facilitate and promote the integral development of every individual
- To develop and encourage an education system satisfies the requirements of Papua New Guinea and its people
- To establish, preserve and improve standards of education throughout Papua New Guinea
- To make the benefits of such education available as widely as possible to all of the people
- To make the education accessible to the poor and physically, mentally and socially handicapped as well as to those who are educationally disadvantaged.

The college is enhanced to provide alternative and comparable pathways for students and adults to complete their education through a one system, many pathways and same outcomes.

It is our vision that Papua New Guineans' harness all appropriate and affordable technologies to pursue this program.

I commend all those teachers, curriculum writers, university lecturers and many others who have contributed in developing this course.

UKE KOMBRA, PhD

Secretary for Education

UNIT INTRODUCTION

Dear Student,

Welcome to Unit 5 of your Grade 9 Science Course! I hope that you enjoyed studying the earlier Units. I also hope that this Unit, Electricity, will be an interesting and enjoyable subject to study too.

In this Unit, there are 13 Lessons on four Topics. The four topics are:

- **Types of Electricity**
- **Electric Circuits**
- **Uses of Electricity**
- **Generating Electricity**

There are four Lessons in the first Topic. The lessons will discuss about static electricity. It will also cover current electricity. You will also learn from this Topic about the relationship of current and voltage and safety prevention in case of fire.

The second Topic is composed of three Lessons and will discuss about the series circuits. You will also learn in this Topic the advantages of parallel circuits from series circuits and the importance of Ohm's law.

In the third Topic, there are again three Lessons that will discuss about the lighting and heating effects. It will also talk about electromagnetism and the factors affecting the strength of electromagnets.

The last Topic has three Lessons. It will talk about electrical power and costing and conservation of electrical energy. You will also learn from this Topic the advantages and disadvantages of hydroelectricity.

Remember, you have to do all the activities and carry out the Practice Exercises after each lesson. Answers to Practice Exercises are at the end of each Topic.

If you have any problems in understanding any of the lessons in this Unit, please do not hesitate to inform the Science Department at FODE Headquarters. This will help the teacher to revise the lessons for the next edition.

You may study this Unit now following the Study Guide on the next page.

Good luck!

STUDY GUIDE

Follow the steps given below and work through the lessons.

Step 1 Start with Topic 1 and work through it in order. You may come across new terms in your lessons which are written in bold with an asterisk (*) For example in Lesson 1, you will come across **static*.** Words like this will require you to look up their meaning in the glossary section at the end of this book.

Step 2 When you study Lesson 1, do the given Activities. When you complete the Activities, check your work. The answers are given at the end of the Lesson. (Note: Short lessons may not have an activity.)

Step 3 You will also do a Practice Exercise at the end of each Lesson. After you have completed the Practice Exercise, correct your work. The answers are given at the end of each Topic.

Step 4 Then, revise and correct any mistake.

Step 5 When you have completed all of these steps, tick the check box for Lesson 1, on the Contents page, like this:

☑ Lesson 1: Static Electricity

Then, go on to the next Lesson. Repeat this process until you complete all the Lessons on a Topic. When you have done this, revise using the Review Section.

Remember, as you complete each lesson; tick the box for that lesson on the Contents page. This will help you check your progress.

Assignment: Topic Tests and Unit Test

When you have completed all the lessons in a Topic, do the Topic Test for that Topic, in your Assignment Book. The Unit Book tells you when to do this. When you have completed all the Topic Tests for the Unit, revise well and do the Unit Test. The Assignment Book tells you when to do the Unit test.

When you have completed the entire Assignment Book, check and revise again before sending it to the Provincial Centre. If you have any questions, write them on the Student's page. Your teacher will advise you when he/she returns your marked Assignment.

The Topic Tests and the Unit Test in each Assignment will be marked by your Distance Teacher. The marks you score in each Assignment will count towards the final result. If you score less than 50%, you will repeat that Assignment.

Remember, if you score less than 50% in three consecutive Assignments, your enrolment will be cancelled. So, work carefully and ensure that you pass all Assignments.

TOPIC 1

TYPES OF ELECTRICITY

In this topic you will learn about:

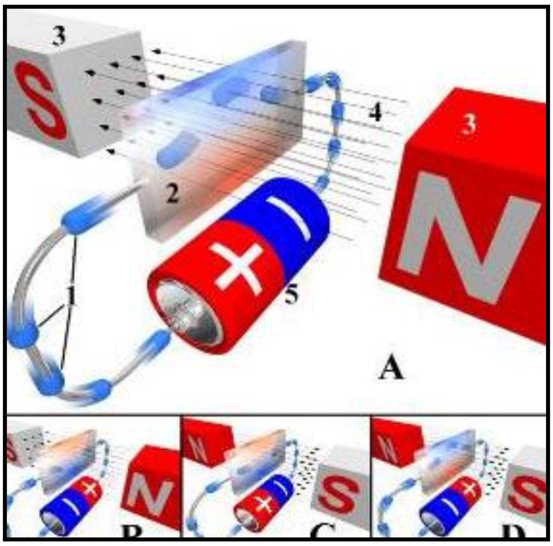
- **static electricity**
- **current electricity**
- **current and voltage**
- **safety and prevention**

INTRODUCTION TO TOPIC 1: TYPES OF ELECTRICITY

Electricity is a type of energy that can build up in one place or flow from one place to another. When electricity gathers in one place it is known as static electricity (the word static means something that does not move); electricity that moves from one place to another is called current electricity.

Static electricity often happens when you rub things together. If you rub a balloon against your jumper 20 or 30 times, you'll find the balloon sticks to you. This happens because rubbing the balloon gives it an electric charge (a small amount of electricity).

When electrons move, they carry electrical energy from one place to another. This is called current electricity or an electric current. A lightning bolt is one example of an electric current, although it does not last very long.



Electric currents are also involved in powering all the electrical appliances that you use, from washing machines to flashlights and from telephones to MP3 players. These electric currents last much longer.

Questions will arise such as:

- What is the relationship between current and voltage?
- How are fire extinguishers important during electric fires?
- What are the basic steps in applying first aid procedures for electric shock?

In this Topic, you will find the answers to these questions and other questions relating to types of electricity.

Lesson 1: Static Electricity

Welcome to Lesson 1. All matter (solids, liquids, and gases) are made of atoms. Electrons are the smallest and lightest of the particles in an atom. They are in constant motion as they circle around the nucleus of that atom and are said to have a negative charge. The electric charge is an invisible property acquired by matter that can be observed by the interactions it produces. As we go on with the lesson you will study all of these and the static electricity.

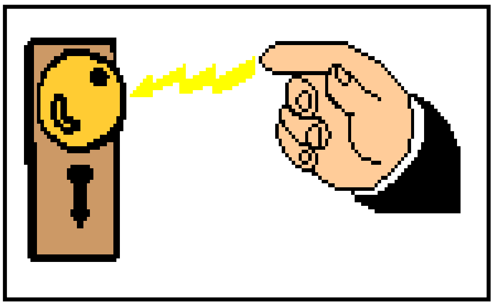
Your Aims:

- define electricity and static electricity
- explain atomic models
- state the laws of static charge

What is Static Electricity?

Electricity is a form of energy resulting from the existence of charged particles either statistically as build- up of charged or dynamically as a current. Static electricity is fast movement of electrons makes energy in electricity.

Static electricity is an energy that stays in one place while current electricity moves as current to produce heating, lightning, cooking, washing clothes and others.



Did you ever get a shock after walking across a carpet and touching a metal doorknob? That shock came from static electricity. As you walk across a carpet, electrons move from the rug to you.

Now you have extra electrons and a negative static charge. Touch a door knob and zap! The door knob is a conductor. The electrons jump from you to the knob, and you feel the static shock.

Electrons that move away from their atoms cause static electricity. Static electricity is the build- up of an electric charge in a certain location. The charge does not move, it stays in one place. When electricity gathers in one place it is known as static electricity (the word static means something that does not move).

You can make static electricity by rubbing certain materials together. Run a plastic comb through your hair. Be sure your hair is clean and dry. Electrons jump from your hair to the comb. This gives the comb a negative electric charge. Your hair loses electrons. This gives your hair a positive electric charge. Hold the comb above your head and watch some of your hairs stand on end. Your hair stands on end because the positive and negative charges are pulling toward one another.

To understand static electricity, we have to learn a little bit about the nature of matter. Or in other words, what is all the stuff around us made of?

Everything we see is made up of tiny little parts called atoms. The **atoms** are made of even smaller parts. These are called protons, electrons and neutrons. They are very different from each other in many ways. One way they are different is their "charge." Protons have a positive (+) charge. Electrons have a negative (-) charge. Neutrons have no charge and are neutral.

Usually, atoms have the same number of electrons and protons. Then the atom has no charge, it is "neutral." But if you rub things together, electrons can move from one atom to another. Some atoms get extra electrons. They have a negative charge. Other atoms lose electrons. They have a positive charge. When charges are separated like this, it is called static electricity.

Everything is made of atoms

Imagine a pure gold ring. Divide it in half and give one of the halves away. Keep dividing and dividing and dividing. Soon you will have a piece so small you will not be able to see it without a microscope. It may be very, very small, but it is still a piece of gold. If you could keep dividing it into smaller and smaller pieces, you would finally get to the smallest piece of gold possible. It is called an atom. Scientists so far have found only 115 different kinds of atoms. Everything you see is made of different combinations of these atoms.

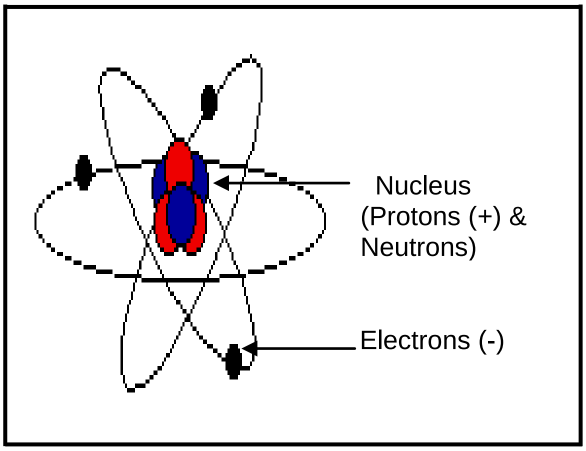
Microscope

Parts of an atom

So what are atoms made of?

In the middle of each atom is a "nucleus." The nucleus contains two kinds of tiny particles, called protons and neutrons. Orbiting around the nucleus are even smaller particles called electrons. The 115 kinds of atoms are different from each other because they have different numbers of protons, neutrons and electrons.

It is useful to think of a model of the atom as similar to the solar system. The nucleus is in the centre of the atom, like the sun in the centre of the solar system.



Parts of an atom

The electrons orbit around the nucleus like the planets around the sun. Just like in the solar system, the nucleus is large compared to the electrons. The atom is mostly empty space. And the electrons are very far away from the nucleus.

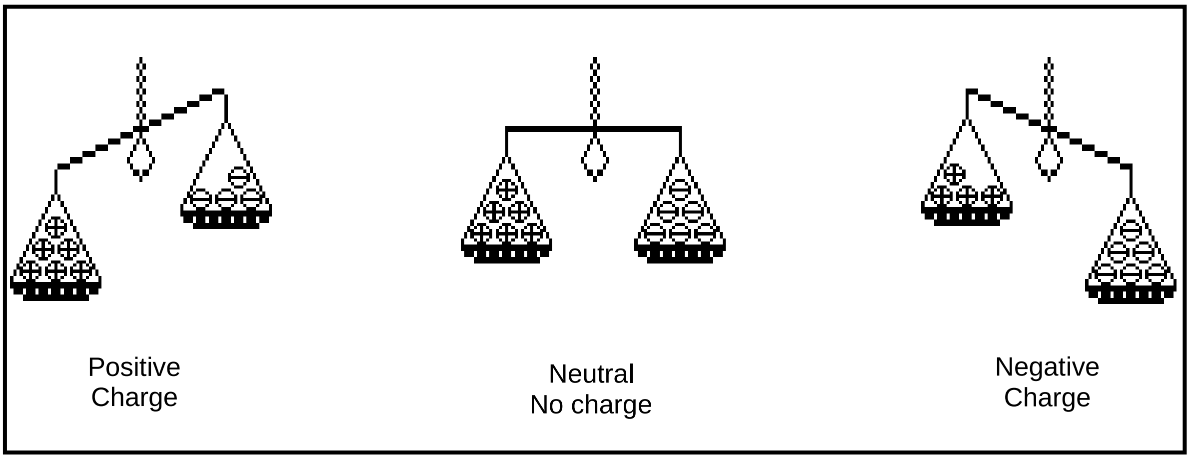
Electrical charges
Electric charge comes from the parts inside atoms. There are two kinds of electric charge called **positive charge** and **negative charge**.

Positive charge comes from the nucleus of an atom. **Negative charge** comes from electrons. Atoms do not normally have any overall charge because their positive and negative charges cancel each other out. Charge comes when electrons move away from an atom.

Protons, **neutrons** and **electrons** are very different from each other. They have their own properties, or characteristics. Protons have what we call a "positive" (+) charge. Electrons have a "negative" (-) charge. Neutrons have no charge, they are neutral. The charge of one proton is equal in strength to the charge of one electron. When the number of protons in an atom equals the number of electrons, the atom itself has no overall charge, it is neutral.

Electrons can move
The protons and neutrons in the nucleus are held together very tightly. Normally the nucleus does not change. But some of the outer electrons are held very loosely. They can move from one atom to another.

An atom that loses electrons has more positive charges (protons) than negative charges (electrons). It is positively charged. An atom that gains electrons has more negative than positive particles. It has a negative charge. A charged atom is called an "**ion**."

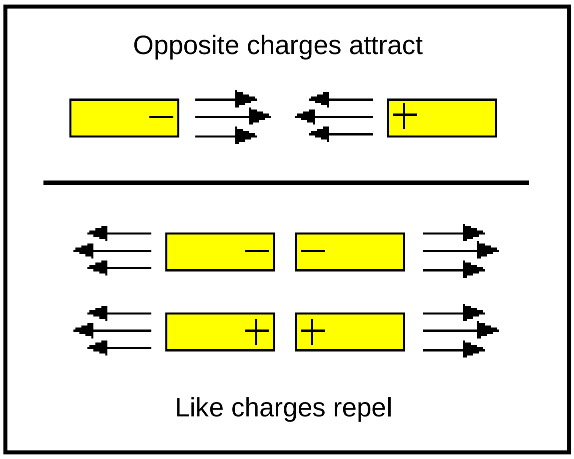


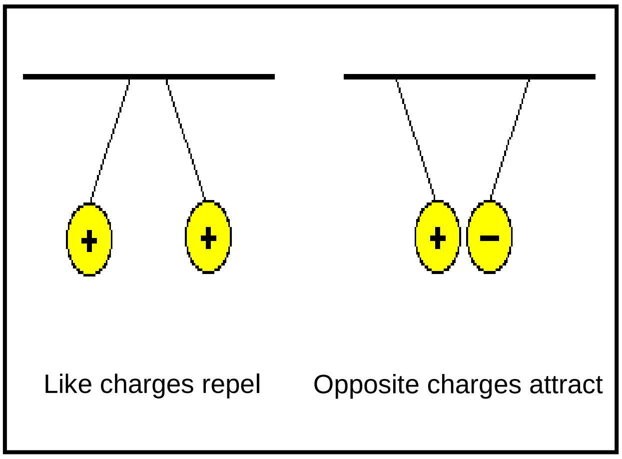
Some materials hold their electrons very tightly. Electrons do not move through them very well. These things are called insulators. Plastic, cloth, glass and dry air are good insulators. Other materials have some loosely held electrons, which move through them very easily. These are called conductors. Most metals are good conductors.

How can we move electrons from one place to another? One very common way is to rub two objects together. If they are made of different materials, and are both insulators, electrons may be transferred (or moved) from one to the other. The more rubbing, the more electrons move, and the larger the static charge that builds up.

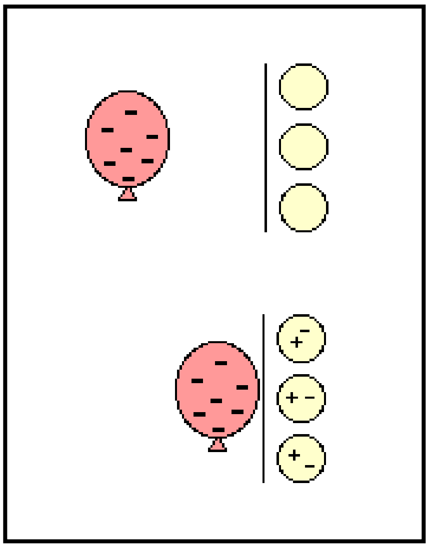
Opposites attract

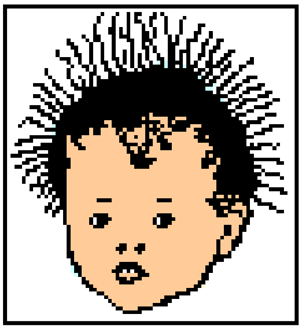
Now, positive and negative charges behave in interesting ways. Did you ever hear the saying that opposites attract? Well, it's true. Two things with opposite, or different charges (a positive and a negative) will attract, or pull towards each other. Things with the same charge (two positives or two negatives) will repel, or push away from each other.





A charged object will also attract something that is neutral. Think about how you can make a balloon stick to the wall. If you charge a balloon by rubbing it on your hair, it picks up extra electrons and has a negative charge. Holding it near a neutral object will make the charges in that object move. If it is a conductor, many electrons move easily to the other side, as far from the balloon as possible. If it is an insulator, the electrons in the atoms and molecules can only move very slightly to one side, away from the balloon. In either case, there are more positive charges closer to the negative balloon. Opposites attract. The balloon sticks. (At least until the electrons on the balloon slowly leak off.) It works the same way for neutral and positively charged objects.





So what does all this have to do with static shocks? Or static electricity in hair? When you take off your wool hat, it rubs against your hair. Electrons move from your hair to the hat. A static charge builds up and now each of the hairs has the same positive charge. Remember, things with the same charge repel each other. So the hairs try to get as far from each other as possible. The farthest they can get is by standing up and away from the others. And that is how static electricity causes a bad hair day.

Remember: Things with the same charge repel each other and things with opposite charges attract.

Activity: Now test yourself by doing this activity.

Circle the letter of the correct answer.

1. Two objects have collected static electricity with the same charge. What would the objects do when placed near each other?

   A. Repel B. Attract

   C. Nothing D. Stick together

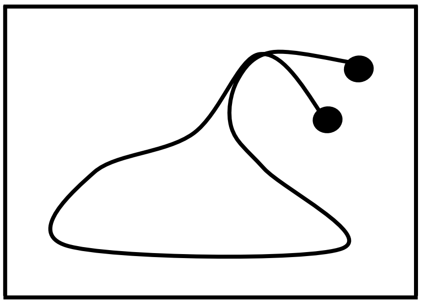
2. Why does static electricity move from you to a metal object after you have walked over new carpet?

   A. It is attracted to you
   B. It is made in your shoes
   C. It is attracted to the metal.
   D. It is attracted to the carpet.

3. How can you tell when static electricity has been discharged?

   A. Heat is released that can be felt.
   B. Light is released and you can feel a shock.
   C. Static electricity gives off many different colours.
   D. The object begins to spin rapidly when it is shocked.

Refer to the diagram below to answer Questions 4and 5.
The diagram is a homemade electroscope. The circles are cheerios that will make a static charge.



4. In the diagram, the cheerios are apart. What does that indicate about the charge on the cheerios?

   A. Both cheerios are positive.
   B. Both cheerios are negative.
   C. The cheerios have the same charge.
   D. One cheerio is positive, the other is negative.

5. Why would a comb that had been run through hair touch one cheerio and cause the two cheerios to come together. The comb had

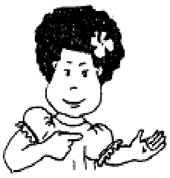
   A. a positive charge.

   B. a negative charge.

   C. the same charge as the cheerios already had.

   D. a different charge than the cheerios already had.

CHECK YOUR WORK. ANSWERS ARE AT THE END OF LESSON 1.



Summary

You have come to the end of lesson 1.In this lesson you have learnt that:

- static electricity is the build-up of an electric charge in a certain location. It stays in one place and does not move.
- everything we see is made up of tiny little parts called atoms.
- in the middle of each atom is a "nucleus."
- the nucleus contains two kinds of tiny particles, called protons and neutrons.
- orbiting around the nucleus are even smaller particles called electrons.
- electric charge comes from the parts inside atoms.
- positive charge comes from the nucleus of an atom. Protons have a positive (+) charge.
- electrons have a negative (-) charge.
- neutrons have no charge.
- charge comes when electrons move away from an atom.
- electrons that move away from their atoms cause static electricity.
- electrons do not move through some materials that hold their electrons very tightly. These things are called insulators.
- other materials have some loosely held electrons, which move through them very easily. These are called conductors.
- two things with opposite, or different charges (a positive and a negative) will attract or pull towards each other.
- things with the same charge (two positives or two negatives) will repel or push away from each other.
- a charged object will also attract something that is neutral.

NOW DO PRACTICE EXERCISE 1 ON THE NEXT PAGE.

Practice Exercise 1

Answer the following questions.

1. Define static electricity.

   ____

   ____

2. Describe the parts of an atom.

   ____

   ____

   ____

   ____

   ____

   ____

3. State the 3 laws of static charge.

   a. ____

   ____

   b. ____

   ____

   c. ____

   ____

   ____

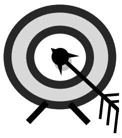
CHECK YOUR WORK. ANSWERS ARE AT THE END OF TOPIC 1.

Answers to Activity

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

Lesson 2: Current Electricity

Welcome to Lesson 2. You have learned from the previous lesson, that static electricity does not move. You explained atomic models and also learned the laws of static charge. When electricity moves from one place to another, it is called current electricity. We use current electricity in our homes, businesses and schools. This means that the electricity moves in a current.



Your Aims:

- define current electricity
- differentiate static from current electricity
- describe how electricity was made and moves
- differentiate electrical conductors and insulators

What is Current Electricity?

When electrons move, they carry electrical energy from one place to another. This is called current electricity or an electric current. A lightning bolt is one example of an electric current, although it does not last very long. Electric currents are also involved in powering all the electrical appliances that you use, from washing machines to flashlights and from telephones to MP3 players. These electric currents last much longer.

Have you heard of the terms potential energy and kinetic energy? Potential energy means energy that is stored somehow for use in the future. A car at the top of a hill has potential energy, because it has the potential (or ability) to roll down the hill in future. When it's rolling down the hill, its potential energy is gradually converted into kinetic energy (the energy has changed because it is moving).

Static electricity and current electricity are like potential energy and kinetic energy. When electricity gathers in one place, it has the potential to do something in the future.

Electricity stored in a battery is an example of electrical potential energy. You can use the energy in the battery to power a flashlight, for example. When you switch on a flashlight, the battery inside begins to supply electrical energy to the lamp, making it give off light. All the time the light is switched on, energy is flowing from the battery to the lamp. Over time, the energy stored in the battery is gradually turned into light (and heat) in the lamp. This is why the battery runs flat.

A battery like this stores electrical potential energy in a chemical form. When the battery is flat, it means you have used up all the stored energy inside by converting it into other forms.

The table below differentiates static from current electricity.

Static Electricity	Current Electricity
A build-up of electrons.	The steady flow of electrons between objects or places. It comes from far away on wires.
Stays in one place until it jumps to an object.	Needs a conductor, a substance that allows electrons to move easily through it.
Does **not** need a circuit.	Needs a closed circuit to flow.
The kind of electricity you feel after you drag your feet across a carpet and touch someone or something.	The kind of electricity that powers the appliances and heat in your home.
Lightning is static electricity on a more spectacular scale.	The kind of electricity in a battery.

How is electricity made?
Electricity is produced in generating stations by burning fossil fuels or running water (hydroelectric power station).

Fossil fuels were formed hundreds of millions of years ago and are made up of decomposed plant and animal matter. The three major forms of fossil fuel are coal, oil and natural gas. These fuels are burned at a very high temperature in a large boiler. The walls of the boiler are made up of tubes that carry water. As the fuels burn, the water temperature increases until it turns into steam. The steam, under considerable pressure and at a very high temperature, is piped to a steam turbine.

The steam turbine turns under the pressure of the steam. The turbine is connected directly to a large electromagnet in the generator. The rotating turbine causes the electromagnet to revolve. The magnet causes electrons to move, making electricity or an electric current.

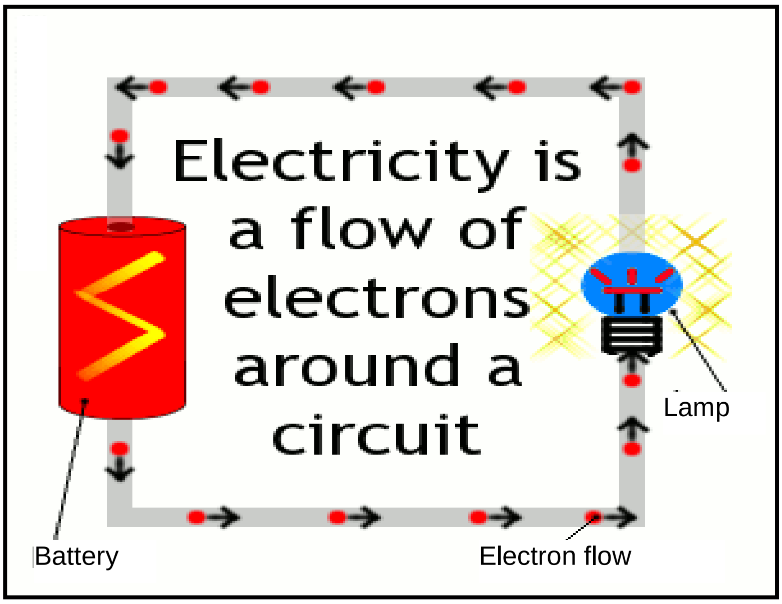
How does electricity get to the house?
Once the electricity is produced, it is sent through high voltage transmission lines to substations. At substations, the voltage of the electric power is lowered. Voltage is the force that pushes electricity along wires. Then, the power is sent to your neighbourhood through distribution lines located underground or on poles.

Electricity enters your home through a meter. It then goes to the circuit panel in your house. In the panel, the electricity is divided into circuits. Each circuit forms a loop, carrying electricity to outlets and returning to the panel. For instance, a circuit might include everything in the kitchen. Another might have a couple of bedrooms. The circuit panel uses a circuit breaker for each circuit. This will shut off the flow of electricity when too much electricity is being used.

How does electricity moves in a circuit?

Materials such as copper metal that conduct electricity (allow it to flow freely) are called **conductors.** Materials that do not allow electricity to pass through them so readily, such as rubber and plastic, are called i**nsulator**s. What makes copper a conductor and rubber an insulator?

A current of electricity is a steady flow of electrons. When electrons move from one place to another, round a circuit, they carry electrical energy from place to place like marching ants carrying leaves. Instead of carrying leaves, electrons carry a tiny amount of electric charge.



Electricity can travel through something when its structure allows electrons to move through it easily**.** Metals like copper have "free" electrons that are not bound tightly to their parent atoms. These electrons flow freely throughout the structure of copper and this is what enables an electric current to flow. In rubber, the electrons are more tightly bound. There are no "free" electrons and, as a result, electricity does not really flow through rubber at all. Conductors that let electricity flow freely are said to have a high conductance and a low resistance; insulators that do not allow electricity to flow are the opposite: they have a low conductance and a high resistance.

The power of electricity

Before the invention of electricity, people had to make energy wherever and whenever they needed it. Thus, they had to make wood or coal fires to heat their homes or cook food. The invention of electricity changed all that. It meant energy could be made in one place then supplied over long distances to wherever it was needed. People no longer had to worry about making energy for heating or cooking: all they had to do was plug in and switch on—and the energy was there as soon as they wanted it.

Another good thing about electricity is that it's like a common "language" that all modern appliances can "speak." You can run a car using the energy in gasoline, or you can cook food on a barbecue in your garden using charcoal, though you can't run your car on charcoal or cook food with gasoline. But electricity is quite different. You can cook with it, run cars on it, heat your home with it, and charge your cell phone with it. This is the great beauty and the power of electricity: it is energy for everyone, everywhere, and always.

Activity: **Now test yourself by doing this activity.**

A. Circle the letter of the correct answer.

1. Substances whose atoms have more free electrons are called __________.

   A. conductors   B. insulators

   C. electrolytes   D. semiconductors

2. When performing an experiment with electricity, which materials would act as an insulator?

   A. Wire   B. Staple

   C. Paper clip   D. Popsicle stick

3. Which type of electricity moves along a path to turn on a light?

   A. Static electricity   B. Turbine electricity

   C. Current electricity   D. Lightning energy

4. The free electrons of a metal

   A. are free to fall into the nuclei.
   B. do not collide with each other.
   C. are free to escape through the surface.
   D. are free to move anywhere in the metal.

5. When there is an electric current passing through a wire, the particles moving are __________.

   A. ions   B. atoms

   C. protons   D. electrons

6. Which material acts as a conductor of electricity?

   A. Paper clip   B. Rubber glove

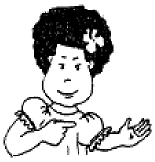
   C. Plastic button   D. Popsicle stick

B. Use the words below to complete the sentences.

Safer water batteries mains dangerous

Electrical appliances run on mains or (1) __________ or sometimes both. The mains supply of electricity is very (2) __________.Batteries are usually (3)__________ than the (4) __________. Never let (5) __________ near electrical appliances.

CHECK YOUR WORK. ANSWERS ARE AT THE END OF LESSON 2.



Summary

You have come to the end of lesson 1.In this lesson you have learnt that:

- current electricity is the movement of electrons that carry electrical energy from one place to another.
- static electricity is the build -up of an electric charge in a certain location. It stays in one place and does not move.
- electric currents are involved in powering all the electrical appliances that you use, from washing machines to flashlights and from telephones to MP3 players.
- electricity is produced in generating stations by burning fossil fuels. Fossil fuels were formed hundreds of millions of years ago and are made up of decomposed plant and animal matter.
- electricity produced is sent through high voltage transmission lines to substations. then, the power is sent to your neighbourhood through distribution lines located underground or on poles.
- electricity enters your home through a meter and then goes to the circuit panel in your house. In the panel, the electricity is divided into circuits.
- materials such as copper metal that conduct electricity (allow it to flow freely) are called conductors and are said to have a high conductance and a low resistance
- materials that do not allow electricity to pass through them so readily, such as rubber and plastic, are called insulators and have a low conductance and a high resistance.

NOW DO PRACTICE EXERCISE 2 ON THE NEXT PAGE.

Practice Exercise 2

Answer the following questions.

1. Define current electricity.

____

____

____

2. Differentiate electrical conductors and insulators.

Conductors

____

____

____

Insulators

____

____

____

3. Fill in the table below.

Static Electricity	Current Electricity
Stays in ___________ place until it jumps to an object.	Needs a ___________, a substance that allows electrons to move easily through it.
Does not need a ___________.	Needs a ___________ circuit to flow.
The kind of electricity you feel after you ___________ your feet across a carpet and ___________someone or something.	The kind of electricity that powers the appliances and ___________in your home.
___________ is static electricity on a more spectacular scale.	The kind of electricity in a ___________.

CHECK YOUR WORK. ANSWERS ARE AT THE END OF TOPIC 1.

Answers to Activity

A.

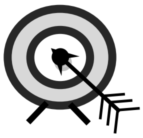
1.	A	3.	C	5.	D
2.	D	4.	D	6.	A

B.. (1) batteries
(2) dangerous
(3) safer
(4) mains
(5) water

Lesson 3: Current and Voltage

Welcome to Lesson 3. From the previous lessons, you have learned about static and current electricity. You explained the difference between the two and how electricity was made and moves. When electric charges move in a wire, we say that an electric current flows in the wire. It's like the way a current of water flows in a river. For an electric current to flow, we need two things:

- something to make the electricity flow, such as a battery or power pack and
- a complete path for the current to flow in. This is called an electric circuit.



Your Aims:

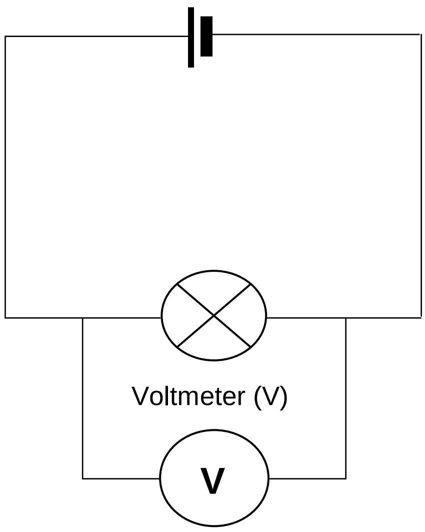
- define current and voltage
- differentiate current and voltage
- describe the relationship between cells, current and voltage

Voltage

Everyone uses this term, even though they might not understand it. You probably know that a single cell from a flashlight creates an electrical force of 1.5 Volts. You also know that a transistor radio battery (with the snaps on the top) creates an electrical force of 9 Volts. (There are six little cells of 1.5 Volts each inside of the 9 Volt batteries.) You know that household electrical outlets are 120 Volts, and you know that "High Voltage" is dangerous. What else should you know about voltage? Again, let us look at the atomic level.

Electrons do not move from atom to atom without a reason. When electrons are flowing, there is an electrical force somewhere, pushing them along. In older text books, you might see references to Electromotive Force, or "**EMF**". We usually refer to this force as "**Voltage**".

