IDC102:Hands-on Electronics
Lecture - 1

IISER

Satyajit Jena, 07/05/2022

IDC102: Course Objectives

- Introduction to electronics.
- Learn basic electrical quantities
- Learn basic ideas about circuits

- Recognize discrete components in electronics.
- Recognize the laboratory equipment.
- Learn to use components
- Learn to use a multimeter

- Working experience with prototype board
- Assemble simple circuits over a PCB.

IDC102: What is Electronics?

- General Definition
  - The science dealing with the development and application of devices and systems involving the flow of electrons in a vacuum, in gaseous media, and in semiconductors.

- Modern Definition
  - The science dealing with the development and application of devices and systems involving the flow of electrons in semiconductors.

IDC102: Electronics vs. Electrical

- According to Wikipedia
  - Electrical Engineering: is a field of engineering that generally deals with the study and application of electricity, electronics, and electromagnetism.
  - Electronic Engineering: is an engineering discipline where non-linear and active electrical components such as electron tubes, and semiconductor devices, especially transistors, diodes and integrated circuits, are utilized to design electronic circuits, devices and systems.
- Main Difference:
  - Electrical Engineering
    - Study and utilization/ Application of flow of electrons
  - Electronic Engineering
    - Study and utilization/ Application of flow of charges (Electrons or holes)

IDC102: Electronics vs. Electrical

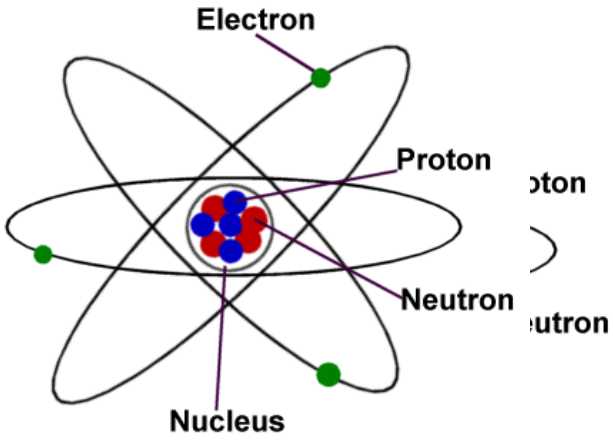
- Electrical Technology: Electrical technology is the technology of producing, storing, controlling, transmitting and getting work from electrical energy. (Example applications: power plant generator, flashlight, electric motor in a can opener, doorbell, electric heater, hair dryer.)

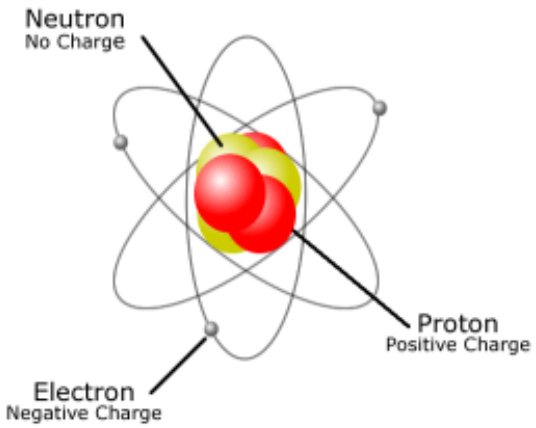
- Electronic Technology: Electronic technology as the technology of using small amounts of electricity for controlling; detecting; and information collecting, storing, retrieving, processing, and communicating. (Example applications: thermostat for controlling temperature, a metal detector, video tape recorder, computer, pocket calculator, telephone, radio, television.)

Let's start from some basics

IDC102: Basics

We know that matter is composed of atoms, which are composed of protons, neutrons, and electrons.



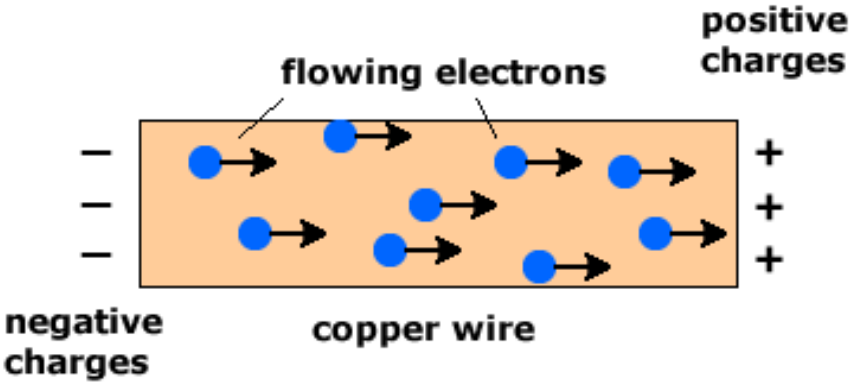


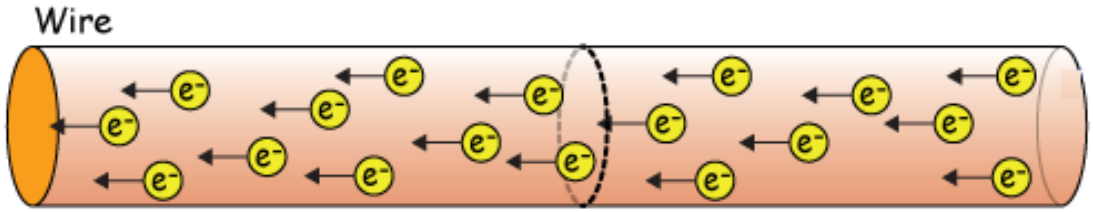
The protons are positively charged and are found "locked" in the nucleus with the neutrons.

The electrons are negatively charged and are moving around in the electron clouds and are not "locked" into position.

IDC102: Basics

- In fact, electrons can and do move between atoms, and can be transferred to other materials and move around quite freely at times.
- This "free movement" of electrons is what we call electricity.
- The flow of charged particles is an electric current.





IDC102: Basics

Current always flows from a positively charged source to a negatively charged source.

$$+ \rightarrow -$$

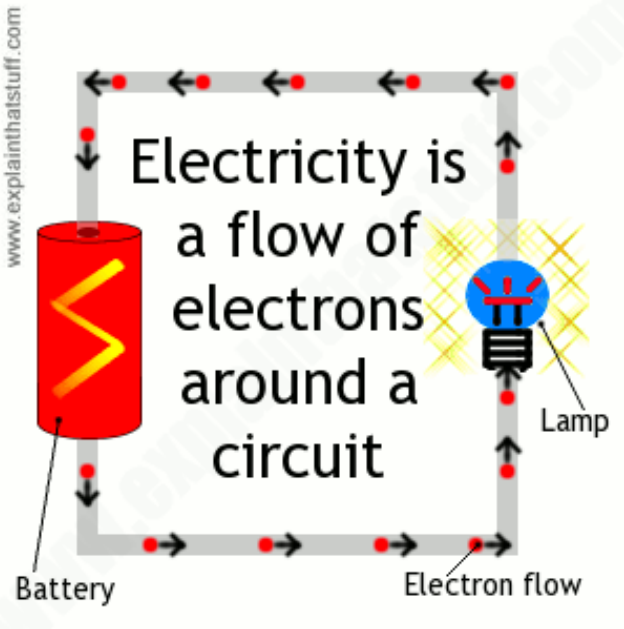
However, **electrons** always flow from negative (high concentration of electrons) to positive (low concentration of electrons).

$$- \rightarrow +$$

IDC102: Basics

- The rate of movement of electrons can be measured over a certain amount of time.

