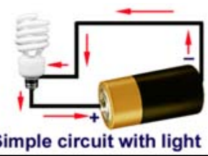
Current and Circuits

Current flows from a higher potential to a lower potential (We need a voltage)

A circuit is a continuous loop of flowing charge. It must be a closed loop in order to work

A voltage source (a battery or wall outlet) will cause the current to flow.



1

Voltage (V) – Electrical Potential

$$\Delta V = V_A - V_B$$

Voltage (V, sometimes E) measures the electrical potential per charge between terminals. Voltage does not move, it pushes electrons.

Voltage can be thought of as "Electrical Pressure"

$$1\ V = \frac{1\ Joule}{1\ Coulomb}$$

2

Voltage Sources

A **voltage source** provides a sustained potential difference to allow electrons to flow.

Batteries (dry cells and wet cells) and generators are common voltage sources.

Batteries have two terminals.
One positive terminal
One negative terminal

Batteries use a chemical reaction and a generator converts mechanical energy into electrical energy.

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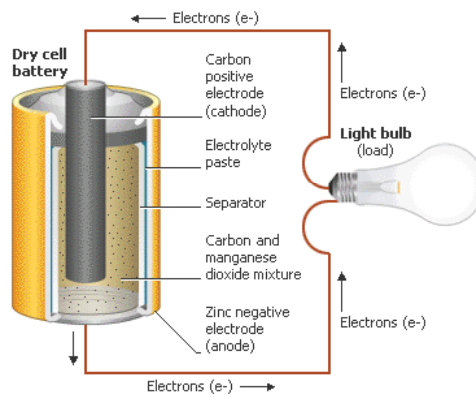
Dry Cell Voltage Source



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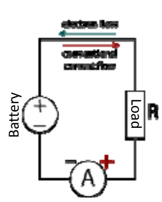
Current (I)

Current is the flow rate of electric charge

Current (I) is measured in:
Ampere(A) = 1 Coulomb / s

Current flows from the positive(+) terminal to the negative(-) terminal.

Electrons flow in the opposite direction of the current.



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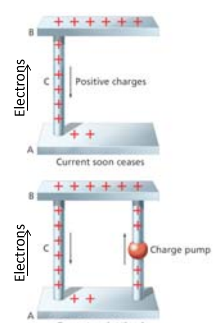
Current

Conventional current is defined as positive charges flowing from the positive plate to the negative plate



A generator pumps the positive charges back to the positive plate and maintains the current

In most metals, negatively-charged electrons actually flow from the negative to the positive plate, creating the appearance of positive charges that are moving in the opposite direction.

Resistance (R)

Resistance is a lot like "friction on electrons". It determines how much current will flow.
The higher the number the worse of a conductor.

Resistance (R) is measured in Ohms (Ω)
Resistance is what causes heat from an electric current. More resistance causes more heat.

Ohm's Law $$R = \frac{\text{voltage}}{\text{current}} = \frac{V}{I}$$

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Materials and Resistance

Conductors have very low resistance

Insulators have very high resistance

Semiconductors have a resistance in between insulators and conductors

Superconductors have 0 resistance. This is a perfect flow of electrons without energy loss.

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Power (P)

Power is the work performed over time.

Power (P) is measured in:
Watts = 1 Joule / s

$$Power = current \times voltage$$

$$P = IV$$

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Energy Loss to Heat From Power Line

Energy in a power line is lost due to resistance. This is lost in the form of heat and is related to the current of the wire.

When power lines travel long distances, the voltage is typically very high to result in a very low current.

$$P_{Lost} = I^2 R$$

Ohm's Law

Using $P = IV$ and $R = \frac{V}{I}$

A total of 12 equations relate P, I, R, and V

If you have any two of these measurements, you may find out the other two.