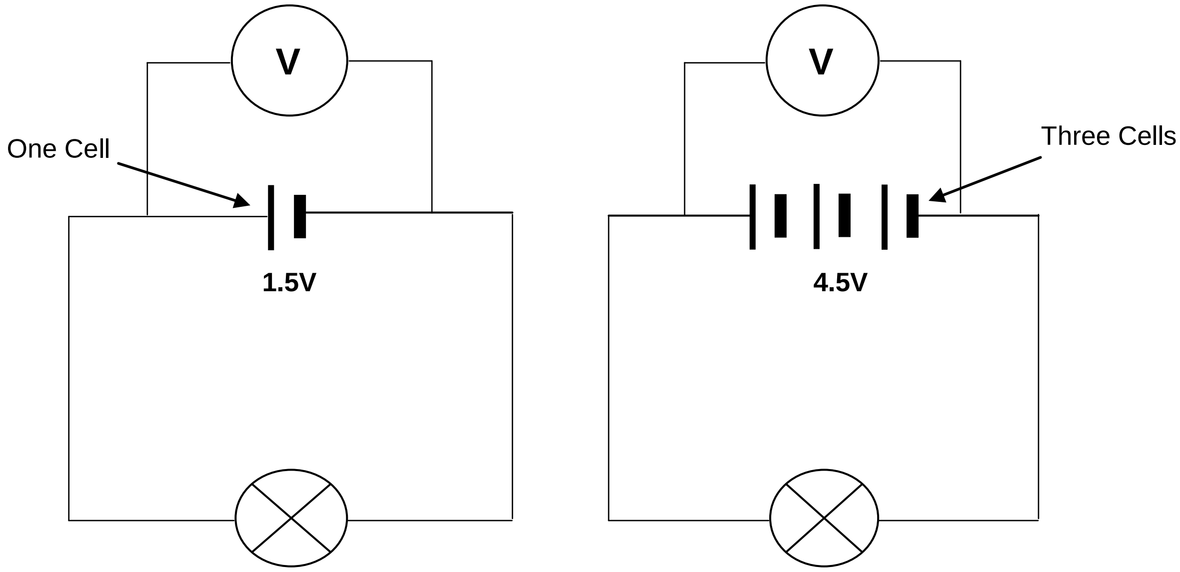
Voltage is the electric force that causes the free electrons to move from one atom to another. It measures the difference in electrical energy between two parts of a circuit; the bigger the difference in energy, the bigger the voltage. Just like water needs pressure to force it through a hose, electrical current needs some force to make it flow. Voltage is usually supplied by a battery or a generator. It is measured in volts. A **volt** is the measure of **electric pressure**. The symbol for volts is **V**. For example, 230V is a bigger voltage than 12V.



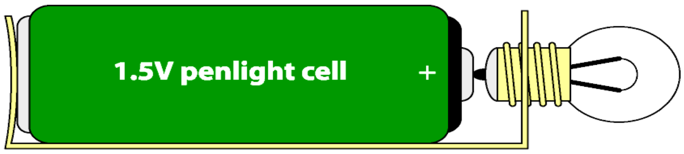
Connecting a voltmeter in a parallel circuit

Voltage is measured using a **device** called **voltmeter**. Some types of voltmeter have a pointer on a dial, but most have a digital display. To measure the voltage across a component in a circuit, you must connect the voltmeter in parallel with it.

You can measure the voltage across a cell or battery using a voltmeter; the more cells, the bigger the voltage.



The picture below illustrates a single cell pocket flashlight. The 1.5 Volt cell is pushing the electrons through the bulb and wire. Without this push, the electrons would be happy to remain stationary. In this case, chemical action within the battery causes the push. When the battery wears out, its chemical reaction slows down and its internal push gets weaker and weaker. (That is why the bulb gets dim).



Current

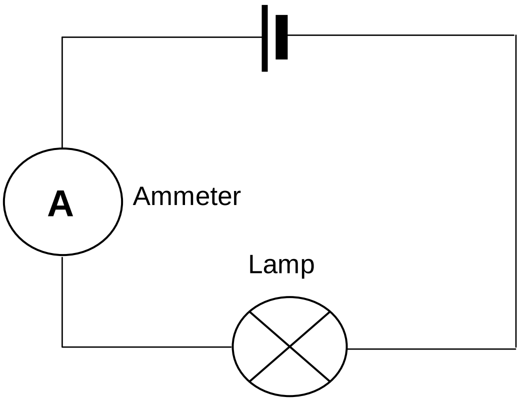
Again, everyone uses this term without really knowing what it means. In very simple terms, **current** is the flow rate of the electrons in the circuit. It is electricity in motion. It measures the amount of electrons that can flow through a material like a conductor. The more that flows, the bigger the current.

Electrical current is measured in **amperes** or "amps" for short. The symbol for amps is **A**. For example, 20A is a bigger current than 5A. Amperes is like the amount of water flowing through a hose in a certain amount of time or the amount of electricity flowing through a wire. How is that different from voltage? Let us use a water tank and a pipe as an example.

In some neighbourhoods you will see a water tank raised high above the ground on strong posts. The water in this tank has been raised up there to give it pressure. A series of pipes carry the water down from the tank, underground, into your house, and then to each sink, bathtub, and toilet. The water in your pipes is under pressure because the water in the tank is pushing down on it. This pressure is similar to voltage. Voltage is the pressure pushing on the electrons in a circuit.

If all of the faucets in your house are closed, no water flows through the pipes. If you open one faucet, some water flows. If you open all of the faucets, a lot of water flows. This flow of water is similar to electrical current. Current is the flow rate of electrons through the circuit.

A **device** called an **ammeter** is used to measure current. Some types of ammeter have a pointer on a dial, but most have a digital display. To measure the current flowing through a component in a circuit, you must connect the ammeter in series with it.



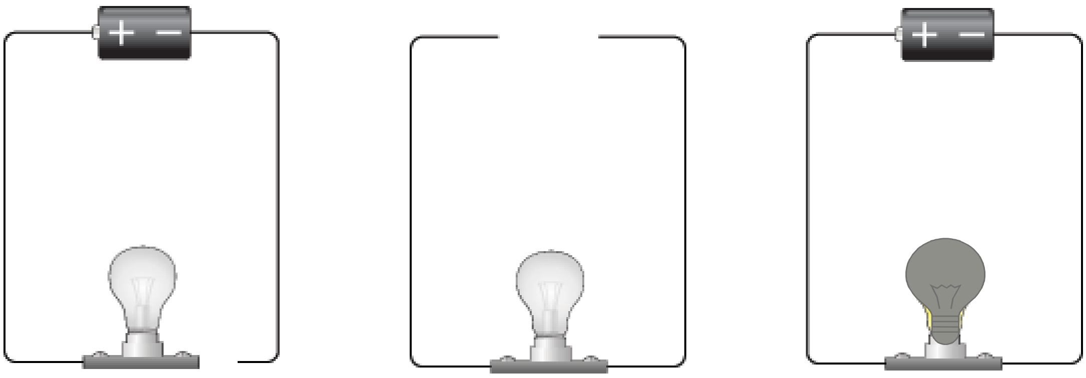
Connecting an ammeter in a series circuit

Electric circuits

An electric current will not flow if we do not have a **power source** (a cell, battery or power pack). It also would not flow if the circuit is not **complete**. One end of the power source must be joined to the other end by the wires and components of the circuit.

The simplest complete circuit is a piece of wire from one end of a battery to the other. An electric current can flow in the wire from one end of the battery to the other, but nothing useful happens. The wire just gets hot and the battery goes flat.

To do something useful with the electric current, we need to put an electrical **component** into the circuit, such as a lamp or motor that can use the current to make something happen.

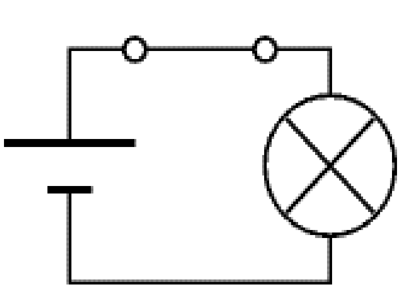


Incomplete Circuit | No Battery | Complete Circuit

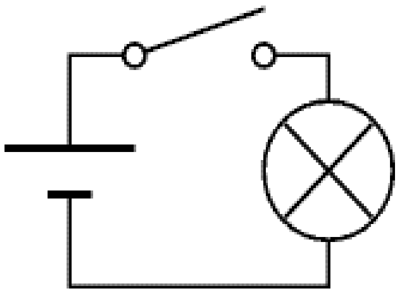
The bulb will only light if there is a battery and a complete circuit. We usually add in a **switch** to the circuit, so that we can break the circuit and stop the electric current when we want to.

Voltage is the cause, current is the effect
Are voltage and current related? Voltage and current is not the same thing, although they are closely related. In simple terms, **Voltage causes current**. Given a Voltage and a path for the electrons, current will flow. Given the path, but no voltage, or voltage without the path, there will be no current.

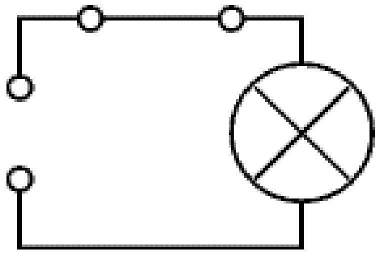
Voltage attempts to make a current flow, and current will flow if the circuit is complete. Voltage is sometimes described as the 'push' or 'force' of the electricity, it is not really a force but this may help you to imagine what is happening. It is possible to have voltage without current, but current cannot flow without voltage.



Voltage and Current
The switch is closed making a complete circuit so current can flow.



Voltage but No Current
The switch is open so the circuit is broken and current cannot flow.



No Voltage and No Current
Without the cell there is no source of voltage so current cannot flow.

Remember:

	Current	**Voltage**
Measured in	Amps, A	Volts, V
Measured with	Ammeter in series	Voltmeter in parallel
Circuit symbol of measuring devise	—(A)—	—(V)—

An ammeter measures electric current, in amps, by measuring how much charge is flowing in the circuit. A voltmeter measures, in volts, the difference in electrical energy between two points of a circuit.

An increase in voltage means an increase in energy and therefore an increase in current. A decrease in voltage means a decrease in energy and therefore a decrease in current.

Activity: Now test yourself by doing this activity

Circle the letter of the correct answer.

1. Which is a unit of electrical force shown on a battery?

   A. Amps B. Volts

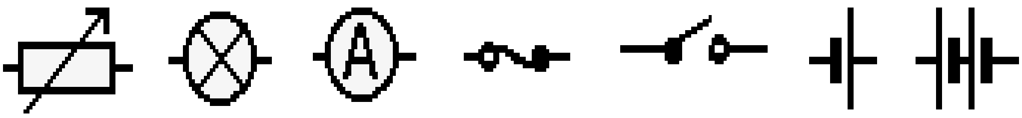
   C. Series D. Joules

2. The term used to designate electrical pressure is __________.

   A. Current B. Voltage

   C. Resistance D. Conductance

3. Which of the circuit symbols means a "switch closed"?



Sym 01 Sym 02 Sym 03 Sym 04 Sym 05 Sym 06 Sym 07

   A. Sym 01 B. Sym 04

   C. Sym 05 D. Sym 07

4. Current is the

   A. repulsion of electrons.
   B. movement of electrons.
   C. abundance of electrons.
   D. presence of positive charge.

5. A voltmeter is used

   A. to measure current.
   B. to measure coulombs.
   C. in series with the circuit.
   D. in parallel with the circuit.

6. A voltage will influence current only if the circuit is __________.

   A. open B. closed

   C. insulated D. high resistance

7. Which type of meter is place in the path of a circuit to measure current?

A. Ammeter
B. Voltmeter
C. Power supply
D. Frequency meter

8. A short circuit will have

A. no current flow
B. some current flow
C. a small current flow
D. a large current flow

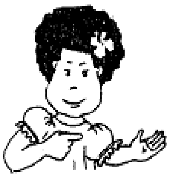
9. A circuit having a complete path will be described as

A. a closed circuit.
B. an open circuit.
C. a pictorial circuit.
D. a shorted circuit.

10. Voltage and current in a given circuit are considered as being

A. directly proportional.
B. equal to conductance.
C. the same in meaning.
D. inversely proportional.

CHECK YOUR WORK. ANSWERS ARE AT THE END OF LESSON 3.



Summary

You have come to the end of lesson 3. In this lesson you have learnt that:

- voltage is the electric force that causes the free electrons to move from one atom to another.
- a volt is the measure of electric pressure.
- voltage is measured using a device called voltmeter.
- to measure the voltage across a component in a circuit, you must connect the voltmeter in parallel with it.
- you can measure the voltage across a cell or battery using a voltmeter; the more cells, the bigger the voltage.
- current is the flow rate of electrons in the circuit.
- electrical current is measured in amperes or "amps" for short.
- a device called an ammeter is used to measure current.
- to measure the current flowing through a component in a circuit, you must connect the ammeter in series with it.
- an electric current will not flow if we do not have a power source (a cell, battery or power pack). It also would not flow if the circuit is not complete.
- voltage causes current.
- given a voltage and a path for electrons, current will flow.
- given a voltage without path, there will be no current flow.
- an increase in voltage means an increase in energy and therefore an increase in current.
- a decrease in voltage means a decrease in energy and therefore a decrease in current.

NOW DO PRACTICE EXERCISE 3 ON THE NEXT PAGE.

Practice Exercise 3

A.. **Define**

(1) Current - ____

(2) Voltage - ____

B. **Choose the correct words in the box to complete the paragraph below.**

amps	cells	power source	path
parallel	current	voltage	decrease
voltmeter	complete	volts	series
ammeter	increase	atom	circuit

(1) __________ is the electric force that causes the free electrons to move from one (2) __________to another. A (3) __________is a device which measures voltage, in (4) __________. To measure the voltage across a component circuit, you must connect the voltmeter in (5) __________ with it. The more (6) __________that you use, the bigger the voltage. Current will flow, given a voltage and a (7) __________ for the electrons, but given a voltage without the path, there will be no current.

(8) __________is the flow rate of the electrons in the circuit. An (9) __________ measures current, in (10) __________, by measuring how much charge is flowing in the (11) __________. To measure the current flowing through a component in a circuit, you must connect the ammeter in (12)__________with it.

An electric current will not flow if we do not have a (13) __________ (a cell, battery or power pack). It also would not flow if the circuit is not (14) __________. An (15) __________ in voltage means an increase in energy and therefore an increase in current. A (16) __________ in voltage means a decrease in energy and therefore a decrease in current.

CHECK YOUR WORK. ANSWERS ARE AT THE END OF TOPIC 1

Answers to Activity

1. B
2. B
3. B
4. B
5. D
6. B
7. A
8. D
9. A
10. A

Lesson 4: Safety and Prevention

Welcome to Lesson 4. You have learned from the previous lesson about current and voltage. You have described the relationship between current and voltage in an electric circuit. Electricity is basically safe, provided you follow a few common-sense rules. If you use it in the wrong way, and you run the risk of starting a fire, getting an electric shock or even being electrocuted. As we study this lesson on safety and prevention, you will find out how to keep your children and yourself safe with electricity.

Your Aims:
- discuss electric fires
- discuss fire safety and prevention
- discuss first aid procedures for electric shock

Electric Fires

Electric fires are becoming more common as appliances and electric feeds are used more and more in our daily lives. Electric fires are different from regular fires. They cannot be put out the same way and they are not caused by the same things. They cannot be put out with water. They do not start from a cigarette butt landing on some papers.

Like other fires, electric fires require three elements, both to ignite and to continue burning:
Heat - common heat sources include a hot stove burner, a spark from a worn electrical wire or a burning cigarette.
Fuel - just about everything in your home can start a fire — clothing, food, furniture, clutter, paper, plastics and more.
Oxygen - the oxygen in the air around us also fuels a fire.

As a fire burns, the heat it creates warms nearby items, making it even easier for them to start burning too. The bigger the fire gets, the more quickly it spreads. In less than 30 seconds, a small flame can turn into a major blaze. Because most people do not realise how quickly a fire grows, they often overestimate their ability to extinguish it – and underestimate the amount of time they need to escape.

There are several ways that electric fires start. Some common causes of electric fires and explosions include insufficient insulation and improper grounding. To prevent electric fires, check your electric cords and make sure that the rubber insulation that is around the electric wires which are inside the cord is not beaten up or worn out. Your cords need to be in good condition or they could cause an electric fire. If you find a cord that is beaten up or worn out, you need to get it replaced as soon as possible.

If you do happen to have an electric fire, you need to know how to put it out. The most important thing to remember is that you must **never put water on an electric fire**. That is very dangerous because the electricity from the fire can shoot through the water and shock you possibly to death. To put an electric fire out, you unplug whatever it is that is on fire. That will eliminate the electricity that is causing the fire. If you cannot unplug immediately what is burning, there is a special type of fire extinguisher that you can use.

Poisonous smoke
Fire creates poisonous smoke. Smoke's poisonous gases spread quickly from where the fire begins and can overwhelm you long before you see any flames. Inhaling these gases can disorient you and slow your reaction time, making escaping the fire more difficult.

Two common deadly gases in any fire are carbon monoxide and carbon dioxide. Carbon monoxide displaces oxygen from the blood and carbon dioxide causes people to breathe more quickly and inhale more poisonous gas. Understanding the dangers of smoke inhalation is important to fire safety.

Intense heat
Fire creates intense heat. In the first few minutes of fire, room temperature can reach 100ºF (37.8^{o}C) at floor level and 600ºF (315.6^{o}C) at eye level. This intense heat can cause serious injuries and death. The heat can melt clothing onto skin, causing severe burns. Moreover, breathing this superheated air causes rapid, severe lung damage, and unconsciousness follows in just minutes.

In just five minutes, the room temperature can reach 1100ºF (593.33^{o}C) hot enough to ignite every combustible object in the room simultaneously. This event is called flashover. After flashover, conditions in a burning room deteriorate rapidly, making survival unlikely.

Emotional trauma
Fire creates emotional trauma. In addition to the physical dangers, fire takes a tremendous emotional toll on people and their families. Losing one's home, treasured possessions and photographs is traumatic. Belongings collected throughout your lifetime or handed down from generations are impossible to replace.

Rebuilding and recovery can be overwhelming. Fire victims must recall, record and replace everything they own while coming to terms with the tragedy. They must do this while rebuilding their homes and their lives.

Fire Safety for Children

Fires can be caused by many things we use in our homes, the stove, electric blankets, heaters and clothes dryers. A few simple safety precautions can help to prevent a fire harming your family and damaging your home:

- Install smoke alarms in hallways and bedrooms, and check the batteries regularly.
- Dispose of cigarette and fireplace ashes into metal bins and leave to cool.
- Check electrical equipment and extension cords for signs of wear.
- Keep heaters a metre away from curtains, furniture and children.

Children are naturally drawn to the heat and light of a fire. Unfortunately during a fire, many children will try to hide from a fire, often in a closet, under a bed, or in a corner. But if taught basic fire drills, they would be able to protect themselves. Sit down with the whole family and talk about what to do if there is a fire. It is important to talk through with children what to do if there is a fire. Do not avoid it for fear of frightening them.

Children need to know the basics of how to react, because there may not be an adult around to tell them what to do if a fire happens. Tell them that fires spread quickly, that most fire-related deaths are not from burns but from smoke inhalation, and that dangerous fumes can overcome a person in just a few minutes. Another way to teach your kids about fire safety is by example.

Let your children see you being sensible and careful with cooking, candles, electrical equipment and smoking. It is also important that children learn the following safety tips in case of fire.

- Cover their mouths and noses with a moist towel or an article of clothing to keep out dangerous fumes while evacuating.
- Crawl under the smoke to safety, staying as low to the ground as possible (smoke always rises).
- Touch any door (not the doorknob) to see if it is hot, and if it is, do not open; find another exit.
- Locate the nearest stairway marked "Fire Exit" if they live in an apartment building, or a fire escape if the stairway is not accessible; kids should know to always avoid elevators during a fire.
- Never stop to take personal belongings or pets or to make a phone call while evacuating.
- Never go back into a burning building once safely outside.
- Stop, drop, and roll to extinguish flames if an article of clothing catches on fire.

Fire Prevention

Of course, the best way to practice fire safety is to make sure a fire does not break out in the first place. That means you should always be aware of potential hazards in your home. The chance of fire is greatly decreased by good housekeeping. Keep rags containing oil, gasoline, alcohol, paint, varnish, in a covered metal container. Keep debris in a designated area away from the building. You can start fire prevention by keeping these tips in mind.

A. Be sure to check all electrical appliances, cords, and outlets

- Are your electrical appliances in good condition, without loose or frayed cords or plugs?
- Did you unplug your mobile phone charger when you are not using it, so it cannot overheat and cause a fire?
- Are your outlets overloaded with plugs from the TV, computer, printer, video game system, and stereo?
- Are you overusing an extension cord?
- Do the light fixtures in your home contain bulbs that are the correct watts?
- Does your home contain GFCIs (ground-fault circuit interrupters) and/or AFCIs (arc-fault circuit interrupters), which prevent electrical shock and fire by shutting off faulty circuits?

Look around your house for potential problems. And unless you are a trained electrician, be careful about do-it-yourself electrical projects. Studies have shown that many home fires are caused by improper installation of electrical devices.
Other tips:

- Replace or professionally repair any appliances that spark, smell unusual, or overheat.
- Do not run electrical wires under rugs.
- Make sure lamps and night-lights are not touching bedspreads, drapes, or other fabrics.
- Do not let your children use kitchen appliances by themselves and always supervise any art or science projects that involve electrical devices.
- Cover any outlets that are not in use with plastic safety covers if you have toddlers or young children in your home.
- If you have to use an adaptor, use a 'bar-type' fused adaptor with a lead. This puts less strain on the socket than a 'block-type' adaptor you plug straight into the socket.
- Make sure children know that water and electricity do not mix.
- Teach young people to keep mains-powered electrical appliances out of the bathroom, or anywhere else that wires could trail into water. This includes hairdryers, hair straighteners and plugged-in radios even if they are plugged on outside the room.
- Turn off electrical appliances when you go out or go to bed. Unless they are designed to be left on – like fridges and freezers.

B. Be careful in the kitchen

Did you know that cooking is the leading cause of home fires everywhere? The kitchen is rife with ways for a fire to start: food left unsupervised on a stove or in an oven or microwave; grease spills; a dish towel too close to the burner; a toaster or oven flares up; a coffee pot accidentally left on.

Always supervise children while cooking and practice safe cooking habits; like turning all pot handles in so they cannot be accidentally knocked over and not wearing loose-fitting clothing that could catch fire while the stove is left on.

C. Beware of cigarettes

According to research, cigarettes are the number 1 cause of fire deaths in countries like United States and Canada, killing about 1,000 people per year. Most fires are started when ashes or butts fall onto couches and chairs. If you smoke, be especially careful around upholstered furniture, never smoke in bed, and be sure cigarettes are completely out before you toss them into the trash.

D. Never let children play with matches and lighters

You have heard it again and again, but children playing with matches are still the leading cause of fire-related deaths and injuries for children younger than 5. Always keep matches and lighters out of children's reach. Make sure you store flammable materials such as gasoline, kerosene, and flammable cleaning supplies outside of your home and away from children.

E. Use candles safely

As decorative candles become more popular, candle fires are on the rise. If you light candles, keep them out of reach of children and pets, away from curtains and furniture, and extinguish them before you go to bed. Make sure candles are in sturdy holders made of non-flammable material that would not tip over. Do not let older children and teenagers use candles unsupervised in their rooms.

F. Have your smoke alarms in good condition

Make sure all smoke alarms are in working order. It is a fact, having a smoke alarm in the house cuts your risk of dying in a fire in half. Almost 60% of all fatal residential fires occur in homes that do not have smoke alarms, so this may be the single most important thing you can do to keep your family safe from fires.

If your home does not have smoke alarms, now is the time to install them on every level of your home and in each bedroom. If possible, choose one with a 10-year lithium battery. If your smoke alarm uses regular batteries, remember to replace them every 10 years. Test your smoke alarms monthly, and be sure your children are familiar with the sound of the alarm.

Because smoke rises, smoke detectors should always be placed on ceilings or high on walls. If a smoke detector near the kitchen goes off while you are cooking, do not take the battery out of it; you may forget to replace it. Open the doors and windows instead. If you are having a new home built or remodeling an older home, you may also want to consider adding a home sprinkler system. These are already found in many apartment buildings and dormitories.

Smoke alarm

G. Keep fire extinguishers handy

Be prepared for any accidents by having fire extinguishers strategically placed around your house; in the kitchen (this one should be an all-purpose extinguisher, meaning it can be used on grease and electric fires), the basement, garage, or workshop area. Keep them out of reach of children. Fire extinguishers are best used, when a fire is contained in a small area.

Always remember the word **PASS** when operating an extinguisher:

Pull the pin.	Release the lock with the nozzle pointing away from you.
Aim low.	Point the extinguisher at the base of the fire.
Squeeze.	Squeeze the lever slowly and evenly.
Sweep.	Sweep the nozzle from side to side.

Fire extinguishers have gauges on them indicating when they need to be replaced and should be checked regularly to make sure they are still functional.

Fire extinguisher

H. Plan escape routes

Planned escape routes are a necessity, especially if a fire were to occur during the night. Go through each room in your house and think about the possible exits. Inspect the room to make sure that furniture and other objects are not blocking doorways or windows. Make sure that the windows in every room are easy to open and are not painted over or nailed shut; remember these may be your only way out in a fire. If you live in an apartment building, make sure any safety bars on windows are removable in an emergency. Be sure to know the locations of the closest stairwells or fire escapes and where they lead.

If your house is more than one story tall or if you live above the ground floor of an apartment building, an escape ladder is an important safety feature. You should have one escape ladder made of fire-safe material (aluminum, not rope) in each upper-story bedroom that is occupied by a person who is capable of using it.

Like fire extinguishers, escape ladders should be operated by adults only. The ladder’s length must be appropriate for your home, and it must support the weight of the heaviest adult in the house. Be sure babysitters in your home know all escape plans in case of fire.

First Aid for Electric Shock

Shock is a common occupational hazard associated with electricity. A person who has stopped breathing is not necessarily dead but is in immediate danger. Life is dependent on oxygen, which is breathed into the lungs and then carried by the blood to every body cell. Since body cells cannot store oxygen and since the blood can hold only a limited amount (and only for a short time), death will surely result from continued lack of breathing.

However, the heart may continue to beat for some time after breathing has stopped, and the blood may still be circulated to the body cells. Since the blood will, for a short time, contain a small supply of oxygen, the body cells will not die immediately. For a very few minutes, there is some chance that the person's life may be saved.

The process by which a person who has stopped breathing can be saved is called artificial ventilation (respiration). The purpose of artificial respiration is to force air out of the lungs and into the lungs, in rhythmic alternation, until natural breathing is re-established. Records show that seven out of ten victims of electric shock were revived when artificial respiration was started in less than three minutes. After three minutes, the chances of revival decrease rapidly. Artificial ventilation should be given only when breathing has stopped.

Do not give artificial ventilation to any person who is breathing naturally. You should not assume that an individual who is unconscious due to electrical shock has stopped breathing. To tell if someone suffering from an electrical shock is still breathing, place your hands on the person's sides at the level of the lowest ribs. If the victim is breathing, you will usually feel movement.

The danger from an electrical shock depends on the type of current, how high the voltage is, how the current travels through the body, the person's overall health and how quickly the person is treated.

Call your local emergency number immediately if any of these signs or symptoms occurs:

- Cardiac arrest
- Heart rhythm problems (arrhythmias)
- Respiratory failure
- Muscle pain and contractions
- Burns
- Seizures
- Numbness and tingling
- Unconsciousness

While waiting for medical help, follow these steps:

Look first. Do not touch. The person may still be in contact with the electrical source. Touching the person may allow the current to pass through you.
.
Turn off the source of electricity, if possible. If not, move the source away from you and the person, using a non-conducting object made of cardboard, plastic or wood.

Check for signs of circulation (breathing, coughing or movement). If absent, begin cardiopulmonary resuscitation (CPR) immediately.

Prevent shock. Lay the person down and, if possible, position the head slightly lower than the trunk, with the legs elevated. After coming into contact with electricity, the person should see a doctor to check for internal injuries, even if he or she has no obvious signs or symptoms.

Caution:
Do not touch the person with your bare hands if he or she is still in contact with the electrical current.

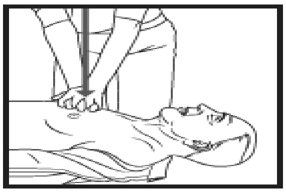
Do not get near high-voltage wires until the power is turned off. Stay at least 20 feet away farther if wires are jumping and sparking.

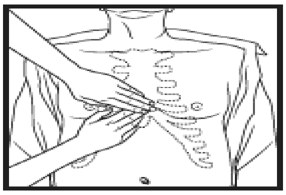
Do not move a person with an electrical injury unless the person is in immediate danger.

Remember:

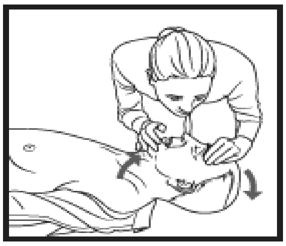
1. **Call**
   Check the victim for <u>unresponsiveness</u>. If the person is not responsive and not breathing or not breathing normally call local emergency number immediately and return to the victim.

2. **Pump**
If the victim is still not breathing normally, coughing or moving, begin chest compressions. Push down in the centre of the chest 2 inches 30 times. Pump hard and fast at the rate of at least 100/minute, faster than once per second.





3. **BLOW**
Tilt the head back and lift the chin. Pinch nose and cover the mouth with yours and blow until you see the chest rise. Give 2 breaths. Each breath should take 1 second.



Activity: **Now test yourself by doing this activity.**

Circle the letter of the correct answer.

1. The leading cause of home fire deaths are __________ and __________.

   A. smoking, heating
   B. cooking ,heating
   C. cooking. electrical
   D. smoking, electrical

2. You should stay in the kitchen when you are __________.

   A. frying B. baking

   C. steaming D. simmering

3. You should never smoke in a home with

   A. gas heat .
   B. older adults.
   C. paper clutter.
   D. oxygen in use.

4. What will you do if you leave the room in which there is a candle burning?

   A. Blow out the candle.
   B. Check the candle frequently
   C. Take children and pets with you
   D. Move the candle away from anything that can burn.

5. Smoke alarms should be replaced every __________.years.

   A. 5 B. 10

   C. 15 D. 20

6. Smoke alarms should be placed in

   A. bedrooms, outside sleeping areas and kitchens.
   B. kitchens, outside sleeping areas and on every level of the home.
   C. bedrooms, outside sleeping areas and on every level of the home.
   D. outside sleeping areas and on every level of the home including the attic.

7. You should call a professional electrician when

   A. your outlets are warm.
   B. you purchase a home.
   C. you lose your electricity.
   D. your circuit breaker trips.

8. If there are smokers in your home, they should smoke

   A. in the garage.
   B. in the kitchen.
   C. in the basement.
   D. outside the home.

9. If oil catches fire in a pan while cooking, you should

   A. carry the pan to the sink.
   B. throw water on the pan and turn the burner off
   C. slide a lid over the pan and turn off the burner off.
   D. put the fire out with baking soda and turn the burner off.

10. Extension cords should be

A. secured under furniture so it is out of the way.

B. placed under a carpet so it does not get damaged

C. used only if it has the label of a recognized testing laboratory and following instructions provided.

D. all of the above.

CHECK YOUR WORK. ANSWERS ARE AT THE END OF LESSON 4.

Summary

You have come to the end of lesson 4. In this lesson you have learnt that:

- electric fires require three elements, both to ignite and to continue burning
  heat - common heat sources include a hot stove burner, a spark from a worn electrical wire or a burning cigarette.
  fuel - just about everything in your home can fuel a fire — clothing, food, furniture, clutter, paper, plastics and more.
  oxygen - the oxygen in the air around us also fuels a fire.
- never put water on an electric fire because the electricity from the fire can shoot through the water and shock you possibly to death.
- a simple safety precautions can help prevent a fire harming your family and damaging your home:
  - install smoke alarms in hallways and bedrooms, and check the batteries regularly.
  - dispose of cigarette and fireplace ashes into metal bins and leave to cool.
  - check electrical equipment and extension cords for signs of wear.
  - keep heaters a metre away from curtains, furniture and children.
- be prepared for any accidents by having fire extinguishers strategically placed around your house. keep fire extinguishers handy.
- do not give artificial ventilation to any person who is breathing naturally.
- call local emergency number immediately if the victim is unresponsive and not breathing normally. Administer the following:
  - begin chest compressions if the victim is still not breathing normally, coughing or moving. Push down in the centre of the chest 2 inches 30 times. pump hard and fast.
  - tilt the head back and lift the chin of the victim if still unresponsive. pinch nose and cover the mouth with yours and blow until you see the chest rise.

NOW DO PRACTICE EXERCISE 4 ON THE NEXT PAGE.

Practice Exercise 4

1. Discuss the three elements needed for electric fires to ignite and burn.

2. Why is it important for children to learn the basic facts of fire?

3. What is the purpose of artificial respiration?

4. Identify eight (8) fire safety and preventive measures.
   a.
   b.
   c.
   d.
   e.
   f.
   g.
   h.

5. Discuss first aid procedures for electric shock while waiting for medical help.

CHECK YOUR WORK. ANSWERS ARE AT THE END OF TOPIC 1

Answers to activity

1.	A	6.	C
2.	A	7.	A
3.	D	8.	D
4.	A	9.	C
5.	B	10.	C

Answer to Practice Exercises 1 - 4

Practice Exercise 1

1. Static electricity is the build-up of an electric charge in a certain location. It stays in one place and does not move.

2. An atom is the smallest particle of an element. So, everything we see is made up of tiny little parts called atoms. In the middle of each atom is a "nucleus." The nucleus contains two kinds of tiny particles, called protons and neutrons. Orbiting around the nucleus are even smaller particles called electrons. Electric charge comes from the parts inside atoms. Positive charge comes from the nucleus of an atom. Protons have a positive (+) charge and electrons have a negative (-) charge while neutrons have no charge. Charge comes when electrons move away from an atom. Electrons that move away from their atoms cause static electricity.

3. a. Two things with opposite, or different charges (a positive and a negative) will attract or pull towards each other.
   b. Things with the same charge (two positives or two negatives) will repel or push away from each other.
   c. Neutral objects are attracted to charged objects. (A charged object will also attract something that is neutral)

Practice Exercise 2

1. Current electricity is the movement of electrons that carry electrical energy from one place to another.

2. Conductors are materials such as copper metal that conduct electricity (allow it to flow freely) and are said to have a high conductance and a low resistance. Insulators are materials that do not allow electricity to pass through them so readily, such as rubber and plastic and have a low conductance and a high resistance.

3.

Static electricity	Current electricity
Stays in **one** place until it jumps to an object.t	Needs a **conductor,** a substance that allows electrons to move easily through it.
Does not need a **circuit**	Needs a **closed** circuit to flow
The kind of electricity you feel after you **drag** your feet across a carpet and **touch** someone or something.	The kind of electricity that powers the appliances and **heat** in your home.
Lightning is static electricity on a more spectacular scale.	The kind of electricity in a **battery.**

Practice Exercise 3

A. (1) Current - is the flow rate of the electrons in the circuit.

(2) Voltage -is the electric force that causes the free electrons to move from one atom to another.

B. (1) Voltage
(2) atom
(3) voltmeter
(4) volts
(5) parallel
(6) cells
(7) path
(8) Current
(9) ammeter
(10) amps
(11) circuit.
(12) series
(13) power source
(14) complete
(15) increase
(16) decrease

Practice Exercise 4

1. Electric fires require three elements, both to ignite and to continue burning:
Heat - Common heat sources include a hot stove burner, a spark from a worn electrical wire or a burning cigarette.
Fuel - Just about everything in your home can start a fire — clothing, food, furniture, clutter, paper, plastics and more.
Oxygen - The oxygen in the air around us also fuels a fire.

2. So they would know how to react properly and be able to protect themselves because there may not be an adult around to tell them what to do if a fire happens.

