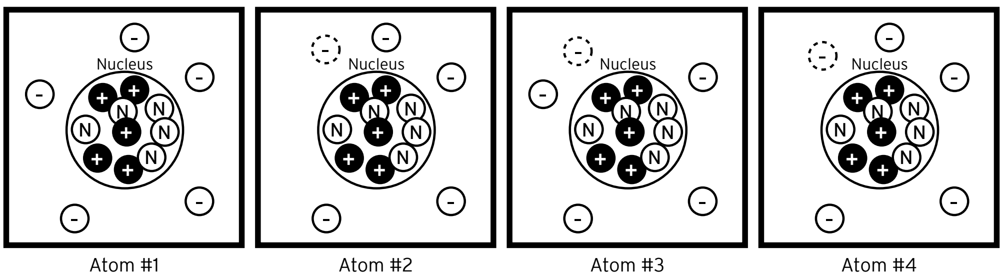
Electricity concepts teacher backgrounder

What is electricity, where does it come from and what do we use it for?

Scientifically, electricity is the movement of electrons from one atom to another. This movement of electrons creates a current or "flow" of electrons from atom to atom. As atoms lose an electron, they become positively charged, while the free electron has a negative charge that seeks a positive charge to balance it out. We call the total attraction between positive and negative groups a charge.

Electricity—The flow of electrons between atoms



Electricity can be generated in a variety of ways, but it always involves the transformation of energy from one type to another and eventually to electrical energy.

In B.C., hydroelectric dams generate most of our electricity. There is potential energy in the water stored in reservoirs behind a dam. This energy is transformed to kinetic energy as the water flows down a large tube, called a penstock, from the dam. The kinetic energy then turns a turbine to generate electrical energy.

Hydroelectricity is carried long distances along transmission lines. Transformers along the lines control the voltage of the electricity, either increasing or decreasing it as needed. The low voltage electricity generated at the dam site is often increased to about 500,000 volts to travel the distances from the dam to substations in various communities. The substations then use transformers to lower the voltage to between 20,000 and 35,000 volts, before the electricity is carried along power lines within cities and towns. Distribution transformers lower the voltage further (to between 120 and 600 volts) as the electricity moves along distribution lines to businesses, schools and homes.

Other ways to generate electricity include natural gas, coal, solar, wind, tides/oceans, geothermal and nuclear.

Electricity is everywhere in our lives. We use it to light up and heat our homes, cook our food, and power our devices and appliances. It's become an essential part of our modern world.

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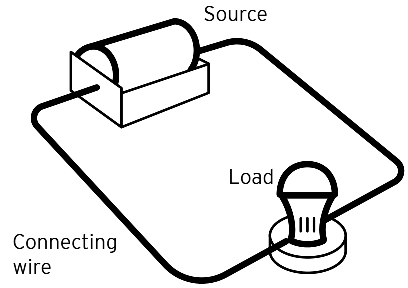
What is a circuit and how does it work?

A circuit is a closed loop allowing the electrons to “flow”. Once an electric charge has been generated, it can be conducted or carried elsewhere as a current along any conducting material (e.g. wire). Electric charge can be stored (e.g. in a dry cell battery) to create a power source. The charge then moves as current from the negative pole to the positive pole through the conducting material. This flow of current in a circuit is used to ‘do work’ along the way, such as heating the filament in a light bulb to give off light (transforming electric energy into heat and light energy). Appliances, devices etc. that are attached to circuits and require electricity to work are called loads.

Essential parts of a circuit include a source, conducting material and a load. Optional components include switches, meters, resistors, etc. Note that loads also create resistance in a circuit.

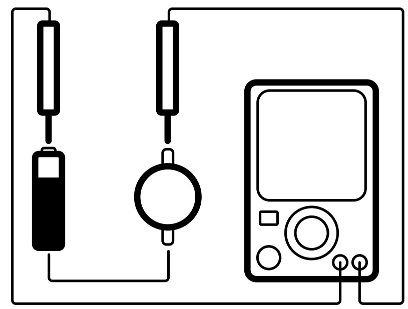
Simple Circuit



What is current and how is it measured?

