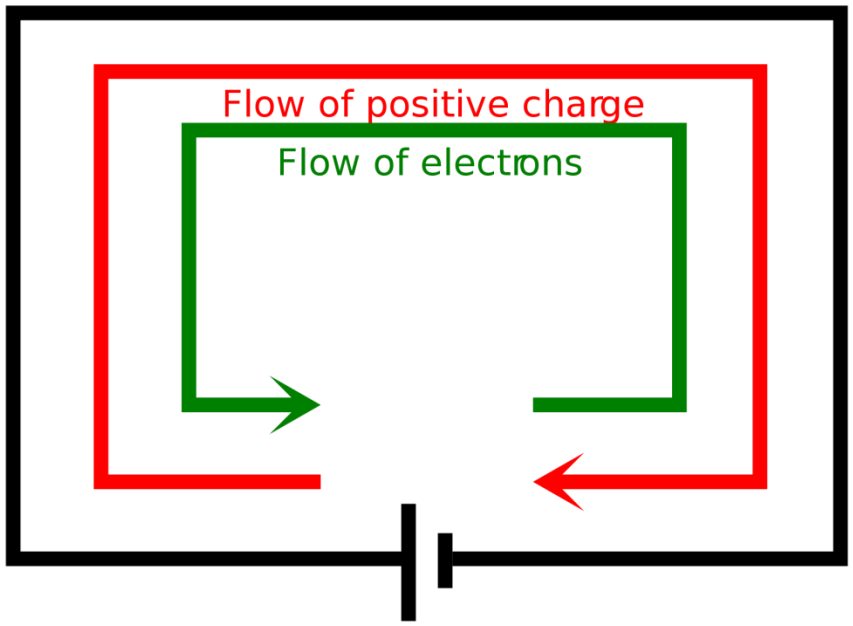
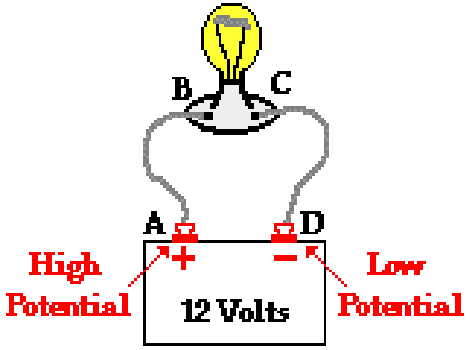
Electric Current
Ohm's Law
Resistance