3. The purpose of artificial respiration is to force the air out of the lungs and into the lungs, in rhythmic alternation, until natural breathing is re-established.

4. a. Be sure to check all electrical appliances, cords, and outlets.
b. Be careful in the kitchen when cooking.
c. Beware of cigarettes.
d. Never let children play with matches and lighters.
e. Use candles safely.
f. Have your smoke alarms in good condition.
g. Keep fire extinguishers handy.
h. Plan escape routes.

5. Look first. Do not touch. The person may still be in contact with the electrical source. Touching the person may pass the current through you.

   Turn off the source of electricity, if possible. If not, move the source away from you and the person, using a non-conducting object made of cardboard, plastic or wood.

   Check for signs of circulation (breathing, coughing or movement). If absent, begin cardiopulmonary resuscitation (CPR) immediately.

   Prevent shock. Lay the person down and, if possible, position the head slightly lower than the trunk, with the legs elevated.

REVISE TOPIC 1 USING THE MAIN POINTS ON THE NEXT PAGE.

REVIEW OF TOPIC 1: TYPES OF ELECTRICITY

Revise all the Lessons in this Topic and then do **ASSIGNMENT 5.**
Here are the main points to help you revise.

Lesson 1: Static Electricity

- Static electricity is the build-up of an electric charge in a certain location. It stays in one place and does not move.
- Everything we see is made up of tiny little parts called atoms.
- In the middle of each atom is a "nucleus."
- The nucleus contains two kinds of tiny particles, called protons and neutrons.
- Orbiting around the nucleus are even smaller particles called electrons.
- Electric charge comes from the parts inside atoms.
- Positive charge comes from the nucleus of an atom. Protons have a positive (+) charge.
- Electrons have a negative (-) charge.
- Neutrons have no charge.
- Charge comes when electrons move away from an atom.
- Electrons that move away from their atoms cause static electricity.
- Electrons do not move through some materials that hold their electrons very tightly called insulators.
- Other materials have some loosely held electrons, which move through them very easily called conductors.
- Two things with opposite, or different charges (a positive and a negative) will attract or pull towards each other.
- Things with the same charge (two positives or two negatives) will repel or push away from each other.
- A charged object will also attract something that is neutral.

Lesson 2: Current Electricity

- Current electricity is the movement of electrons that carry electrical energy from one place to another.
- Electric currents power all the electrical appliances that you use, from washing machines to flashlights and from telephones to MP3 players.
- Electricity is produced in generating stations by burning fossil fuels. Fossil fuels were formed hundreds of millions of years ago and are made up of decomposed plant and animal matter.
- Electricity produced is sent through high voltage transmission lines to substations. Then, the power is sent to your neighbourhood through distribution lines located underground or on poles.
- Electricity enters your home through a meter and then goes to the circuit panel in your house. In the panel, the electricity is divided into circuits.
- Materials such as copper metal that conduct electricity (allow it to flow freely) are called conductors and are said to have a high conductance and a low resistance
- Materials that do not allow electricity to pass through them so readily, such as rubber and plastic, are called insulators and have a low conductance and a high resistance.

Lesson 3: Current and Voltage

- Voltage is the electric force that causes free electrons to move from one atom to another.
- A volt is the measure of electric pressure.
- Voltage is measured using a device called voltmeter.
- To measure the voltage across a component in a circuit, you must connect the voltmeter in parallel with it.
- You can measure the voltage across a cell or battery using a voltmeter; the more cells, the bigger the voltage.
- Current is the flow rate of the electrons in the circuit.
- Electrical current is measured in amperes or "amps" for short.
- A device called an ammeter is used to measure current.
- To measure the current flowing through a component in a circuit, you must connect the ammeter in series with it.
- An electric current will not flow if we do not have a power source (a cell, battery or power pack). It also would not flow if the circuit is not complete.
- Voltage causes electric current to flow.
- Given a voltage and a path for the electrons, electric current will flow.
- Given a voltage without the path, there will be no current.
- An increase in voltage means an increase in energy and therefore an increase in current.
- A decrease in voltage means a decrease in energy and therefore a decrease in current.

Lesson 4: Safety and Prevention

- Electric fires require three elements, both to ignite and to continue burning:
  Heat - common heat sources include a hot stove burner, a spark from a worn electrical wire or a burning cigarette.
  Fuel - just about everything in your home can fuel a fire — clothing, food, furniture, clutter, paper, plastics and more.
  Oxygen - the oxygen in the air around us also fuels a fire.
- Never put water on an electric fire because the electricity from the fire can shoot through the water and shock you possibly to death.
- A simple safety precautions can help prevent a fire harming your family and damaging your home:
  - Install smoke alarms in hallways and bedrooms, and check the batteries regularly.
  - Dispose of cigarette and fireplace ashes into metal bins and leave to cool.
  - Check electrical equipment and extension cords for signs of wear.
  - Keep heaters a metre away from curtains, furniture and children.
- Be prepared for any accidents by having fire extinguishers strategically placed around your house. Keep fire extinguishers handy.
- Do not give artificial ventilation to any person who is breathing naturally.
- Call local emergency number immediately if the victim is unresponsive and not breathing normally.

REVISE WELL AND THEN DO TOPIC TEST 1 IN YOUR ASSIGNMENT 5.

TOPIC 2

ELECTRIC CIRCUITS

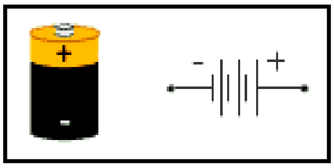
In this topic you will learn about:

- **series circuits**
- **parallel circuits**
- **ohm's law**

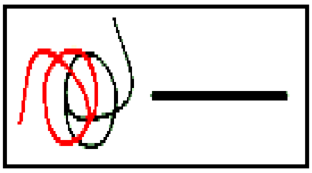
INTRODUCTION TOPIC 2: ELECTRIC CIRCUITS

When you flip a light switch on and off, you are closing and opening a circuit. A circuit is the path that electricity follows. For electrons to travel (creating an electric current), the circuit must be closed. When you flip the light switch off, you are opening the circuit and the lights turn off. When you flip the switch on, the circuit is closed and the lights come on.

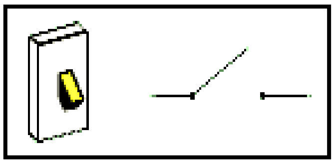
Here are common circuit parts along with how the part is drawn in a circuit diagram:



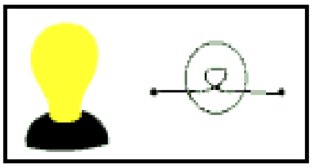
Voltage source



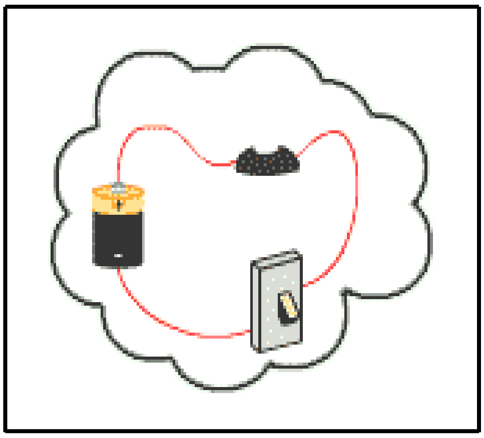
Conductor



Switch



Load

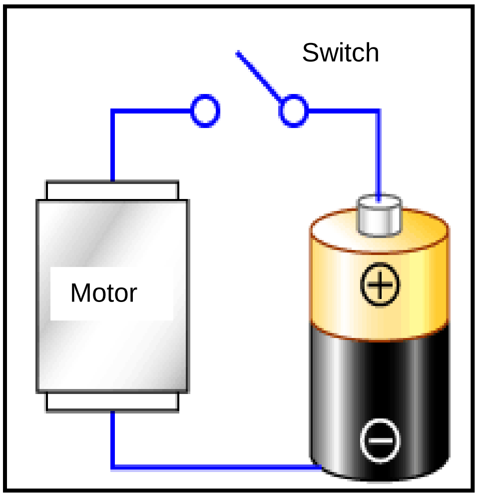


Circuit Diagram

Whether you are using a battery, a fuel cell or a solar cell to produce electricity, three things are always the same:

The source of electricity must have two terminals: a positive terminal and a negative terminal.

1. The source of electricity (whether it is a generator, battery or something else) will want to push electrons out of its negative terminal at a certain voltage. For example, one AA battery typically wants to push electrons out at 1.5 volts.
2. The electrons will need to flow from the negative terminal to the positive terminal through a copper wire or some other conductor. When there is a path that goes from the negative to the positive terminal, you have a **circuit**, and electrons can flow through the wire.



An AA battery pushing its electrons

Questions will arise such as

- What are the different circuit symbols?
- How is series circuit different from parallel circuit?
- What are the basic rules that apply to the series and parallel circuits?

In this Topic, you will find the answers to these questions and other questions relating to electric circuits.

Lesson 5: Series Circuits

Welcome to Lesson 5. You should know the importance of an electric circuit, especially in your everyday life. An electrical circuit is a closed loop formed by a power source, wires, a fuse, a load, and a switch. When the switch is turned on, the electrical circuit is complete and current flows from the negative terminal of the power source, through the wire to the load, to the positive terminal. Any device that consumes the energy flowing through a circuit and converts that energy into work is called a load. A light bulb is one example of a load; it consumes the electricity from a circuit and converts it into work — heat and light.

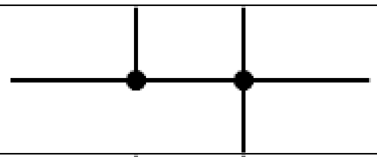
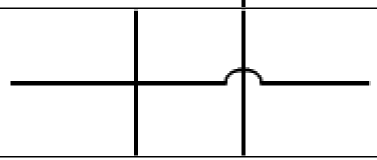
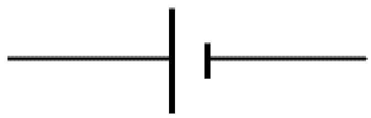
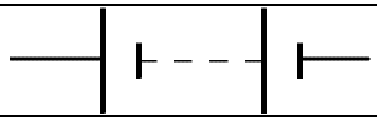
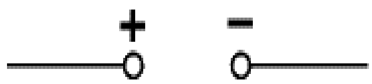
Your Aims:

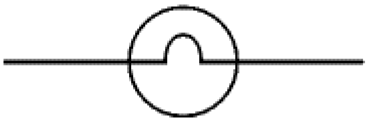
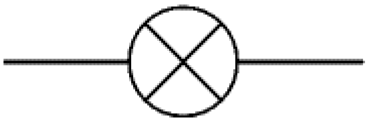
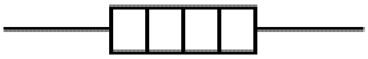
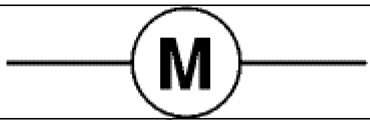
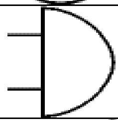
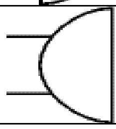
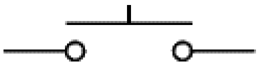
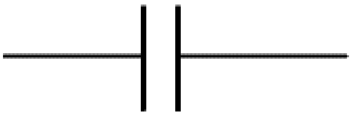
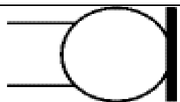
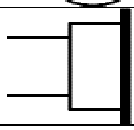
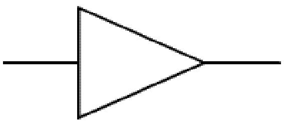
- state the function of different circuit symbols
- discuss resistance, current and voltage in series circuits

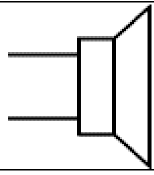
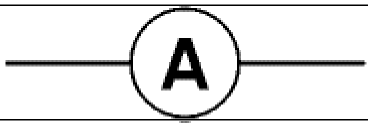
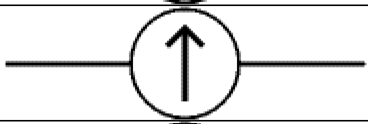
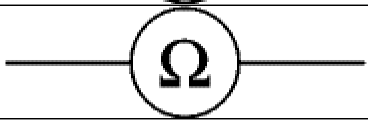
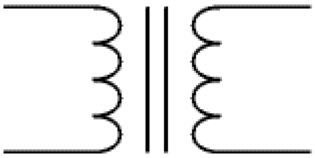
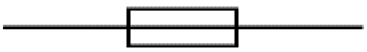
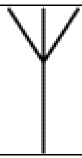
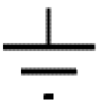
Circuit Symbols

Circuit symbols are used in circuit diagrams which show how a circuit is connected together electrically. They are used when designing and testing circuits, and for understanding how they work. The diagram below shows the standard circuit symbols you need to know.

Circuit Symbols

Component	Symbol	Function of Component
Wire		To pass current easily from one part of a circuit to another
Wires joined		This symbol is used in circuit diagrams where wires cross to show that they are connected (joined).
Wires not joined		In complex circuit diagrams it is often necessary to draw wires crossing even though they are not connected.
Cell		It supplies electrical energy. Single cells are often wrongly called a battery, but strictly a battery is two or more cells joined together.
Battery		It supplies electrical energy. A battery is more than one cell.
DC supply		It supplies electrical energy.
AC supply		It supplies electrical energy.

Component	Symbol	Function of Component
Lamp (lighting)		A transducer which converts electrical energy to light. This symbol is used for a lamp providing illumination, for example a car headlamp or torch bulb.
Lamp (indicator)		A transducer which converts electrical energy to light. This symbol is used for a lamp which is an indicator, for example a warning light on a car dashboard.
Heater		A transducer which converts electrical energy to heat.
Motor		A transducer which converts electrical energy to kinetic energy (motion).
Bell		A transducer which converts electrical energy to sound.
Buzzer		A transducer which converts electrical energy to sound.
Push Switch (push-to-make)		A push switch allows current to flow only when the button is pressed. This is the switch used to operate a doorbell.
On-Off Switch (SPST)		SPST = Single Pole, Single Throw. An on-off switch allows current to flow only when it is in the closed (on) position.
Resistor		A resistor restricts the flow of current, for example to limit the current passing through an LED. A resistor is used with a capacitor in a timing circuit.
Capacitor		A capacitor stores electric charge. A capacitor is used with a resistor in a timing circuit. It can also be used as a filter, to block DC signals but pass AC signals.
Microphone		A transducer which converts sound to electrical energy
Earphone		A transducer which converts electrical energy to sound.
Amplifier (general symbol)		An amplifier circuit with one input. Really it is a block diagram symbol because it represents a circuit rather than just one component.

Component	Symbol	Function of Component
Loudspeaker		A transducer which converts electrical energy to sound
Voltmeter		A voltmeter is used to measure voltage. The proper name for voltage is 'potential difference', but most people prefer to say voltage.
Ammeter		An ammeter is used to measure current.
Galvanometer		A galvanometer is a very sensitive meter which is used to measure tiny currents, usually 1mA or less.
Ohmmeter		An ohmmeter is used to measure resistance. Most multimeter's have an ohmmeter setting.
Inductor (Coil, Solenoid)		A coil of wire which creates a magnetic field when current passes through it. It may have an iron core inside the coil. It can be used as a transducer converting electrical energy to mechanical energy by pulling on something.
Transformer		Two coils of wire linked by an iron core. Transformers are used to step up (increase) and step down (decrease) AC voltages. Energy is transferred between the coils by the magnetic field in the core. There is no electrical connection between the coils.
Fuse		A safety device which will 'blow' (melt) if the current flowing through it exceeds a specified value.
Aerial (Antenna)		A device which is designed to receive or transmit radio signals. It is also known as an antenna.
Earth (Ground)		A connection to earth. For many electronic circuits this is the 0V (zero volts) of the power supply, but for mains electricity and some radio circuits it really means the earth. It is also known as ground.

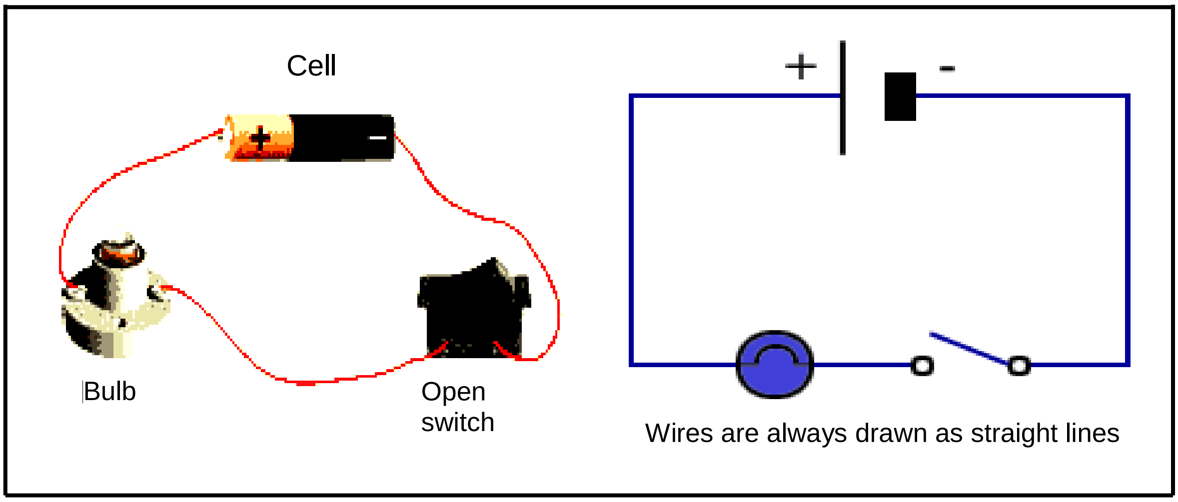
All electrical circuits have a cell or battery which provides electric current. If the circuit is complete, the current will flow from one end of the cell or battery through any wires, devices or components which make up the circuit and then back again to the other end of the cell or battery.

Drawing Circuits

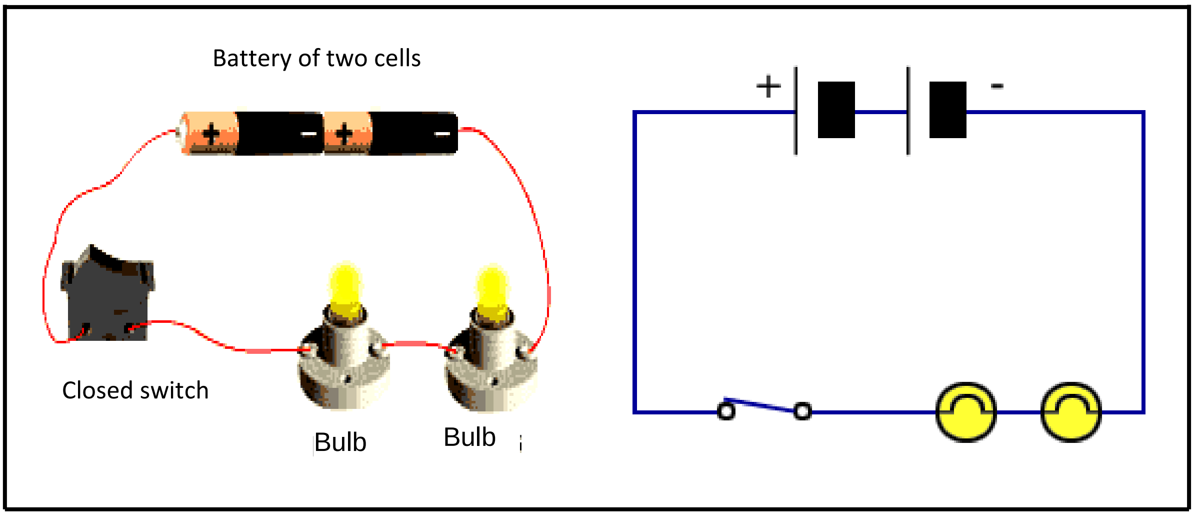
To represent a circuit using symbols all you have to do is this:

- Firstly draw your cell or battery.
- Work your way round from one end of the cell or battery to the other end, drawing the symbols for all wires, devices and components as you go along. You must remember that wires are always drawn as straight lines.

Both of the circuits shown here are examples of **series circuits** as everything is connected together in one loop.



In this circuit there is an **open switch**. The circuit has a **break in it** and **no current** flows. The bulb is **'off'.**



In this circuit there is a **closed switch**. The circuit has **no break in it** and **current flows**. The bulbs are **'on'.**

Series Circuits

A series circuit is a circuit where there is only one path from the source through all of the loads (light bulbs) and back to the source. This means that all of the current in the circuit must flow through all of the loads (Figure 1).

One example of a series circuit is a string of old Christmas lights. There is only one path for the current to flow. Opening or breaking a series circuit such as this at any point in its path causes the entire circuit to "open" or stop operating. That is because the basic requirement for the circuit to operate a continuous, closed loop path is no longer met.

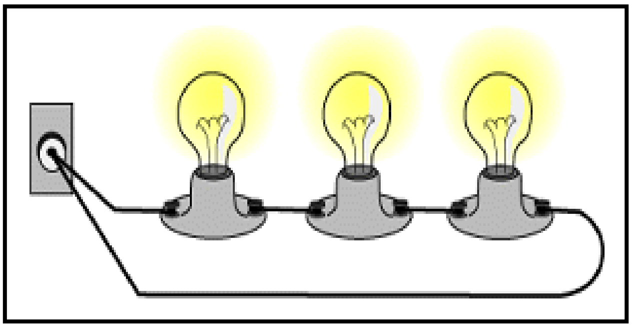


Figure 1

This is the main disadvantage of a series circuit. If any one of the light bulbs or loads burns out or is removed, the entire circuit stops operating. Many of today's circuits are actually a combination of elements in series and parallel to minimize the inconvenience of a pure series circuit.

Let us take a closer look at how a series circuit operates and the way resistance affects the current flow.

Consider a simple series circuit consisting of a 120 volt outlet as the source, a switch, and a 60 watt light bulb. When the switch is open, the light cannot operate since the circuit is not complete. There is no closed-loop path for the current to flow through the circuit. When the switch is closed, the light bulb operates since the current flows through the circuit. The bulb glows at its full brightness since it receives its full 120 volts and has the design current flow (Figure 2).

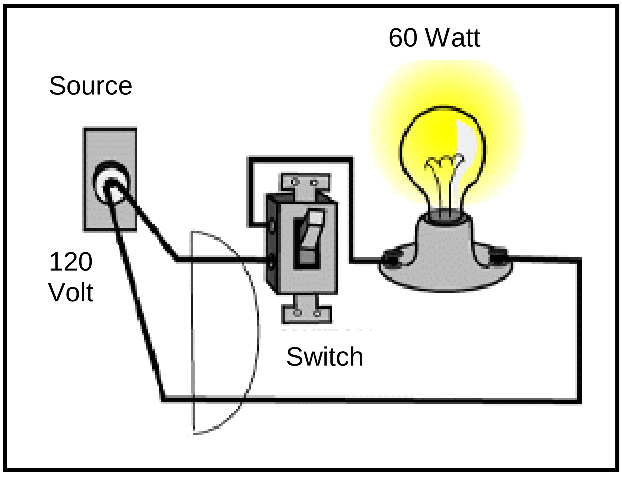


Figure 2

If two light bulbs are connected to the circuit in series, the resistance of the circuit doubles (Figure 3).

The current flow is now half of what it was when only one lamp was in the circuit as before. The voltage across each lamp is now 60 volts due to the reduced current flow. Each bulb is operating at only one-half its intended voltage, which will reduce its brightness. Since each bulb is the same size, they each see equal voltage drop.

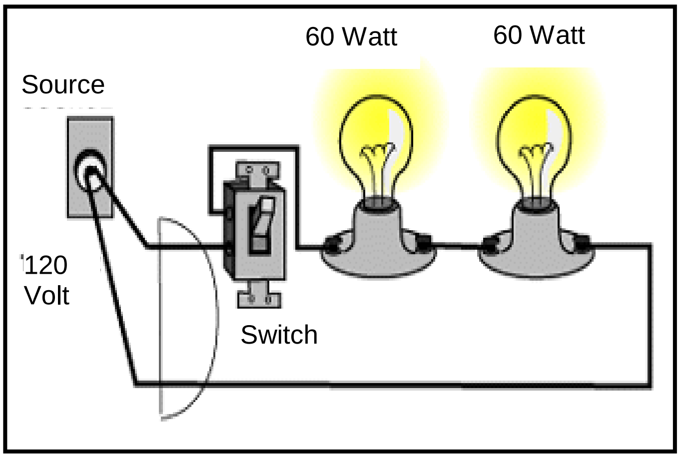


Figure 3

If we add a third 60-watt bulb to the circuit, then each bulb will receive a third of the total circuit voltage, or 40 volts (Figure 4). Each bulb will produce even less light than before because we continue to add more resistance to the circuit each time we add a bulb.

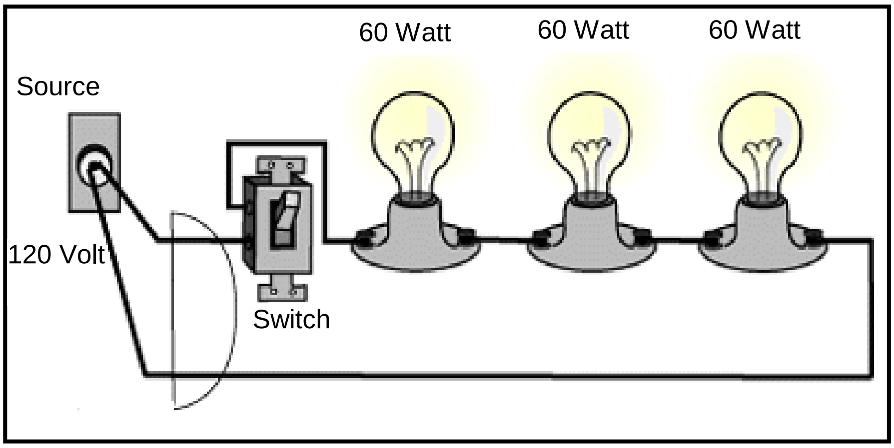


Figure 4

To further demonstrate how changing resistance in series affects current flow and voltage across each bulb, let us replace the third bulb with a 10-watt bulb (Figure 5). What will happen?

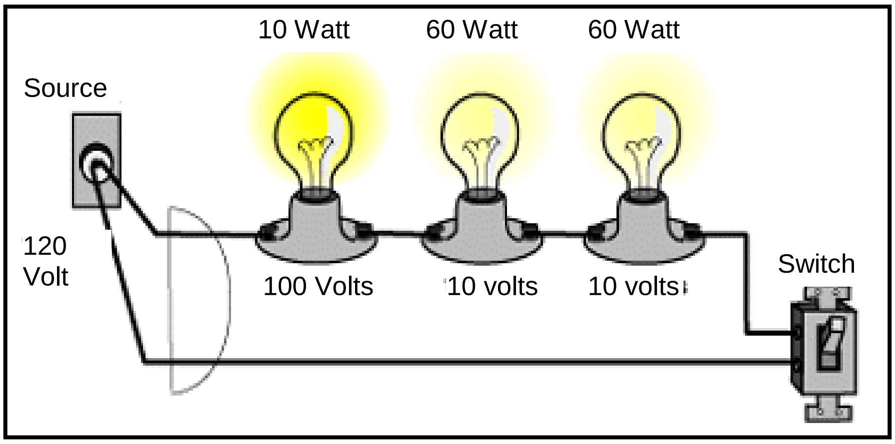


Figure 5

The 10-watt bulb will glow brightly but the other two will barely produce light. The 10-watt bulb has such a large resistance compared to the other two 60-watt bulbs that the 10-watt bulb gets the highest percentage of the voltage. The position of the bulbs in the circuit does not matter. It is the resistances that determine how much voltage each of the bulbs will ultimately receive. In this arrangement, the 10-watt bulb receives 110 volts, and each of the 60-watt bulbs is receiving 5 volts. The 5 volts received by the 60-watt bulbs makes them barely glow, while the 110 volts received by the 10-watt bulb makes it glow at close to, but not all of, its full, intended brightness.

Why bulbs in series circuits are dimmer?

The bulbs are dim for two reasons:

1. The current going through them is smaller because two bulbs in series have a higher resistance than a single bulb.

2. Each charge only gives up some of its energy in each bulb that is the voltage across each bulb is smaller.

If the bulbs are the same then each charges will give up half its energy. Remember there is no 'first' bulb. The charges are already there and they flow everywhere at the same time. The current is the same all the way round a series circuit.
Imagine putting brakes all the way round a bicycle wheel. You would not say that any of the brakes was first.

Brightness depends on power. Power depends on both voltage and current. With two bulbs in series you half the voltage and roughly half the current so the power dissipated in each bulb, and hence the brightness, is roughly a quarter what it would be if the bulb was connected alone.

How do the charges 'know' to keep some energy for the second bulb?
The key is that the current must be the same everywhere in the circuit. You do not know what that current will actually be unless you calculate it but you do know that it cannot be different in each bulb.

For the current to be the same, then you need a big voltage across a big resistance and a small voltage across a small resistance. These two voltages must add up to the battery voltage.

When you connect the circuit, the electrons take a few millionths of a second to settle down into a stable current. During this tiny fraction of a second, the current may be different in different parts of the circuit.

High resistance bulbs are brighter in series circuits
If two bulbs in series are not identical then one bulb will be brighter than the other. Brightness depends on both current and voltage.

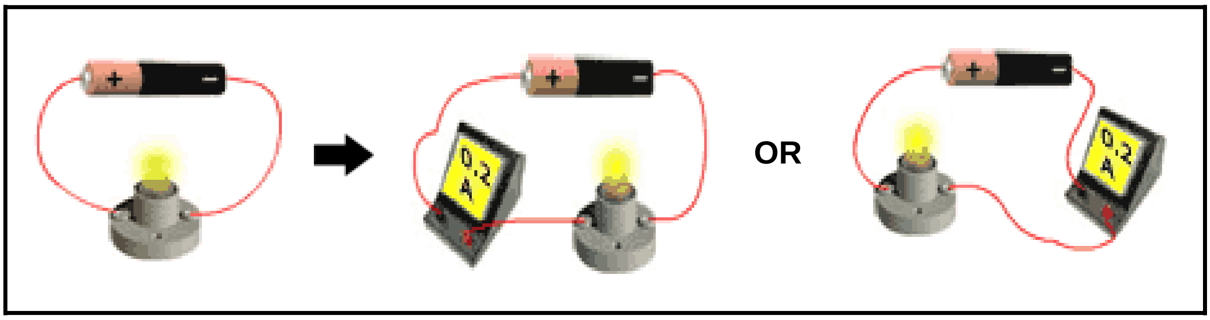
Remember the current through both must be the same because the current is the same everywhere in a series circuit. This means the voltage across the bulbs must be different for their brightness's to be different.

The brightest bulb will have the biggest voltage across it. If a bulb needs a big voltage for a given current then it must have a high resistance. So in series circuits high resistance bulbs are brighter because they have a bigger voltage across them.
In parallel circuits low resistance bulbs are brighter because they have a bigger current through them for the same voltage.

The more bulbs that are added, the less bright they shine. It is possible to add so many bulbs that they do not light up at all. This is due to the resistance in each bulb. If any of the bulbs fail, current cannot flow through the circuit and the other components will not work.

Measuring Electric Current

The **electric current** that flows through a **complete** series circuit can be measured using an ammeter. Electric current is measured in amps, (A). In the simplest series circuit, that is, one cell and one bulb, the current flowing can be measured by connecting an ammeter into the circuit as shown in the diagram on the next page.



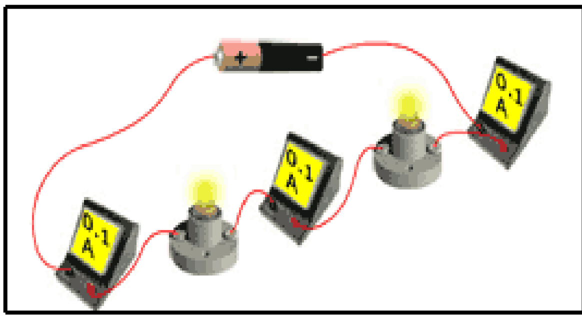
You will notice that **both** ammeter readings are the same which shows that:

1. It does not matter where you position the ammeter in a series circuit.
2. Electric current does not get 'used up' by the bulb; it simply flows around the circuit.

Factors Affecting the Size of the Current

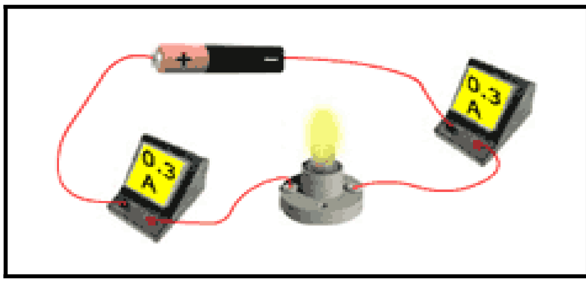
The amount of electric current that flows depends on:

1. The number of components (examples bulbs) in the circuit



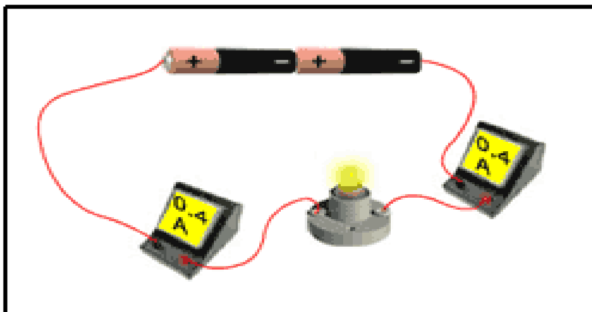
If we increase the number of bulbs in the circuit, the current reading decreases. All components have **resistance** which means they resist the flow of electric current. Two bulbs together provide a greater resistance than one bulb resulting in a smaller current flow.

2. The type of components (examples Bulbs) in the circuit



A different bulb may have a **different resistance**. This bulb has a smaller resistance resulting in a larger current flow.

3. The number of cells in the circuit

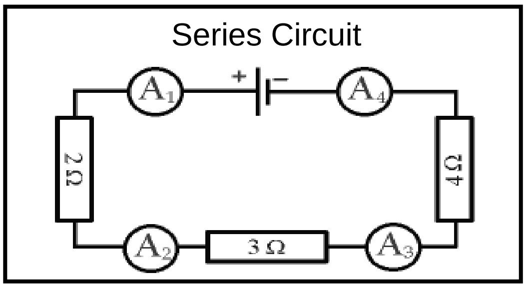


The voltage is the driving force which pushes current around the circuit. A battery of two cells provides a greater voltage which results in a larger current flow and a greater transfer of electrical energy from the battery to the bulb.

Remember:

A. **Current** in a Series Circuit

The current in a series circuit is the same everywhere.