Electric current is the flow of charge through a circuit or the rate at which charge passes a point in the circuit. It is measured in amperes (or amps) with each ampere equal to one coulomb of charge passing a point in the circuit per second.

Current can be measured using an ammeter (or a multimeter) placed in series with the circuit (becoming part of the single path) so that all electrons flowing through the circuit also go through the ammeter (or multimeter).

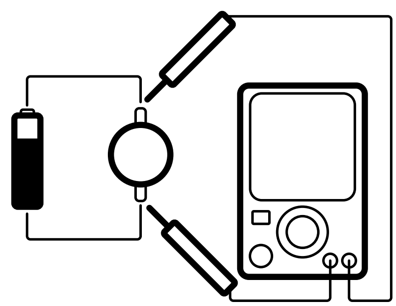


Connect the multimeter in series to measure the current flow through a load.

What is voltage and how is it measured?

Voltage is a measure of the electric potential energy per unit of charge or potential difference in charge between two points in a circuit. Voltage, measured in volts (V), is the pressure from the source that drives current through a circuit. The higher the voltage, the greater the flow of current (how fast a charge passes a point in the circuit).

Because it’s the difference in charge between two points in a circuit, voltage is measured by touching the leads of a voltmeter (or multimeter) to any two points of the circuit (i.e. parallel to). Generally, this is first done on either side of the power source (e.g. dry cell battery) and then is measured at different locations in the circuit.



Connect the multimeter in parallel to measure the voltage drop across the load.

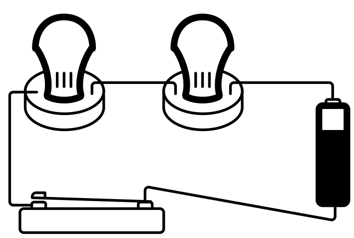
How to safely construct circuits and use multimeters.

1. Put the dry cells in the battery holders.
2. Connect the dry cells and load by completing the circuit using the wires and clips. Connect the red wire(s) to the positive terminal of the battery and black wire(s) to the negative terminal of the battery.
3. To use multimeters:
   a. Connect the black probe to the COM port and the red probe to the VΩmA port.
   b. Set to DC (V with ⎓ symbol).
   c. Set to maximum voltage that may be calculated (i.e. if >2 V is expected, set to 20V).
   d. Connect the other end of the black probe to the negative wire(s) and the other end of the red probe to the positive wire(s).

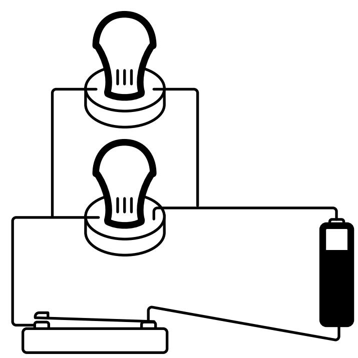
What are series and parallel circuits? How are they different?

Simple circuits, with just a source, conductor and load are not often found in practical applications. Generally, we use circuits with more than just these basic components. There are two common ways to connect multiple circuit components: series and parallel.

In a series circuit, sources and/or loads are connected in series or end-to-end. This forms a single path for current to flow. In a parallel circuit, components are connected across each other's leads creating multiple paths for current to flow. Each path in a parallel circuit is called a branch.



Series Circuit



Parallel Circuit

Both series and parallel circuits include the required components of a circuit and can use multiple sources and/or loads. Series circuits have their sources and loads in a line so that the voltage changes (increases with each added source and decreases with each added load). On the other hand, parallel circuits have their sources and/or loads in different branches so the current has to split and thus changes. Voltage remains constant in a parallel circuit.

What is resistance and how does it affect circuits?

Electrical resistance is a measure of how well something conducts electricity. Some materials conduct electricity well (e.g. copper wire) and are called conductors. Other materials conduct electricity poorly (e.g. rubber) and are called insulators. Resistance is measured in ohms.