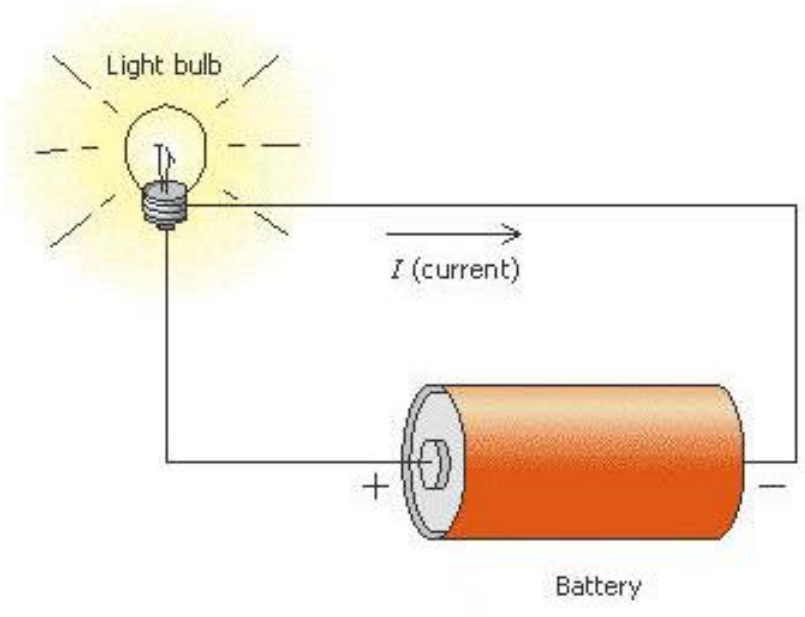
Static Electricity vs. Electric Current

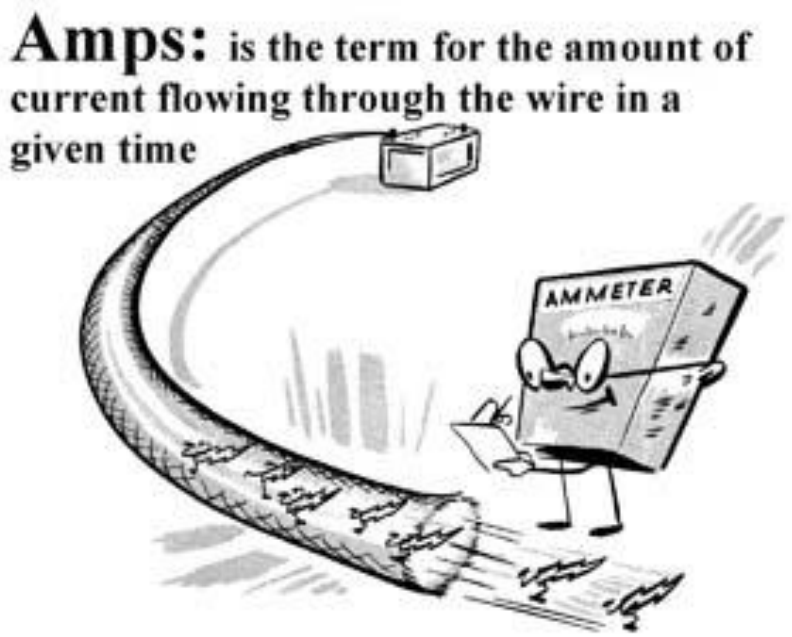
Static electricity is a one time event.

Electric current is a constant flow.



Electric current (I) is the rate at which charge passes a given point in a electric circuit.





An electric circuit is a closed path along which charged particles move.

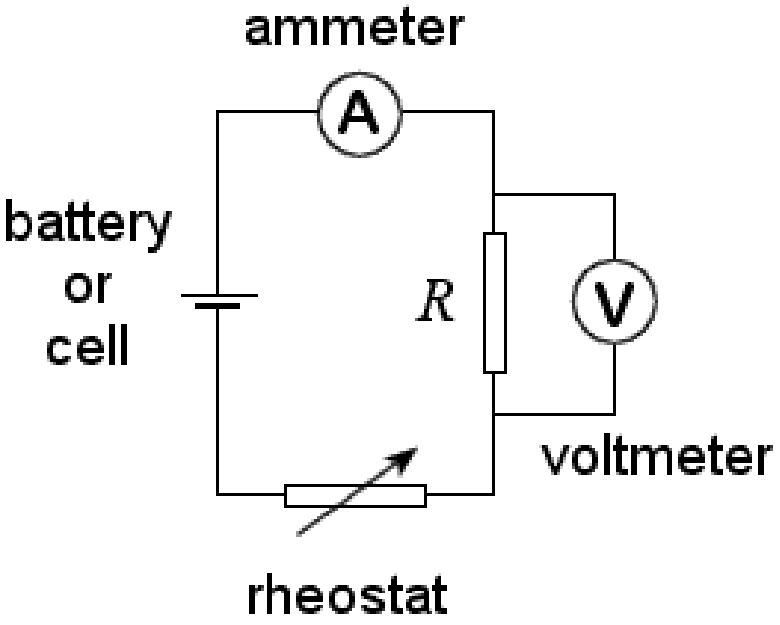
Current Formula:

$$I = \frac{\Delta q}{t}$$

I = C/s = ampere (A)

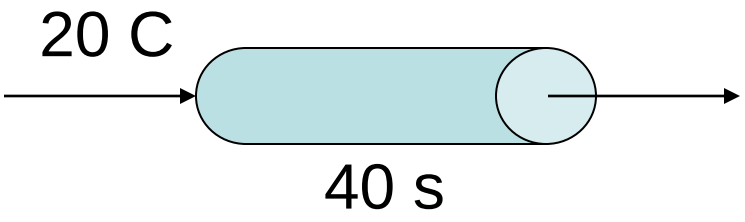
amp

An ammeter is a device used to measure current.



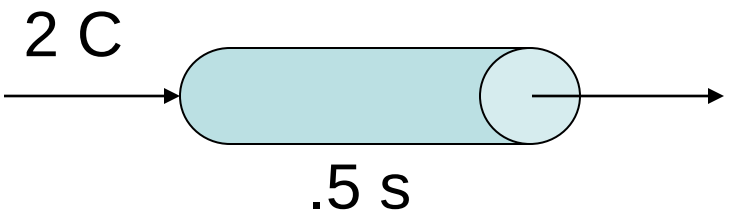
Determine the current for these situations:

1. A cross section of wire is isolated and 20 C of charge are determined to pass through it in 40 s.



$$I = \frac{\Delta q}{t} = \frac{20\ C}{40\ s} = .5\ A$$

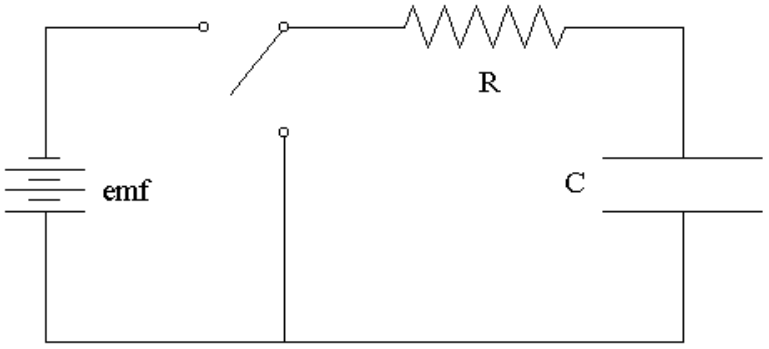
2. A cross section of wire is isolated and 2 C of charge are determined to pass through it in .5 s.

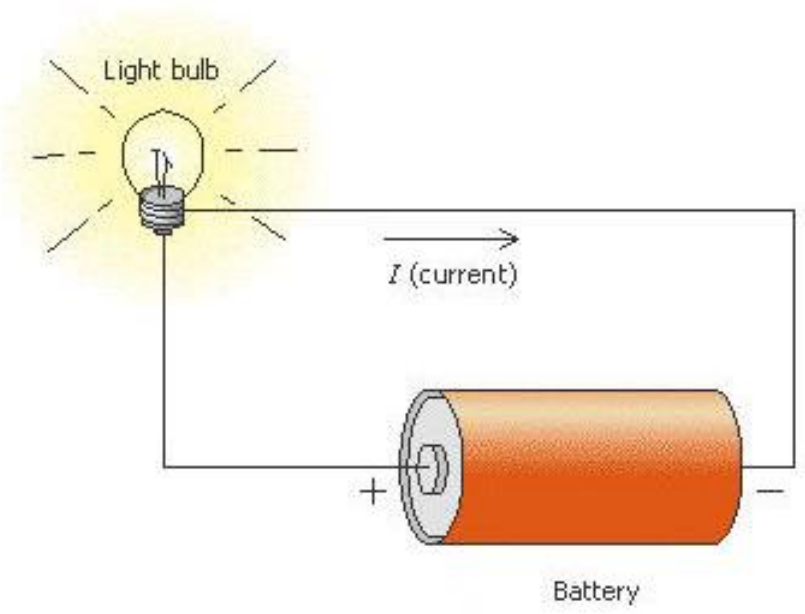


$$I = \frac{\Delta q}{t} = \frac{2\ C}{.5\ s} = 4\ A$$

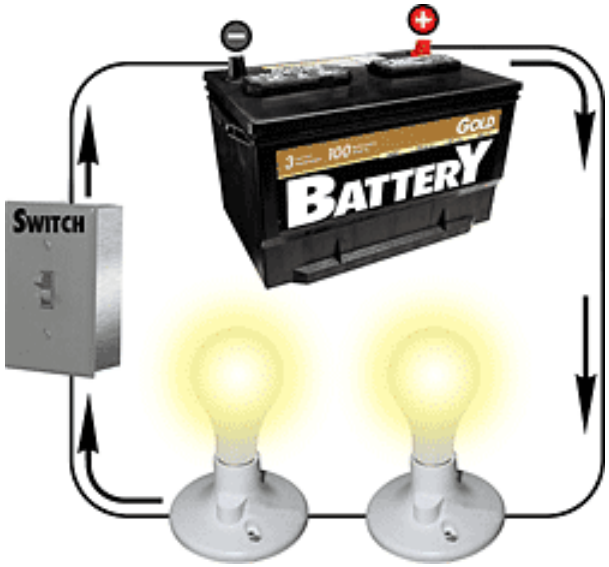
Requirements necessary for an electric current:

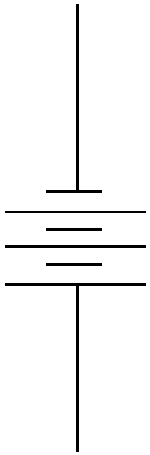
1. There must be a closed conducting path which extends from the positive terminal to the negative terminal of a cell or battery (combination of cells).