An ammeter placed anywhere in a series circuit always gives the same reading. In the circuit above,

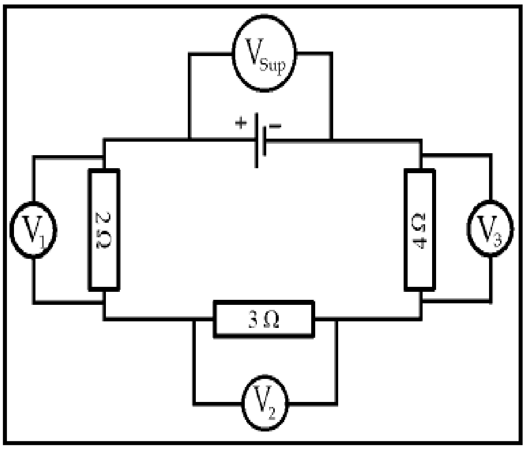
$$A_1 = A_2 = A_3 = A_4$$

If an identical cell (battery) is placed in series with the original cell, the current doubles because the **total voltage** of the circuit doubles. However, two cells together provide electricity for only the same amount of time as one cell before they both run out.

B. **Voltage** in a Series Circuit.

1. The **voltage** for each **component** depends on its **resistance**.
   To calculate the voltages, we need to know the total resistance of the circuit, and the current flowing through it.

2. The voltage across all of the components adds up to the supply voltage from the cell or battery. In energy terms, the work done by the cell on each coulomb of charge equals the work done on the components of the circuit.



$$V_{sup} = V_1 + V_2 + V_3$$

The supply voltage is divided (shared) between the components. If there is a change in the resistance of one component then the voltage across all of the components will change. If more cells or batteries are connected together in series the total voltage is the sum of the individual voltages for each cell.

C. **Resistance** in a Series Circuit.

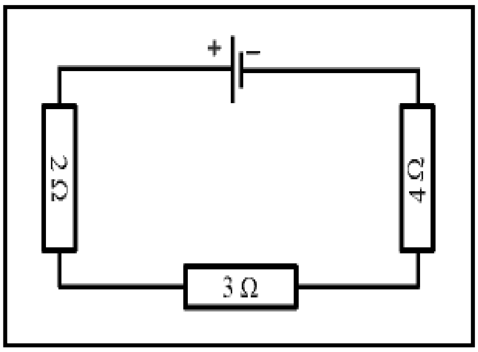
You can calculate the total resistance of a series circuit by adding up the resistance of each component.

$$R_{total} = R_1 + R_2 + R_3$$

In the given circuit,

$$R_{total} = 2 + 3 + 4$$

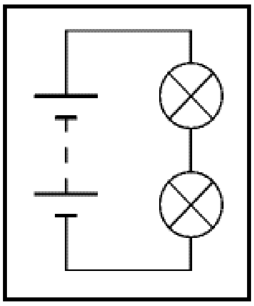
$$= 9 \text{ Ohms}$$



Activity: Now test yourself by doing this activity.

Circle the letter of the correct answer.

1. What kind of circuit is this?



A. Series B. Parallel

C. Ring main D. None of these

2. Look at the circuit shown in Q1. The current from the battery is 4Amps. What is the current through the lamps?

A. 1 amps B. 2 amps

C. 4 amps D. 8 amps

3. What can you say about the current in a series circuit?

A. It is the same everywhere
B. It is biggest near the battery
C. It splits up in each component
D. it gets less as you go around the circuit

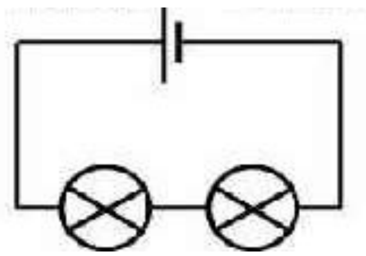
4. What can you say about the voltages in a series circuit?

A. The voltage is the same everywhere
B. The voltage is the same as the current
C. The voltage across each component is the same as the supply voltage
D. The voltage across each component added together is equal to the supply voltage

5. What happens when one light goes out or is removed in a series circuit?

A. Nothing happens
B. All the lights go out
C. Only that light goes out
D. Half of the lights go out

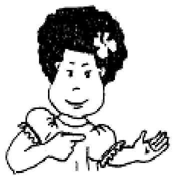
6. The battery is rated as 12 volts. There is 4 volts across one of the lamps. What is the voltage across the second lamp?



A. 4 volts B. 8 volts

C. 12 volts D. 16 volts

CHECK YOUR WORK. ANSWERS ARE AT THE END OF LESSON 5.



Summary

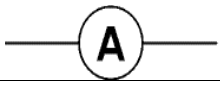
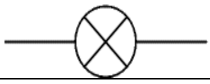
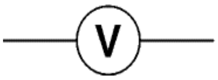
You have come to the end of lesson 5. In this lesson, you have learnt that:

- circuit symbols are used in circuit diagrams which show how a circuit is connected together electrically.
- any device that consumes the energy flowing through a circuit and converts that energy into work is called a load.
- an electrical circuit is a closed loop formed by a power source, wires, a fuse, a load, and a switch.
- a series circuit is a circuit where there is only one path from the source through all of the loads (light bulbs) and back to the source.
- the electric current that flows through a complete series circuit can be measured using an ammeter.
- the current in a series circuit is the same everywhere. An ammeter placed anywhere in a series circuit always gives the same reading
  $a1 = a2 = a3 = a4$
- the voltage across all of the components in a series circuit adds up to the supply voltage from the cell or battery.
  $v\ sup = v1+ v2+ v3$
- you can calculate the total resistance of a series circuit by adding up the resistance of each component.
  $r\ total = r1 + r2 + r3$

NOW DO PRACTICE EXERCISE 5 ON THE NEXT PAGE.

Practice Exercise 5

A. Name and give the functions of the following circuit symbols.

Name	Symbols	Functions
		
		
		
		
		
		

B. State the rules for current, voltage and resistance in a series circuit.

1. Current____

____

2. Voltage____

____

3. Resistance____

____

C. Multiple Choice Questions. Circle the letter of the correct answer.

1. A series circuit consists of three resistors with values of 120 Ω, 270 Ω,and 330 Ω.The total resistance is

A. 120 Ω B. 720 Ω

C. less than 120 Ω D. the average of the values

2. Five resistors are connected in a series and there is a current of 3 A into the first resistor. The amount of current into the second resistor is

A. 0.3 A
B. 1 A
C. 3 A
D. 4 A

3. To measure the current out of the second resistor in a circuit consisting of four resistors, an ammeter can be placed

A. at any point in the circuit
B. between the third and fourth resistor
C. at the negative terminal of the source
D. between the second and third resistor

CHECK YOUR WORK. ANSWERS ARE AT THE END OF TOPIC 2.

Answers to Activity

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

Lesson 6: Parallel Circuits

Welcome to Lesson 6. From the previous lesson, you have learned that there are two types of circuits: the series and parallel circuits. You also learnt that series circuit is a circuit where there is only one path from the source through all of the loads (light bulbs) and back to the source. This means that all of the current in the circuit must flow through all of the loads. The main disadvantage of a series circuit is that if any one of the light bulbs or loads burns out or is removed, the entire circuit stops operating. For this lesson, you will study the other kind of circuit; the parallel circuit.

Your Aims:

- define parallel circuit
- differentiate series circuits from parallel circuits
- discuss the current and voltage in parallel circuits

Parallel Circuits

A parallel circuit is a circuit in which there are at least two independent paths in the circuit to get back to the source. In a parallel circuit, the current will flow through closed paths and not through open paths. Consider a simple circuit with an outlet, a switch and a 60 watt light bulb (figure 1). If the switch is closed, the light operates.

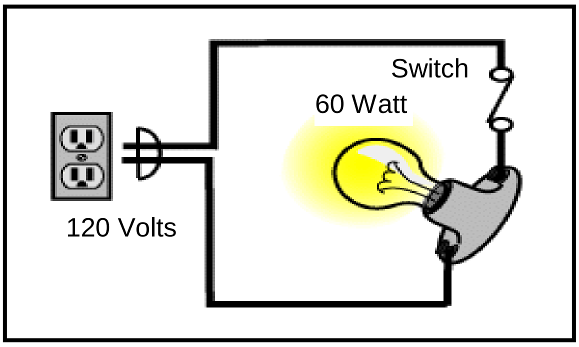


Figure 1

When a second 60 watt bulb is added to the circuit in parallel with the first bulb (Figure 2), it is connected so that there is a path to flow through to the first bulb or a path to flow through to the second bulb. Note that both bulbs glow at their intended brightness, since they each receive the full circuit voltage of 120 volts. Every load connected in a separate path receives the full circuit voltage.

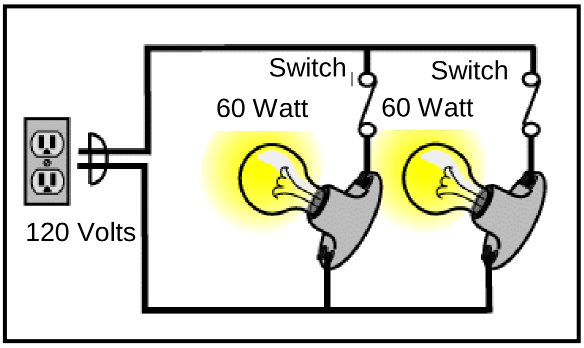


Figure 2

If a third 60-watt bulb is added to the circuit (Figure 3), it also glows at its intended brightness since it also receives its full 120 volts from the source.

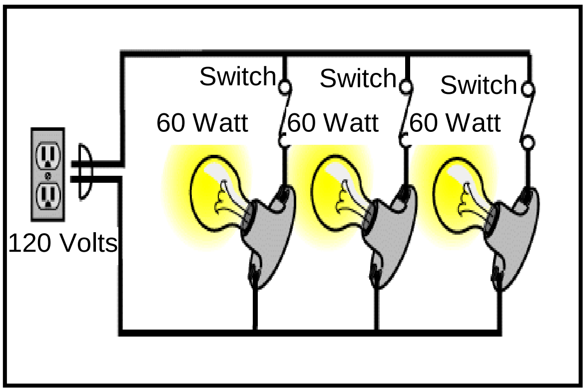
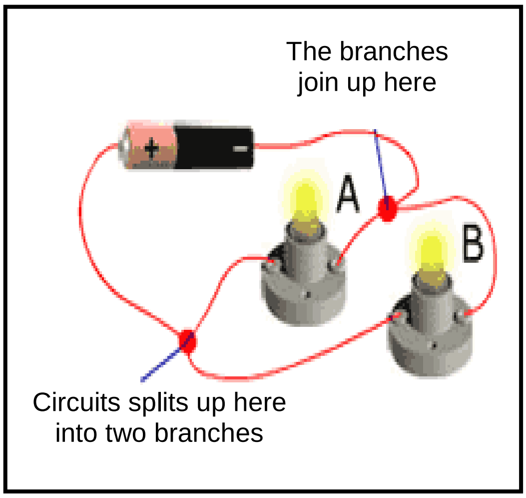


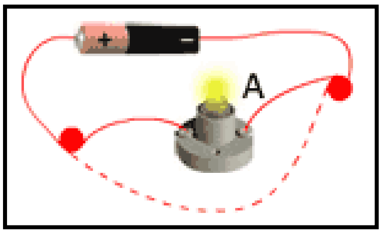
Figure 3

One special concern in parallel circuits is that the amperage from the source increases each time another load is added to the circuit in parallel. Therefore, it is very easy to keep adding loads or plugging them in parallel and thereby overloading a circuit by requiring more current to flow than the circuit can safely handle.

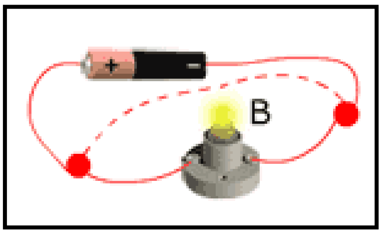
In a parallel circuit every component is connected separately in its own loop going from one end of the cell or battery to the other end. The simplest parallel circuit is one cell and two bulbs.



Bulb **A** has its own loop ➡



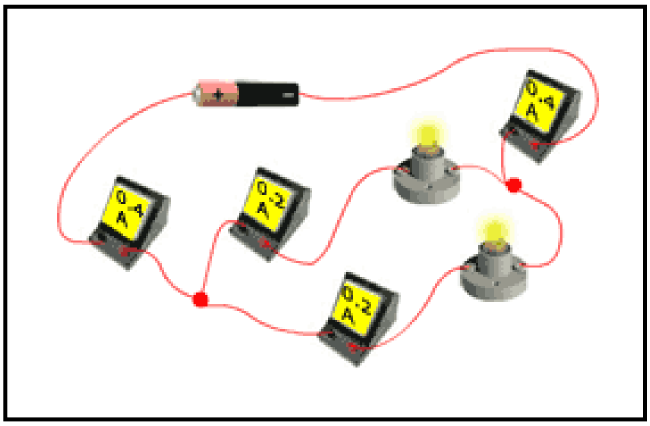
Bulb **B** has its own loop ➡



An obvious advantage of parallel circuits is that the burnout or removal of one bulb does not affect the other bulbs They continue to operate because there is still a separate, independent closed path from the source to each of the other loads.

That is why parallel circuits are used for wiring lighting and receptacle outlets. If one light on a parallel circuit burns out, the other lights wired in parallel stay on.

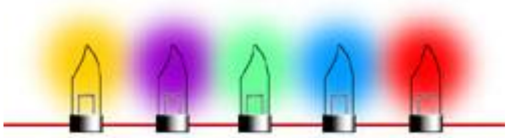
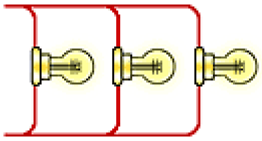
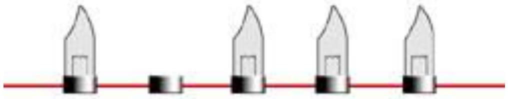
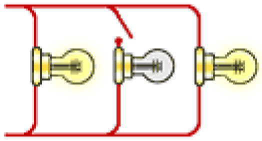
Measuring electric current in a parallel circuit
If we now include ammeters in the circuit above, and make sure that both bulbs are identical.



You will notice that:

- The total current in the two branches (0.2A and 0.2A) is equal to the current in the main circuit (0.4A). Try to think of this as water flowing through a main pipe which divides into two pipes. The amount of water flowing in the main pipe is the same as the total in the two pipes added together.
- Since the bulbs are identical, the same current passes through each one and each bulb has the same brightness.

Comparing series and parallel circuits

Series Circuits	Parallel Circuits
Christmas tree lights are often connected in series. **All** the **bulbs** will be **on** if the circuit is **complete**. 	House lights are connected in parallel. **Individual bulbs** in separate branches can be switched **'on' or 'off'** regardless of the other bulbs. 
If the circuit is **incomplete** because a bulb has failed or has been removed then **all the bulbs will be off.** 	If **one bulb fails**, is removed, or switched off the **other bulbs still work**. 

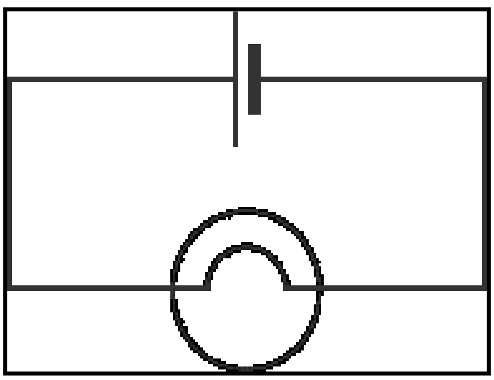
Remember:

1. Parallel circuits have two advantages when compared with series circuits.
   - The first advantage of a parallel circuit is that a failure of one component does **not** lead to the failure of the other components. This is because a parallel circuit consists of more than one loop and has to fail in more than one place before the other components fail.
   - The second advantage of parallel circuits is that more components may be added in parallel without the need for more voltage.
2. If the circuit **does not** have branches, then it is a series circuit.
3. If the circuit have branches, then it is a parallel circuit.

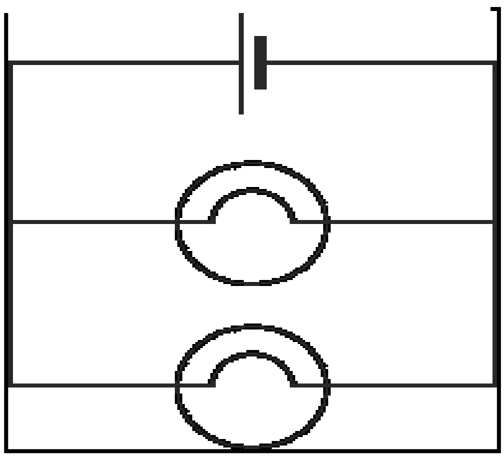
Energy Consumption in Parallel Circuits

The more components connected in parallel, the more energy is used. For example, if each of the circuits used the same type of cell and same type of lamp.

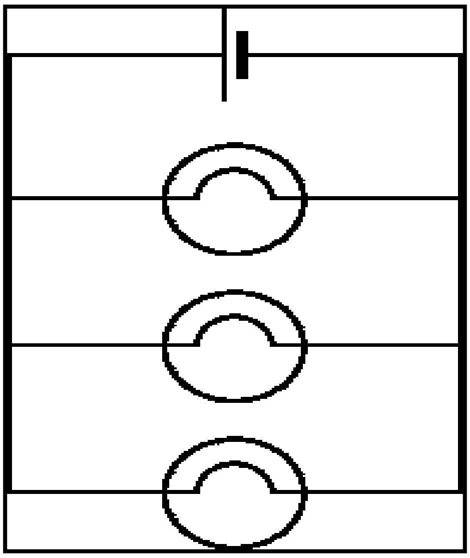
..the circuit below would light **one** lamp for **12 hours**



…the circuit below would light **two** lamps for **6 hours**



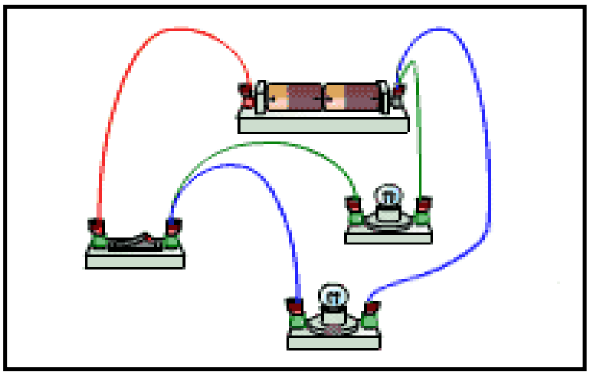
…the circuit below would light **three** lamps for **4 hours**



Let us look at the diagram below.

Keep them bright

These two lamps are connected in **parallel** with each other. When the switch is closed, they both light up with normal brightness (the same as a single lamp connected to the cell on its own).
Each lamp feels the full push of the battery.



The lamps in a parallel circuit come on with normal brightness - the same as a single lamp.

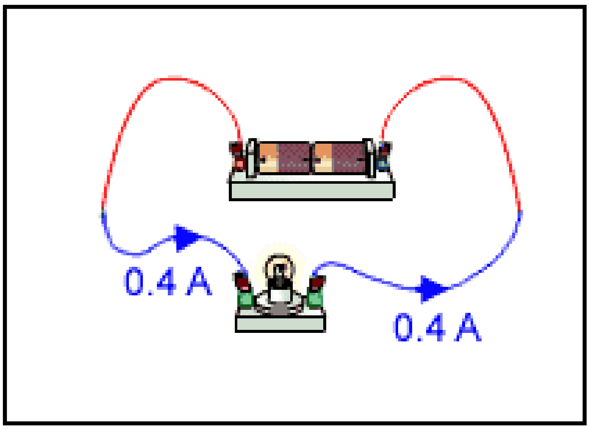
What is the cost?

You may think that we are getting something for nothing - an extra light on full brightness. However, there is a cost: the battery will run down in half the time. This is because it has to supply twice the current that it did before.

What happens to the current?

When we connect one lamp to the battery it takes a current of 0.4 amps from the battery. When we connect the second lamp in parallel, it comes on with the same brightness. So it is also taking a current of 0.4 amps.

But now, what is the current from the battery? At points X and Y, the current adds up. So the current being taken from the battery is 0.8 amps i.e. twice as much as it was before. You can see that the two currents flow parallel to one another.

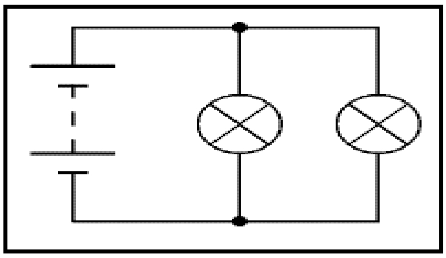


What happens to the current in a parallel circuit?

Activity: **Now test yourself by doing this activity.**

Circle the letter of the correct answer.

1. What kind of circuit is this?



A. Ring Main B. Series Circuit

C. Parallel circuit D. None of these

2. What can you say about the voltages in a parallel circuit?

A. It is the same across each component
B. There is no voltage in a parallel circuit
C. It is the same across each branch as the supply voltage
D. When you add the voltage across each component together it is equal to the supply voltage

3. From Q.1 diagram, what is the voltage across each of the lamps, if the battery can supply a voltage of 6 volts?

A. 2 volts B. 3 volts

C. 6 volts D. 12 volts

4. From Q. 1 diagram, what current is drawn from the battery if the current through the first lamp is 1 Amp and the current through the second lamp is 3 Amps?

A. 1 Amp B. 2 Amps

C. 3 Amps D. 4 Amps

5. What can you say about the current in a parallel circuit?

   A. None of these.

   B. It is the same everywhere

   C. it is the same in each component.

   D. The supply current is equal to the current in each branch added together.

6. What happens when one light goes out, or is removed in a parallel circuit?

   A. nothing happens

   B. all the lights go out

   C. only that light goes out

   D. half of the lights go out

7. What arrangement would make the brightest light?

   A. 2 bulbs connected in series to 1 battery

   B. 2 batteries connected in series to 1 bulb

   C. 2 bulbs connected in parallel to a 1 battery

   D. 2 batteries connected in parallel with 1 bulb

CHECK YOUR WORK. ANSWERS ARE AT THE END OF LESSON 6.

Summary

You have come to the end of lesson 5. In this lesson, you have learnt

- a parallel circuit is a circuit in which there are at least two independent paths in the circuit to get back to the source.
- in a parallel circuit every component is connected separately in its own loop going from one end of the cell or battery to the other end.
- an advantage of parallel circuits is that the burnout or removal of one bulb does not affect the other bulbs in parallel circuits. They continue to operate because there is still a separate, independent closed path from the source to each of the other loads.
- in parallel circuits, more components may be added in parallel without the need for more voltage.
- the more components connected in parallel, the more energy is used.
- the voltages in parallel circuits are the same across each branch as the supply voltage.
- the current in a parallel circuit is equal to the current in each branch added together.

NOW DO PRACTICE EXERCISE 6 ON THE NEXT PAGE.

Practice Exercise 6

---

1. Define parallel circuits.

____

____

2. Differentiate series from parallel circuits.

Series	Parallel

3. What can you say about the current and the voltage in parallel circuits?

Current =____

Voltage = ____

4. **True or False. Write T if the statement is true and F if it is false.**

_____a. Parallel circuits are characterised by the fact that there are multiple pathways by which charge can travel from the + terminal to the - terminal.

_____b. During any single loop of charge around a parallel circuit, the charge will pass through each resistor in the circuit.

_____c. The overall resistance of a circuit increases as more and more resistors are placed in parallel in the circuit.

_____d. The total current in a circuit increases as more and more resistors are placed in parallel in the circuit.

_____e. Suppose that three identical resistors with a resistance of 3-ohms are placed in parallel with a 12-Volt battery. The current in the circuit is 1 Amp.

_____f. Suppose that three identical resistors with a resistance of 3-ohms are placed in parallel with a 12-Volt battery. The electric potential difference across each resistor is 12 Volts.

_____g. Suppose that two identical resistors are placed in parallel with a 12-Volt battery. The overall current in the circuit is 6 amps. The resistance of each resistor is 4 ohms.

CHECK YOUR WORK. ANSWERS ARE AT THE END OF TOPIC 2.

Answers to Activity

1. C
2. C
3. C
4. D
5. A
6. C
7. D

Lesson 7: Ohm's Law

Welcome to Lesson 7. You have learned from the previous lessons the series and parallel circuits. A series circuit is a circuit where there is only one path from the source through all of the loads (light bulbs) and back to the source while a parallel circuit is a circuit in which there are at least two independent paths in the circuit to get back to the source. You also studied the resistance, current and voltage in these circuits. The relationship between these three is what you are going to learn.

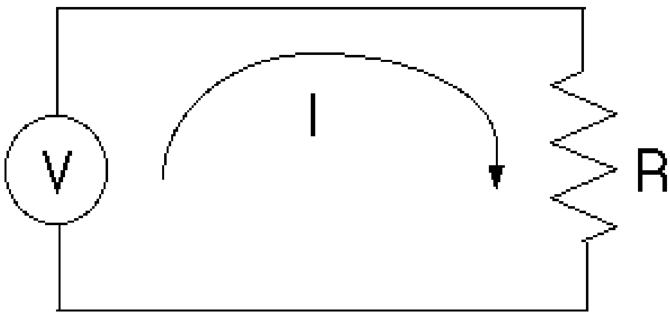
Your Aims:

- define Ohm's law
- calculate the resistance, current and voltage using Ohm's law
- explain the connection of resistance to the length and thickness of the wire.

Ohm's Law

The relationship between current, voltage, and resistance is given by **Ohm's law**. This law states that the amount of current passing through a conductor is directly proportional to the voltage across the conductor and inversely proportional to the resistance of the conductor.

To make a current flow through a resistance there must be a voltage across that resistance. Ohm's Law shows the relationship between the voltage (V), current (I) and resistance (R). It can be expressed as an equation and can be written in three ways:



$$V = I \times R \quad \text{or} \quad I = \frac{V}{R} \quad \text{or} \quad R = \frac{V}{I}$$

Where: V = voltage in volts (V) - the difference in volts between two locations

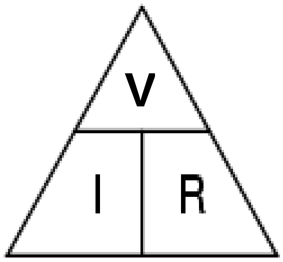
I = current in amps (A) - the amount of current in amperes that is flowing between two locations.

R = resistance in ohms (Ω) – the resistance of the conductor between two locations.

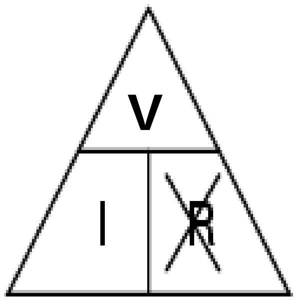
If any **two** of the quantities are known, the third can be calculated.

Ohm's Law is a very simple and useful tool for analysing electric circuits. It is used so often in the study of electricity and electronics that you need to be committed to memory. For those who are not yet comfortable with algebra, there is a trick to remembering how to solve for any one quantity, given the other two.

First, arrange the letters V, I, and R in a triangle like this:

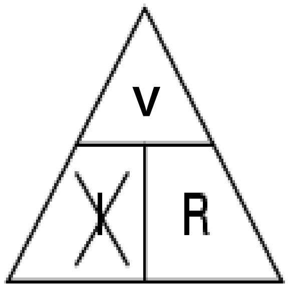


If you know V and I, and wish to determine R, just eliminate R from the picture and see what is left:



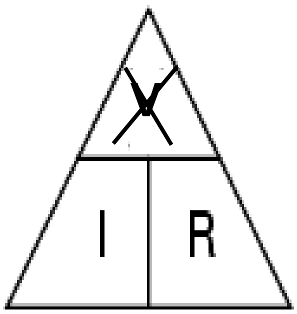
$$R = \frac{V}{I}$$

If you know V and R, and wish to determine I, eliminate I and see what is left:



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

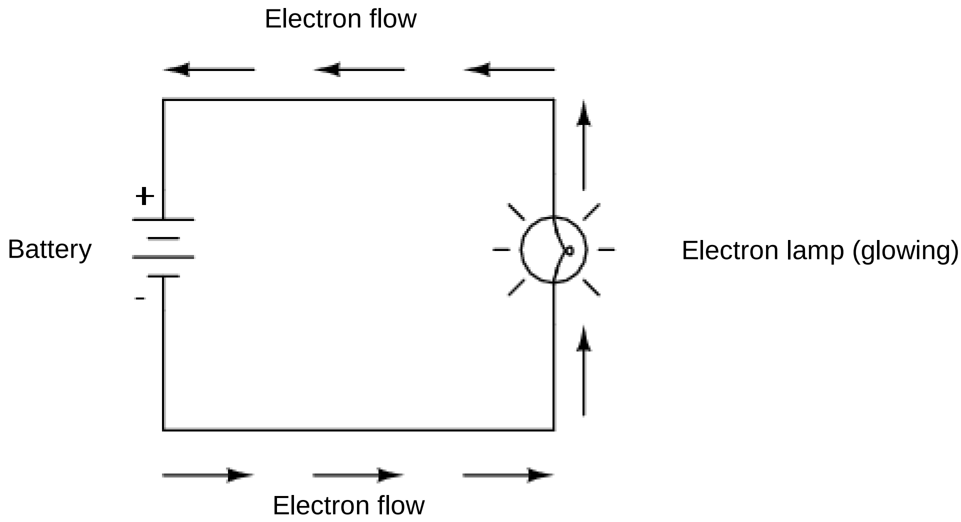
Lastly, if you know I and R, and wish to determine V, eliminate V and see what is left:



$$V = I\,R$$

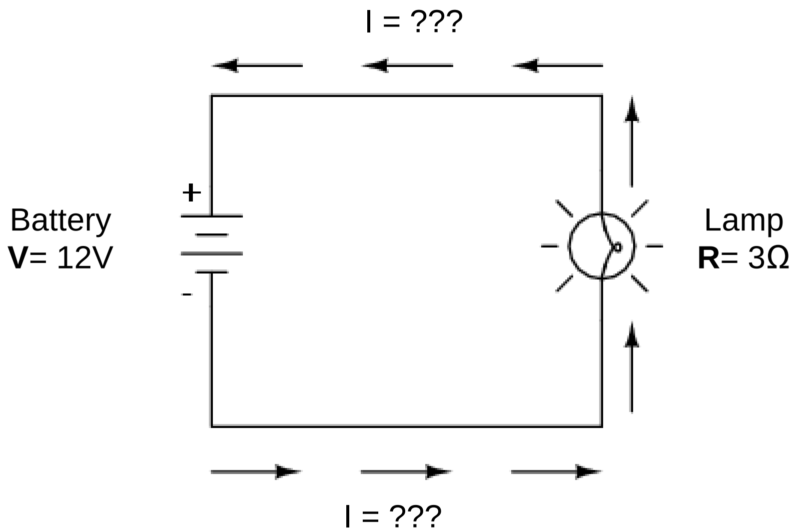
This tip can make your first calculations a little easier to remember.

Let us see how these equations might work to help us analyse simple circuits:



In the above circuit, there is only one source of voltage (the battery, on the left) and only one source of resistance to current (the lamp, on the right). This makes it very easy to apply Ohm's Law. If we know the values of any two of the three quantities (voltage, current, and resistance) in this circuit, we can use Ohm's Law to determine the third.

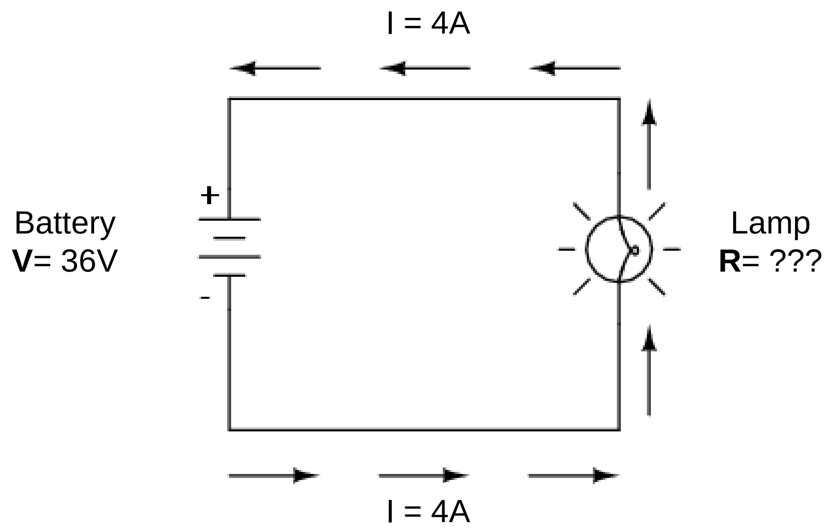
In this first example, we will calculate the amount of current (I) in a circuit, given values of voltage (V) and resistance (R):



What is the amount of current (I) in this circuit?

$$\mathbf{I} = \frac{V}{R} = \frac{12V}{3\Omega} = 4A$$

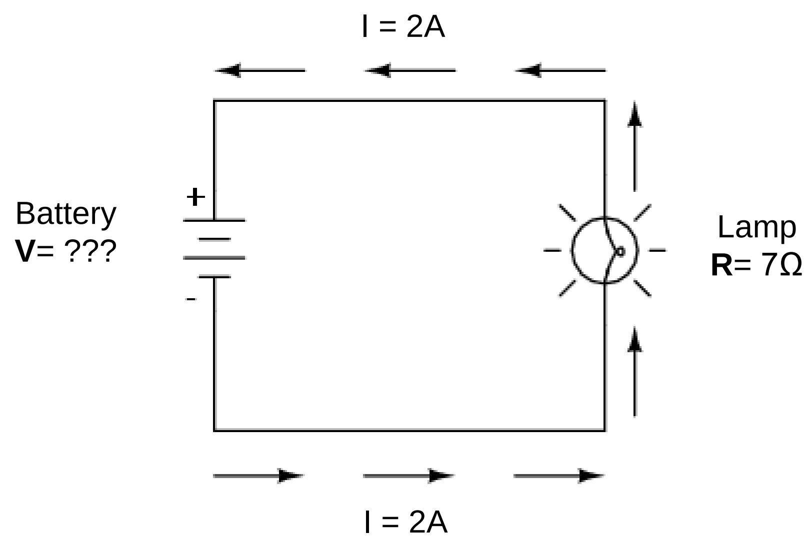
In this second example, we will calculate the amount of resistance (R) in a circuit, given values of voltage (V) and current (I):



What is the amount of resistance (R) offered by the lamp?

$$R = \frac{V}{I} = \frac{36V}{4A} = 9\Omega$$

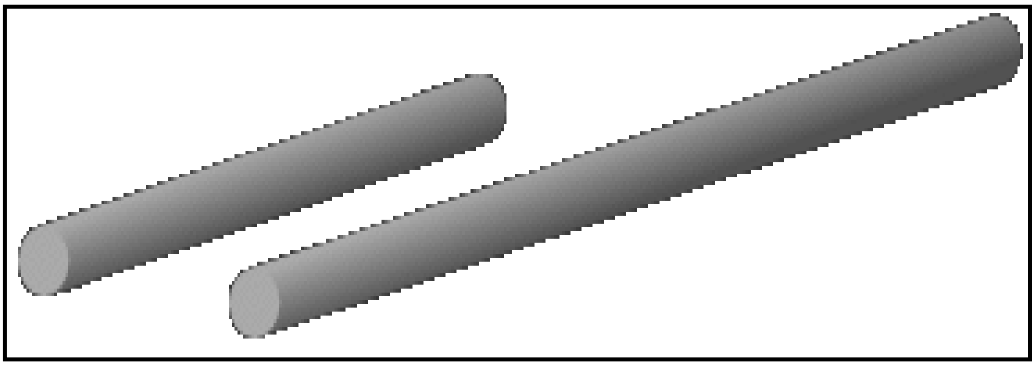
In the last example, we will calculate the amount of voltage supplied by a battery, given values of current (I) and resistance (R):



What is the amount of voltage provided by the battery?