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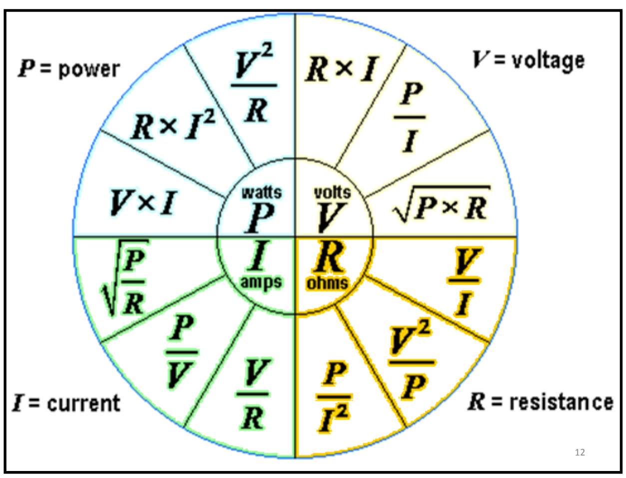

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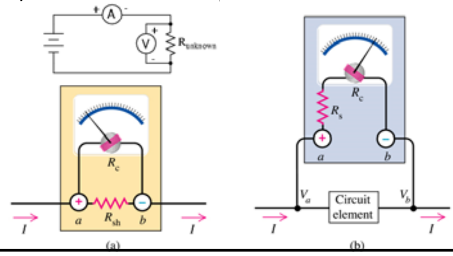
ELECTRICAL METERS
(a) Ammeter – Used to measure current in Amperes. This is connected as a part of the circuit in a series.

(b) **Voltmeter** – Used to measure the voltage between two points in a circuit (usually around a part of the circuit). This is connected parallel to the circuit.

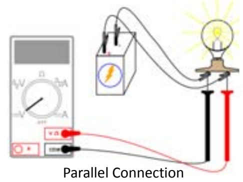


Using a Digital Multimeter

Digital multimeters often have different plugs for voltage and current.

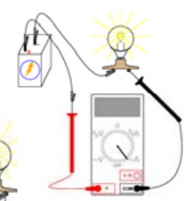
Be sure to have the multimeter on the correct setting and start with the highest range.

Voltage



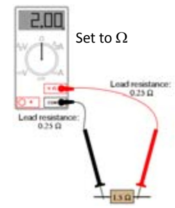
Parallel Connection

Current



Series Connection

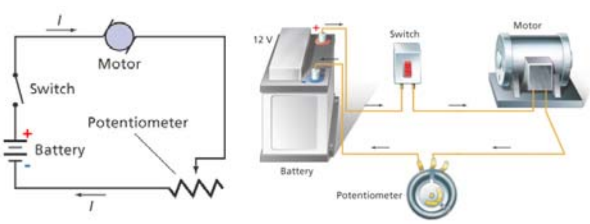
Resistance



Open Circuit
Test Parts of Circuit

Potentiometer

This is used to adjust the current in a circuit by varying the resistance of the device. Setting different lengths of the wire coil inside will have different resistances.



Electricity in Your House

The **kilowatt-hour** is used to measure the energy used in the house.

Kilowatt–Hour (kWh) = 3,600,000 J

A 1000 W hair dryer running for 1 hour will use 1 kWh

- House voltage in the USA is 120 V from an outlet
- Car voltage is 12 V from the battery

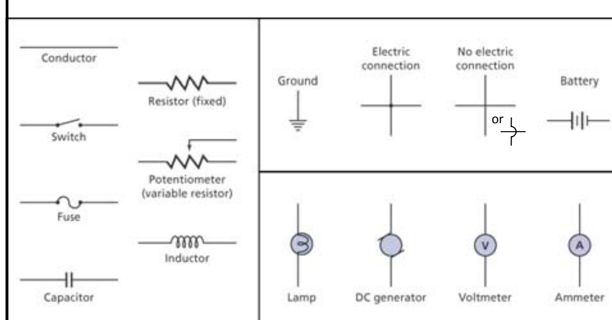
Energy Used = Power × time

This could be in the form of energy used by a light bulb, thermal energy from a heating element, etc.

$$E = Pt$$

$$E = I^2 R t \qquad E = \left(\frac{V^2}{R}\right) t$$

Common Circuit Symbols



Series Circuits

In a series circuit, charges must pass through both bulbs to complete the circuit.

If one bulb fails, the whole circuit will fail.