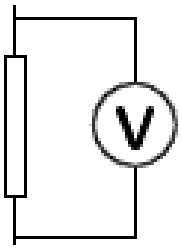


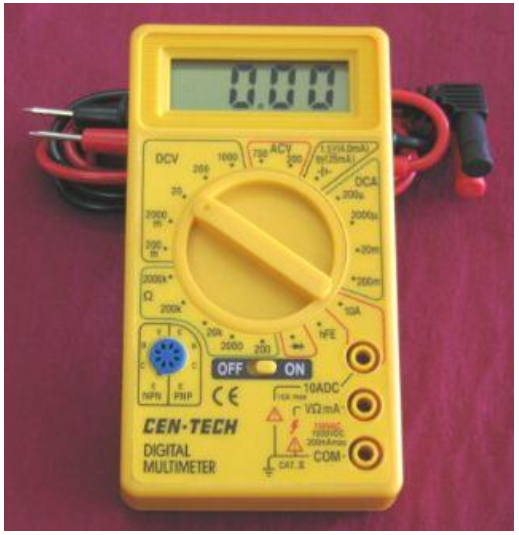


2. There must be a difference in electric potential between the two end points in the circuit. The potential difference may be supplied by a cell or battery. In other words you need an energy source.





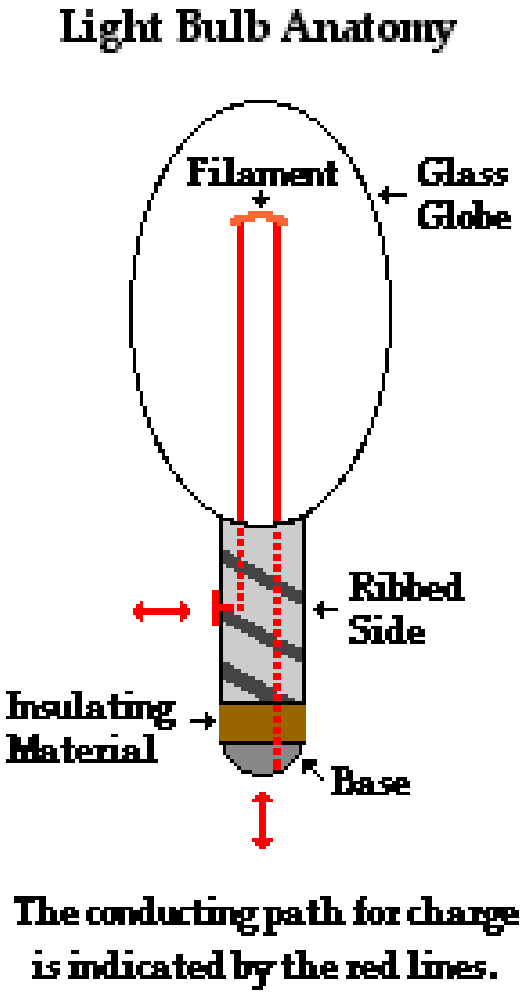




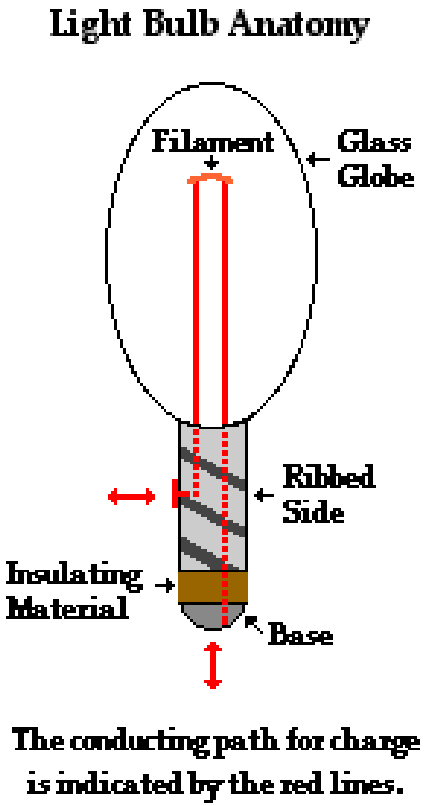
The potential difference or voltage of a circuit can be measured using a voltmeter.