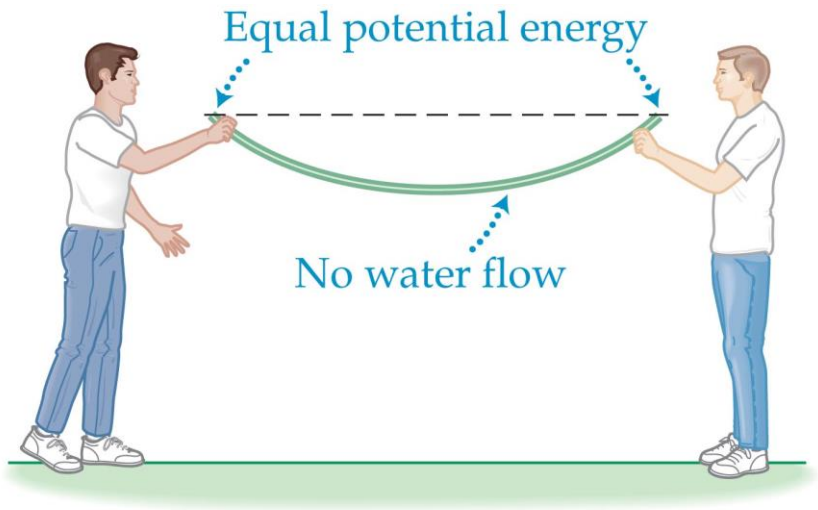
- The current is defined as the rate of charge movement or the movement of electrons through an area over a given amount of time.



- Remember the Law of Conservation of Energy, which states that energy cannot be created or destroyed, but may only change form. This law applies here as electrical charges can be transferred between objects.

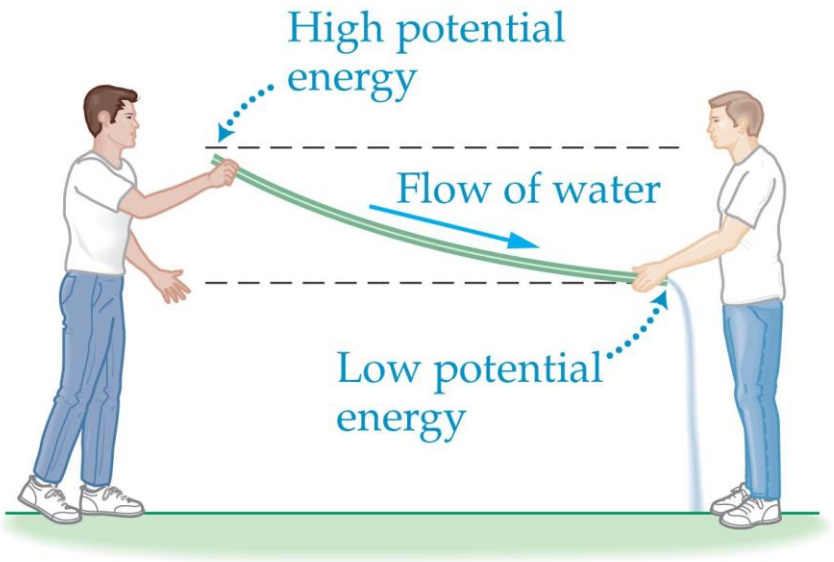
- Although electrons move fairly freely in metal wires, something has to push on them to get them going and keep them going. It's like water in a garden hose; the water flows only when a force pushes on it. Similarly, electrons flow in a circuit only when an electrical force pushes on them.

- Figure (a) below shows that there is no water flow if both ends of the garden hose are held at the same level.



(a) Equal potential energy → no flow

- Figure (b) shows that water flows from the end where the gravitational potential energy is high to the end where it is low. The difference in gravitational potential energy between the two ends of the hose results in a force on the water—which in turn produces a flow. A battery performs a similar function in an electric circuit.



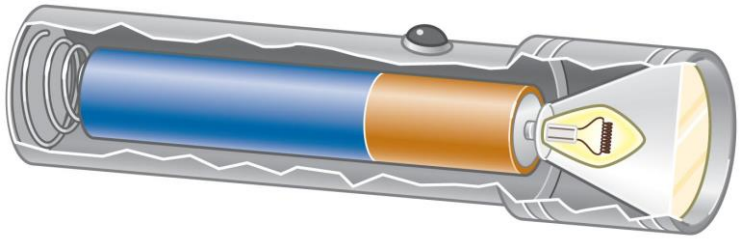
(b) Water flows from high potential energy to low.

IDC102: Basics

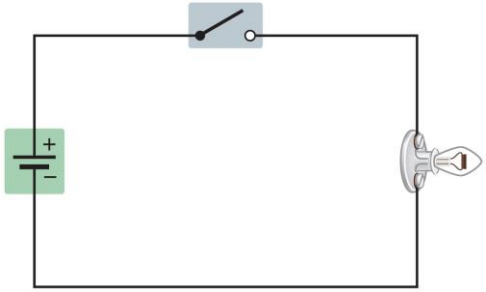
- A battery uses chemical reactions to produce a difference in electric potential between its two ends, which are referred to as the terminals. The symbol for a battery is .
- A battery's positive terminal has a high electrical potential and is denoted with a plus (+) sign; the negative terminal has a low electric potential and is denoted with a minus sign (−).

- When a battery is connected to a circuit, electrons move in a closed path from one terminal of the battery through the circuit and back to the other terminal of the battery. The electrons leave from the negative terminal of the battery and return to the positive terminal.
- The situation is similar to the flow of blood in your body. Your heart acts like a battery, causing blood to flow through a closed circuit of arteries and veins in your body.

- The figure below shows a simple electrical system consisting of a battery, a switch, and a lightbulb connected together in a flashlight.

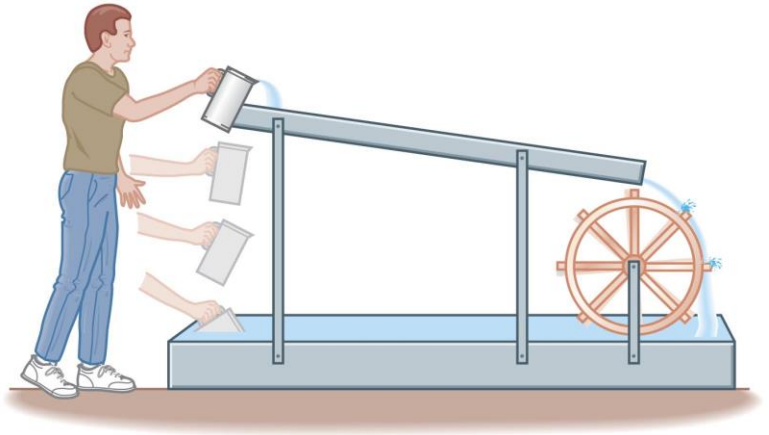


(a) A simple flashlight



(b) Circuit diagram for flashlight

- The figure below shows a mechanical equivalent of the flashlight circuit. The person lifting the water corresponds to the battery, the paddle wheel corresponds to the lightbulb, and the water is like the electric charge.

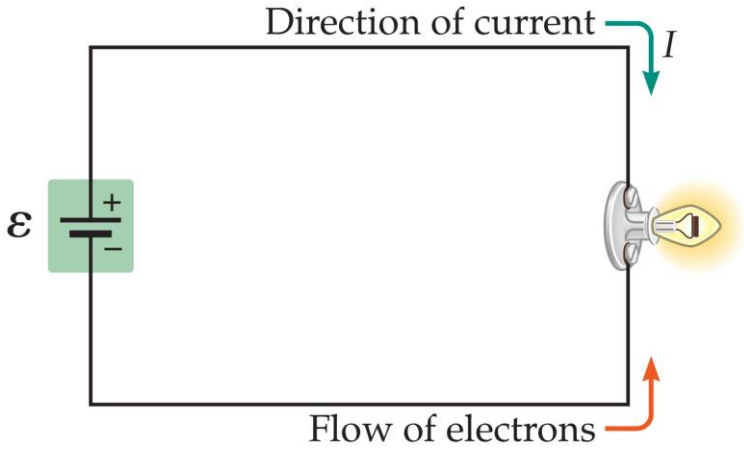


IDC102: Basics

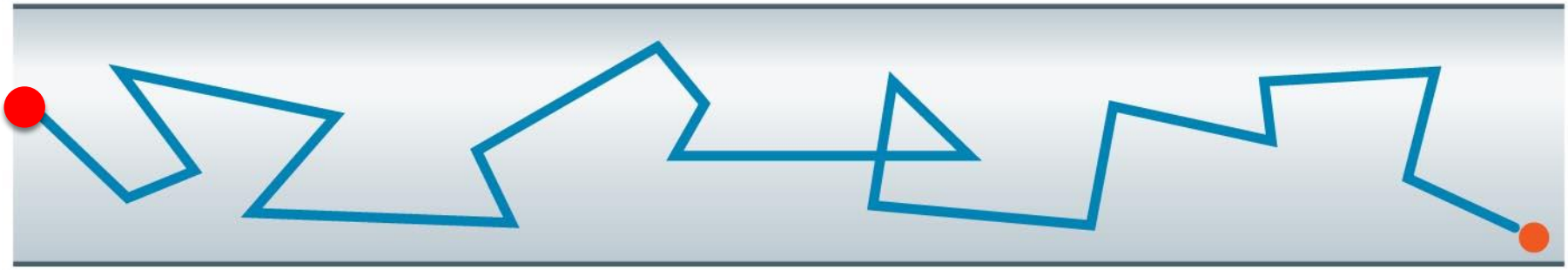
- The difference in electric potential between the terminals of the battery is the electromotive force, or emf. Symbolically, the electromotive force is represented by the symbol ε (the Greek letter epsilon). The unit of emf is the same as that of electrical potential, namely, the volt.