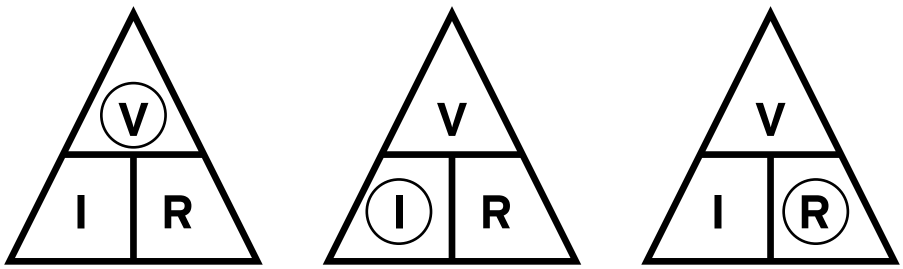
Resistors are devices that limit the flow of electrons, thus reducing the electrical current. There are different kinds of resistors and each is made from different materials. Resistors can be fixed or variable. The most common type of resistor is fixed (i.e. they have a constant and single value of resistance). Variable resistors, as the name suggests, can be adjusted to change the amount of resistance in the circuit.

What is Ohm's Law and how is it useful?

Ohm's Law describes the relationship between voltage, current and resistance in a simple electrical circuit. First formulated by Georg Ohm in 1827, it states that the current passing through a conductor is directly proportional to the voltage across the conductor. The easiest form of the equation is V = I x R where V is the voltage (in volts), I is the current (in amps) and R is the resistance (in ohms).

Ohm's Law allows you to calculate one variable if you know the value of the other two. For example, if you know the current and resistance of a circuit, you can calculate the voltage using V = I x R. Using algebra, you can rearrange the variables depending on the unknown value. If you know the voltage and resistance, you can find the current using I = V / R. Or, if you know the voltage and current, you can find the resistance using R = V / I.

Ohm's law triangle



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

Voltage, current and resistance in series and parallel circuits

Series circuits

The logic of series circuit electricity is the easiest starting point in understanding the relationships and mathematics involved in these calculations. While current is constant as it flows through each point in a series circuits, each load or resistance results in the voltage decreasing, while voltage increases as additional sources are added (in series).

Summary: In a series circuit, the current stays the same through each part of the circuit. The total resistance of a series circuit is the sum of individual resistances. The voltage applied to a series circuit is the sum of the individual voltages of the sources.

Parallel circuits

In parallel circuits, voltage and current behave opposite to series circuits. Voltage in each branch of the circuit remains constant and current is the sum of each of the branches in the circuit (as it gets split into the branches).

Summary: Voltage is the same across each component of the parallel circuit. The sum of the currents through each path is equal to the total current that flows from the source.

Helpful mnemonics to remember how voltage and current differ between series and parallel circuits are:

SASS – Series circuits Amps Stay the Same

PVSS – Parallel circuits Voltage Stays the Same

Compound circuits

If students are interested, you can calculate voltage and current values in compound circuits, which include both series and parallel circuits (which most real circuits do). There is a simple logic to first addressing resistance in the different branches, and then summing these values to arrive at a simplified series circuit:

1. Calculate the equivalent resistances of resistors in parallel.
2. Calculate the equivalent resistances of resistors in series.
3. By repeating steps 1 and 2, as needed, the circuit can be simplified to an equivalent series circuit.
4. Simply add the equivalent resistances of the simplified equivalent series circuit to find the total resistance of the compound circuit.

Circuits found in our homes

Our homes are full of circuits and other equipment to create a safe and efficient system to deliver electricity for our daily needs. Electricity enters our homes through a main line from the nearest distribution pole, through an electricity meter that tracks use, to a main circuit breaker panel. From the circuit panel, electricity is split into separate circuits and travels through wiring to outlets, light fixtures, appliances and other devices. Switches are placed on walls in convenient locations so we can turn circuits 'on' or 'off'.