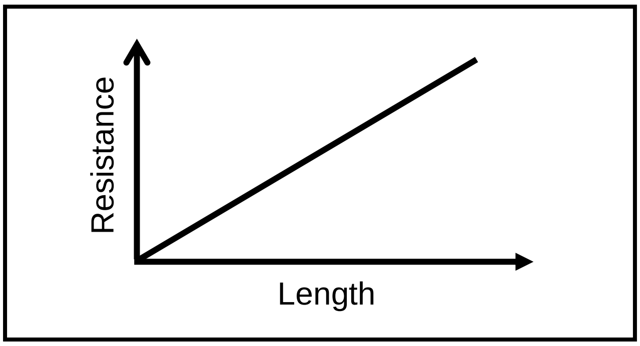
Resistance and Length

Resistance increases with length because the electrons have further to go, so suffer greater collisions with atoms in the material. Look at these wires:



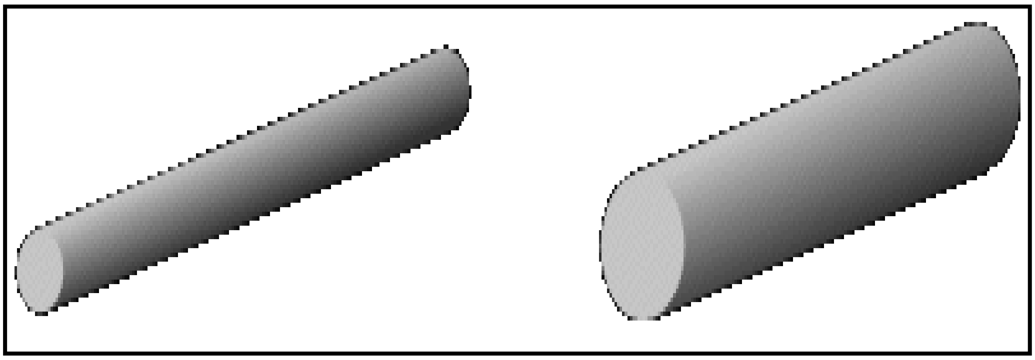
Electrons moving through the short wire only feel resistance for a short time compared to the longer one. This means its resistance is less.
Think of the long wire as being a traffic jam on a motorway. It takes ages to get to where you are going. The short wire, however, is like a queue at a roundabout - you soon get where you want to be.

If we plot a graph to show how resistance varies with length, we should find:



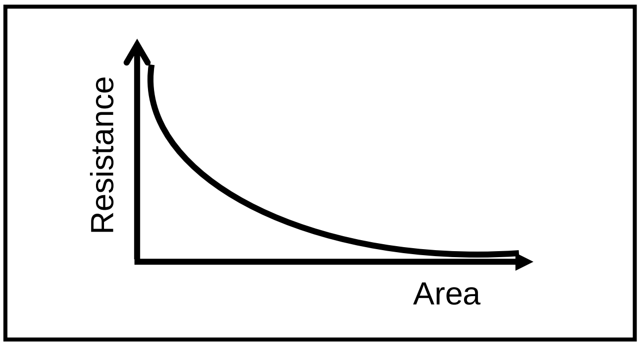
The graph passes through the origin (where l=0 so R=0) which makes sense. However much we increase the length (e.g. 3×) the resistance will increase by the same amount.

Resistance and Area
Resistance decreases if the cross-sectional area is increased. This sometimes confuses people, as it is not obvious. Look at these two pieces of metal:



The narrow wire has fewer paths available for the electrons to move through. Whilst the larger wire has many more routes they could take. This makes conduction easier.
Think of the fat wire as being a 6-lane motorway. There is always somewhere to go, so going quickly is easy. The thin wire is like a narrow countryside lane. Movement is restricted, so you have to drive slowly.

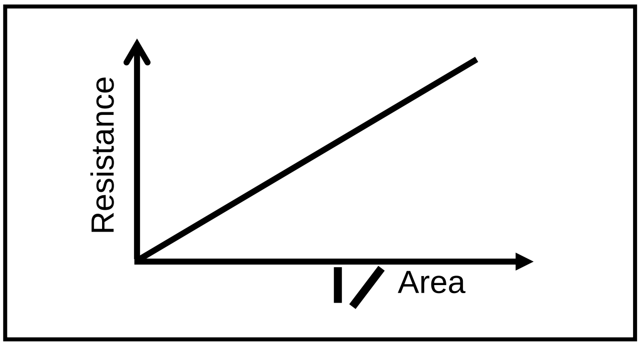
If we plot a graph to show how resistance varies with area, we should find:



Unlike the graph for length, the line does not pass through the origin. However

$R \propto \frac{1}{A}$ means that a graph of *R* against **1/A** will show direct proportion.

If we plot a graph to show how resistance varies with **1/area**, we find:



Like the length graph, the line passes through the origin. This tells us that however much we increase the cross-sectional area, the resistance will decrease by the same amount.

Remember:

- current is what flows on a wire or conductor. it flows from negative to positive on the surface of a conductor and it is measured in amperes or amps (A).
- voltage is the difference in electrical potential between two points in a circuit.it is the push or pressure behind current flow through a circuit, and is measured in volts (V).
- resistance determines how much current will flow through a component. a very high resistance allows a small amount of current to flow. a very low resistance allows a large amount of current to flow. resistance is measured in Ω ohms.
- the **longer** a conductor, the **greater** its resistance. specifically, resistance is directly proportional to length.
- the **thicker** a conductor, the **lower** its resistance. specifically, resistance is inversely proportional to its cross-sectional area.
- you must use thick wire to carry a large current, or the wire will get too hot and melt.
- with **resistance steady**, current follows voltage (an increase in voltage means an increase in current and vice versa).
- with **voltage steady**, changes in current and resistance are opposite (an increase in current means a decrease in resistance and vice versa). with **current steady**, voltage follows resistance (an increase in resistance means an increase in voltage).

Activity: **Now test yourself by doing this activity.**

Circle the letter of the correct answer.

1. For a fixed supply voltage the current flowing through a conductor will decrease when

   A. length of the conductor is reduced.
   B. length of the conductor is increased.
   C. cross-sectional area of the conductor is increased.
   D. cross-sectional area is increased and length is decreased.

2. Ohm's law for current is

   A. I = V / R   B. I = R / V
   C. I = V R   D. I = R V

3. Ohm's law for voltage is

   A. V = I2R   B. V = R / I
   C. V = I R   D. V = I / R

4. Ohm's law for resistance is

   A. R = I V   B. R = V / I
   C. R = I / V   D. R = V I

5. For a circuit with I = 2 A and *V* = 40 V, the resistance is

   A. R = 20 Ω   B. 40 Ω
   C. R = 60 Ω   D. 80 Ω

6. For a circuit with R = 10 Ω and V = 40 V, the current is

   A. I = 0.25 A   B. I = 2 A
   C. I = 3 A   D. I = 4 A

7. For a circuit with I = 2 A and R = 40Ω, the voltage is

   A. V = 20 V   B. V = 40 V
   C. V = 60 V   D. V = 80 V

8. A resistance of 3.3 MΩ is connected across a 500 V source. The resulting current is approximately

A. 15.1 µA B. 151 µA

C. 66 mA D. 660 mA

9. When 12 V are applied across a 68 Ω resistor, the current is

A. 8.16 mA B. 17.6 mA

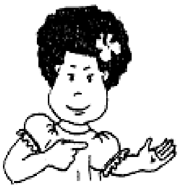
C. 176 mA D. 816 mA

10. What is the approximate filament resistance of a light bulb if it operates from a 110 V source and 0.6 A of current is flowing?

A. 6.6 Ω B. 18.3 Ω

C. 66 Ω D. 183 Ω

CHECK YOUR WORK. ANSWERS ARE AT THE END OF LESSON 7.



Summary

You have come to the end of lesson 7. You have learnt that:

- ohm's law states that the amount of current passing through a conductor is directly proportional to the voltage across the conductor and inversely proportional to the resistance of the conductor.
- ohm's law can be expressed as an equation and can be written in three ways:

$$V = I \times R \quad \text{Or} \quad I = \frac{V}{R} \quad \text{Or} \quad R = \frac{V}{I}$$

- current is what flows on a wire or conductor. It flows from negative to positive on the surface of a conductor and it is measured in amperes or amps (A).
- voltage is the difference in electrical potential between two points in a circuit. It is the push or pressure behind current flow through a circuit, and is measured in volts (V).
- resistance determines how much current will flow through a component. A very high resistance allows a small amount of current to flow. A very low resistance allows a large amount of current to flow. Resistance is measured in ohms.(Ω).
- the longer a conductor, the greater its resistance. Specifically, resistance is directly proportional to length.
- the thicker a conductor, the lower its resistance. Specifically, resistance is inversely proportional to its cross-sectional area.
- you must use thick wire to carry a large current, or the wire will get too hot and melt.
- with resistance steady, current follows voltage (an increase in voltage means an increase in current and vice versa).
- with voltage steady, changes in current and resistance are opposite (an increase in current means a decrease in resistance and vice versa).
- with current steady, voltage follows resistance (an increase in resistance means an increase in voltage).

NOW DO PRACTICE EXERCISE 7 ON THE NEXT PAGE.

Practice Exercise 7

A. Define Ohm's Law

B. Circle the letter of the correct answer.

1. The formula to find I when the values of V and R are known is

   A. I=VR B. I=R/V

   C. V=IR D. I=V/R

2. An electric heater draws 3.5 A from a 110 V source. The resistance of the heating element is approximately

   A. 3.1 Ω B. 31 Ω

   C. 38.5 Ω D. 385 Ω

3. What is the voltage source for a circuit carrying 2 A of current through a 36 Ω resistor?

   A. 1. 8 V B. 7. 2 V

   C. 18 V D. 72 V

4. Approximately how much current flows through a 3.3 MΩ resistor across a 30 V source?

   A. 9 μA B. 90 μA

   C. 900 μA D. 9000 μA

5. How much voltage is needed to produce 2.5 A of current through a 200 Ω resistor?

   A. 8 V B. 50 V

   C. 80 V D. 500 V

6. How much resistance is required to limit the current from a 12 V battery to 3.6 mA?

   A. 2.2 Ω B. 3.3 Ω

   C. 22 Ω D. 33 Ω

C. Explain the connection of resistance to the length and thickness of the wire.
Length

____

____

Thickness

____

____

CHECK YOUR WORK. ANSWERS ARE AT THE END OF TOPIC 2.

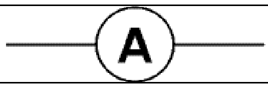
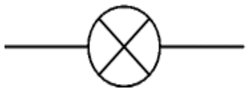
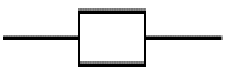
Answers to activity

1. B
2. A
3. C
4. B
5. A
6. D
7. D
8. B
9. C
10. D

Answer to Practice Exercises 5-7

Practice Exercise 5

A.

Name	Symbols	Functions
Fuse		A safety device which will 'blow' (melt) if the current flowing through it exceeds a specified value
Ammeter		An ammeter is used to measure current.
Lamp (Indicator)		A transducer which converts electrical energy to light. This symbol is used for a lamp which is an indicator, for example a warning light on a car dashboard.
Ohmmeter		An ohmmeter is used to measure resistance. Most multimeter's have an ohmmeter setting.
Voltmeter		A voltmeter is used to measure voltage. The proper name for voltage is 'potential difference', but most people prefer to say voltage.
Resistor		A resistor restricts the flow of current, for example to limit the current passing through an LED. A resistor is used with a capacitor in a timing circuit.

B.

1. The current in a series circuit is the same everywhere. An ammeter placed anywhere in a series circuit always gives the same reading.

$$A_1 = A_2 = A_3 = A_4$$

2. The voltage across all of the components in a series circuit adds up to the supply voltage from the cell or battery.

$$V_{sup} = V_1 + V_2 + V_3$$

3. You can calculate the total resistance of a series circuit by adding up the resistance of each component.

$$R_{total} = R_1 + R_2 + R_3$$

C.

1 (B.) 720 Ω

2. (C.) 3 A

3. (A.) at any point in the circuit

Practice Exercise 6

1. A **parallel circuit** is a circuit in which there are at least two independent paths in the circuit to get back to the source.

2.

Series	Parallel
All the bulbs will be on if the circuit is complete.	Individual bulbs in separate branches can be switched 'on' or 'off' regardless of the other bulbs.
If the circuit is incomplete because a bulb has failed or has been removed then all the bulbs will be off.	If one bulb fails, is removed, or switched off the other bulbs still work.

3. **Current** = the current in a parallel circuit is equal to the current in each branch added together.

   Voltage = the voltages in parallel circuits are the same across each branch as the supply voltage.

4. a. **T** b. **F** c. **F** d. **T**
   e. **F** f. **T** g. **T**

Practice Exercise 7

A. Ohm's law states that the amount of current passing through a conductor is directly proportional to the voltage across the conductor and inversely proportional to the resistance of the conductor.

B. 1. (D.) I=V/R 4. (A.) 9 μA
   2. (B.) 31 Ω 5. (D.) 500 V
   3. (D.) 72 V 6. (B.) 3.3 Ω

C. The thicker a wire/conductor, the lower its resistance. Specifically, resistance is inversely proportional to cross-sectional area. The longer a wire/conductor, the greater its resistance. Specifically, resistance is directly proportional to length.

REVISE TOPIC 2 USING THE MAIN POINTS ON THE NEXT PAGE.

REVIEW OF TOPIC 2: ELECTRIC CIRCUITS

Revise all the Lessons in this Topic and then do **ASSIGNMENT 5.**
Here are the main points to help you revise.

Lesson 5: Series Circuits

- Circuit symbols are used in circuit diagrams which show how a circuit is connected together electrically.
- Any device that consumes the energy flowing through a circuit and converts that energy into work is called a load.
- An electrical circuit is a closed loop formed by a power source, wires, a fuse, a load, and a switch.
- A series circuit is a circuit where there is only one path from the source through all of the loads (light bulbs) and back to the source.
- The electric current that flows through a complete series circuit can be measured using an ammeter.
- The current in a series circuit is the same everywhere. An ammeter placed anywhere in a series circuit always gives the same reading.

$$A_1 = A_2 = A_3 = A_4$$

- The voltage across all of the components in a series circuit adds up to the supply voltage from the cell or battery.

$$V_{sup} = V_1 + V_2 + V_3$$

- You can calculate the total resistance of a series circuit by adding up the resistance of each component.

$$R_{total} = R_1 + R_2 + R_3$$

Lesson 6: Parallel Circuits

- A parallel circuit is a circuit in which there are at least two independent paths in the circuit to get back to the source.
- In a parallel circuit every component is connected separately in its own loop going from one end of the cell or battery to the other end.
- An advantage of parallel circuits is that the burnout or removal of one bulb does not affect the other bulbs in parallel circuits. They continue to operate because there is still a separate, independent closed path from the source to each of the other loads.
- In parallel circuits, more components may be added in parallel without the need for more voltage.
- The more components connected in parallel, the more energy is used.
- The voltages in parallel circuits are the same across each branch as the supply voltage.
- The current in a parallel circuit is equal to the current in each branch added together.

Lesson 7: Ohm's Law

- Ohm's law states that the amount of current passing through a conductor is directly proportional to the voltage across the conductor and inversely proportional to the resistance of the conductor.
- Ohm's law can be expressed as an equation and can be written in three ways:

$$\boxed{V = I \times R} \quad \text{Or} \quad \boxed{I = \frac{V}{R}} \quad \text{Or} \quad \boxed{R = \frac{V}{I}}$$

- Current is what flows on a wire or conductor. It flows from negative to positive on the surface of a conductor and it is measured in (A) amperes or amps.
- Voltage is the difference in electrical potential between two points in a circuit. It is the push or pressure behind current flow through a circuit, and is measured in volts (V).
- Resistance determines how much current will flow through a component. A very high resistance allows a small amount of current to flow. A very low resistance allows a large amount of current to flow. Resistance is measured in ohms Ω.
- The longer a conductor, the greater its resistance. Specifically, resistance is directly proportional to length.
- The thicker a conductor, the lower its resistance. Specifically, resistance is inversely proportional to cross-sectional area.
- You must use thick wire to carry a large current, or the wire will get too hot and melt.
- With resistance steady, current follows voltage (an increase in voltage means an increase in current and vice versa).
- With voltage steady, changes in current and resistance are opposite (an increase in current means a decrease in resistance and vice versa).
- With current steady, voltage follows resistance (an increase in resistance means an increase in voltage).

REVISE WELL AND THEN DO TOPIC TEST 2 IN YOUR ASSIGNMENT 5.

TOPIC 3

USES OF ELECTRICITY

In this topic you will learn about:

- **lighting effects**
- **heating effects**
- **electromagnetism**

INTRODUCTION TO TOPIC 3: Uses of Electricity

Electricity is used to describe the behaviour of electrons and protons. The flow of electrons creates the current we use to power everything from radios to refrigerators.

Food, water and oxygen are essential to your survival. How about electricity? It is a part of life most of us just take for granted. We flip a switch or push a button and there is light.

Can you name all the ways you use electricity at home? We use electricity almost every minute from the time we get up in the morning until we go to bed at night. Take a look at all the things we depend on each day that need electricity:

In the kitchen:

Refrigerators

Dishwasher

Stoves

In the family room:

Lamps

Computers

Air conditioning

Outdoors:

Outdoor lighting

Electric lawn mower

Pool heater

So what would life be like without it? To understand just how important electricity is, let us explore more about its uses. Some questions will arise such as

- What are lighting and heating effects?
- How important are these effects in the production of electricity?
- What is electromagnetism? How is its application relevant to electricity?

In this Topic, you will find the answers to these questions and other questions relating to uses of electricity.

Lesson 8: Lighting Effects

Welcome to Lesson 8. There are many forms of energy and they can be converted into one another. For example electrical energy can be changed to light energy, heat energy or magnetic energy. In everyday life we find bulbs in lampshades or fluorescent tubes all around us in houses, offices, restaurants etc. You must have wondered what causes the bulb or the tube to light up? Actually they need the electricity to light up. Electricity passes through wires that are attached to them and it makes the bulbs and tubes glow. For this lesson, you will be learning about the lighting effects of electricity.

Your Aims:

- differentiate light bulbs from fluorescent tubes
- discuss the uses and features of different lightning devices

Light is a Kind of Energy

Electricity is one of the most important sources of energy. Appliances used in our day to day life are based on the principles of electricity. Lights, fans, motors, radios and television are some common appliances which work on electricity. Batteries produce electricity by converting chemical energy into electrical energy. It provides electricity to torches, transistors, toys, clocks and watches.

As you probably know, the Sun is a nuclear fireball spewing energy in all directions. The light that we see is simply one part of the energy that the Sun makes that our eyes can detect. When light travels between two places (from the Sun to the Earth or from a flashlight to the sidewalk in front of you on a dark night), energy makes a journey between those two points.

Sun

The energy travels in the form of waves (similar to the waves on the sea but about 100 million times smaller); a vibrating pattern of electricity and magnetism that we call electromagnetic energy.

If our eyes could see electricity and magnetism, we might see each ray of light as a wave of electricity vibrating in one direction and a wave of magnetism vibrating at right angles to it. These two waves travel in step and at the speed of light.

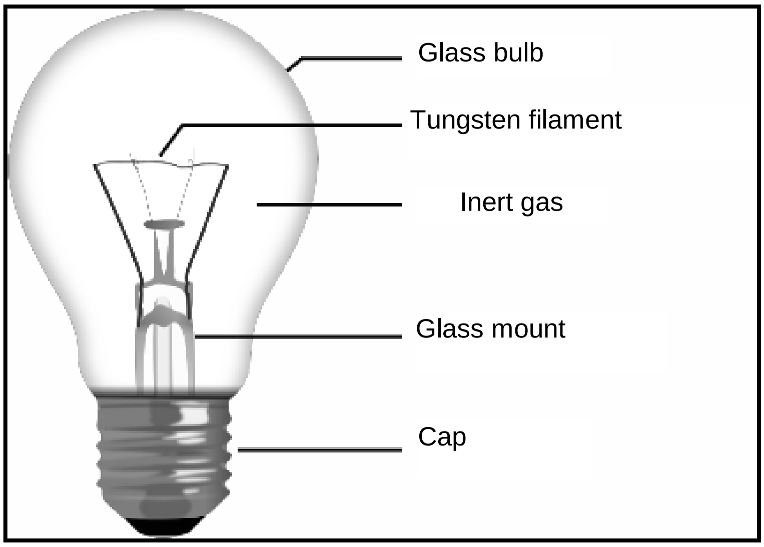
Light is made inside **atoms** when they get "excited". That is not excited in the silly, giggling sense of the word, but in a more specialized scientific sense. Think of the electrons inside atoms as a bit like fireflies sitting on a ladder. When an atom absorbs energy, for one reason or another, the electrons get promoted to higher energy levels. Visualise one of the fireflies moving up to a higher rung on the ladder.

Unfortunately, the ladder is not quite so stable with the firefly wobbling about up there, so the firefly takes little persuading to leap back down to where it was before. In so doing, it has to give back the energy it absorbed and it does that by flashing its tail.

Light Bulb Structure

Light bulbs have a very simple structure. At the base, they have two metal contacts, which connect to the ends of an electrical circuit. The metal contacts are attached to two stiff wires, which are attached to a thin metal **filament**. The filament sits in the middle of the bulb, held up by a **glass mount**. The wires and the filament are housed in a glass bulb, which is filled with an **inert gas**, such as **argon**.

When the bulb is hooked up to a power supply, an **electric current** flows from one contact to the other, through the wires and the filament. Electric current in a solid conductor is the mass movement of **free electrons** (electrons that are not tightly bound to an atom) from a negatively charged area to a positively charged area.



Light Bulb Structure

As the electrons zip along through the filament, they are constantly bumping into the atoms that make up the filament. The energy of each impact **vibrates** an atom -- in other words, the current **heats** the atoms up. A thinner conductor heats up more easily than a thicker conductor because it is more resistant to the movement of electrons.

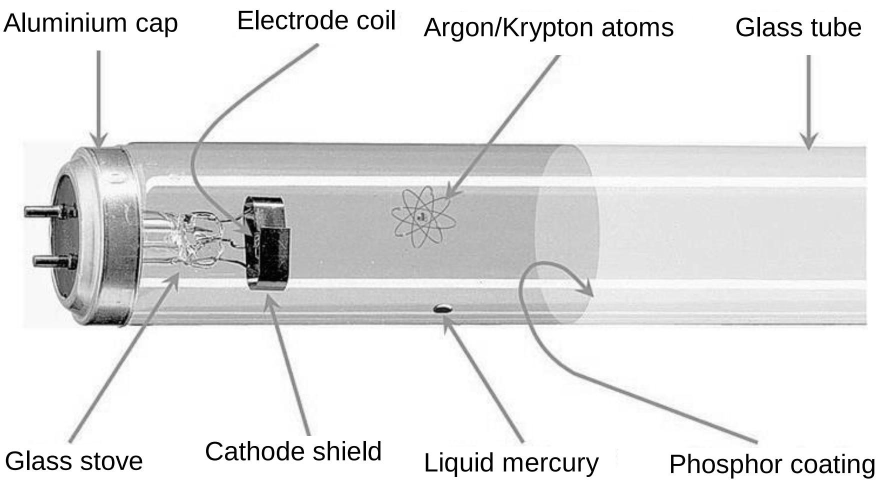
The filament in a light bulb is made of a long; incredibly thin length of **tungsten** metal. The tungsten is arranged in a **double coil** in order to fit it all in a small space. That is, the filament is wound up to make one coil, and then this coil is wound to make a larger coil. In a 60-watt bulb, the coil is less than an inch long. Tungsten is used in nearly all incandescent light bulbs because it is an ideal filament material.

Fluorescent lamps

You see fluorescent lighting everywhere these days -- in offices, stores, warehouses, street corners. You will even find fluorescent lamps in peoples' homes. But even though they are all around us, these devices are a total mystery to most people. Just what is going on inside those white tubes? How fluorescent lamps emit such a bright glow without getting scalding hot like an ordinary light bulb? Why fluorescent lamps are more efficient than incandescent lighting? Let us see how technology is used in these sorts of lamps.

Down the tubes

The central element in a fluorescent lamp is a **sealed glass tube**. The tube contains a small bit of **mercury** and an inert gas, typically **argon**, kept under very low pressure. The tube also contains a **phosphor powder**, coated along the inside of the glass. The tube has two **electrodes**, one at each end, which are wired to an electrical circuit.

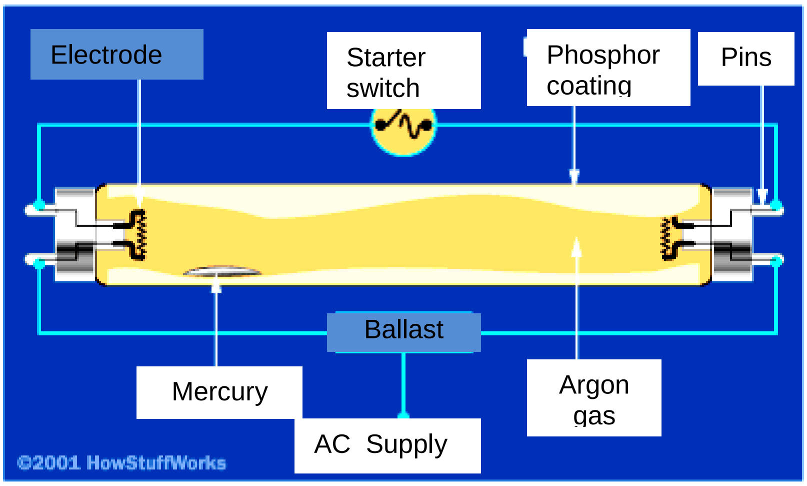


Parts of fluorescent lamp

When you turn the lamp on, the current flows through the electrical circuit to the electrodes. There is a considerable voltage across the electrodes, so electrons will migrate through the gas from one end of the tube to the other. This energy changes some of the **mercury** in the tube from a liquid to a gas. As electrons and charged atoms move through the tube, some of them will **collide** with the gaseous mercury atoms. These collisions excite the atoms, bumping electrons up to higher energy levels. When the electrons return to their original energy level, they release light photons.

Phosphors are substances that give off light when they are exposed to light. When a photon hits a phosphor atom, one of the phosphor's electrons jumps to a higher energy level and the atom heats up. When the electron falls back to its normal level, it releases energy in the form of another photon. In a fluorescent lamp, the emitted light is in the visible spectrum -- the phosphor gives off **white light** we can see.

Conventional light bulbs also emit a good bit of ultraviolet light, but they do not convert any of it to visible light. Consequently, a lot of the energy used to power a light bulb is wasted. A **fluorescent lamp** puts this invisible light to work, and so is **more efficient**. Light bulbs also lose more energy through heat emission than do fluorescent lamps. Overall, a typical fluorescent lamp is four to six times more efficient than an incandescent light bulb. As we have seen, the entire fluorescent lamp system depends on an electrical current flowing through the gas in the glass tube.



Remember:
Incandescent light bulbs are terribly inefficient, turning only 5% of the electricity they consume into light. Fluorescent lamps are better, using up to 25% of its energy as light.

Lighting Devices

1. Flashlight

This heavy duty torch offers combine's superior technique along with remarkable material. It helps make your work and journey convenient by offering defect less performance. Highly useful in journeys, night time, factories and mines.

Features and specification

- Bright focused long range beam.
- Suitable for factories, farms, shops, hospitals and houses.
- Powered by bright white.
- Long battery life.
- Low power consumption and eco-friendly design.

2. Rear Turn/Tail/Stop Tail Light

This device can be used as turn, tail, and stop light in vehicles. It is brighter and efficient than conventional tail lights using incandescent lamps. Moreover, it is more eco-friendly than its conventional counterparts.
Features and specification

- It is brighter than the filament bulb based tail lights.
- Shock and vibration resistant.
- Very low power consumption.
- Waterproof covering.
- Eco-friendly product.

3. Rechargeable Lamp

This durable product combines the bright and pleasant light along with the recharging facility. This lamp can be used in homes and shops especially during the power failures.

Features and specification

- It is water, oil and shock resistant.
- Can work up to 8 hours after a single recharge.
- Eco-friendly.
- In-built charging indicator.
- Comes with a charger.

4. Solar Home Lighting System

This system can be used to fulfil the electricity needs at home, offices, schools, clinics and it can also be used to run electrical devices like TV, computer, refrigerator and others.

Features and specification

- Both solar as well as electric input.
- Easy to install and virtually free from maintenance.
- Environment friendly device.
- Longer lifespan.

5. Solar Camp Light

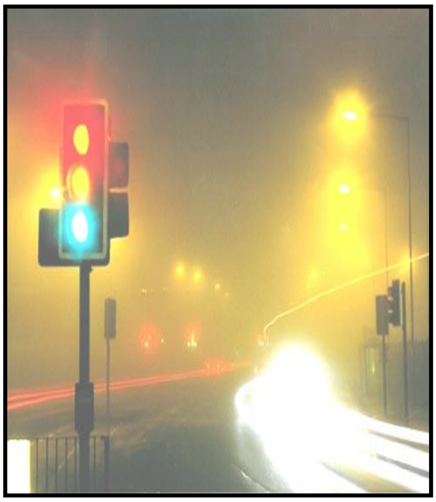
Solar camp lights are suitable for isolated homes, shops, restaurants, hospitals, picnic spots, farm houses, military outposts and other indoor and outdoor purposes. A solar camping light provides a reliable and long lasting earth-friendly outdoor lighting source.

Features and specification

- Rechargeable batteries (1.2V) store the energy to light the lantern.
- Encompassed with plastic body and input voltage of 110-220 V.

- Solar charge for one day, could light for 24 hours.
- Green energy lighting and long span lifetime (25 years).
- Does not need any fuel, gas and flame.
- Easy to operate, compact size and robust in design.

6. Traffic Lights



These powered traffic lights dissipate very little heat, are highly energy efficient and eco-friendly. They can be used for a variety of application in traffic lights, in road, rail, aviation traffic control office equipments, boilers and other measuring equipments.

Features and specification

- Input voltage range 90-264VAC.
- Power Dissipation 27W.
- Long life more than 60,000 hours.

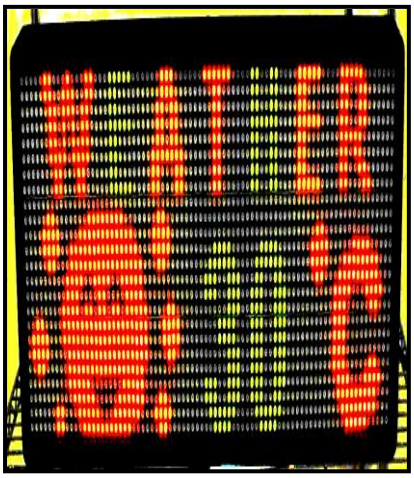
7. Solar Mobile/Laptop Charger

This solar charger uses solar cells to convert solar energy into electrical energy and then use it to charge the devices. These can be custom made for any portable electronic device, the only flip side is that they cannot supply direct electricity to any of these devices; their function is limited to charging portable devices like laptops, ipods, mobile phones.

Features and specification

- Input voltage 100V – 240V ac.
- Charging time is around one hour.
- Environment friendly and energy efficient device

8. Clock and Temperature Displays



Digital Clock is the perfect solution for a wide range of applications where accurate, synchronised time is required. Now all your clocks can display the same precise, legal time, whether in the office, factory, and warehouse, school or retail business.

It may be used as stand-alone time displays, or synchronised to a single master clock or PC and provides a variety of time zones with 12 or 24-hour display formats. With the battery backup capability, its accuracy is unaffected by power failure, and maintains accurate time as soon as power is restored.

Features and specification

- 12 or 24-hour time format switch selectable.
- Keeps all clocks synchronised.
- Adjustable high/low luminance.
- Set up time to start or close the clock display accordingly.
- With cell button battery to keep time running.

Activity: **Now test yourself by doing this activity**

Choose the letter of the correct answer.

1. Substances whose atoms have more free electrons are called __________.

A.	conductors	B.	insulators
C.	electrolytes	D.	semiconductors

2. The filament of bulb is made of __________.

A.	Mercury	B.	Copper
C.	Tungsten	D.	Aluminium

3. The device that maintains electric potential difference between two points is called electric __________.

A.	cell	B.	circuit
C.	current	D.	potential difference

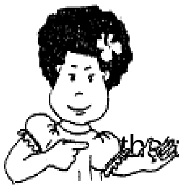
4. The central element is a fluorescent bulb is called __________.

A.	filament	B.	double coil
C.	glass mount	D.	sealed glass tube

5. __________ are substances that give off light when they are exposed to light.

A.	Argon	B.	Mercury
C.	Inert gas	D.	Phosphors

CHECK YOUR WORK. ANSWERS ARE AT THE END OF LESSON 7.



Summary

You have come to the end of lesson 8. In this lesson you have learnt

- electricity is one of the most important sources of energy
- sun is a nuclear fireball spewing energy in all directions. The energy travels in the form of waves.
- light is made inside atoms when they get "excited".
- the filament in a light bulb is made of a long; incredibly thin length of tungsten metal.
- tungsten is used in nearly all incandescent light bulbs because it is an ideal filament material.
- phosphors are substances that give off light when they are exposed to light.
- incandescent light bulbs produce light from a heated filament while fluorescent lamps produce light by way of a gas discharge.
- incandescent light bulbs are much cheaper than fluorescent lamps.
- incandescent light bulbs produce a warmer light than fluorescent lamps.
- fluorescent lamps are more efficient using up to 25% of its energy as light compared to incandescent light bulbs which turn only 5% of the electricity they consume into light.
- fluorescent lamps produce lesser heat than incandescent bulbs that is why fluorescent lamps are more efficient.
- fluorescent lamps last longer than incandescent light bulbs.

