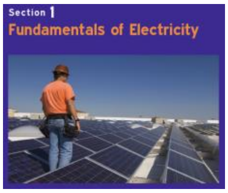


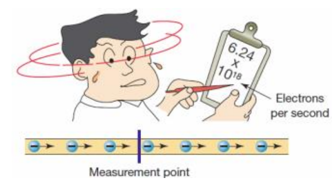
Electrical Quantities and Ohm's Law

Current, Voltage, and Resistance

Current

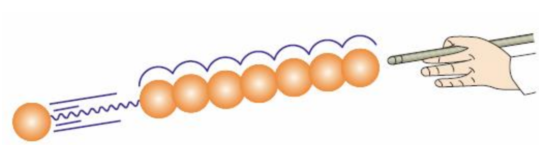
The **coulomb** is a measurement for a **quantity** of electrons, and the unit for an electric **charge**.

Current (I) is the **rate of flow** of electrons through a conductor and is measured in **Amperes (A)**.



One ampere of current is equal to **1 coulomb** of charge moving past a given point in **1 second**.

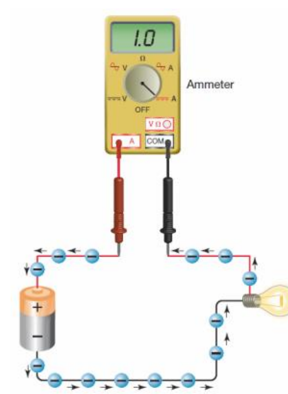
The electric current is the **impulse** of electric energy that **one electron transmits to another** as it changes orbit.



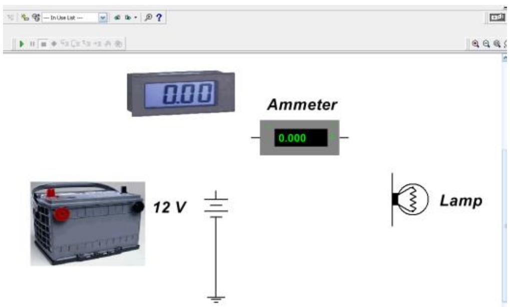
While the **individual electrons** travel less than an inch per second, the current effectively travels through the conductor nearly at the **speed of light**.

An **ammeter** is used to measure **current** flow in a circuit.

The ammeter is inserted **into the path** of the current flow, or in **series**, to measure current.



Simulated Ammeter Connection



The ammeter measures electron flow in **amperes**.

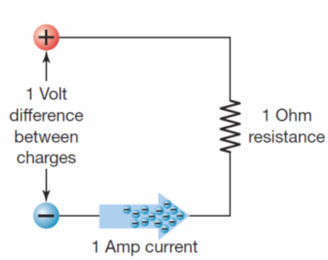
Current	Base Unit	Units for Very Small Amounts		Units for Very Large Amounts	
Symbol	A	µA	mA	kA	MA
Pronounced As	Ampere (Amp)	Microampere	Milliampere	Kiloampere	Megampere
Multiplier	1	0.000001	0.001	1,000	1,000,000

Micro (1/1,000,000) and **Milli (1/1,000) amperes** represent very small amounts of current.

Kilo (1,000) and **Mega (1,000,000) amperes** represent very large amounts of current.

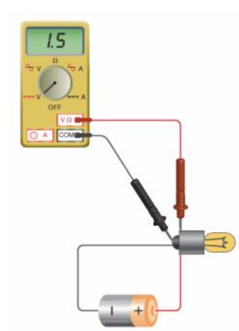
Voltage

Voltage (*V, EMF,* or *E*) is the difference in electric charge between two points and is measured in **volts (V)**.



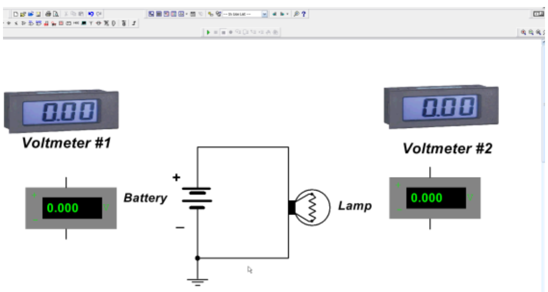
A voltage of **1 volt** is required to force **1 ampere** of current through **1 ohm** of resistance.