- The electromotive force is not really a force. Instead, the emf determines the amount of work a battery does to move a certain amount of charge around a circuit.

- When drawing an electric circuit, it's helpful to include an arrow to indicate the flow of current. By convention, the direction of the current in an electric circuit is the direction in which a positive test charge would move.
- In typical circuits, the charges that flow are actually negatively charged electrons. As a result, the flow of electrons and the current arrow point in opposite directions, as indicated in the figure below.



- As surprising as it may seem, electrons move rather slowly through a wire. Their path is roundabout because they are involved in numerous collisions with the atoms in the wire, as indicated in the figure below.



- A electron's average speed, or drift speed, as it is called, is about 10^{-4} m/s—that's only about a hundredth of a centimeter per second!

- At this speed, it would take an electron about 3 hours to go from a car's battery to the headlights. However, we know that the lights come on almost immediately. Why the discrepancy?

- While the electrons move with a rather slow average speed, the influence they have on one another, due to the electrostatic force, moves through the wire at nearly the speed of light.

IDC102: Basics

- Electrons flow through metal wires with relative ease. In the ideal case, the electrons move with complete freedom. Real wires, however, always affect the electrons to some extent.

- Collisions between electrons and atoms in a wire cause a resistance to the electron's motion. This effect is similar to friction resisting the motion of a box sliding across a floor.

What is current?

When matter has an unequal number of protons (+) and electrons (-) it becomes charged. Two objects of different charge that come into contact with one another will cause a **flow of charge known as current**.

- Resistance - The opposition to the flow of electrical charge.
- Conduction - The movement of electrically charged particles through a transmission medium.
- Conductor - A material containing many free electrons that move through the material easily.

Conductors and Insulators

Electrical Conductor – Charge can flow easily.

Electrical Insulator – Charge cannot flow easily.

Why are some good conductors?

Conductors – electrons that are not tightly bound and free moving. do to the sea of electrons.

IDC102: Basics

- Sometimes the flow of electrons is slowed down by any number of factors. These factors include:

1. Materials – what the electrons are moving through
2. Temperature – how warm or cold the materials are
3. Length – how far the electrons need to move
4. Cross section – how wide the area is the electrons are trying to move through

Table 19-2 Factors that affect resistance

Factor	Less resistance	Greater resistance
length	L_1	L_2
cross-sectional area	A_1	A_2
material	Copper	Aluminum
temperature	T_1	T_2

IDC102: Basics

- Electric Charge: Objects become positively charged when they lose electrons and negatively charged when they gain electrons; objects with like charges repel and objects with opposite charges attract

- Since charge is measured in a unit called coulombs and energy is in joules, as the charges gain energy the potential difference is 9 joules per coulomb = 9 volts of potential difference.

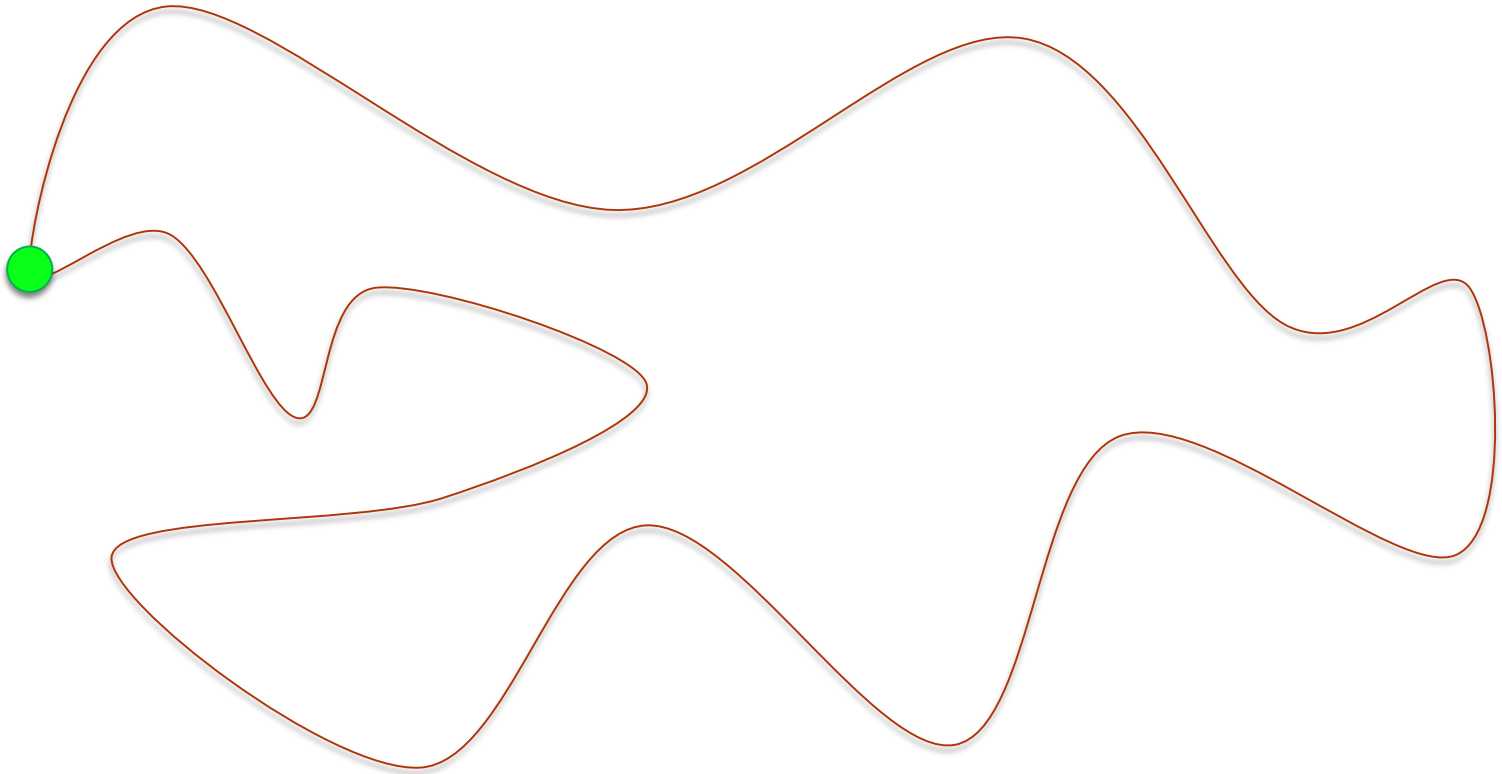
- Charge
  - Measured in Coulombs (C): number of electrons (or positive charges) present.
  - Charge of single electron is 1.602*10-19 C: One Coulomb = 6.24*1018 electrons.
  - Charge is always multiple of electron charge: charge cannot be created or destroyed, only transferred.
- Current
  - The movement of charge: we always note the direction of the equivalent positive charges, even if the moving charges are negative.
  - It is the time derivative of charge passing through a circuit branch
  - Unit is Ampere (A), is one Coulomb/second
  - Customarily represented by *i (AC)* or *I (DC)*.

$$i \equiv \frac{dq}{dt}$$

- Voltage (Potential Difference)
  - a *difference* in electric potential always taken between two points.
  - It is a line integral of the force exerted by an electric field on a unit charge.
  - Customarily represented by *u (AC)* or U (DC) or v and V alternativelly.
  - The SI unit is the Volt [V].
- Power
  - **Power** is the product of voltage by current.
  - It is the time derivative of energy delivered to or extracted from a circuit branch.
  - Customarily represented by *P* or S or W.
  - The SI unit is the Watt [W].