NOW DO PRACTICE EXERCISE 8 ON THE NEXT PAGE.

Practice Exercise 8

1. Write incandescent light bulbs or fluorescent lamps to fill the table below.

	Incandescent light bulbs /fluorescent lamps
Produce light from a heated filament.	
Produce light by gas discharge.	
Produce warmer light.	
Produce lesser heat.	
Much cheaper.	
More efficient.	
Last longer.	

2. Give two (2) features of the following lighting devices.

A. Rechargeable Lamp

1. ______________________

2. ______________________

B. Solar Home Lighting System

1. ______________________

2. ______________________

C. Clock and Temperature Display

1. ______________________

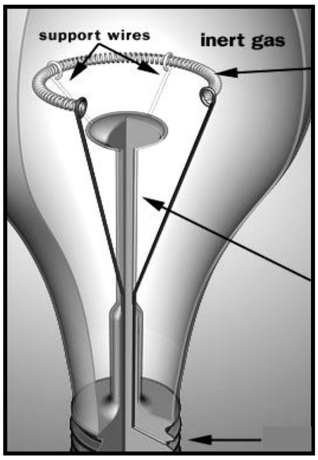
2. ______________________

3. Label the diagram.

A. ______________

B. ______________

C. ______________



A

B

C

CHECK YOUR WORK. ANSWERS ARE AT THE END OF TOPIC 3

Answers to activity

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

Lesson 9: Heating Effects

Welcome to Lesson 9. We use many devices in which electrical energy is converted into heat energy. When electric current is passed through a wire, it is heated up and the electrical energy is converted into heat energy. The devices like the filament of an electric heater, geyser, light bulb utilize this 'heating effect of current'. Why is heat produced when current is passed through a conductor? For this lesson, you will learn the answer to this question and other questions pertaining to heating effects of electric current.

Your Aims:

- explain heating effects
- describe the application of heating devices

Heating Effect of Electric Current

Energy exists in various forms such as mechanical energy, heat energy, chemical energy, electrical energy, light energy and nuclear energy. According to the law of conservation of energy, energy can be transformed from one form to another.

In our daily life we use many devices where the electrical energy is converted into heat energy, light energy, chemical energy or mechanical energy.

An oven

When an electric current is passed through a metallic wire like filament of an electric heater, oven or geyser, the filament gets heated up and here electrical energy is converted into heat energy. This is known as 'heating effect of current'. It is a common experience that a wire gets heated up when electric current flows through it. Why does this happen?

Why is heat produced when current is passed through a conductor?

A metallic conductor has a large number of free electrons available in it. When a potential difference is applied across the ends of a wire, the free electrons begin to drift from a region of low potential to a region of high potential. These electrons collide with the positive ions (the atoms which have lost their electrons). These collisions transfer the energy of the electron to the positive ions which begin to vibrate more violently. As a result, heat is produced.

The greater the number of electrons flowing per second, the greater will be the rate of collisions and so more heat is produced. When the cross sectional area of the conductor is greater, collisions is avoided and hence less heat is produced.

Application of the Heating Effect of Current

The heating effect of current has many practical applications. It is utilised in the electrical heating appliances such as electric iron, room heaters and water heaters. All these heating appliances contain coils of high resistance wire made of nichrome alloy. When these appliances are connected to power supply by insulated copper wires then a large amount of heat is produced in the heating coils. This is because they have high resistance, but a negligible heat is produced in the connecting wires because the wires have low resistance.

1. Electric fuse

An 'electric fuse' is an important application of the heating effect of current. When the current drawn in a domestic electric circuit increases beyond a certain value, the fuse wire gets over heated, melts and breaks the circuit. This prevents fire and damage to various electrical appliances.

An electric fuse

2. Electric iron

An electric iron used for ironing clothes consists of a coil of high resistance covered by insulating mica sheets and kept inside heavy metal block. When electric current passes through the coil it gets heated. The iron metal block gets hot and can be used for ironing clothes.

An electric iron

3. Electric bulb

An electric light bulb contains a thin filament of metal like tungsten. It has high melting point. When current passes through the filament it is heated to high temperature and emits light. This is the principle on which electric incandescent light bulb works.


An electric bub

4. Electric space heater

A space heater is a self-contained device for heating an enclosed area. Space heating is generally employed to warm a small space, and is usually held in contrast with central heating, which warms many connected spaces at once. It is usually portable or wall-mounted and often seen in hotel rooms.

It may have ceramic or nichrome heating elements, and a blower to improve heat transfer. These often

An electric space heater

employ efficient heat pumps, which use reverse-cycle air conditioning to transfer heat to the inside from the outside.

5. Fan heaters

A fan heater, also called a forced convection heater includes an electric fan to speed up the airflow. This reduces the thermal resistance between the heating element and the surroundings faster allowing heat to be transferred more quickly. They operate with considerable noise caused by the fan. They have a moderate risk of ignition hazard in the event that they make unintended contact with furnishings. This type of heater is a good choice for quick heating of enclosed spaces.

A fan heater

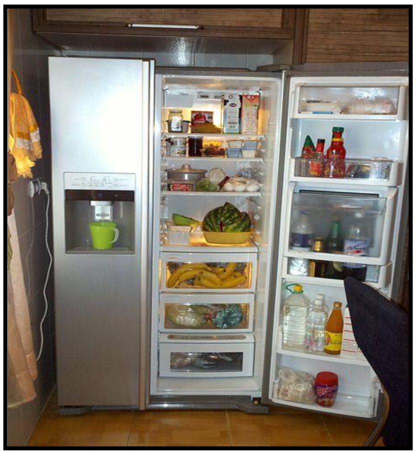
6. Microwave oven

A microwave oven, or simply a microwave, is a kitchen appliance that heats food by dielectric heating. This is accomplished by using microwave radiation to heat polarised molecules within the food. This excitation is fairly uniform, leading to food being more evenly heated throughout. Basic microwave ovens heat foods quickly and efficiently, but, unlike conventional ovens, do not brown or bake food. This makes them unsuitable for cooking certain foods, or to achieve certain culinary effects.

A microwave oven

7. Refrigerator

A refrigerator (commonly abbreviated as fridge) is a cooling apparatus. This common household appliance consists of a thermally insulated compartment and a heat pump which transfers heat from the inside of the fridge to its external environment (that is the room in which it is located); so that the inside of the fridge is cooled to a temperature below the ambient temperature of the room. Cooling is a popular food storage technique in developed countries and works by decreasing the reproduction rate of bacteria. The device is thus used to reduce the rate of spoilage of foodstuffs.



A refrigerator

8. Kitchen stove

A kitchen stove, cooking stove, cook stove, or cooker is a kitchen appliance designed for the purpose of cooking food. Kitchen stoves rely on the application of direct heat for the cooking process and may also contain an oven, used for baking. In the industrialised world stoves replaced open fires and braziers as a source of more efficient and reliable heating. Modern kitchen stoves have both burners on the top and an oven.

A kitchen stove

9. Tankless water heater

Tank less water heaters, also called continuous flow, inline, flash, on-demand or instant-on water heaters, are also available and gaining popularity. These water heaters instantly heat water as it flows through the device, and do not retain any water internally except for what is in the heat exchanger coil.


A tankless water heater

Tank less heaters are often installed throughout a household at more than one point-of-use. The main advantages of tank less water heaters are a continuous flow of hot water and energy savings (as compared to a limited flow of continuously heating hot water from conventional tank water heaters).

10. Heat pump

A heat pump is a machine or device that diverts heat from one location (the 'source') at a lower temperature to another location (the 'sink' or 'heat sink') at a higher temperature using mechanical work or a high-temperature heat source. A heat pump can be used to provide heating or cooling. In other words a heat pump can change, which coil is the condenser and which the evaporator. This is normally achieved by a reversing valve. In cooler climates it is common to have heat pumps that are designed only to provide heating.


A heat pump

11. Washing machine

Washing machines wash clothes using a mixture of heated water, detergent action and mechanical action. If a washing machine possesses water heating function, the process of water heating takes the largest portion of its total energy consumption.


A washing machine

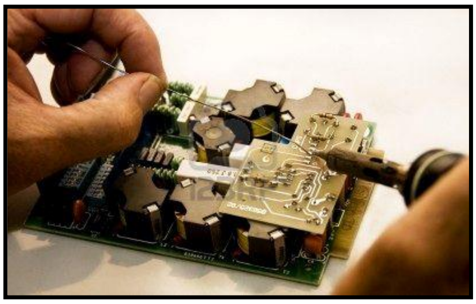
The technology of washing machines is mature, but further improvement are being made in reducing the temperature and quantity of water needed, reducing the size of the structure, optimisng the power of the motor, applying electronic controls and optimising the agitation phase in the washing cycle.

12. Soldering

In industry soldering, welding, cutting, drilling and working of electric furnaces are based on heating of electric current.

13. Surgery

In surgery, a fine heated platinum wire is used for cutting tissues much more efficiently than knife.


Working on electronic furnaces

Activity: Now test yourself by doing this activity.

Circle the letter of the correct answer.

1. If you run a refrigerator in a closed room with the refrigerator door open, the room temperature will __________.

   A. increase B. decrease

   C. increase then decrease D. decrease then increase

2. When heat is added to boiling water, the water temperature

   A. increases B. decreases

   C. stays the same D. will be different

3. Will a can of beverage cool faster in the coldest part of a refrigerator?

   A. Correct B. Wrong

   C. Sometimes D. Nothing will happen

4. A device that transforms electrical energy to mechanical energy is a __________.

   A. motor B. magnet

   C. generator D. transformer

5. When there is an electric current passing through a wire, the particles moving are __________.

   A. ions B. atoms

   C. protons D. electrons

6. A positive charge released from rest

   A. does not move.
   B. moves towards the regions of lower potential.
   C. moves towards the regions of equal potential.
   D. moves towards the regions of higher potential.

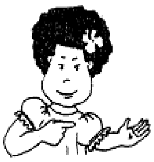
7. The free electrons of a metal

   A. are free to fall into the nuclei.
   B. do not collide with each other.
   C. are free to escape through the surface.
   D. are free to move anywhere in the metal.

8. The current in a wire

   A. depends only on the resistance of the wire.
   B. depends only on the potential difference applied.
   C. depends on both resistance and potential difference
   D. does not depend on resistance and potential difference

CHECK YOUR WORK. ANSWERS ARE AT THE END OF LESSON 9.



Summary

You have come to the end of lesson 9. In this lesson you have learnt that:

- the law of conservation of energy states that energy can be transformed from one form to another.
- when electric current is passed through a wire, like filament of an electric heater, oven or geyser, the filament gets heated up and electrical energy is converted into heat energy. This is known as 'heating effect of current'.
- when the cross sectional area of the conductor is greater, collisions is avoided and hence less heat is produced.
- when the current drawn in a domestic electric circuit increases beyond a certain value, the fuse wire gets over heated, melts and breaks the circuit. This prevents fire and damage to various electrical appliances.
- an electric iron consists of a coil of high resistance covered by insulating mica sheets kept inside a heavy metal block. When electric current passes through the coil it gets heated and the metal block can be used for ironing clothes.
- when current passes through the filament in an electric light bulb, it is heated to high temperature and emits light.
- a space heater is a self-contained device for heating an enclosed area; is generally employed to warm a small space, and is usually held in contrast with central heating, which warms many connected spaces at once.
- a fan heater includes an electric fan to speed up the airflow. This reduces the thermal resistance between the heating element and the surroundings faster allowing heat to be transferred more quickly.

- a microwave oven is a kitchen appliance that heats food by dielectric heating. This is accomplished by using microwave radiation to heat polarised molecules within the food.
- a refrigerator (commonly abbreviated as fridge) is a cooling apparatus, consists of insulated compartment and a heat pump which transfers heat from the inside of the fridge to its external environment.
- tank less water heaters instantly heat water as it flows through the device, and do not retain any water internally except for what is in the heat exchanger coil.
- a heat pump is a device that diverts heat from one location at a lower temperature to another location at a higher temperature using mechanical work or a high temperature heat source. A heat pump can be used to provide heating or cooling.

NOW DO PRACTICE EXERCISE 9 ON THE NEXT PAGE

Practice Exercise 9

1. What is a heating effect?

____

____

2. Describe the following heating devices.

a. Refrigerator

____

____

b. Electric iron

____

____

c. Space heater

____

____

d. Tank less water heater

____

____

e. Fan heater

____

____

f. Microwave oven

____

____

g. Fuse wire

____

____

h. Surgery

____

____

CHECK YOUR WORK. ANSWERS ARE AT THE END OF TOPIC 3

Answers to Activity

1. A
2. C
3. A
4. A
5. D
6. B
7. D
8. C

Lesson 10: Electromagnet

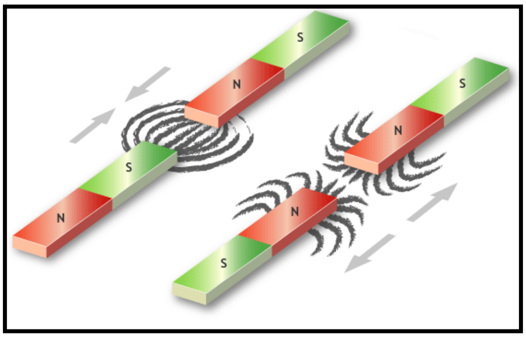
Welcome to Lesson 10. Electricity is very closely related to magnets. A **magnet** is a material that attracts other objects containing the elements iron, nickel or cobalt. All magnets have two ends, called poles. One pole is the magnetic north pole, and the other is the magnetic south pole. The pull of a magnet is strongest at its poles. Opposite poles attract each other and similar poles repel each other. As electrical current flows through a wire, a weak magnetic field forms around the wire. The magnetic field can be made stronger if the wire is coiled around an iron bar. As the electricity flows, it creates a temporary magnet called an **electromagnet**. Electric motors are electromagnets in use. They transform electrical energy into mechanical energy using magnets and a coil of wire. So, for this lesson, you will learn more about an electromagnet.

Your Aims:

- define electromagnet
- identify the basic parts of an electromagnet
- describe some applications of electromagnet
- list the factors that affect the strength of electromagnet

Magnetic Effect of Electric current

The "magnetic effect of current" means that "a current flowing in a wire produces a magnetic field around it". The magnetic effect of current was discovered by Hans Christian Oersted in 1820. Oersted found that an electric current moves a compass needle and this effect lasts as long as the current flows through the wire. The magnetic effect of current is called electromagnetism which means that electricity produces magnetism.



Magnetic Field

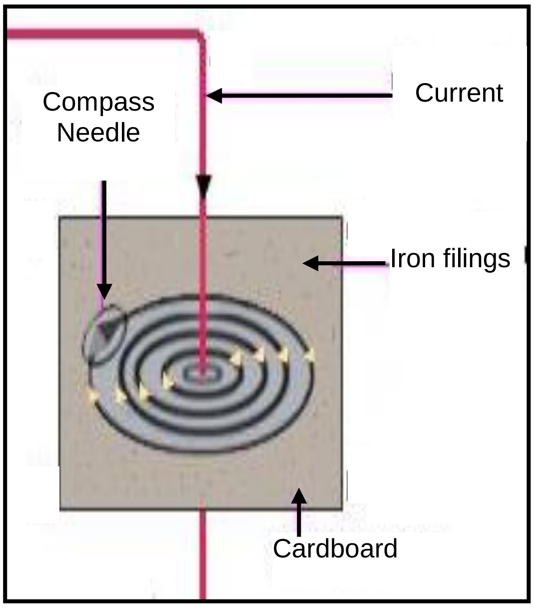
A magnetic field is defined as a region in which a magnetic force is present. In a magnetic field, the magnetic dipole (two equal and oppositely charged or magnetised poles separated by a distance) experiences a turning force, which tends to align it parallel to the direction of the field. The concept of a magnetic field can be understood with the help of the following activity:

- Place a piece of cardboard over a magnet.
- Sprinkle some iron filings onto the cardboard.
- Tap the cardboard gently and draw what you see.
- The iron filings show the magnetic field of the magnet.

Magnetic Lines of Force Due To Current in a Straight Wire

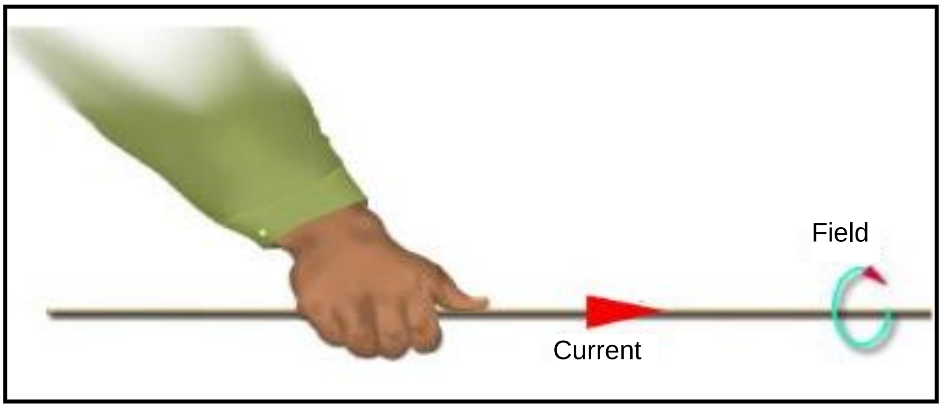
The direction of the magnetic field due to a current may be studied by drawing the magnetic lines of force. A vertical wire is passed through a horizontal cardboard. Iron filings are sprinkled on the cardboard. Current is passed through it by connecting a battery to it. Iron filings spread evenly on the cardboard. When a compass needle is placed on the cardboard, the direction of the needle will show the direction of the magnetic field. The point on the cardboard where the north pole of the needle is situated is marked. The needle is **shifted** a little so that its south pole takes the same position where the north pole was situated previously. The position of the north pole is marked. If the current is strong the lines will be circular. The **arrows** on the circular lines show the direction of the **magnetic field**.

Remember:
The greater the current in the wire, the stronger will be the magnetic field produced. And the greater the distance of a point from the current-carrying wire, the weaker will be the magnetic field produced at that point.



Maxwell's Right Hand Grip Rule

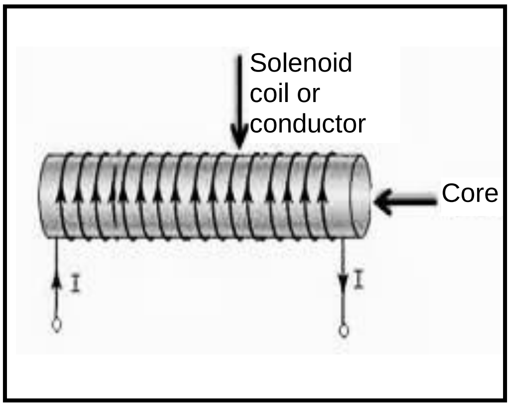
The direction of the magnetic field around a current carrying conductor can be explained by a simple rule known as Maxwell's right hand grip rule. If we hold the current carrying wire in our right hand in such a way that the thumb is stretched along the direction of the current, then the curled fingers give the direction of the magnetic field produced by the current.



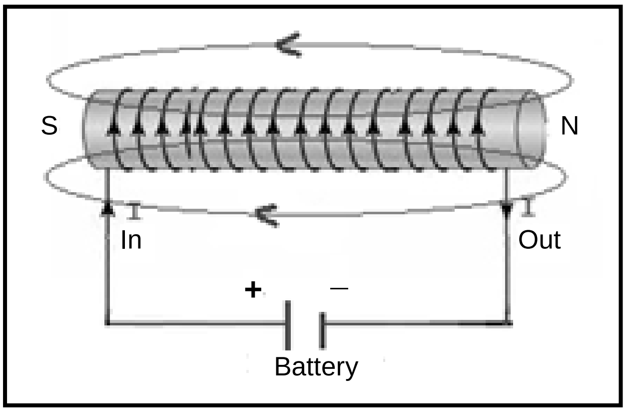
Maxwell's Right Hand Grip Rule

Magnetic Field due to a Solenoid

When a long wire is coiled in the shape of a spring so that the turns are closely spaced and insulated from each other, it forms a solenoid. Generally, a wire is coiled over a non-conducting hollow cylindrical tube. An iron rod is often inserted inside the hollow tube. This rod is called the core.



Magnetic field due to a solenoid



Direction of flux around a solenoid

The free ends of the solenoid are connected to a battery to pass current through the solenoid. This produces a magnetic field. The magnetic field inside the coil is almost constant in magnitude and direction. The current carrying solenoid produces magnetic field similar to that of a bar magnet. One end of the solenoid becomes the north pole and the other end becomes a south pole.

The magnitude of the field depends on the following factors.

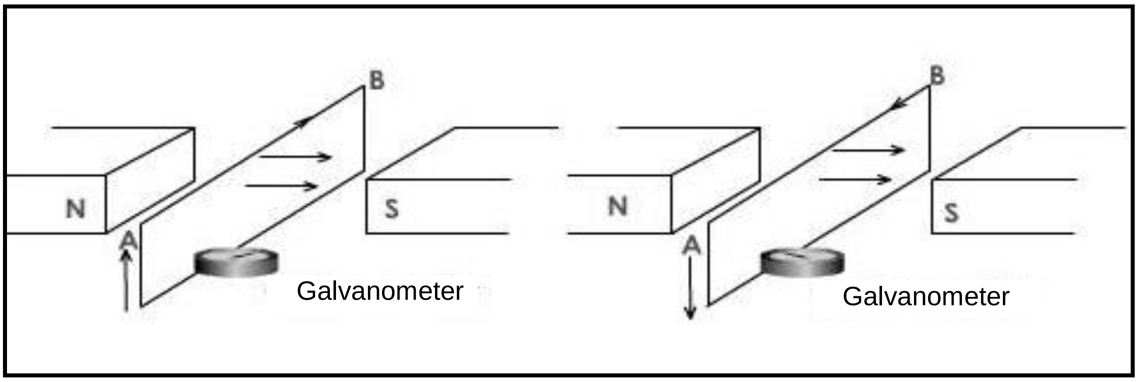
- the amount of current passing through the solenoid
- the number of turns of the solenoid. It also depends on the core material.

Since the magnetic field formed by the solenoid is temporary it is used to make electromagnets. Electromagnets are used in electric bells, and cranes.

Electromagnetic Induction

Electric current can also be induced through a wire loop, by moving it near a fixed magnet. So a current is induced either by moving a magnet near the loop or by moving the loop near a magnet. It is the relative motion between the two which is important. Thus the electromagnetic induction takes place because of the relative motion between a magnet and a coil. The induced current exists as long as there is a relative motion between the coil and the magnet. When the magnet is moved faster, the amount of current induced is found to be higher. Normally moving the magnets in a linear fashion is difficult. Hence a different arrangement is used.

The figure given below shows a wire loop, a section AB of which lies in a magnetic field. A galvanometer is connected to the loop.

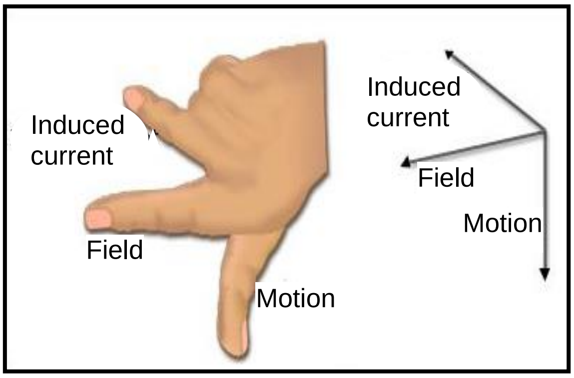


Electromagnetic Induction

The wire is directed along south-north direction and the magnetic field is from west to east. When the loop is pulled up such that the wire AB moves **upwards** in the field, a current is induced in the loop as shown in the figure. The direction of the current will be from **A** to **B** that is from south to north. If the loop is pushed **down vertically**, the direction of the current in the wire will be from **B** to **A**.

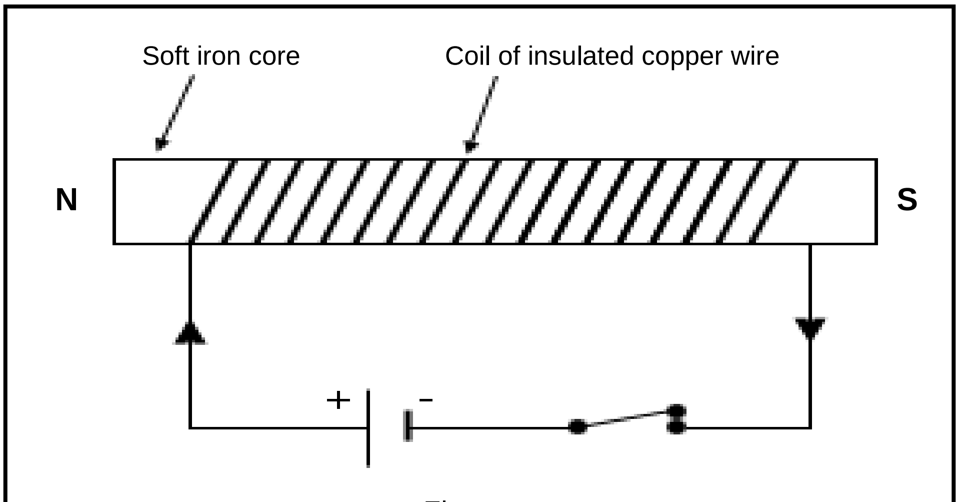
Fleming's Right Hand Rule

The direction of the current in a wire moving perpendicular to itself and to a magnetic field may be found by Fleming's right hand rule. If the thumb, forefinger and middle finger of the right hand are stretched in a perpendicular direction, in such a way that the forefinger directs towards the magnetic field, the thumb shows the motion of the wire, then the middle finger shows the direction of the induced current.



Electromagnet
An electromagnet can be defined as a soft-iron core that is magnetised temporarily by passing a current through a coil of wire wound on the core.
An electromagnet is just like any other magnet and will attract certain metals (iron and steel) and other magnets. The difference is that, an electromagnet only works when electricity is flowing through it. So what components make up an electromagnet and how does it work?

Regular magnets have two magnetic poles, north and south. Like poles repel and opposite poles attract. So the south pole of one magnet would attract the north pole of another magnet but two south poles would repel. The magnetic field of an electromagnet acts the same as a regular magnet except the poles can be reversed by switching the flow of electricity (change the positive and negative terminals to the power supply). This comes in handy when creating electric motors, speakers, and solenoids.



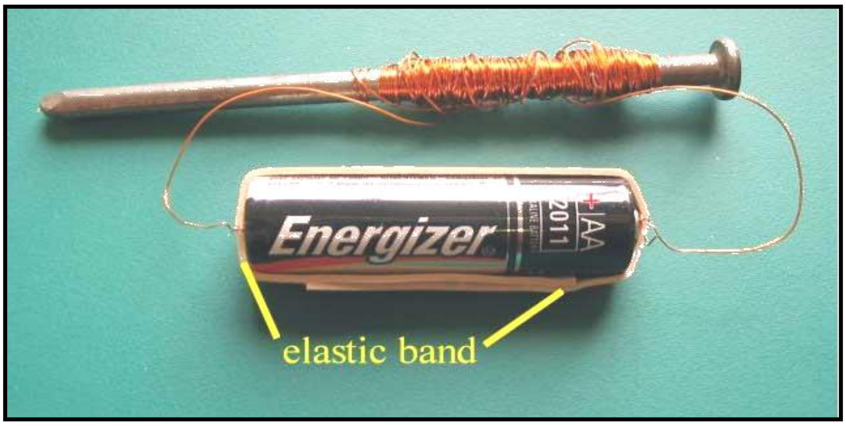
Electromagnet

Parts of an electromagnet and how they work

First we must understand a little bit about electricity. Every time electricity flows through a wire, electrons are in motion and a small magnetic field is generated. This magnetic field is like an imaginary ring around the wire. One way to increase the size of the magnetic field generated is to coil the wire. With wire coiled on top of it, the small magnetic field builds with each successive layer of wire to produce a large magnetic field.

Electromagnets consist of wire coiled around a core. The core can be anything from air to a nail or even a pencil. Since electrons flow freely through a conductive core, (like a nail), an electromagnet made with a metal core will have a larger magnetic field (and thus be stronger) than an electromagnet with a wooden core. The strength of an electromagnet is related to the number of times the wire is coiled around the core and the distance the wire covers across the core. The more coils wrapped closer together, the stronger an electromagnet will be. The amount of voltage running through the wire also plays a role in an electromagnet's strength. More voltage means more electrons moving through the wire and thus a stronger magnet.

Since an electromagnet will not work without electricity, we also need a power source such as a battery. The power source provides the electricity to charge an electromagnet into action. Power runs through the wire, around the coil, and back to the battery to produce the magnetic field.



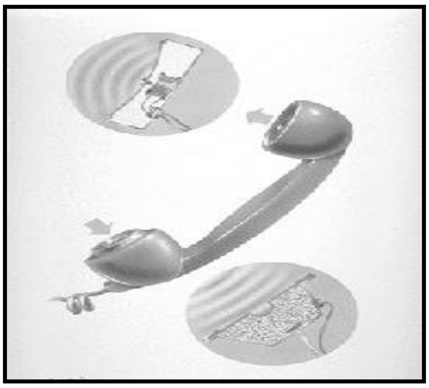
If you disconnect the battery, the electromagnet no longer functions. If the battery is reconnected with the positive and negative terminals reversed, current will flow through the wire in the opposite direction. This results in a switch of the magnetic poles in the electromagnet. Metal objects or other magnets can be moved back and forth (attracted and repelled) by repeatedly switching the poles of an electromagnet.

So, the three necessary parts of an electromagnet is a soft iron core, a coil of wire, and a battery or some other source that gives current.

Why an electromagnet works

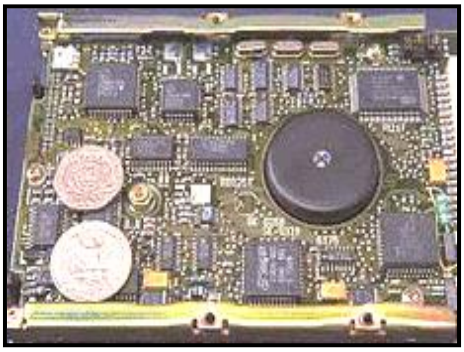
As stated previously, electromagnets need electricity to work. The wire coil wrapped around a core means that millions of electrons are flowing in a small space. As the electrons flow through the wire, other electrons around them and in the core are excited and begin moving. The result is a magnetic field that grows until electricity is flowing freely through the coil.

Uses for electromagnets
Electromagnets have several uses and practical applications. They can be found in various everyday electronics and are also used for industrial purposes ourselves. You can say that the electromagnet made much of the modern age possible harnessing electricity as a practical force in the same way that mankind used windmills and dams to harness wind and water. Here are some of the ways that electromagnets are used.



1. Relays. Electromagnets are used to control the switches in relay. This is important especially when it comes to things like making a telephone call. The first telephones and loudspeakers made use of this type of relay that performed the rudimentary logic and memory functions.

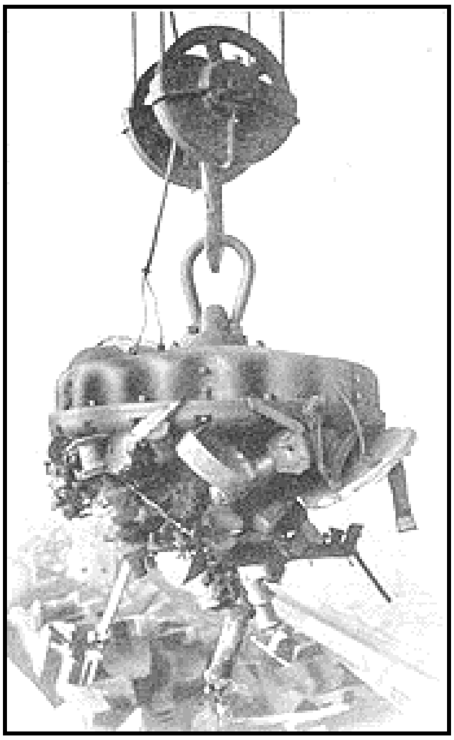
2. They can be used in the home in circuit breakers, door bells, door locks, switches, fans, refrigerators, in music amplifiers for guitars and even propulsion systems for spacecraft



Computer chips

3. Electromagnets play an important role in PCs. One new use that will be vital in new computing systems is the solid state memory. Like the relay predecessors this new type of memory will rely on electromagnets.

4. They are also used in transportation. Trains in Asia and Europe use electromagnets to levitate the cars. This helps them to move at phenomenal speeds.



Crane

5. Lifting of massive objects. You have probably seen cars and other heavy metal objects in junk yard being lifted by a crane with a round plate at the end. That round plate is an electromagnet. Using an electromagnet is an efficient way to sort these metals out.

6. Motors and Generators. In any electrical appliance the motor is moved by the magnetic field produced by the electric current flowing from your socket to the appliance. A generator uses the opposite principle and an outside force normally wind, moving water, or steam, rotates a shaft which rotates a set of magnets around a coiled wire to create an electric current. This is how we get electric power.

7. The medical industry uses them to remove imbedded objects from peoples' eyes, and in CAT scanner device like those shown on the left.

No matter what electromagnets are used for, they have advanced technology and made the impossible seem a little closer. From science experiments to electromagnet powered cars, electromagnets are an amazing accomplishment and a great benefit for all.

What are the factors affecting the strength of an electromagnet?
The two main factors are the power source and the number of windings in your electromagnet. Higher wattage input can produce a stronger magnetic field. More windings will also increase the strength of the field. Other factors to consider are the type and gauge of the conductor, the diameter of the coils, and the inductor core material. All of these will also affect performance of an electromagnet.

Make a simple ring of wire, maybe a dozen windings, attach a power source, and you will have an electromagnet (though not very useful in that form). Wrapping a wire around a large iron nail and attaching a power source will prove more effective.

In the first example the core material is natural air. Air does not induce well, and therefore does not create a good magnet. In the second example, the iron core (the nail) through induction, greatly increases the magnetic field. The iron can also become temporarily magnetized through this process.

Note: Do NOT use household line voltage, as this may be too powerful and cause injury.