A **voltmeter** is used to measure the **potential difference** across two points in an electrical circuit.



The voltmeter is connected in **parallel** across the circuit element.

Simulated Voltmeter Connection



The voltmeter measures potential difference in **volts**.

Voltage	Base Unit	Units for Very Small Amounts		Units for Very Large Amounts	
Symbol	V	µV	mV	kV	MV
Pronounced As	Volt	Microvolt	Millivolt	Kilovolt	Megavolt
Multiplier	1	0.000001	0.001	1,000	1,000,000

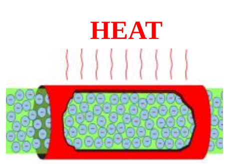
Small voltage values are expressed in **millivolts** (**1/1,000**) and **microvolts** (**1/1,000,000**)

High voltage values are expressed in **kilovolts** (**1,000**) and **megavolts** (**1,000,000**)

Resistance

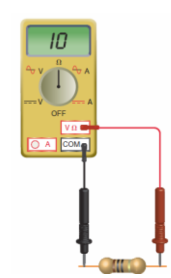
Resistance (*R*) is the **opposition** to the flow of electrons or current and measured in **ohms (Ω)**.

Resistance creates **heat** caused by the **collision** of **electrons** and **atoms**.



The **higher the resistance** the **greater is the opposition** to current flow.

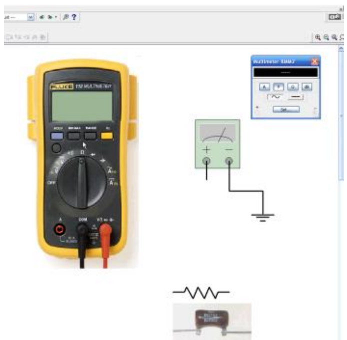
An **ohmmeter** is used to measure **resistance**.



The ohmmeter applies an internal battery voltage into the circuit, measures the resulting current, and then calculates the resistance.

Ohmmeters should never be connected to live circuits!

Simulated Resistance Measurement



Power

Electric power (*P*) is the amount of electric energy **converted** to another form of energy in a given length of **time**.

Power = voltage × current
Watts = volts × amperes
$P = E \times I$
$E = P \div I$

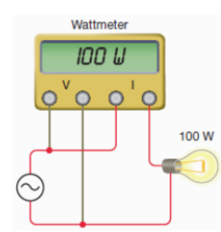
where
***P* = the power in watts**
***E* = the voltage in volts**
***I* = the current in amperes**

Problem: An iron draws 10 A from an 120-V household supply. How much power is used?

Solution:
$P = E \times I$
= 120 V × 10 A
= 1,200 W or 1.2 kW

Power can be **measured** using a **wattmeter**.

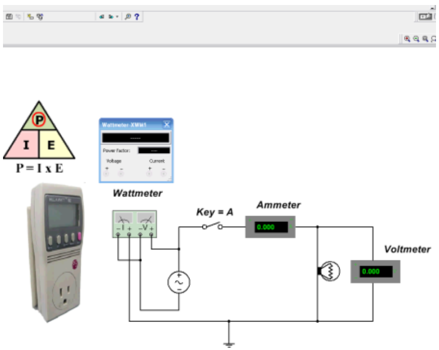
The wattmeter is basically a **voltmeter** and **ammeter** combined into one instrument.



Power = voltage × current
Watts = volts × amperes

The wattage rating of a lamp indicates the **rate** at which it can convert **electric energy into light**.

Watts = Volts x Amps



Energy

Electric energy refers to the **energy of moving electrons**.

Power and **time** are the factors in determining the amount of **energy used**.