Electrical safety at home

Numerous safety features are built into our home electricity system. The circuit panel (also known as a fuse box in older homes) contains a main breaker or switch to turn off power in the entire home. Each branch circuit has its own breaker and can also be switched off. The circuit panel has a grounding circuit to direct electricity away from the house and into the ground. Wall outlets may contain a ground fault circuit interrupter (GFCI), especially in kitchens or bathrooms where water may be present. GFCIs detect tiny changes in current and can switch off the circuit to avoid electric shock.

Students may or may not be aware of the risks around electricity.

- Unplug cords by the plug not the cord (damage to the plug and/or cord).
- Never link extension cords together (risk of overheating)
- Avoid pinching extension cords in doors or other sharp edges.
- Replace extension cords with visible plug or sheath damage.
- Don't plug more than two appliances into outlets.
- Use power bars when more outlets are required.
- Stay away from overhead power lines.
- Keep electrical appliances and cords away from water.

The slideshow notes for Lesson 5 highlight key content for electrical safety measures students need to be aware of. For a more in depth exploration of electrical safety, download and teach the Grade 8/9 Electrical Safety Lesson found on the Energy Leaders site. Find additional background information, go to **fortisbc.com/Safety/ElectricalSafety**.

What is AC and DC power?

AC and DC type voltage are used in many different applications in our homes and communities. Alternating current (AC) alternates directions regularly and supplies our homes and community buildings. Electricity is moved as AC because it's easy to change the voltage and much more efficient to transport power long distances in the AC format. AC tends to be used in simple heating operations (toasters, dryers, ovens, water heaters), home lighting and for larger motors (e.g. fans) found in community and industrial operations.

Direct current (DC) flows in one direction only and is used in some devices and other lower voltage applications. All computer circuits operate on DC. AC is easily and cheaply converted to DC in households (with an AC adaptor), which allows for easy operation of lower voltage circuits types (e.g. clocks, digital displays, computer circuits). For this reason, many household devices use AC plugs, but convert power to DC for electronics and/or DC motor operations.

Energy efficiency at home

Energy efficiency means reducing the amount of energy required to provide products and services. In a home, using less energy to achieve the same degree of warmth and comfort would be a measure of energy efficiency. Technology is the primary way to achieve efficiency in homes. Raising awareness of the environmental and economic benefits involved will help people understand the value of replacing or retrofitting appliances, upgrading insulation and windows, and other energy efficiency options.

Some key areas for home energy efficiency are heating and hot water. The energy required to heat and cool homes represents 52 per cent of the total energy used, while the energy for heating water represents 25 per cent of home energy use. Combined, that's more than 75 per cent of home energy use. Some ways to improve efficiency in these areas include:

- draftproof to reduce drafts (weatherstrip windows and doors; caulk floor, door and window seams)
- add insulation (especially the attic, crawl space or basement)
- upgrade the furnace to a higher efficiency model
- replace old hot water heaters with new energy-efficient models
- install a programmable or "smart learning" thermostat
- install hot water pipe insulation
- install water-efficient showerheads and faucet aerators
- use digital technologies including 'smart' plugs and power bars that are Wi-Fi enabled

Appliances such as refrigerators, dryers and dishwashers use about 17 per cent of home energy. Upgrading appliances to energy-efficient models can provide substantial savings. The EnerGuide or ENERGY STAR® labels on appliances provide certified guidance on what devices are most energy efficient. Helpful tips can be found at **fortisbc.com/Rebates/SavingEnergy/SavingEnergyAtHome/EnergySavingTipsForHome**.

Conserving electricity

In addition to focusing on energy efficiency, we can also change our behaviour to conserve electricity in our lives. Conserving electricity and other forms of energy means you only use it when necessary and avoid wasting it. We can save money and reduce our need for electricity, as well as help to ensure there will be an adequate supply for the future.

In most cases, students have far more control over their daily actions than they do the systems and technologies in their home. Simple actions like turning off lights, taking shorter showers, turning off devices and appliances when not in use and using power bars that can be turned off are a few examples. Encourage students to find other ways to conserve and explore how, by creating a personal conservation plan, they can conserve electricity in their daily lives.

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