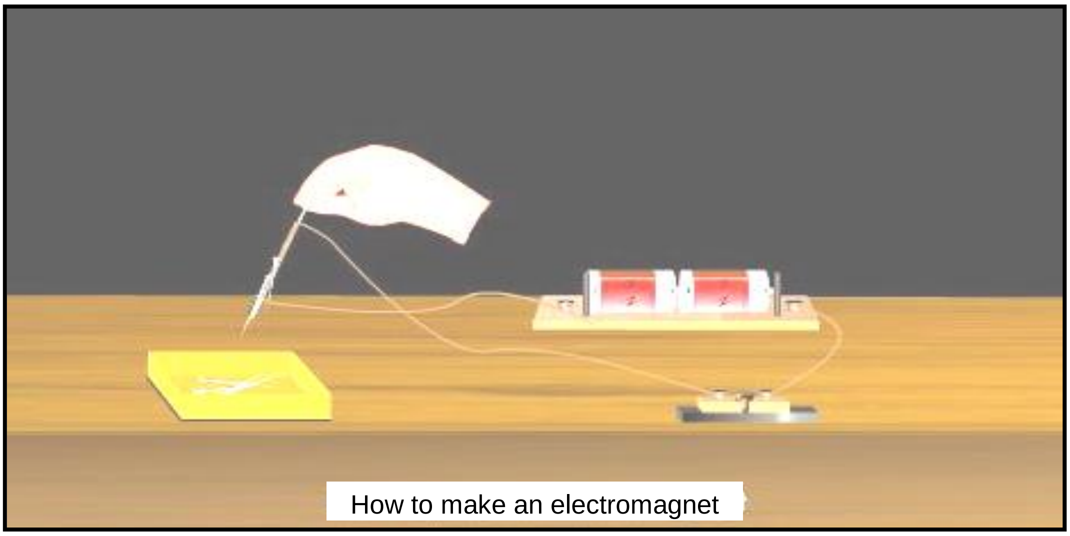
Making an Electromagnet

First step is to gather the materials.

You will need a fairly long iron nail or small iron rod, enamelled or insulated copper wire, a pair of wire strippers, switch or key, pins and a battery.

The insulation at both ends of the copper wire must be removed so that it can be connected to a battery. Use the pair of wire strippers to remove the insulation. Wrap the wire tightly and closely around the nail. Wind the wire in one direction only. This is because the direction of the magnetic field depends on the direction of the electric current creating it. If you wrap a part of the wire around the nail in one direction and the other part of the wire in other direction, then the magnetic fields from the different sections are oppositely directed and they cancel out.

Connect the bare ends of the wire to the battery and the switch as shown here.



How to make an electromagnet

Place some pins in a box just below the nail and switch on the key. The pins readily jump towards the nail. This shows that the nail has acquired magnetism. That is, the nail is an electromagnet. Switch off the circuit and observe. The pins fall into the box.

Activity: **Now test yourself by ding this activity.**

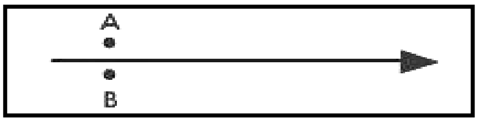
Circle the letter of the correct answer.

1. A magnetic field line is used to find the direction of __________.

   A. south-north B. a bar magnet

   C. magnetic field D. a compass needle

2. An electric current passes through a straight wire in the direction of south to north. Magnetic compasses are placed at points A and B as shown in the figure.



   What is your observation?

   A. The needle will not deflect
   B. Only one of the needles will deflect
   C. Both the needles will deflect in the same direction
   D. The needles will deflect in the opposite directions

3. The magnetic field lines due to a straight wire carrying a current are __________.

A. straight
B. circular
C. elliptical
D. parabolic

4. The magnetic field lines inside a long, current carrying solenoid are nearly __________.

A. straight
B. circular
C. elliptical
D. parabolic

5. A soft iron bar is introduced inside a current carrying solenoid. The magnetic field inside the solenoid

A. will increase.
B. will decrease.
C. will become zero.
D. will remain unaffected.

6. Who first discovered the relationship between electricity and magnetism?

A. Newton
B. Faraday
C. Maxwell
D. Oersted

7. In an electric motor, the energy transformation is from

A. chemical to light.
B. electrical to chemical.
C. mechanical to electrical.
D. electrical to mechanical.

8. For making a strong electromagnet, the material of the core should be

A. steel
B. brass
C. copper
D. soft iron

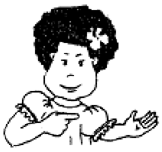
9. The direction of induced current is obtained by

A. Ampere's rule.
B. Fleming's left-hand rule.
C. Fleming's right-hand rule.
D. Maxwell's right-hand thumb rule.

10. Magnetic field inside a long solenoid carrying current is

A. zero.
B. different at all points.
C. same at all points (uniform).
D. different at poles and centre.

CHECK YOUR WORK. ANSWERS ARE AT THE END OF LESSON 9.



Summary

You have come to the end of lesson 10. In this lesson you have learnt that:

- the "magnetic effect of current" means that "a current flowing in a wire produces a magnetic field around it".
- a magnet is a material that attracts other objects containing the elements iron, nickel or cobalt.
- the magnetic effect of current was discovered by Hans Christian Oersted in 1820.
- a magnetic field is defined as a region in which a magnetic force is present.
- the greater the current in the wire, the stronger will be the magnetic field produced. The greater the distance of a point from the current-carrying wire, the weaker will be the magnetic field produced at that point.
- the direction of the magnetic field around a current carrying conductor can be explained by Maxwell's right hand grip rule.
- when a long wire is coiled in the shape of a spring so that the turns are closely spaced and insulated from each other, it forms a solenoid.
- the electromagnetic induction takes place because of the relative motion between a magnet and a coil. The induced current exists as long as there is a relative motion between the coil and the magnet.
- the direction of the current in a wire moving perpendicular to itself and to a magnetic field may be found by Fleming's right hand rule.
- an electromagnet can be defined as a soft-iron core that is magnetised temporarily by passing a current through a coil of wire wound on the core.
- the three necessary parts of an electromagnet is a soft iron core, a coil of wire, and a battery or some other source that gives current.
- uses of electromagnets include relay, motors and generators, lifting heavy objects, pcs, transportation, fans, refrigerators, amplifiers, loudspeakers, switches, door locks , door bells and medical industry.
- factors affecting the strength of electromagnets include the power source, number of windings, the type and gauge of the conductor, the diameter of the coils and the inductor core material.

NOW DO PRACTICE EXERCISE 10 ON THE NEXT PAGE.

Practice Exercise 10

Read the passage below. Fill in the blank using the words in the box.

north	force	magnetic	attract	south
magnets	iron	easier	field	wire
electricity	current	permanent	electromagnet	

(1)__________ are materials that attract pieces of iron or steel. In ancient times, people first discovered magnetism when they found some naturally (2) __________ pieces of rock in the earth. They called these rocks lodestone. Nickel, cobalt, certain types of ceramics and certain blends of metals can also make good magnets.

Magnets have north and south poles. The (3) __________ pole of one magnet will repel, or push away, the north pole of another magnet, and the south pole of one magnet will repel the (4) __________ pole of another magnet. But, if you put the north pole of one magnet near the south pole of another magnet, you will feel an attractive (5) __________.You may have heard the saying "opposites (6) __________ ".Most of the magnets are made from metals rich in (7) __________.

Permanent magnets are one kind of magnet, but there is another kind of magnet called an (8) __________. Electromagnets are made from metal and electricity. When the (9) __________ is on, you have a magnet, but turn the power off, and you just have a hunk of metal and some wire. Unlike (10) __________ magnets, the strength of an electromagnet is easy to change. One way to do this is to change the amount of current used. Another way is to change the amount of (11) __________ you have wrapped around the metal core. You see, when you wind wire in coils around a piece of metal that has a lot of iron in it, and then you run electricity through the wire, it creates a magnetic (12) __________. More coils of wire or more electric (13) __________ creates a stronger magnetic field. This magnetic field causes the atoms in the core to align, giving the metal magnetic properties. Electromagnets used in many devices really make our lives (14) __________ and more fun, too.

CHECK YOUR WORK. ANSWERS ARE AT THE END OF TOPIC 3

Answers to activity

1. C
2. D
3. B
4. A
5. A
6. D
7. D
8. D
9. C
10. C

Answer to Practice Exercises 8 - 10

Practice Exercise 8

1.

	Incandescent light bulbs /fluorescent lamps
Produce light from a heated filament	Incandescent light bulbs
Produce light by gas discharge	Fluorescent lamps
Produce warmer light	Incandescent light bulbs
Produce lesser heat	Fluorescent lamps
Much cheaper	Incandescent light bulbs
More efficient	Fluorescent lamps
Last longer	Fluorescent lamps

2. A. Rechargeable Lamp
   - It is water, oil and shock resistant.
   - Can work up to 8 hours after a single recharge
   - Eco-friendly
   - In-built charging indicator
   - Comes with a charger

   B. Solar Home Lighting System
   - Both solar as well as electric input
   - Easy to install and virtually free from maintenance
   - Environment friendly device
   - Longer lifespan

   D. Clock and Temperature Display
   - 12 or 24-hour time format switch selectable
   - Keeps all clocks synchronized
   - Adjustable high/low luminance
   - Set up time to start or close the clock display accordingly
   - With cell button battery to keep time running

3. A. Tungsten filament

   B. Glass mount

   C. Screw thread contact

Practice Exercise 9

1. When electric current is passed through a wire, like filament of an electric heater, oven or geyser, the filament gets heated up and here electrical energy is converted into heat energy. This is known as 'heating effect of current'.

2. a. Refrigerator

A refrigerator (commonly abbreviated as fridge) is a cooling apparatus consists of insulated compartment and a heat pump which transfers heat from the inside of the fridge to its external environment.

b. Electric iron

An electric iron consists of a coil of high resistance covered by insulating mica sheets and kept inside heavy metal block. When electric current passes through the coil it gets heated and the metal block can be used for ironing clothes.

c. Space heater

A space heater is a self-contained device for heating an enclosed area; is generally employed to warm a small space, and is usually held in contrast with central heating, which warms many connected spaces at once.

d. Tank less water heater

Tank less water heaters instantly heat water as it flows through the device, and do not retain any water internally except for what is in the heat exchanger coil.

e. Fan heater

A fan heater includes an electric fan to speed up the airflow. This reduces the thermal resistance between the heating element and the surroundings faster allowing heat to be transferred more quickly.

f. Microwave oven

A microwave oven is a kitchen appliance that heats food by dielectric heating. This is accomplished by using microwave radiation to heat polarised molecules within the food.

g. Fuse wire

When the current drawn in a domestic electric circuit increases beyond a certain value, the fuse wire gets over heated, melts and breaks the circuit. This prevents fire and damage to various electrical appliances.

h. Surgery

In surgery, a fine heated platinum wire is used for cutting tissues much more efficiently than knife.

Practice Exercise 10

(1)	**Magnets**	(8)	**electromagnet**
(2)	**magnetic**	(9)	**electricity**
(3)	**north**	(10)	**permanent**
(4)	**south**	(11)	**current**
(5)	**force**	(12)	**field**
(6)	**attract**	(13)	**current**
(7)	**iron**	(14)	**easier**

REVISE TOPIC 3 USING THE MAIN POINTS ON THE NEXT PAGE.

REVIEW OF TOPIC 3: USES OF ELECTRICITY

Revise all the Lessons in this Topic and then do **ASSIGNMENT 5.**
Here are the main points to help you revise.

Lesson 8: Lighting Effects

- Electricity is one of the most important sources of energy
- Sun is a nuclear fireball spewing energy in all directions. The energy travels in the form of waves.
- Light is made inside atoms when they get "excited".
- The filament in a light bulb is made of a long; incredibly thin length of tungsten metal.
- Tungsten is used in nearly all incandescent light bulbs because it is an ideal filament material.
- Phosphors are substances that give off light when they are exposed to light.
- Incandescent light bulbs produce light from a heated filament while fluorescent lamps produce light by way of a gas discharge.
- Incandescent light bulbs are much cheaper than fluorescent lamps.
- Incandescent light bulbs produce a warmer light than fluorescent lamps.
- Fluorescent lamps are more efficient using up to 25% of its energy as light compared to incandescent light bulbs which turn only 5% of the electricity they consume into light.
- Fluorescent lamps produce lesser heat than incandescent bulbs that is why fluorescent lamps are more efficient.
- Fluorescent lamps last longer than incandescent light bulbs.

Lesson 9: Heating effects

- The law of conservation of energy states that energy can be transformed from one form to another.
- When electric current is passed through a wire, like filament of an electric heater, oven or geyser, the filament gets heated up and here electrical energy is converted into heat energy. This is known as 'heating effect of current'.
- When the cross sectional area of the conductor is greater, collisions is avoided and hence less heat is produced.
- When the current drawn in a domestic electric circuit increases beyond a certain value, the fuse wire gets over heated, melts and breaks the circuit. This prevents fire and damage to various electrical appliances.
- An electric iron consists of a coil of high resistance covered by insulating mica sheets and kept inside heavy metal block. When electric current passes through the coil it gets heated and the metal block can be used for ironing clothes.
- When current passes through the filament in an electric light bulb, it is heated to high temperature and emits light.
- A space heater is a self-contained device for heating an enclosed area; is generally employed to warm a small space, and is usually held in contrast with central heating, which warms many connected spaces at once.
- A fan heater includes an electric fan to speed up the airflow. This reduces the thermal resistance between the heating element and the surroundings faster allowing heat to be transferred more quickly.

- A microwave oven is a kitchen appliance that heats food by dielectric heating. This is accomplished by using microwave radiation to heat polarized molecules within the food.
- A refrigerator (commonly abbreviated as fridge) is a cooling apparatus consists of insulated compartment and a heat pump which transfers heat from the inside of the fridge to its external environment.
- Tank less water heaters instantly heat water as it flows through the device, and do not retain any water internally except for what is in the heat exchanger coil.
- A heat pump is a device that diverts heat from one location at a lower temperature to another location at a higher temperature using mechanical work or a high-temperature heat source. A heat pump can be used to provide heating or cooling.

Lesson 10: Electromagnetism

- The "magnetic effect of current" means that "a current flowing in a wire produces a magnetic field around it".
- A magnet is a material that attracts other objects containing the elements iron, nickel or cobalt.
- The magnetic effect of current was discovered by Hans Christian Oersted in 1820.
- A magnetic field is defined as a region in which a magnetic force is present.
- The greater the current in the wire, the stronger will be the magnetic field produced. And the greater the distance of a point from the current-carrying wire, the weaker will be the magnetic field produced at that point.
- The direction of the magnetic field around a current carrying conductor can be explained by Maxwell's right hand grip rule.
- When a long wire is coiled in the shape of a spring so that the turns are closely spaced and insulated from each other, it forms a solenoid.
- The electromagnetic induction takes place because of the relative motion between a magnet and a coil. The induced current exists as long as there is a relative motion between the coil and the magnet.
- The direction of the current in a wire moving perpendicular to itself and to a magnetic field may be found by Fleming's right hand rule.
- An electromagnet can be defined as a soft-iron core that is magnetised temporarily by passing a current through a coil of wire wound on the core.
- The three necessary parts of an electromagnet is a soft iron core, a coil of wire, and a battery or some other source that gives current.
- Uses of electromagnets include relay, motors and generators, lifting heavy objects, PCs, transportation, fans, refrigerators, amplifiers, loudspeakers, switches, door locks , door bells, and medical industry.
- Factors affecting the strength of electromagnets include the power source, number of windings, the type and gauge of the conductor, the diameter of the coils and the inductor core material.

REVISE WELL AND THEN DO TOPIC TEST 3 IN YOUR ASSIGNMENT 5.

TOPIC 4

GENERATING ELECTRICITY

In this topic you will learn about:

- **electrical power and costing**
- **conservation of electrical energy**
- **hydroelectricity in Papua New Guinea**

INTRODUCTION TO TOPIC 4: Generating Electricity

Saving money on electricity is a big help and it is possible for us to do this. Using power in a minimal way can be very exciting and rewarding and there are several ways to cheaply generate electricity in your home. So in this topic we will show you how.

If you lived halfway up a mountain with a fast flowing stream, plenty of wind and lots of sunshine, you would be in the perfect location for plenty of your own, free, renewable energy. Unfortunately, most of us have to make do with what we have, whether we are on a remote Highlands, or in a flat in the middle of a big city. It is always possible to do something.

Generating electricity using your own small energy system fits the circumstances and values of some home and small-business owners. Although it takes time, many people enjoy the independence they gain and the knowledge that their actions are helping the environment.

To better understand just how important generating electricity is; let us study more about its conservation and uses. Some questions will arise such as

- What are ways to conserve power?
- How important are safety precautions in household electricity?
- How do hydroelectric power generators produce electricity?

In this Topic, you will find the answers to these questions and other questions relating to generating electricity.

Lesson 11: Electrical Power and Costing

Welcome to Lesson 11. Most of mankind's energy needs are met by electric power. It is a willing servant in the home, office, factory, school, and theatre. Electric energy is available almost everywhere. Its ease of production, distribution, and utilisation coupled with stable costs has accounted for the rapid rise of electrical devices during the 20th century. Most electric power is generated in large plants that use coal, gas, oil, or nuclear energy. These are generally called central stations, and they require only a few workers. Power is brought from the generating plant to the user through a network of wires called transmission and distribution lines. The power can be used as needed simply by turning on a switch.

Your Aims:

- describe the relationship between electrical power, current and voltage
- calculate the cost of different electrical appliances using PNG Power formula

Relationship between Voltage, Current and Power

Watt's Law describes a relationship between voltage, current and power in an electric circuit. Understanding Watt's Law is useful for calculating circuit characteristics.

Power is defined as “work done or energy transferred per unit of time," and is represented by the symbol P. In electronics, power (P) can be thought of as the amount of energy given off by a resistance, or load, when current is passed through it. Power is measured in **watts (W)**. One watt is equal to one joule.

A **Joule** is defined as "a unit of electrical energy equal to the work done when a current of one ampere is passed through a resistance of one ohm for one second." James Prescott Joule, an English physicist, recognised this relationship and derived an equation from **Ohm's Law** describing power (P) as the product of voltage (V) and current (I), or P = V x I.

Using Watt's Law

Using the equation, P = V x I, and given any two of the three variables (P, V, or I), the unknown value can be solved. For example, if **P** is covered, **V** by **I** (or **V x I**) will be the equation needed to solve for power. Similarly, if the **V** is covered, **P** over **I** (or **P / I**) will be used to solve for voltage.

Calculating Current Using Watt's Law

Watt's Law can be used when designing a circuit to help determine wire gauge and **circuit protection.** It works with either alternating current **(AC)** or direct current **(DC)** applications. Current for a circuit can be calculated given the total wattage of the loads and the source voltage. Using the solution covering **I**, yields the equation **P / V**.

Determining Wattage for a Load

Wattage for most devices can be found on the UL listing label or in the owner's manual and technical data accompanying the device. The wattage rating will typically be found with the voltage rating, and will be designated with a "W" or, in some cases, **"VA."**

The VA designation stands for **Volt-Amps**, which correlates to power being equal to the product of voltage and current. It should also be noted that the wattage rating reflects maximum-sustained power usage, but does **not** reflect any current spikes that may occur upon start-up.

The relationship between voltage, current and power is the basis of Watt's Law, and it is a useful tool for determining circuit characteristics and design specifications.

List of the Power Consumption of Typical Household Appliances

Turn that TV off if you are not watching it. It is wasting electrically. How much electricity is it really wasting and would it not be better to switch off the 4 lights in the room?

The best way to compare the cost of running different appliances is to look at their power consumption, which is measure of how much power they use in **Watts.** The following list points out typical values for the wattage of some devices you would find in your home so that you can compare them.

Appliances	Watts
60W light bulb	60W
100W light bulb	100W
Toaster	1500W
Electric kettle	2000W
Washing machine	500W
Iron	1000W
Coffee maker	1200W

Appliances	Watts
Laptop computer	50W
Desktop computer	250W
TV 19 “ colour	70W
Clock radio	10W
Fridge/Freezer	500W
Ceiling fan	50W
VCR/DVD	25W

An important point also to bear in mind is the length of time for which the device will be used. For example a 19” colour TV may be used for 3 hours, but a 100W light bulb for 1 hour. Therefore the TV uses 70W x 3 hours/1000 = 0.21kWh. The light bulb uses 100W x 1hour/1000 = 0.1kWh. So using the 19”TV costs roughly twice as much as the 100W light bulb.

Estimating Appliance and Home Electronic Energy Use

If you are trying to decide whether to invest in a more energy-efficient appliance or you would like to determine your electricity loads, you may want to estimate appliance energy consumption.

Formula for Estimating Energy Consumption

You can use this formula to estimate an appliance's energy use:

(Wattage × Hours Used per Day ÷ 1000 = **Daily** Kilowatt-hour (kWh) consumption

(1 kilowatt (kW) = 1,000 Watts)

Multiply this by the number of days you use the appliance during the year for the annual consumption. You can then calculate the annual cost to run an appliance by multiplying the kWh per day by your local utility's rate per kWh consumed. In Papua New Guinea, PNG Power charges the consumers 0.64 toea/ KWh.

Note: To estimate the number of hours that a refrigerator actually operates at its maximum wattage, divide the total time the refrigerator is plugged in by three. Refrigerators, although turned "on" all the time, actually cycle on and off as needed to maintain interior temperatures.

Examples:

Electric kettle:
= (2000 Watts × 4 hours/day) ÷ 1000
= 8 kWh × 0.64toea /kWh
= **K 5.12/day**

Iron:
= (1000 Watts x 3 hours/day) ÷ 1000
= 3 KWh x 0.64 toea /KWh
= **K1.92/day**

Desk top Computer:
= (250 Watts x 8 hours/day) ÷ 1000
= 2 KWh x 0.64 toea /KWh
= K1.28/day

Toaster:
= (1500 Watts x 1 hour/day) ÷ 1000
= 1.5 KWh x 0.64 toea/KWh
= **0.96 toea/day**

Wattage

You can usually find the wattage of most appliances stamped on the bottom or back of the appliance, or on its nameplate. The wattage listed is the maximum power drawn by the appliance. Since many appliances have a range of settings (for example, the volume on a radio), the actual amount of power consumed depends on the setting used at any one time.

If the wattage is not listed on the appliance, you can still estimate it by finding the current draw (in amperes) and multiplying that by the voltage used by the appliance.

Many appliances continue to draw a small amount of power when they are switched "off." These "phantom loads" occur in most appliances that use electricity, such as VCRs, televisions, stereos, computers, and kitchen appliances. Most phantom loads will increase the appliance's energy consumption a few watt-hours. These loads can be avoided by unplugging the appliance from the power point.

Activity: **Now test yourself by doing this activity.**

Circle the letter of the correct answer.

1. Work done = Force x _______.

   A. speed B. distance

   C. velocity D. acceleration

2. 1 joule = 1 _______.

   A. Nm^2 B. Nm

   C. N^2m^2 D. Kgm/s^2

3. Which form of energy does the flowing water possess?

   A. Kinetic B. Electrical

   C. Potential D. Gravitational

4. The unit of power is _______.

   A. joule B. kilojoule

   C. watt per second D. joule per second

5. Power is a measure of the

   A. change of energy.
   B. rate of change of energy.
   C. force which produces motion.
   D. rate of change of momentum.

6. 1.5 kW = ______ watts

A. 15 B. 150

C. 1,500 D. 15,000

7. During one day, a 2.5kW appliance was used for 8 hours. How many Units of electricity were used?

A. 2.5 B. 20

C. 200 D. 2,000

8. During one day, a 3000W appliance was used for 10 hours. How many Units of electricity were used?

A. 5 B. 30

C. 3,000 D. 30,000

9. Name the physical quantity which is equal to the product of force and velocity.

A. Work B. Power

C. Energy D. Acceleration

10. Each Unit of electricity costs 8toea. How much does it cost to run a 500W appliance for 4 hours?

A. 1. 6 B. 10

C. 16 D. 160

CHECK YOUR WORK. ANSWERS ARE AT THE END OF LESSON 11.

Summary

You have come to the end of Lesson 11. In this lesson you have learnt that:

- watt's law describes a relationship between voltage, current and power in an electric circuit.
- power is defined as “work done or energy transferred per unit of time," and is represented by the symbol p.
- power is measured in watts (w). One watt is equal to one joule.
- a joule is defined as a unit of electrical energy equal to the work done when a current of one ampere is passed through a resistance of one ohm for one second.

- volt-amps correlate to power being equal to the product of voltage and current.
- watt's law can be used when designing a circuit to help determine wire gauge and circuit protection.
- the best way to compare the cost of running different appliances is to look at their power consumption, which is measure of how much power they use in watts.
- you can usually find the wattage of most appliances stamped on the bottom or back of the appliance, or on its nameplate. The wattage listed is the maximum power drawn by the appliance.
- you can use this formula to estimate an appliance's energy use:
  (wattage × hours used/day) ÷ 1000 = daily kilowatt-hour (kwh)
  (1 kilowatt (kw) = 1,000 watts)

NOW DO PRACTICE EXERCISE 11 ON THE NEXT PAGE.

Practice Exercise 11

1. Describe the relationship between power, current and voltage.

2. Calculate the cost of the following appliances.

   A. DVD in use for 10 hrs/day @ 0.64 toea/KWh

   B. Washing machine in use for 3 hours @ K2.15/KWh

   C. Coffee maker in use for 2 hours @ K3. 10/KWh

   D. Lap top in use for 7 hours @ K3.50/KWh

   E. Toaster in use for 4 hours @ K 2.00?KWh

CHECK YOUR WORK. ANSWERS ARE AT THE END OF TOPIC 4.

Answers to activity

1.	B	6.	C
2.	B	7.	B
3.	A	8.	B
4.	D	9.	B
5.	B	10.	C

Lesson 12: Conservation of Electrical energy

Welcome to Lesson 12. People are increasingly looking for how to conserve electricity in the house, saving electricity being one key means to reduce energy costs as a whole. In economically hard (or good) times, the effects of the rise in energy related costs are placing an even greater burden on families. With this in mind, the importance of conserving electricity in the house, and taking steps to reduce energy costs is becoming more of an on-going concern to many of us at home. This is not just because it makes sense to consume less energy where possible. It is also about how to reduce energy costs which leads to saving real money for families - the positive effects of conserving electricity or energy conservation in general for that matter which you are going to learn in this lesson.

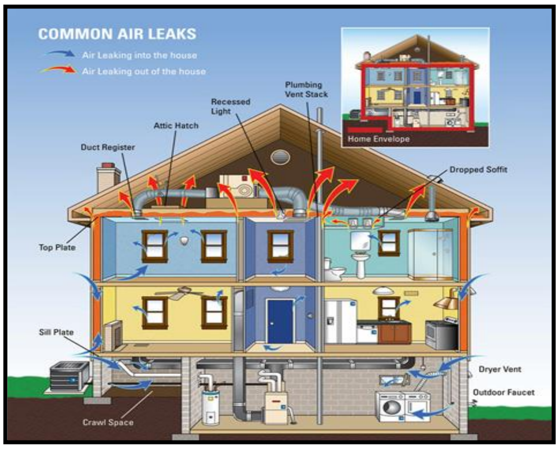
Your Aim:

- describe the different ways to conserve energy

Manage the energy or electricity used at home

Perhaps the best approach to conserve electricity in your house or saving energy overall is to reflect on how much you consume on an annual basis. This will help to put your energy consumption into perspective and potential for saving energy via various energy conservation initiatives.

The general consensus is that a large amount of these energy costs are wasted or could be avoided. So, just how much can you reduce energy costs and save on electricity for example. There are different answers since each of our situations are different in terms of our behaviours, home and usage and therefore the potential waste or opportunity to scale back. The good news is that there are many ways to conserve energy or save electricity at home which are available to us.



First, you need to study behaviours of people in order to trim unnecessary energy use and associated costs. Second, adopt an approach whereby you and other members of the household begin to manage the energy or electricity used in your house. It is about the importance of conserving electricity in the house. Once this is understood, you can start evaluating more closely your energy or electricity use. This will lead to identifying useful actions whereby you can better control and start to manage (conserve electricity in the house).

Basic Concepts of Energy Efficiency

Everybody should try to reduce their energy consumption. Not only will it help you reduce your fuel bills, but you will also help to protect the environment. Not everything costs a lot of money. Here are some no cost and low cost energy saving tips that you should try to introduce into your lifestyle:

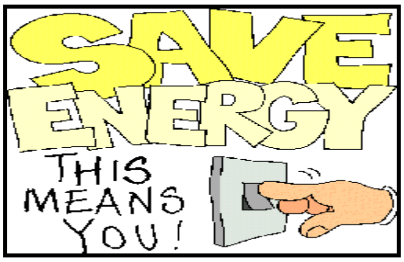
A. Insulation

Insulate your walls and ceilings. This can save 20 to 30 percent of home heating bills and reduce CO_2 emissions by 140 to 2100 pounds per year. You can make a lot of progress toward improving the energy efficiency in your home by simply plugging many places through which air can get in or out. Plugging your home is called "air sealing," and it is one of the most important first steps to take when weatherizing your house to increase its energy efficiency. Increasing the amount of insulation in various places in your home should be a high priority. Insulation, in its many forms, helps stop the transfer of heat from one place to another.

B. Lights Out

Do not leave lights on when no one is in the room. If you are going to be out of the room for more than five minutes, turn off the light. Though it is a simple energy saving step, the concept of turning off lights when leaving a room seems to elude many people who subsequently complain about their utility bills.

The fact is that, if a light is off, it uses no electricity. So only turn on lights that are necessary for use. It is that easy to save energy. If you know of a light that everyone forgets to turn off, make a sticker or a sign to hang next to the switch that says "Lights Out!" or "Do not Forget!"



Where possible, use compact fluorescent light bulbs. These funny-looking bulbs produce the same amount of light by using 1/4 of the electricity. Plus, they last for years and years without burning out. One urban myth says that turning on a light uses far more energy than it consumes while it is operating. Not so. It is true that when an incandescent or fluorescent light bulb is first switched on, it requires a brief surge of electricity. But that surge is so short that it does not make any practical difference. With fluorescents, the electricity consumed during start-up is equivalent to only a few seconds' worth of running the light. So keep bulbs that are not being used turned off and open curtains to allow daylight into rooms.

C. Ceiling Fans

The use of central or room air-conditioning (and the high electrical costs associated with each) can be reduced by getting the air around you to move. A simple desktop or standing fan that sweeps the room every few seconds makes the air seem cooler by several degrees.

Ceiling fans are a great in this regard since they gently move all of the air in a room at once. Ceiling fans can draw up and distribute the cooler air that lies along the floor throughout the entire room.

D. Refrigerator Use

Refrigerators consume a large portion of the household energy budget, but there are several simple things you can do to reduce the cost. You must defrost your fridge / freezer regularly, they will work more efficiently. Make sure the door closes properly; it makes sense to open the refrigerator door once to remove all the food you need at any one time.

Refrigerator

Opening the door repeatedly pulls cool air from within and causes the compressor to come on, making your electric meter spin. Plan what you are going to remove from the refrigerator, open it, remove what you need, and then quickly close it again.

It is also a good idea to allow warm foods to cool to room temperature before putting them to the refrigerator. That way energy would not be required to do work that can take place naturally.

E. Cooking

For optimum energy efficiency, it makes sense in any season to use cooking appliances appropriate to the volume and type of food being cooked. Baking a few potatoes can be done quickly and at much less energy cost in a microwave oven than using a conventional oven.

A toaster oven

Countertop toaster ovens and broilers can prepare a wide variety of foods, and they do not produce the amount of heat or consume nearly the energy that a full-size range does. When possible, cook the foods together in the oven that require similar temperatures.

Choose a saucepan that covers the cooker ring and do not let the gas flame lick up the side of it. Use a saucepan lids not only to prevent heat from escaping the top of the pot but also to reduce cooking time.

An electric water kettle

An oven or range top burner can often be shut off before the food is completely cooked. The food can be allowed to "coast" until it is ready, using the heat built up inside the pot or pan. If this prevents the oven's burner from firing up one last time, that is energy saved. If you are boiling water, only fill the kettle with the amount of water you need. Make sure you cover the element.

In busy families it makes sense to make large batches of frequently eaten foods to be frozen for later use. Volume food processing like this also pays energy dividends. It takes much less energy to turn on the range once to cook a big pot of something rather than to turn it on multiple times to cook smaller portions.

F. Laundry

It is important too, for both water and energy savings, to do **full loads** of laundry whenever possible. Running a washing machine to do one large load as opposed to several smaller ones uses less electricity to power the machine's motor, and overall water consumption will be lower as well. So letting laundry stack up is not a sign of laziness, it is saving energy.

Clothes dryers tumble clothing inside a heated drum to remove moisture soaked up during the washing process. The heat is produced by electricity. But you can avoid using any energy at all to dry clothes by using the sun and wind to do the job. **Clotheslines** and folding dryers are **inexpensive**, and it takes only a few minutes to hang a load of wash. The sun sanitises the clothing, and everything smells fresh.

Another reason of hanging clothing to dry has to do with how using a dryer ages and damages clothing. High heat breaks down material fibers and causes them to fracture and loosen; that is, after all, what dryer lint consists of; broken-off fibers. The tumbling action of clothing rubbing against other clothing is also abrasive, further damaging the material. So, outside line drying pays off not only in terms of energy efficiency but also helps clothes last longer.

G. Do not Leave Things Turned On

Electrical appliances such as TVs, PCs and stereos still use power even when on stand-by, so where possible switch appliances off when they are not in use.

Turn off the TV when no one is watching it. The same goes for computers, radios and stereos - if no one using it, turn it off. Turn off all the appliances at the surge protector/control strip - that four or six plug extension cord that you plug all your appliances into.

A flat screen television

Some devices, like modems or other networking boxes draw small amounts of power all the time. Check with your folks first, but the best thing to do is turn them **all** off at the surge protector.

H. Take Shorter Showers, Smaller Baths

Another simple way to save water and energy is to take shorter showers. You will use less hot water, and water heaters account for nearly 1/4 of your home's energy use. Have a shower instead of a bath.

A shower uses 40% of the hot water needed for a bath. Use less hot water by installing low-flow shower heads and save 300 pounds of CO_2 per year for electrically heated water.

I. Air Filters

Clean or replace air filters as recommended. Energy is lost when air conditioners and hot-air furnaces have to work harder to draw air through dirty filters. Cleaning a dirty air conditioner filter can save 5 percent of the energy used. That could save 175 (lbs) pounds of CO_2 per year.

J. Buying New Appliances

When buying electrical appliances look for the 'energy efficiency recommended' logo and rated category 'A' or better your assurance is that the product saves energy and prevents pollution. Select the most energy-efficient models when you replace your old **appliances**. Buy the product that is sized to your typical needs not the biggest one available.

K. Low-Voltage Exterior Lighting

If you would like your outdoor landscape to be illuminated at night for safety or for aesthetic reasons, there are ways to do it that do not require much electrical power. One product that is popular for such applications is low-voltage lighting.

Low-voltage exterior lightning

While low voltage lights would not illuminate the entire side of a house or reach to the deepest stretches, they can guide the way up front steps or along a walkway without using much electricity.