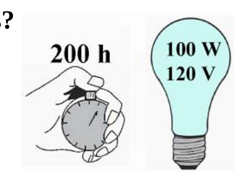
The **watt-hour (Wh)** is the **base unit** for measurement of electric energy.

Energy measurements are used in calculating the **cost** of electric energy.

If power is measured in **watts** and **multiplied** by the **hours** of use, the resultant is **watt-hours (Wh)**.

If power is measured in **kilowatts** and **multiplied** by the **hours of use**, the resultant is **kilowatt-hours (kWh)**.

Problem: Assuming that the cost of electricity is 5 cents ($0.05) per kWh, how much will it cost to operate a 100-W lamp continuously for 200 hours?



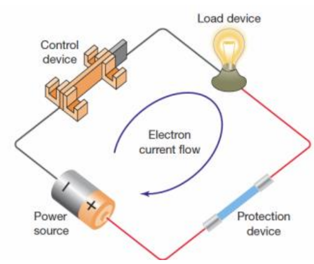
Solution:

$$\text{kWh} = \frac{100\ \text{W} \times 200\ \text{h}}{1{,}000} = 20\ \text{kWh}$$

$$\text{Cost} = \text{kWh} \times \text{rate} = 20 \times \$0.05 = \$1.00$$

Electric Circuit

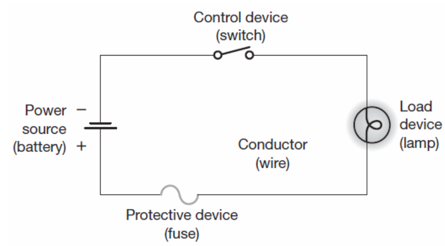
Essential Parts



A complete or **closed circuit** is needed for current to flow.

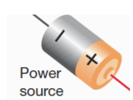
If the circuit is broken at any point **(open circuit)**, there is no longer a closed loop and no current can flow.

Circuit Schematic Diagram



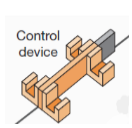
The **schematic** diagram shows the components of the circuit as **symbols**.

Power sources supply the electric pressure or **voltage** required to push current through the circuit.

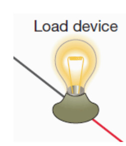


Conductors provide a **low-resistance path** from the source to the load.

Control devices open and close circuits to switch the current flow **OFF and ON**.



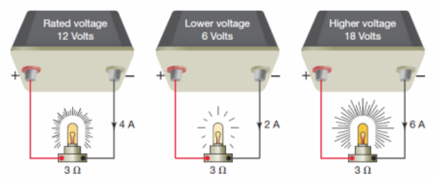
Lamp **load** converts the electric energy from the power source into **light and heat** energy.



Fuse protection devices melt to automatically open the circuit in the event of a **higher** than rated **current** flow.

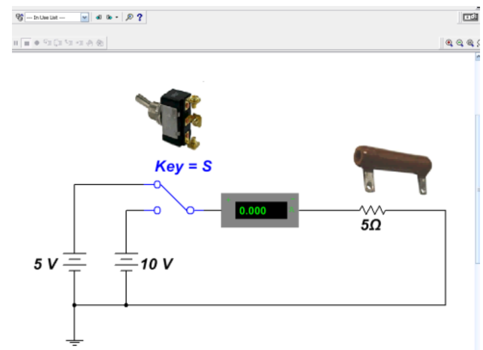
Ohm's Law

According to Ohm's Law the current flowing in a circuit is directly proportional to the applied voltage.

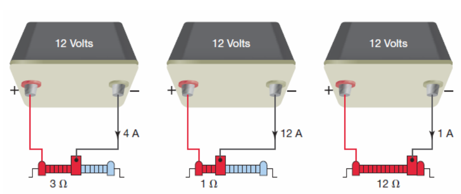


If the **circuit resistance remains constant**, the **higher** the **voltage**, the **higher** the **current**.