IDC102: Basics

- Electric current always follows a fixed or defined path like a roller coaster

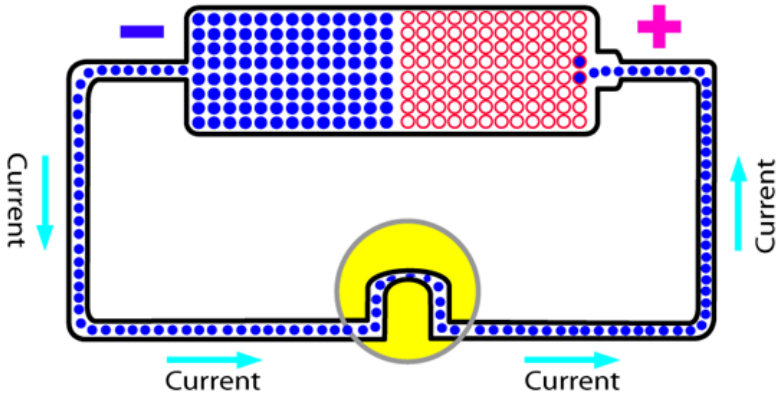


The path of electric charges (current) is called electric circuit

IDC102 - Basics: Electric Circuit

- The path of electric charges (current) is called electric circuit
- An electric circuit allows electrons to flow from a negative pole (excess electrons) to a positive pole (deficient in electrons)

- It provides the path for the electrons to move
- It controls the movement of electrons

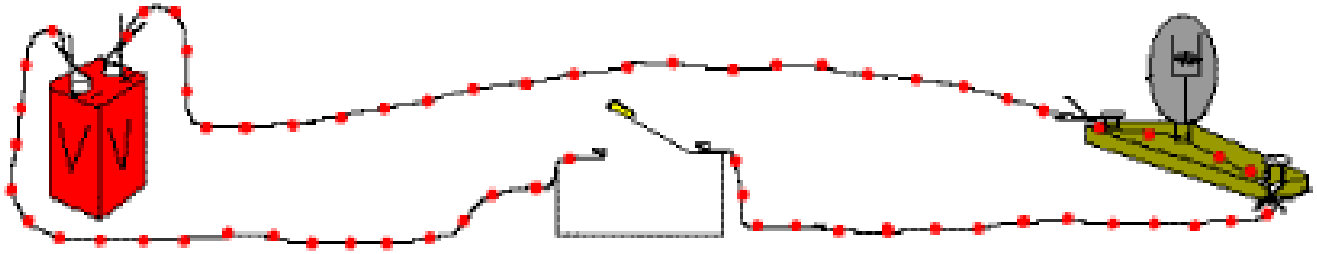


The interesting point is the path of electric circuit is always closed loop for electron to flow

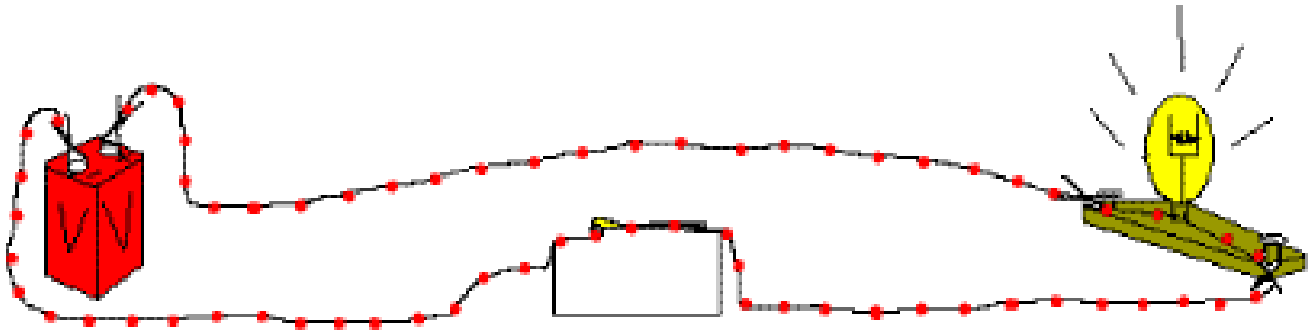
IDC102 - Basics: Electric Circuit

Sometimes a circuit also contains a switch that is used to open and close a circuit.

OPEN CIRCUIT



CLOSED CIRCUIT



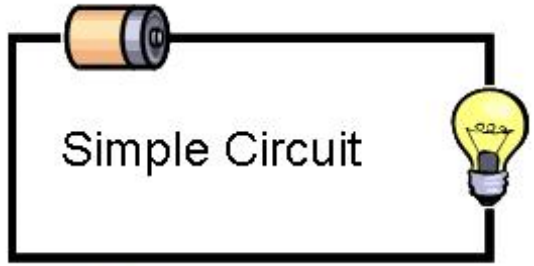
IDC102 - Basics: Electric Circuit

All circuits need three basic parts: an energy source, wires, and the object that is going to change the electrical energy into another form of energy (load).

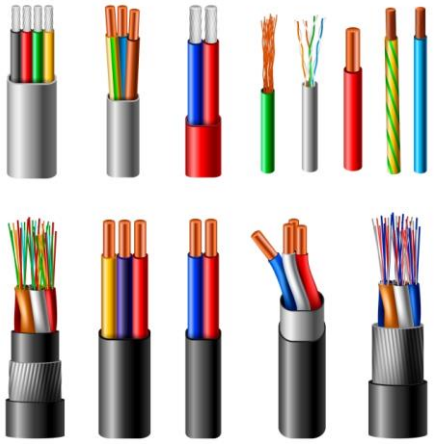
The circuit is established when there is a continuous path for electricity to travel from one end of the energy source to the other end.