Parallel Circuits

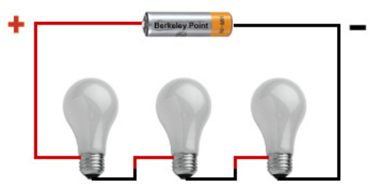
In a parallel circuit, each part has its own wiring so charges have more than one path to follow

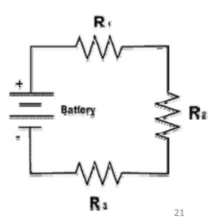
If one bulb fails, the other bulb will still have a complete circuit.

Series Circuits

Current will remain constant throughout the circuit. Voltage will be different for each device. The sum of voltages from each device equals the battery voltage.

$$R_{Total} = R_A + R_B + \ldots$$





Series Circuits

Other useful equations.

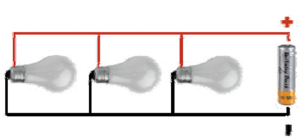
$$V_{Source} = V_A + V_B + \ldots$$

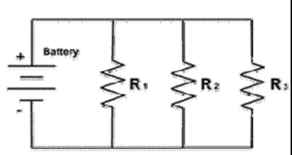
$$I = \frac{V_{Source}}{R_A + R_B + \ldots} = \frac{V_{Source}}{R}$$

Parallel Circuits

Voltage will remain constant throughout the circuit. Current will be different for each device. The sum of current through each device equals the total current.

$$\frac{1}{R_{Total}} = \frac{1}{R_A} + \frac{1}{R_B} + \frac{1}{R_C} + \ldots$$





Parallel Circuits

Other useful equations.

$$I_{Total} = I_A + I_B + I_C + \ldots$$

$$I = \frac{V}{R} \qquad I_A = \frac{V}{R_A} \qquad I_B = \frac{V}{R_B}$$ Etc…

Parallel Circuits in the Home

Parallel circuits are common in home wiring.
Each outlet will have its own wiring.

Some advantages are:

- With a parallel circuit, each outlet can have 120 Volts. More outlets will not change the voltage.
- If one outlet fails, it will not affect all other outlets. Power will only be lost on the specific outlet circuit.

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Electrical Safety

Short Circuit

- Occurs when a circuit of very low resistances is formed
- This results in extremely high currents that generates heat and can start a fire.
- Having too many appliances on a circuit can generate enough heat to melt wire and form a short circuit

Ex: A frayed cord allows the wires to touch forming a short circuit. This has a resistance of 0.01 Ω. At 120 V this would provide 12000 A of current!! Lots of heat!!

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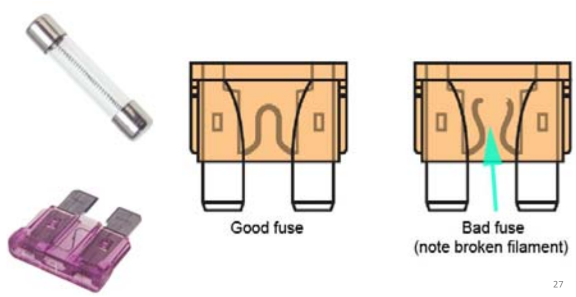
Fuses

A fuse is used to stop a circuit from overloading. This works by melting a metal strip with too much current.



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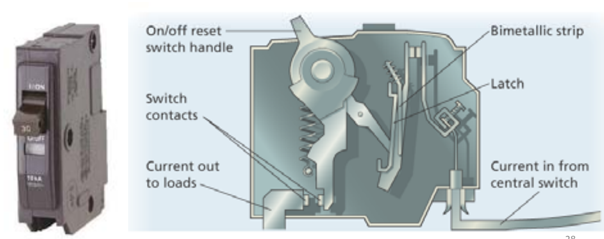
Circuit Breaker

These are switches that are used in homes to protect circuits from overloading. They are reusable unlike a fuse.



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GFCI Outlet (Ground Fault Circuit Interrupter)

This shuts off when there is a small change in current due to a different path (like through a person). This is meant to protect a person from being electrocuted. These are commonly found in bathrooms, kitchens, etc.

A GFCI Prevents

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