Current Is Directly Proportional To Voltage

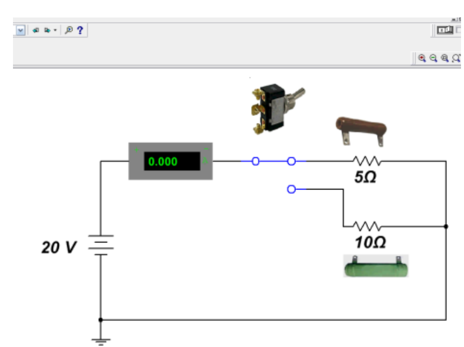


According to Ohm's Law the current flowing in a circuit is inversely proportional to the applied resistance.

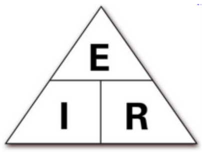


If the **circuit voltage remains constant**, the **higher** the **resistance**, the **lower** the **current**.

Current Is Inversely Proportional To Resistance



Ohm's law can be stated as **mathematical equations**:



$I = \frac{E}{R}$ **(current = voltage *divided by* resistance)**

$E = I \times R$ **(voltage = current *times* resistance)**

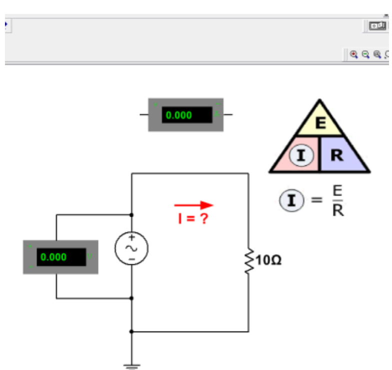
$R = \frac{E}{I}$ **(resistance = voltage *divided by* current)**

Problem: A portable heater with a resistance of 10 Ω is plugged into a 120-volt electrical outlet. How much current will flow to the heater?

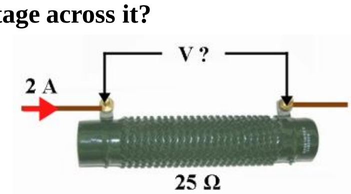
Solution:

$$I = \frac{E}{R} = \frac{120\ \text{V}}{10\ \Omega} = 12\ \text{A}$$

Current = Voltage ÷ Resistance



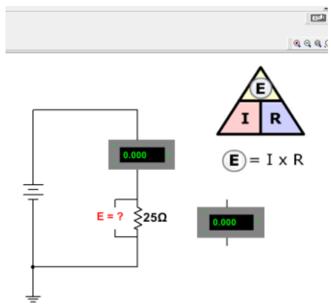
Problem: If a 25-Ω resistor has a current flow of 2 A through it, how much is the voltage across it?



Solution:

$$E = I \times R = 2\ \text{A} \times 25\ \Omega = 50\ \text{V}$$

Voltage = Current x Resistance

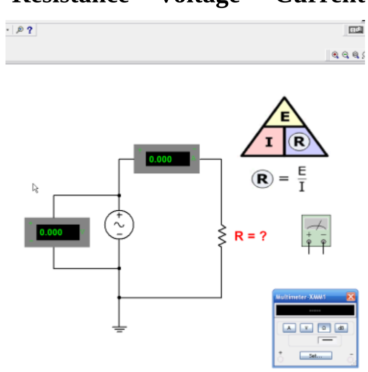


Problem: What is the resistance of a toaster element that is rated for 120 V and 8 A?

Solution:

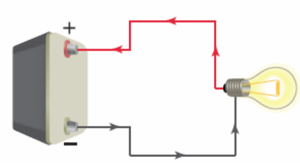
$$R = \frac{E}{I} = \frac{120\ V}{8\ A} = 15\ \Omega$$

Resistance = Voltage ÷ Current



Direction of Current Flow

The **direction of current** flow in a circuit can be designated either as **electron flow** or **conventional current flow**.



Electron flow
(negative to positive)

Electron flow is based on the electron theory of matter and follows the motion of electrons in the circuit from **negative to positive**.

Conventional current flow is based on an older theory of electricity and assumes a current flow in the **opposite** direction from **positive to negative**.