Energy Source

Wire

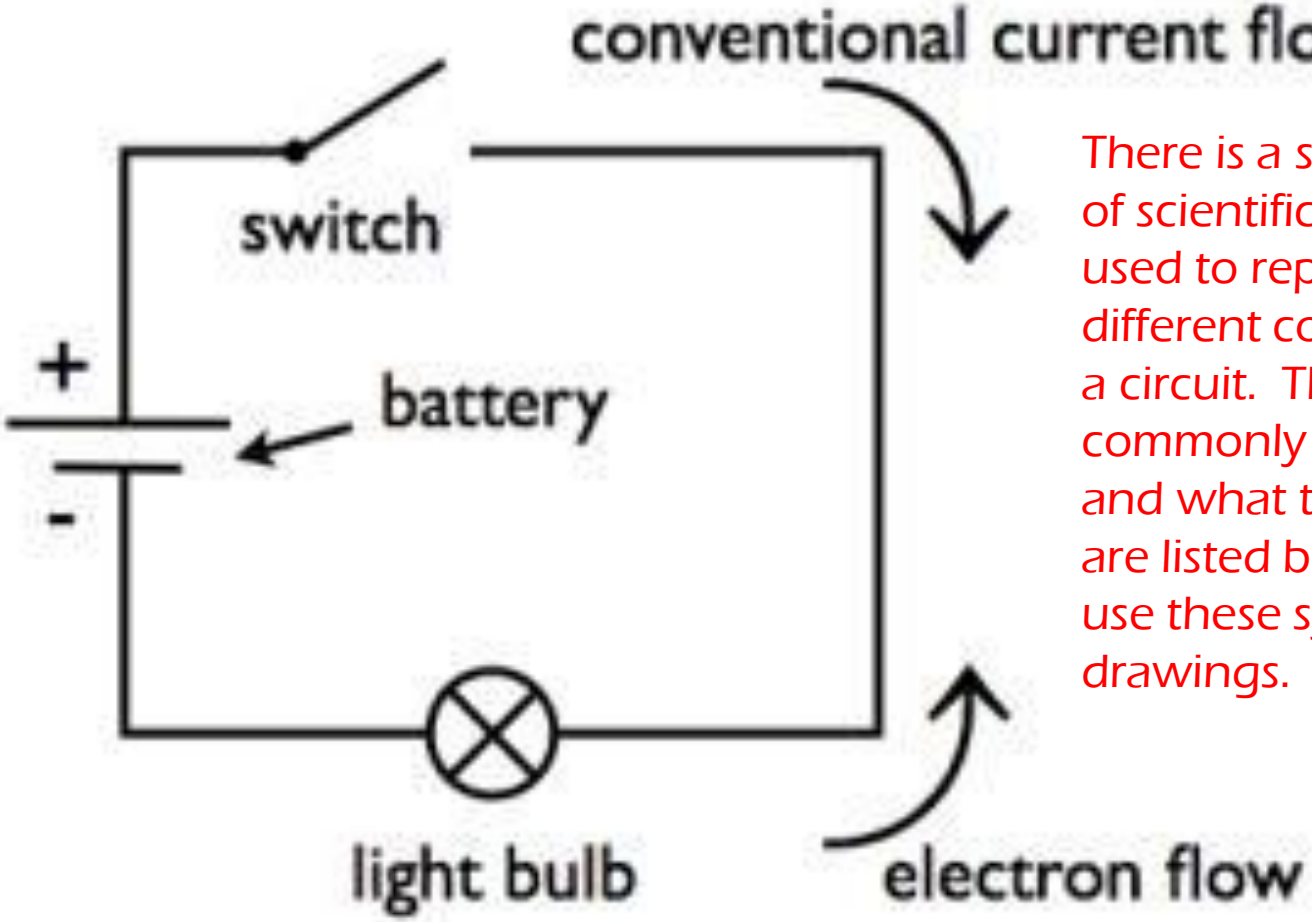


Load



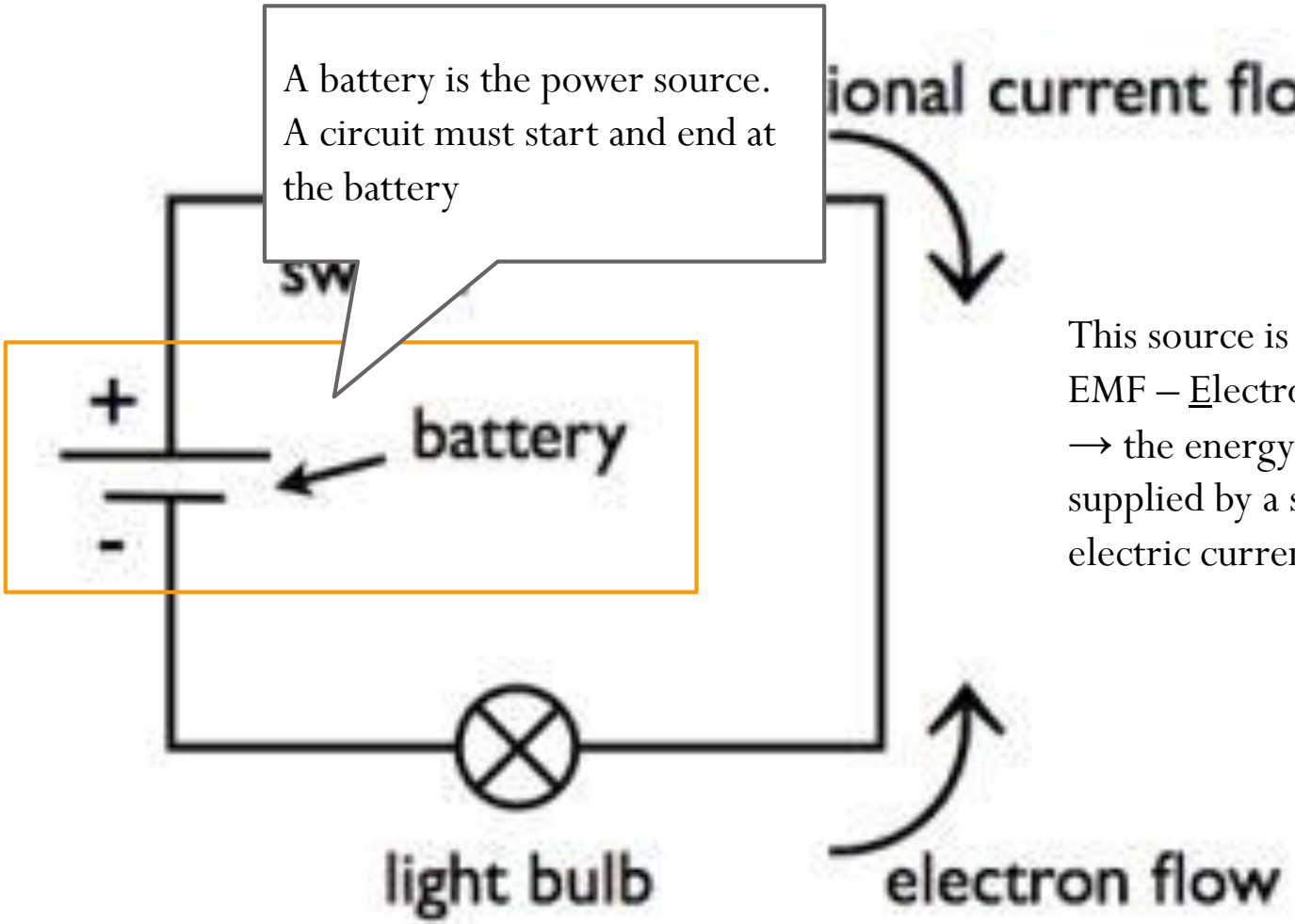
IDC102 - Basics: Circuit Diagram

The drawings are called Schematic diagrams. Schematic diagrams are defined as graphical representations of an electrical circuit.



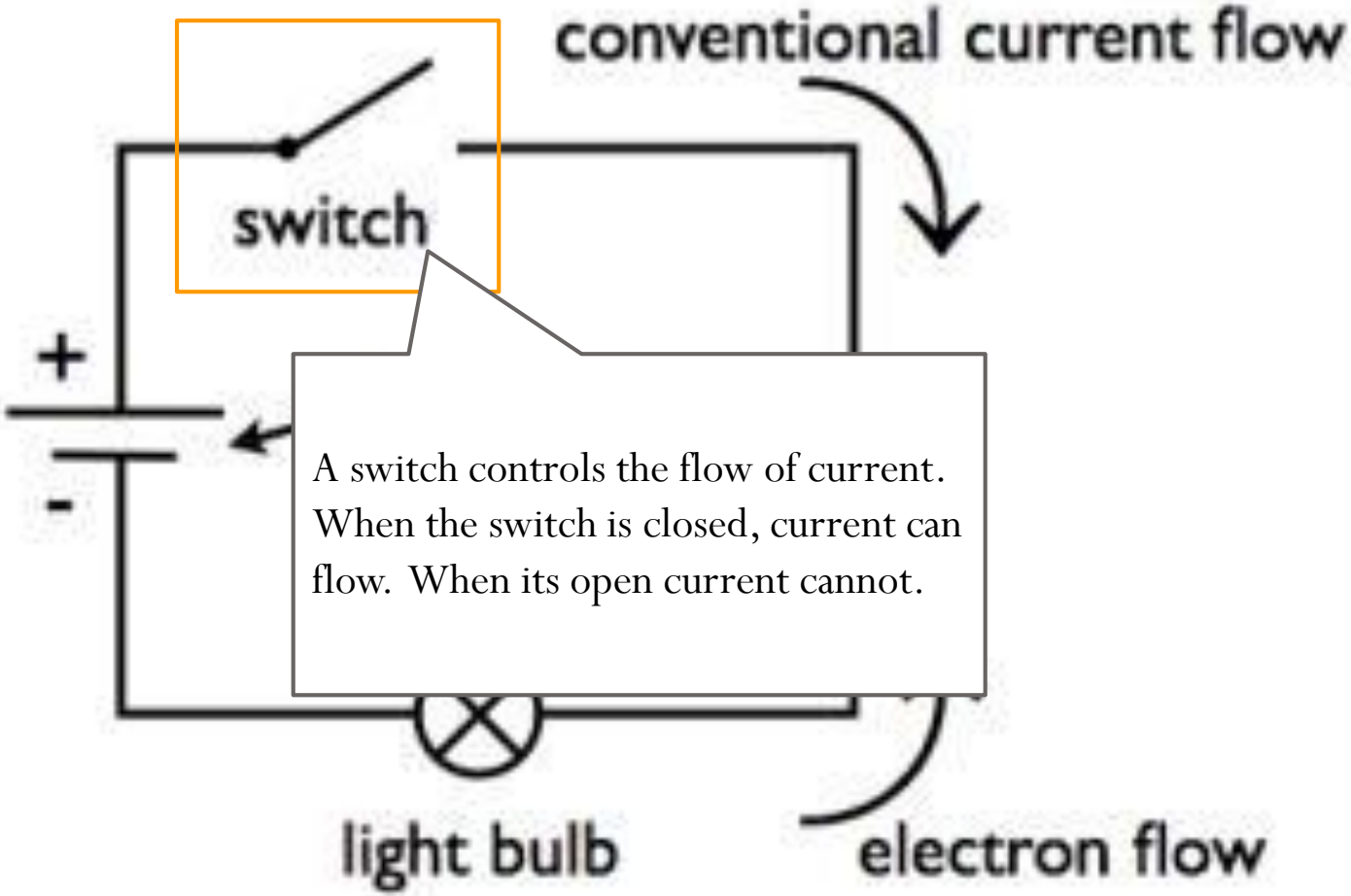
There is a standard set of scientific symbols used to represent different components in a circuit. The most commonly used symbols and what they represent are listed below, we will use these symbols in our drawings.