Many low-voltage outdoor lighting systems operate at 12 volts, which makes the installation safe for use when children or pets are around. Because the lights can be easily moved around the yard, you can change the display to suit the season, adding or subtracting lights as needed. For even better energy performance, putting the system on a timer turns off the lights when not needed and on when they are.

Combining the many simple steps we have outlined can make a big difference in your energy bills. These little steps help you to save energy and lower your utility bills. It just takes a small commitment on your part to conserve energy and put a stop to wasteful energy use in your home.

Activity: **Now test yourself by doing this activity.**

Circle the letter of the correct answer.

1. How could you decrease the heat loss through a window on a cold day?

    A. Use a smaller window.
    B. Decrease the thickness of the glass.
    C. Use a glass with bigger thermal conductivity.
    D. Increase the temperature inside your house.

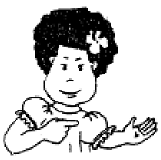
2. You come into a cold room and switch on the space heater. Which statement is true during the time when the temperature in the room is rising? The power delivered by the heater is

    A. larger than the heat lost from the room.
    B. larger than the heat gain from the room.
    C. smaller than the heat lost from the room.
    D. smaller than the heat gain from the room.

3. High efficiency appliances

    A. cost more to buy
    B. reduce energy use
    C. cost less to operate
    D. all of the above answers

CHECK YOUR WORK. ANSWERS ARE AT THE END OF LESSON 12.



Summary

You have to the end of lesson 12. In this lesson you have learnt that:

- to manage the energy or electricity used at home, you must be aware of the behaviours of people around you and by adopting an approach whereby you and other members of the household begin to manage the energy or electricity used in your house.
- some basic concepts of energy efficiency includes:
    A. Insulation - Insulating your walls and ceilings can save 20% to 30% of home heating bills and reduce CO_2 emissions.
    B. <u>Lights out</u> - Do not leave lights on when no one is in the room. The fact is that, if a light is off, it uses no electricity.
    C. <u>Ceiling fans</u> - The use of room air-conditioning and the high electrical costs associated with it can be reduced by using ceiling fans. Ceiling fans are great since they gently move all of

the air in a room at once. Ceiling fans can draw up and distribute the cooler air that lies along the floor throughout the entire room.

D. Refrigerator Use - Defrost your fridge / freezer regularly, they will work more efficiently. Make sure the door closes properly; it makes sense to open the refrigerator door once to remove all the food you need at any one time again. It is also a good idea to allow warm foods to cool to room temperature before putting them to the refrigerator.

E. Cooking - For optimum energy efficiency use cooking appliances appropriate to the volume and type of food being cooked. Cook the foods together in the oven that require similar temperatures. Choose a saucepan that covers the cooker ring and do not let the gas flame lick up the side of it. Use a saucepan with lids to prevent heat from escaping the top of the pot but also to reduce cooking time.

F. Laundry - Do full loads of laundry whenever possible. Running a washing machine to do one large load as opposed to several smaller ones uses less electricity to power the machine's motor, and overall water consumption will be lower as well.

G. Don't Leave Things Turned On - Electrical appliances such as TVs, PCs and stereos still use power even when on stand-by, so where possible switch appliances off when they are not in use.

H. Buying New Appliances - When buying electrical appliances look for the 'energy efficiency recommended' logo and rated category 'A' or better - your assurance is that the product saves energy and prevents pollution.

I. Low voltage exterior lighting – An outdoor lighting system that operates at 12 volts makes the installation safe for use when children or pets are around. You can use it for safety or for aesthetic reasons. You can put the system on a timer to turn “off” the lights when not needed and “on” when needed for better energy conservation.

NOW DO PRACTICE EXERCISE 12 ON THE NEXT PAGE.

Practice Exercise 12

Describe the proper ways of conserving energy at home given the following.

A. The use of refrigerator

B. Lights out

C. Cooking

D. Ceiling fans

E. Laundry

F. Buying New Appliances

G. Low voltage exterior lighting

H. Appliances turned “on”

I. Air filters

CHECK YOUR WORK. ANSWERS ARE AT THE END OF TOPIC 4.

Answers to activity

1. A
2. A
3. A
4. C
5. D
6. A
7. C
8. D
9. D

Lesson 13: Hydroelectricity

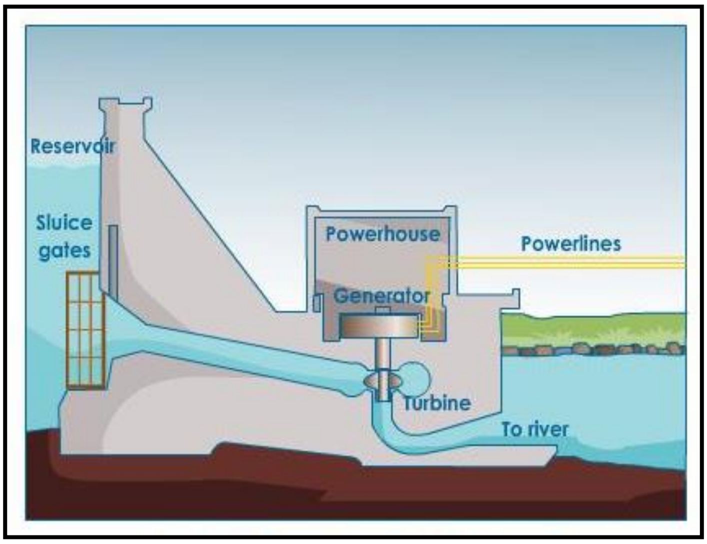
Welcome to Lesson 13. Of the renewable energy sources that generate electricity, hydropower is the most often used. It is one of the oldest sources of energy and was used thousands of years ago to turn a paddle wheel for grinding grain. Until that time, coal was the only fuel used to produce electricity. Because the source of hydropower is water, hydroelectric power plants must be located on a water source. Therefore, it was not until technology to transmit electricity over long distances was developed that hydropower became widely used. Some people regard hydropower as the ideal fuel for electricity generation because, unlike non-renewable fuels used to generate electricity, it is almost free, there are no waste products, and hydropower does not pollute the water or the air. However, it changes the environment by affecting natural habitats.

Your Aims:

- describe how hydroelectric power work
- identify the advantages and disadvantages of hydroelectricity
- describe the different hydroelectric power in PNG

Hydroelectric Power

Hydroelectric power, or hydroelectricity, is generated by the force of falling water. *(*Hydro comes from the Greek word for water.) The energy of flowing water is utilised to produce electricity on a large scale at hydroelectric power plants. Dams are constructed across waterfalls to derive electrical energy from it. It is one of the cleanest and reliable sources of energy. It provides electricity at a reasonable cost to families, schools, farms, factories, and businesses.



Hydroelectric power plant

How does hydroelectric power work?

Water is needed to run a hydroelectric power-generating unit. The water is held behind a dam, forming an artificial lake, or reservoir. The force of the water being released from the reservoir through the dam spins the blades of a giant turbine. The turbine is connected to the generator that makes electricity as it spins. After passing through the turbine, the water flows back into the river on the other side of the dam.

Principle
The water flowing in a river is collected by constructing a high rise dam. This stored water is then allowed to fall from the top of the reservoir on to a water turbine located at the bottom of the dam. The fast moving water rotates the blades of the water turbine, which in turn rotates the armature of the generator and produces electricity.

Construction and Working

Water flowing in high altitude rivers is stored in a man-made reservoir as shown in the figure. The kinetic energy of the flowing water is transformed into potential energy as the water level rises. This water is carried through pipes to the turbine situated at the bottom of the dam. The water turbine has cup-shaped discs around its circumference. A jet of moving water rotates the water turbine rapidly which in turn rotates the shaft which is attached to its centre. The other end of the shaft is connected to the coil of an electric generator. The generator coil rotates and produces electricity.

Advantages of Hydroelectricity
1. The generation of electricity from water does not produce any environmental pollution.
2. Water is a renewable source of energy.
3. The construction of dams on rivers helps controlling floods and also in irrigation.

Disadvantages of Hydroelectricity
1. A vast variety of flora and fauna as well as human settlements get submerged in the water of the reservoir. Thus, animals and people are rendered homeless.
2. It disturbs the ecological balance in the downstream area of the river. As there are no annual floods due to construction of the dam, this downstream region does not get nutrient rich silt which decreases the fertility of the soil and finally the crop yields also decrease.
3. The fish in downstream area do not get sufficient nutrient materials and they die.
4. The vegetation which is submerged rots under anaerobic conditions and gives rise to large amounts of methane which is a green- house gas.
5. It creates the problem of satisfactory rehabilitation of displaced people.

Types of Hydroelectric Power Plants

A. **Micro-Scale**
As their name implies, micro-hydroelectric plants are the smallest type of hydroelectric energy systems. They generate between one kilowatt and one megawatt of power. The main application for these hydro systems is in small, isolated villages in developing countries. They are ideal for powering smaller services such as the operation of processing machines.

B. **Small-Scale**

Small hydropower systems can supply up to 20 megawatts of energy. These systems are relatively inexpensive and reliable. They have the potential to provide electricity to rural areas in developing countries throughout the world. Small systems are especially important to countries that may not afford the costs of importing fossil fuels such as petroleum from other countries.

C. **"Run-of-the-River"**

In some areas of the world, the flow rate and elevation drops of the water are consistent enough that hydroelectric plants can be built directly in the river. The water passes through the plant without greatly changing the flow rate of the river. In many instances a dam is not required, and therefore the hydroelectric plant causes minimal environmental impact on its surroundings. However, one problem with run-of-the-river plants is the obstruction of fish and other aquatic animals.

Hydropower and the Environment

Hydropower is non-polluting, but does have environmental impacts. It does not pollute the water or air. However, hydropower facilities can have large environmental impacts by changing the environment and affecting land use, homes, and natural habitats in the dam area.

Most hydroelectric power plants have a dam and a reservoir. These structures obstruct fish migration and affect their populations. Operating a hydroelectric power plant also change the water temperature and the river's flow. These changes may harm native plants and animals in the river and on land. Reservoirs cover people's homes, important natural areas, agricultural land, and archaeological sites. So building dams can require relocating people. Methane, a strong greenhouse gas, may also form in some reservoirs and be emitted to the atmosphere.

Hydroelectric power sounds great, so why we do not use it to produce all of our power? Mainly because in producing hydroelectric power you need lots of water and a lot of land where you can build a dam and reservoir, which all takes a **lot** of money, time, and construction. In fact, most of the good spots to locate hydro plants have already been taken. In the early part of the century hydroelectric plants supplied a bit less than one-half of the nation's power, but the number is down to about 10 percent today. The trend for the future will probably be to build small-scale hydro plants that can generate electricity for a single community.

Hydroelectricity in PNG

Hydro power provides the base power generation capacity in the Port Moresby, Ramu and Gazelle systems. However, much of the hydro plant is in excess of 30 years old and has not been appropriately maintained but with the improving financial position, PNG Power was able to invest in the resources necessary to establish and implement a program of condition assessment, maintenance planning and refurbishment.

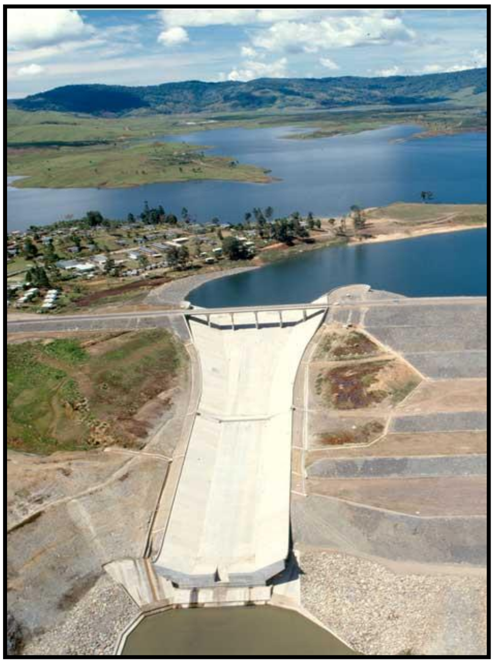
Rouna 2 hydro power station

A. Rouna 2 Hydro Power Station

Rouna 2 is a 30MW (5x6MW) power station built 40 years ago and is the largest hydro power station in the Port Moresby system. In 2004, the PNG Power Board and Management initiated a program to refurbish or replace the Rouna 2 facility. The refurbishment and equipment replacement project will provide an increase in energy output through improved turbine and generator efficiency - reducing the requirement for diesel generation in the Port Moresby power system.

B. Ramu 1 Hydro Power Station

The Ramu 1 power station at Yonki in the Eastern Highlands provides power to the Highlands, Morobe and Madang regions through over 700 kilometers of transmission lines of the Ramu electricity grid. As a result of age and poor maintenance, the Ramu 1 power was not performing efficiently and reliably. PNG Power engaged to review the current state of the plant and to provide guidance on operational management of the facility and an appropriate maintenance management program.



Yonki Dam 1

Yonki Dam 2

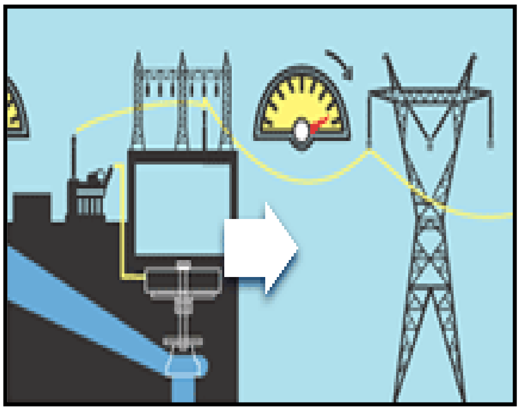
C. Ru Creek Hydro Power Station

PNG Power also refurbished the Ru Creek mini hydro power station near Kimbe in West New Britain.

This mini hydro facility supplements the diesel generators at Kimbe and provides about 20% of the power requirements in this regional centre.

Kimbe diesel power generators

From the Power Station to the Home




Electricity's path from the power station to your home put together a power system!

Inside a generating station, turbines use the driving force of water to set electrons in motion and generate alternating current.

Electricity from the power station has a long way to go before reaching your home.

1. The voltage of the current produced by a generating station can reach 13,800 volts at the generating facility.

2. Thanks to the **voltage step-up transformer** located in the **generating station's switchyard**, the electricity is transmitted at much higher voltages, from 44,000 to 765,000 volts.

3. Once in the transmission system, electricity from each generating station is combined with electricity produced elsewhere.

4. The electricity passes through **cables** which are suspended from **towers**. These towers are arranged in a series from the generating stations to **source substations**–which lower the voltage–and then reach the **satellite substations**, which further reduce the voltage.

5. Leaving the satellite substations, electricity travels through **underground lines**. At some distance from the substations, the distribution system goes from underground to **overhead**, and **transformers attached to poles** lower the voltage one last time. Inside our homes, we use either 120 volts to power our televisions, radios and other regular electrical appliances, or 240 volts for the appliances that require a strong current like the dryer or stove.

6. Electricity is consumed as soon as it is produced. It is transmitted at a very high speed, close to the speed of light (300,000 km/s).

Before electricity is consumed, three steps are followed: production, transmission and distribution. In the first step, the generator produces the electricity from a primary energy source. The transmission step consists of moving the electricity produced at generating stations to consumption locations. Thereafter, the electricity must be distributed to each house, factory or business.

Electricity generated by the generators flows to transformers that step up the voltage in preparation for travel over long distances. Electricity travels more easily at high voltages because there are fewer energy losses.

Transformers - 84 KB

Given the vast expanse of land, electrical energy requires an imposing network of high voltage power lines installed over several thousand kilometres. The transportation network is made up of towers, lines, stations that step voltage up or down and an interconnection. Towers are the most visible pieces of equipment in the electricity transmission chain. Towers support the high-voltage conductors of overhead power lines. The high-voltage conductors on the towers are made of aluminium, a lightweight material and very good conductor offering a better price-quality ratio than other metals such as silver, gold or copper. Each conductor is stranded with wires twisted together around a steel core that gives the conductor its required strength.

Activity: Now test yourself by doing this activity.

Circle the letter of the correct answer.

1. Which statement is correct about hydropower?

   A. It was used thousands of years ago to turn a paddle wheel for purposes such as grinding grain.

   B. Because the source of hydropower is water, hydroelectric power plants must be located on a water source.

   C. Over one-half of the total world hydroelectric capacity for electricity generation is concentrated in one country.

   D. All of the above answers are correct.

2. One of the negative factors for using hydropower is

   A. hydropower requires an expensive fuel.

   B. hydropower causes moderate pollution.

   C. hydropower does change the environment by affecting natural habitats.

   D. none of the above answers.

3. Hydropower production can best be described as changes in energy from:

   A. Chemical --> Solar --> Electrical

   B. Solar ---> Chemical ---> Electrical

   C. Solar ---> Mechanical ---> Electrical

   D. Mechanical ---> Solar ---> Electrical

4. What is hydropower, also known as hydroelectricity?

   A. The making of water by electricity.

   B. The making of electricity by force.

   C. The making of electricity by water.

   D. The making of doughnuts by water.

5. Do hydroelectricity power plants change nutrients that are in water when the water comes out of the plant?

   A. Yes B. No

   C. Depends on the power plant D. Depends on the water

6. What does the word, "hydro", mean?

A. Dirt B. Water

C. Energy D. Electricity

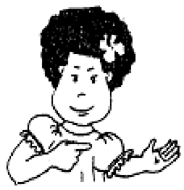
7. Which of the following is true about hydropower?

A. It smells bad.
B. It is a superhero.
C. It is made from sand.
D. It is cheaper than most sources of energy.

8. Why is hydroelectricity so environmentally safe?

A. It is flammable.
B. It burns all oil and gasses.
C. It serves as fertilizer for trees.
D. It does not involve the burning of oil and coal which their outputs are dangerous to animals.

CHECK YOUR WORK. ANSWERS ARE AT THE END OF LESSON 13.



Summary

You have come to the end of lesson 13. You have learnt that:

- hydroelectric power, or hydroelectricity, is generated by the force of falling water.
- hydroelectricity is one of the cleanest and reliable sources of energy. It provides electricity at a reasonable cost to families, schools, farms, factories, and businesses.
- hydropower is non-polluting, but does have environmental impacts. Most hydroelectric power plants have a dam and a reservoir. These structures may obstruct fish migration and affect their populations.
- rouna 2 Hydro Power Station is a 30MW (5x6MW) power station built 40 years ago and is the largest hydro power station in the Port Moresby system.
- the Ramu 1 power station at Yonki in the Eastern Highlands provides power to the Highlands, Morobe and Madang regions through over 700 kilometers of transmission lines of the Ramu electricity grid.
- the Ru Creek mini hydro power station near Kimbe in West New Britain has a facility that supplements the diesel generators at Kimbe and provides about 20% of the power requirements in this regional centre.

- before electricity is consumed, three steps are followed: production, transmission and distribution.
- in production the generator produces the electricity from a primary energy source.
- the transmission step consists of moving the electricity produced at generating stations to consumption locations.
- thereafter, the electricity must be distributed to each house, factory or business.
- electricity travels more easily at high voltages because there are fewer energy losses.
- the transportation network is made up of towers, lines, stations that step voltage up or down and an interconnection.
- towers support the high-voltage conductors of overhead power lines.
- the high-voltage conductors on the towers are made of aluminium, a lightweight material and a very good conductor.

NOW DO PRACTICE EXERCISE 13 ON THE NEXT PAGE.

Practice Exercise 13

1. How does hydroelectric power work?

____

____

____

____

____

2. Enumerate at least three advantages and disadvantages of hydroelectricity.

Advantages

a. ____

____

b. ____

____

c. ____

____

Disadvantages

a. ____

____

b. ____

____

c. ____

____

3. Describe the following.

a. Rouna 2 Hydro Power Station

____

____

b. The Ramu 1 power station at Yonki

____

____

c. The Ru Creek

____

____

CHECK YOUR WORK. ANSWERS ARE AT THE END OF TOPIC 4.

Answers to activity

1.	A	5.	A
2.	C	6.	B
3.	C	7.	D
4.	C	8.	D

Answers to Practice Exercises 11 - 13

Practice Exercise 11

1. Watt's Law describes a relationship between voltage, current and power in an electric circuit; Power is equal to the product of voltage and current (P = V x I).

2. A. DVD in use for 10 hrs/day @ 0.64 toea/KWh

    (25 Watts x 10 hours/day) ÷ 1000
    = 0.25 x 0.64 toea/KWh
    = 0.16toea/KWh

    F. Washing machine in use for 3 hours @ K2.15/KWh

    (500 Watts x 3 hours/day) ÷ 1000
    = 1.5 x K2.15/KWh
    = K3. 23/KWh

    G. Coffee maker in use for 2 hours @ K3. 10/KWh

    (1200 Watts x 2 hours/day) ÷ 1000
    = 2.4 x K3.10/KWh
    = K7.44/KWh

    H. Lap top in use for 7 hours @ K3.50/KWh

    (50 Watts x 7 hours/day) ÷ 1000
    = 0.35 x K3.50/KWh
    = K1.23/KWh

    I. Toaster in use for 4 hours @ K 2.00?KWh

    (1500 Watts x 4 hours/day) ÷ 1000
    = 6 x K2.00/KWh
    = K12.00/KWh

Practice Exercise 12

A. The use of refrigerator - Defrost your fridge / freezer regularly, they will work more efficiently. Make sure the door closes properly; it makes sense to open the refrigerator door once to remove all the food you need at any one time again. It is also a good idea to allow warm foods to cool to room temperature before putting them to the refrigerator.

B. Lights out - Do not leave lights on when no one is in the room. The fact is that, if a light is off, it uses no electricity.

C. Cooking – if possible, cook the foods together in the oven that require similar temperatures. Choose a saucepan that covers the cooker ring and do not let the gas flame lick up the side of it. Use a saucepan with lids not only to prevent heat from escaping the top of the pot but also to reduce cooking time.

D. Ceiling fans - The use of room air-conditioning and the high electrical costs involved can be reduced by using ceiling fans. Ceiling fans are great since they gently move all of the air in a room at once. Ceiling fans can draw up and distribute the cooler air that lies along the floor throughout the entire room.

E. Laundry - Do full loads of laundry whenever possible. Running a washing machine to do one large load as opposed to several smaller ones uses less electricity to power the machine's motor, and lowers water consumption.

F. Buying New Appliances - When buying electrical appliances look for the 'energy efficiency recommended' logo and rated category 'A' or better - your assurance that the product saves energy and prevents pollution.

G. Low voltage exterior lighting – An outdoor lighting system that operates at 12 volts makes the installation safe for use when children or pets are around. You can use it for safety or for aesthetic reasons. You can put the system on a timer to turn "off" the lights when not likely to be needed and "on" when they needed for better energy conservation.

H. Appliances turned "on" - Electrical appliances such as TVs, PCs and stereos still use power even when on stand-by, so where possible switch appliances off when they are not in use.

I. Air filters - Clean or replace air filters as recommended. Energy is lost when air conditioners and hot-air furnaces work harder to draw air through dirty filters. Cleaning a dirty air conditioner filter can save 5 % of the energy used.

Practice Exercise 13

1. Water is needed to run a hydroelectric power-generating unit. The water is held behind a dam, forming an artificial lake, or reservoir. The force of the water being released from the reservoir through the dam spins the blades of a giant turbine. The turbine is connected to the generator that makes electricity as it spins. After passing through the turbine, the water flows back into the river on the other side of the dam.

2. Advantages
   a. The generation of electricity from water does not produce any environmental pollution.
   b. Water is a renewable source of energy.
   c. The construction of dams on rivers helps in controlling floods and also helps in irrigation.

   Disadvantages
   a. A vast variety of flora and fauna as well as human settlements get submerged in the water of the reservoir. Thus, animals and people are rendered homeless.
   b. It disturbs the ecological balance in the downstream area of the river.

c. The fish in the downstream area do not get sufficient nutrient materials and die.

d. The vegetation which is submerged rots under anaerobic conditions and gives rise to large amounts of methane which is a green- house gas.

e. It creates the problem of satisfactory rehabilitation of displaced people

3. a. Rouna 2 Hydro Power Station is a 30MW (5x6MW) power station built 40 years ago and is the largest hydro power station in the Port Moresby system.

b. The Ramu 1 power station at Yonki in the Eastern Highlands provides power to the Highlands, Morobe and Madang regions through over 700 kilometers of transmission lines of the Ramu electricity grid.

c. The Ru Creek mini hydro power station near Kimbe in West New Britain has a facility that supplements the diesel generators at Kimbe and provides about 20% of the power requirements in this regional centre.

REVISE TOPIC 4 USING THE MAIN POINTS ON THE NEXT PAGE.

REVIEW OF TOPIC 4: GENERATING ELECTRICITY

Revise all the Lessons in this Topic and then do **ASSIGNMENT 5.**
Here are the main points to help you revise.

Lesson 11: Electrical Power and Costing

- Watt's Law describes a relationship between voltage, current and power in an electric circuit.
- Power is defined as “work done or energy transferred per unit of time," and is represented by the symbol P.
- Power is measured in watts (W). One watt is equal to one joule.
- A Joule is defined as "a unit of electrical energy equal to the work done when a current of one ampere is passed through a resistance of one ohm for one second.
- Volt-Amps correlate to power being equal to the product of voltage and current.
- Watt's Law can be used when designing a circuit to help determine wire gauge and circuit protection.
- The best way to compare the cost of running different appliances is to look at their power consumption, which is measure of how much power they use in Watts.
- You can usually find the wattage of most appliances stamped on the bottom or back of the appliance, or on its nameplate. The wattage listed is the maximum power drawn by the appliance.
- You can use this formula to estimate an appliance's energy use:

$$(\text{Wattage} \times \text{Hours Used/Day}) \div 1000 = \text{Daily Kilowatt-hour (kWh)}$$

$$(1 \text{ kilowatt (kW)} = 1{,}000 \text{ Watts})$$

Lesson 12: Conservation of Electrical energy

- Manage the energy or electricity used at home, you must be aware of the behaviours of people around you and by adopting an approach whereby you and other members of the household learn to manage the energy or electricity used in your house.
- Some basic concepts of energy efficiency includes:

A. Insulation - Insulating your walls and ceilings can save 20% to 30% of home heating bills and reduce CO_2 emissions.

B. Lights out - Do not leave lights on when no one is in the room. The fact is that, if a light is off, it uses no electricity.

C. Ceiling fans - The use of room air-conditioning and the high electrical costs associated with it can be reduced by using ceiling fans. Ceiling fans are great since they gently move all of the air in a room at once. Ceiling fans can draw up and distribute the cooler air that lies along the floor throughout the entire room.

D. Refrigerator Use - Defrost your fridge / freezer regularly, they will work more efficiently. Make sure the door closes properly; it makes sense to open the refrigerator door once to remove all the food you need at any one time again. It is also a good idea to allow warm foods to cool to room temperature before putting them to the refrigerator.

E. Cooking - For optimum energy efficiency, use cooking appliances appropriate to the volume and type of food being cooked. Cook the foods together in the oven that require similar temperatures. Choose a saucepan that covers the cooker ring and do not let the gas flame lick up the side of it. Use a saucepan with lids to prevent heat from escaping on the top of the pot but also to reduce cooking time.

F. Laundry - Do full loads of laundry whenever possible. Running a washing machine to do one large load as opposed to several smaller ones uses less electricity to power the machine's motor, and overall water consumption will be lower as well.

G. Don't Leave Things Turned On - Electrical appliances such as TVs, PCs and stereos still use power even when on stand-by, so where possible switch appliances off when they are not in use.

H. Buying New Appliances - When buying electrical appliances look for the 'energy efficiency recommended' logo and rated category 'A' or better - your assurance is that the product saves energy and prevents pollution.

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REVISE WELL AND THEN DO TOPIC TEST 4 IN YOUR ASSIGNMENT 5.

GLOSSARY

A

Ammeter
A device used to measure current.

Amperage
The strength of an electric current in amperes.

C

Circuit symbols
Used in circuit diagrams which show how a circuit is connected together electrically.

Current
The flow rate of the electrons in the circuit. It flows from negative to positive on the surface of a conductor and it is measured in amperes or amps (A).

Current electricity
Movement of electrons that carry electrical energy from one place to another.

E

Electrical circuit
A closed loop formed by a power source, wires, a fuse, a load, and a switch.

Electromagnet
A soft-iron core that is magnetised temporarily by passing a current through a coil of wire wound on the core.

F

Fossil fuels
Formed hundreds of millions of years ago and are made up of decomposed plant and animal matter.

H

Heating effect of current
When an electric current is passed through a wire, like filament of an electric heater, the filament gets heated up and electrical energy is converted into heat energy.

Heat pump
Device that diverts heat from one location at a lower temperature to another location at a higher temperature using mechanical work or a high-temperature heat source.

Hydroelectricity
Generated by the force of falling water..

J

Joule
A unit of electrical energy equal to the work done when a current of one ampere is passed through a resistance of one ohm for one second.

L

Law of Conservation of Energy
Energy can be transformed from one form to another.

Load
Any device that consumes the energy flowing through a circuit and converts that energy into work.

M

Magnet
Material that attracts other objects containing the elements iron, nickel or cobalt .

Magnetic effect of current
A current flowing in a wire produces a magnetic field around it.

Magnetic field
A region in which a magnetic force is present.

Microwave oven
Kitchen appliance that heats food by dielectric heating using microwave radiation to heat polarized molecules within the food.

O

Ohm’s law

States that the amount of current passing through a conductor is directly proportional to the voltage across the conductor and inversely proportional to the resistance of the conductor..

P

Parallel circuit

A circuit in which there are at least two independent paths in the circuit to get back to the source.

Phosphorus

Substances that give off light when they are exposed to light.

Power

Work done or energy transferred per unit of time.

R

Resistance Determines how much current will flow through a component.

S

Series circuit

A circuit where there is only one path from the source through all of the loads (light bulbs) and back to the source.

Solenoid

A long wire coiled in the shape of a spring so that the turns are closely spaced and insulated from each other.

Space heater

Self-contained device for heating an enclosed area.

Static

Lacking in movement, action or change especially in an undescribed or uninteresting way.

Static electricity

The build up of an electric charge in a certain location. It stays in one place and does not move.

V

Volt

The measure of electric pressure

Voltage

Difference in electrical potential between two points in a circuit. It is the push or pressure behind current flow through a circuit, and is measured in (V) volts.

Voltmeter

A device used to measure voltage.

W

Watt's Law describes a relationship between voltage, current and power in an electric circuit.

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http://www.soest.hawaii.edu/GG/ASK/atmo-nitrogen.html

FODE PROVINCIAL CENTRES CONTACTS

PC NO.	FODE PROVINCIAL CENTRE	ADDRESS	PHONE/FAX	CUG PHONE (COORDINATOR)	CUG PHONE (SENIOR CLERK)
1	ALOTAU	P. O. Box 822, Alotau	6411343/6419195	72228130	72229051
2	BUKA	P. O. Box 154, Buka	9739838	72228108	72229073
3	CENTRAL	C/- FODE HQ	3419228	72228110	72229050
4	DARU	P. O. Box 68, Daru	6459033	72228146	72229047
5	GOROKA	P. O. Box 990, Goroka	5322085/5322321	72228116	72229054
6	HELA	P. O. Box 63, Tari	73197115	72228141	72229083
7	JIWAKA	c/- FODE Hagen		72228143	72229085
8	KAVIENG	P. O. Box 284, Kavieng	9842183	72228136	72229069
9	KEREMA	P. O. Box 86, Kerema	6481303	72228124	72229049
10	KIMBE	P. O. Box 328, Kimbe	9835110	72228150	72229065
11	KUNDIAWA	P. O. Box 95, Kundiawa	5351612	72228144	72229056
12	LAE	P. O. Box 4969, Lae	4725508/4721162	72228132	72229064
13	MADANG	P. O. Box 2071, Madang	4222418	72228126	72229063
14	MANUS	P. O. Box 41, Lorengau	9709251	72228128	72229080
15	MENDI	P. O. Box 237, Mendi	5491264/72895095	72228142	72229053
16	MT HAGEN	P. O. Box 418, Mt. Hagen	5421194/5423332	72228148	72229057
17	NCD	C/- FODE HQ	3230299 ext 26	72228134	72229081
18	POPONDETTA	P. O. Box 71, Popondetta	6297160/6297678	72228138	72229052
19	RABAUL	P. O. Box 83, Kokopo	9400314	72228118	72229067
20	VANIMO	P. O. Box 38, Vanimo	4571175/4571438	72228140	72229060
21	WABAG	P. O. Box 259, Wabag	5471114	72228120	72229082
22	WEWAK	P. O. Box 583, Wewak	4562231/4561114	72228122	72229062

FODE SUBJECTS AND COURSE PROGRAMMES

GRADE LEVELS	SUBJECTS/COURSES
Grades 7 and 8	1. English
	2. Mathematics
	3. Personal Development
	4. Social Science
	5. Science
	6. Making a Living
Grades 9 and 10	1. English
	2. Mathematics
	3. Personal Development
	4. Science
	5. Social Science
	6. Business Studies
	7. Design and Technology- Computing
Grades 11 and 12	1. English – Applied English/Language& Literature
	2. Mathematics – General/Advance
	3. Science – Biology/Chemistry/Physics
	4. Social Science – History/Geography/Economics
	5. Personal Development
	6. Business Studies
	7. Information & Communication Technology

REMEMBER:

- For Grades 7 and 8, you are required to do all six (6) subjects.
- For Grades 9 and 10, you must complete five (5) subjects and one (1) optional to be certified. Business Studies and Design & Technology – Computing are optional.
- For Grades 11 and 12, you are required to complete seven (7) out of thirteen (13) subjects to be certified.

Your Provincial Coordinator or Supervisor will give you more information regarding each subject and course.

Notes: You must seek advice from your Provincial Coordinator regarding the recommended courses in each stream. Options should be discussed carefully before choosing the stream when enrolling into Grade 11. FODE will certify for the successful completion of seven subjects in Grade 12.

GRADES 11 & 12 COURSE PROGRAMMES			
No	**Science**	**Humanities**	**Business**
1	Applied English	Language & Literature	Language & Literature/Applied English
2	Mathematics -General/Advance	Mathematics -General/Advance	Mathematics –General/Advance
3	Personal Development	Personal Development	Personal Development
4	Biology	Biology/Physics/Chemistry	Biology/Physics/Chemistry
5	Chemistry/ Physics	Geography	Economics/Geography/History
6	Geography/History/Economics	History / Economics	Business Studies
7	ICT	ICT	ICT

CERTIFICATE IN MATRICULATION STUDIES		
No	**Compulsory Courses**	**Optional Courses**
1	English 1	**Science Stream:** Biology, Chemistry, Physics
2	English 2	**Social Science Stream:** Geography, Intro to Economics and Asia and the Modern World
3	Mathematics 1	
4	Mathematics 2	
5	History of Science & Technology	

REMEMBER:

You must successfully complete 8 courses: 5 compulsory and 3 optional.