IDC102 - Basics: Circuit Diagram

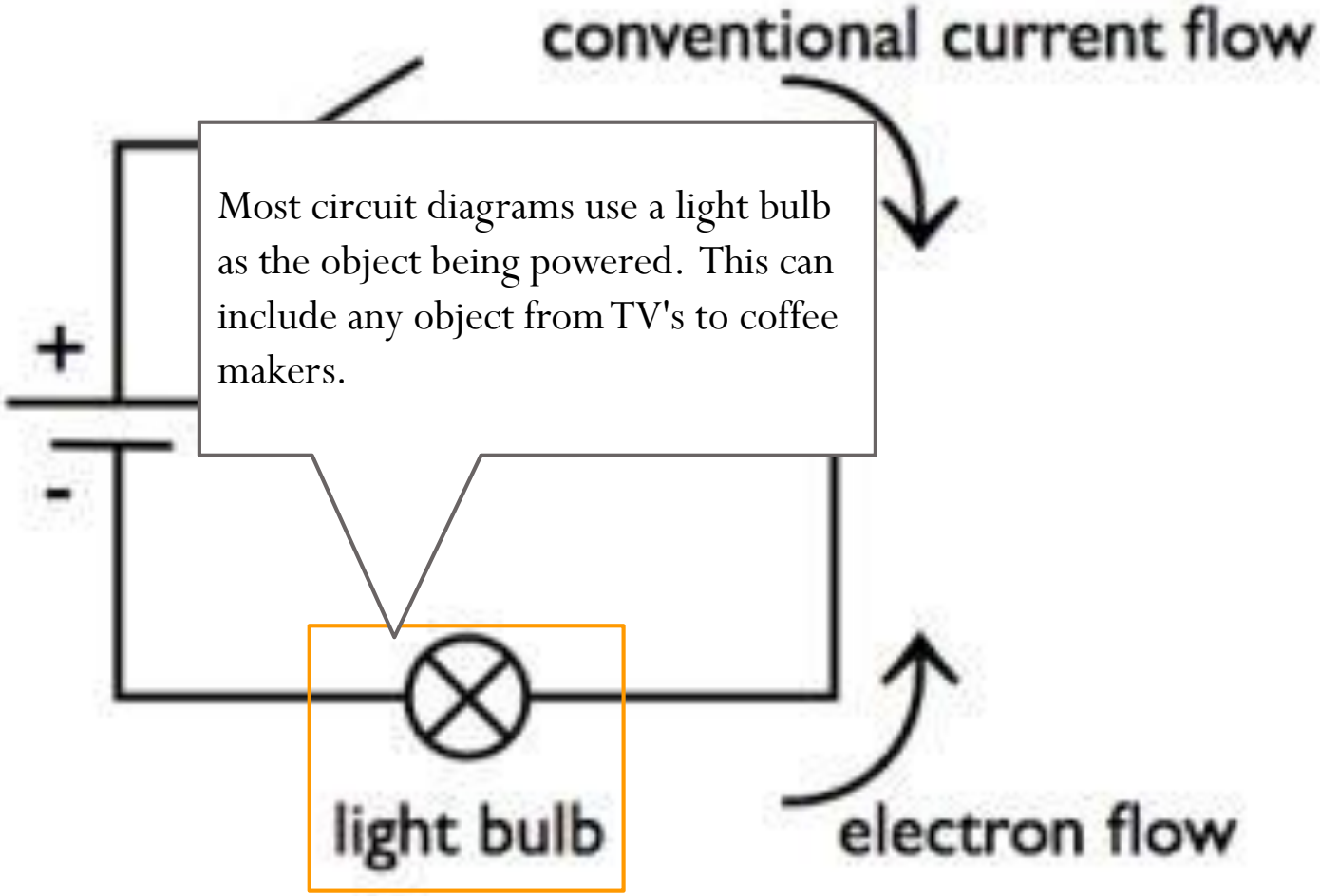


This source is known as the EMF – Electromotive force → the energy per unit charge supplied by a source of electric current

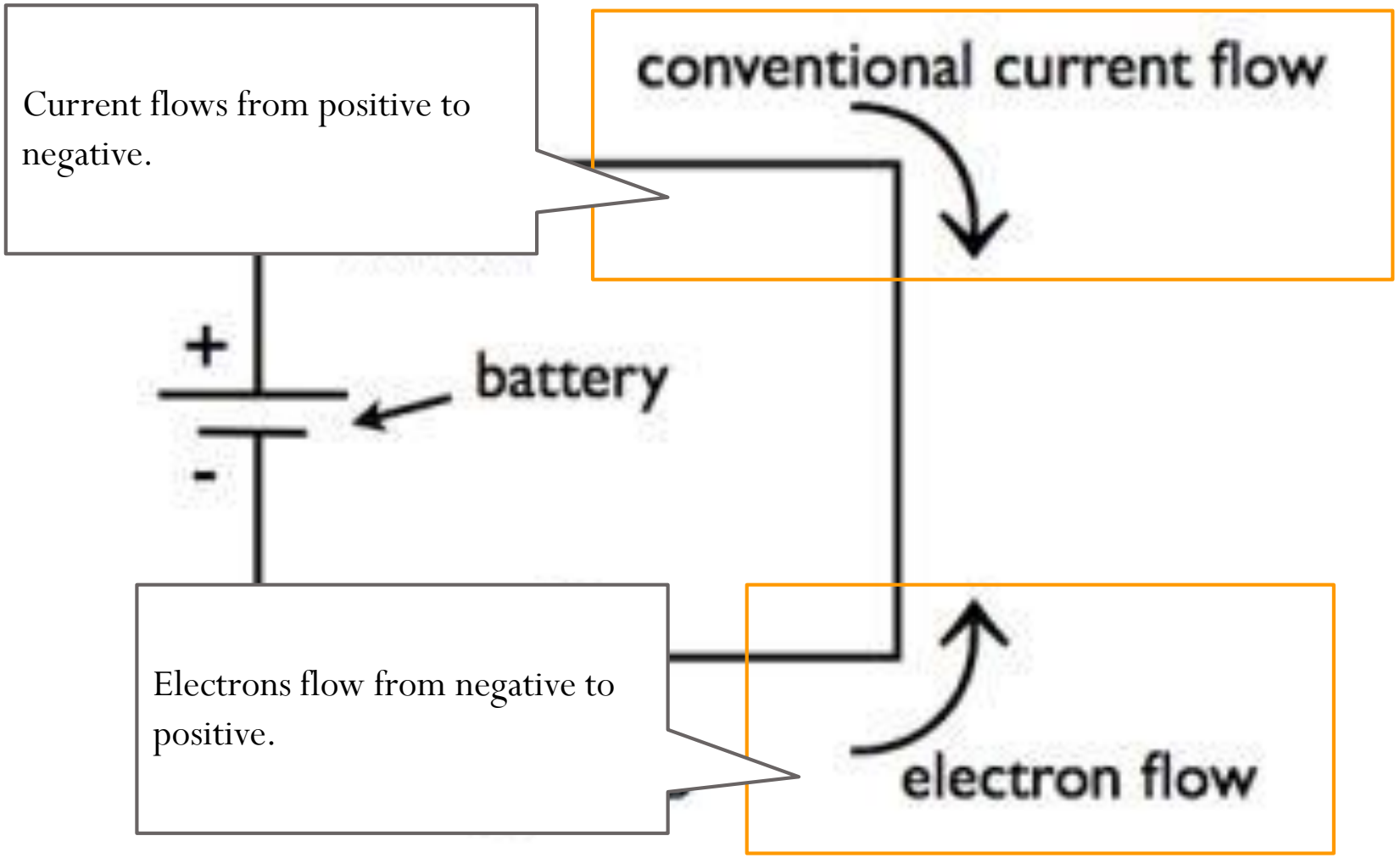
IDC102 - Basics: Circuit Diagram



IDC102 - Basics: Circuit Diagram

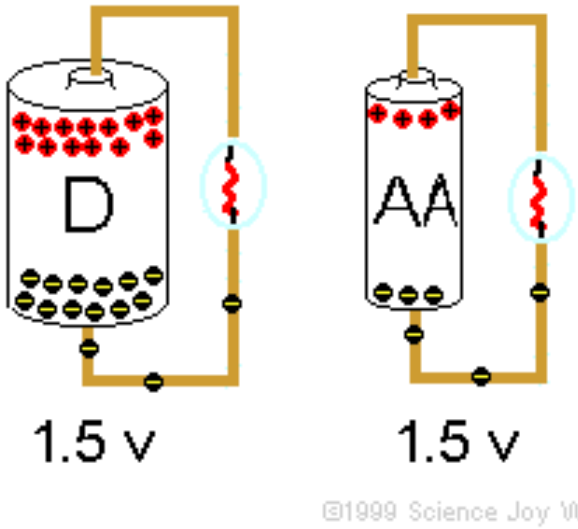


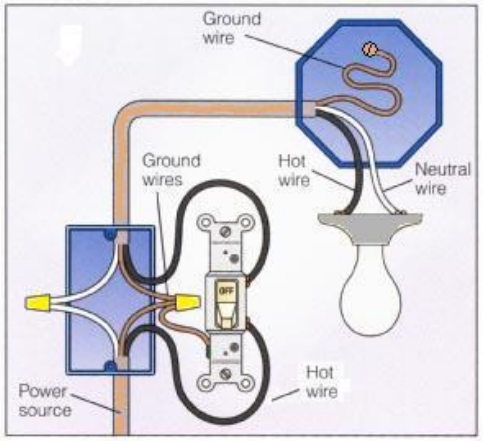
IDC102 - Basics: Circuit Diagram

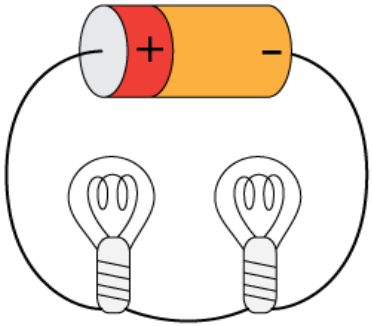


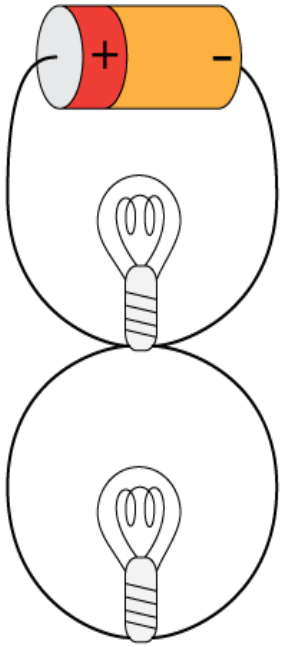
IDC102 - Basics: Type of Circuit

To be able to effectively use electricity, one must understand how electricity moves through different materials in a pathway.









Therefore, we need to know the types of circuits: Circuits are distinguished based on the way in which loads are connected.

IDC102 - Basics: Type of Circuit

There are three different types of electrical circuits:

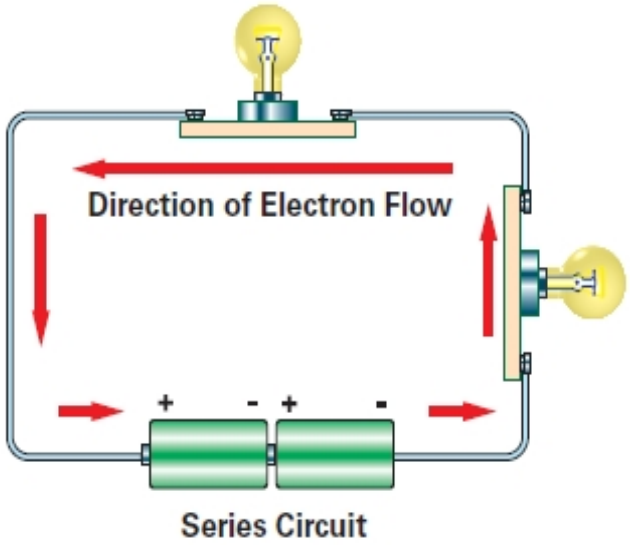
1. Series Circuits - Circuit (or portion of) in which there is a single conducting path without junctions for electricity to follow

2. Parallel Circuits - Circuit (or part of) where components are connected across common points and provides separate conducting paths for electricity to follow

3. Complex Circuits – Circuits with some segments being in series and other segment being in parallel to take advantage of the benefits of both

IDC102 - Basics: series Circuit

- Series Circuits - Circuit (or portion of) in which there is a single conducting path without junctions for electricity to follow
  - In a Series Circuit there is only one path for the electric current or electricity to flow.
  - All of the loads in a series circuit share the same current.
  - If there is any break in the circuit, the charges will stop flowing



Series Circuit

- In a series circuit there is one road and one road only. If part of the road is out, you cannot get where you want to go, no exceptions.

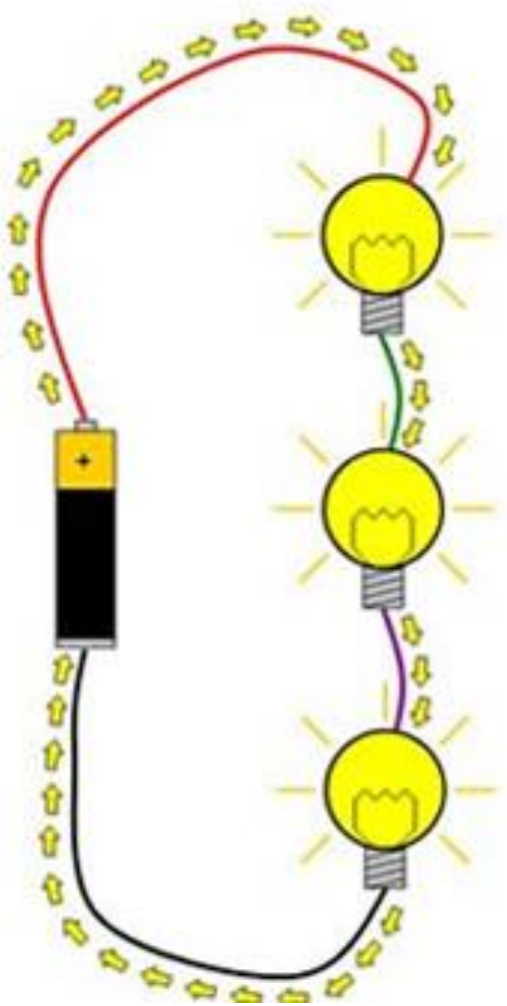
IDC102 - Basics: series Circuit

- All bulbs / resistors / components in series will have the same current. This is because the current can only flow as fast as the slowest (most resistant) component will allow.

- The total current in a series circuit depends on the number of resistors present and resistance of each.
- Below is a list of advantages and disadvantages of series circuits (notice some may be both)

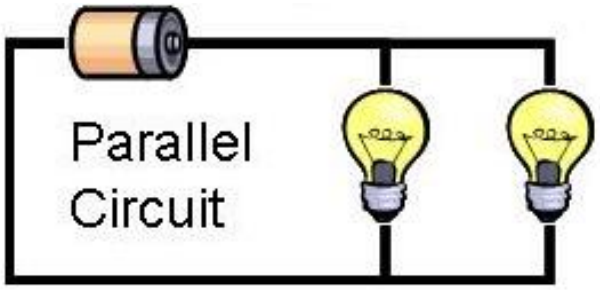
- Advantage of series circuits:

  1. Good for regulating current (all parts have same current)
  2. Good for reducing current on individual parts
  3. Current stops if a component breaks



IDC102 - Basics: Parallel Circuit

- Parallel Circuits - Circuit (or part of) where components are connected across common points and provides separate conducting paths for electricity to follow
  - In a Parallel Circuit there is more than one path for the electric current or electricity to flow.
  - The electric current branches so that electrons flow through each of the paths
  - If one path is broken, electrons continue to flow to the other paths



- In a parallel circuit there is more than one road you can use as a possible route to the store. If one part of the road is out, you can choose a detour around it to still get where you want to go, or if the whole road is working, you can choose your path among several to get to the store.

IDC102 - Basics: Parallel Circuit

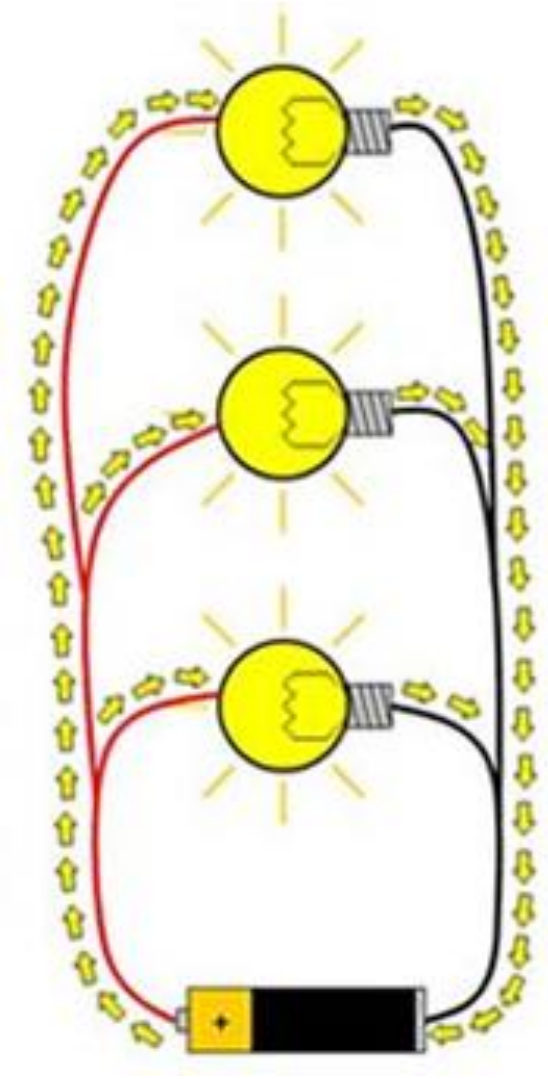
- Parallel circuits give multiple alternate pathways for current flow

- Advantages of parallel:
  - Parallel circuits do not require all elements to conduct
  - One part can malfunction and the rest will continue to work
  - Potential difference does not change for all components when one component fails

- The sum of currents in parallel resistors = total current

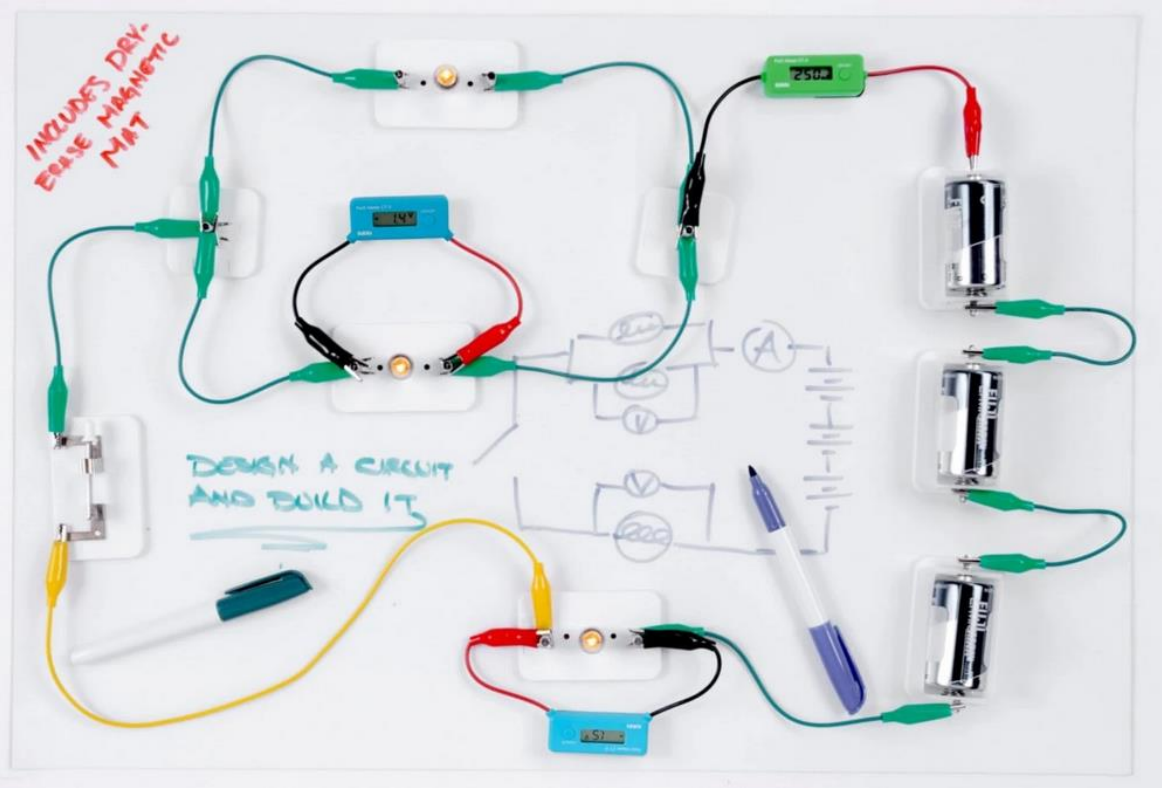
- Disadvantages of parallel:

  1. Current will change if one component fails
  2. Current different in all components



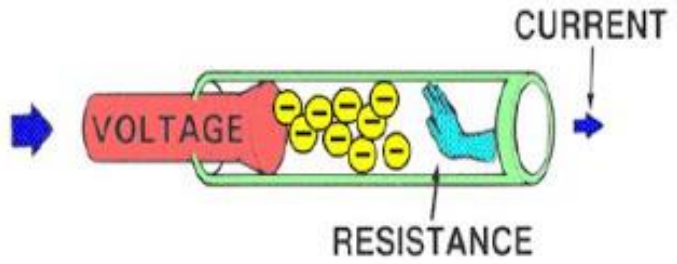
IDC102 - Basics: Complex Circuit

- Complex Circuits - Circuit where components are connected both parallelly and in series which provides a complex conducting paths for electricity to follow



IDC102 - Basics: Series vs Parallel Circuit

In a Series circuit, the current has to travel through each bulb; therefore, adding more light bulbs makes each bulb dimmer because the resistance of the whole circuit has increased.



Think of the relationship between Electric Current, Voltage, and Resistance as shown in the diagram below.

Resistance is how difficult it is for electrons to flow through a material (friction).

As the bucket is raised, potential energy is increased (increase in voltage) and there is less resistance (friction) in the hose; therefore, the flow of water (electric current) is greater

There are several advantages and disadvantages

IDC102 - Basics: Complex Circuit Extra Note

- Sometimes a circuit is complete but there is a problem of the current flowing too fast. This is called short circuit.

- Short circuit – a circuit which contains little or no resistance

  → The components get too hot due to the excess current and not enough resistance to slow it down and can cause fires

- Examples:

  - 2 terminals of a battery directly connected

  - Uninsulated wires come into contact

→ These are very dangerous