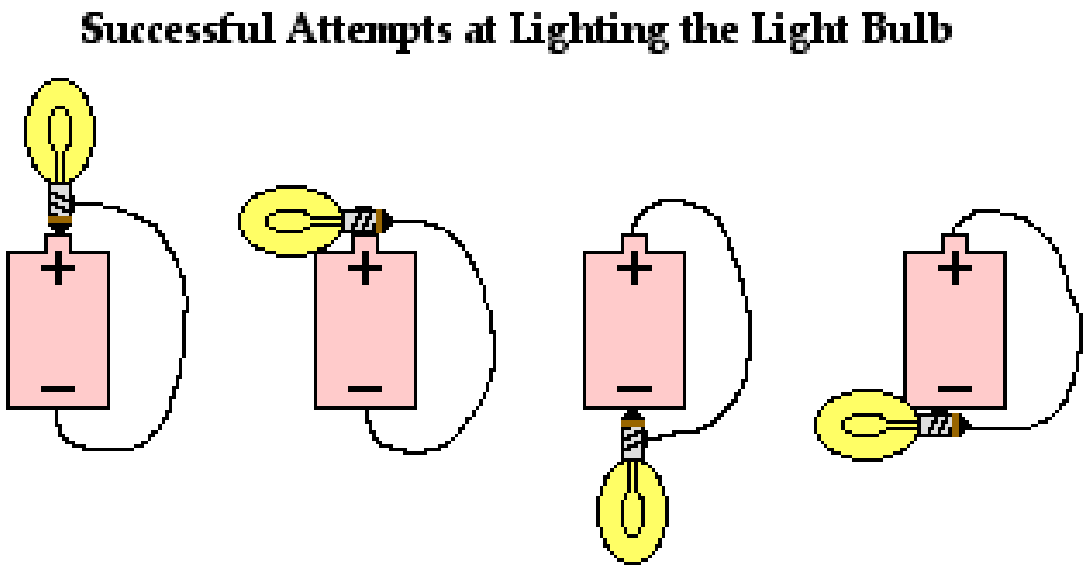
Light Bulbs

- Using only a light bulb, a wire, and a battery come up with 4 ways to create a complete circuit so that the light bulb lights up.



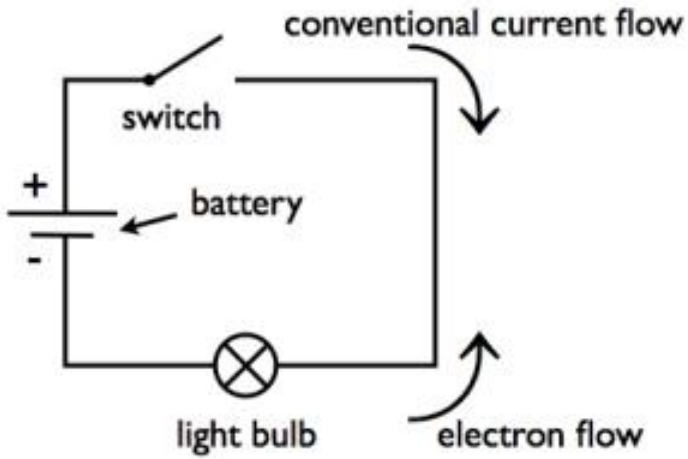
You need to create a closed circuit.





Conventional flow vs. THE TRUTH

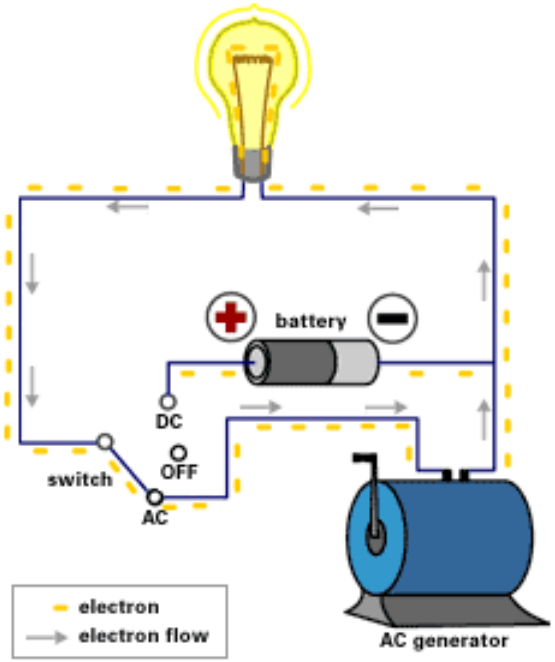
Ben Franklin envisioned positive charges as the carriers of charge. Because of this an early convention for the direction of an electric current was established to be in the direction which positive charges would move. The **direction of an electric current** is by convention the direction in which a positive charge would move. However, we now know that the positive charges (protons) are NOT the charged particles that are moving. IT'S THE ELECTRONS. And the negatively charged electrons would be moving in the opposite direction.



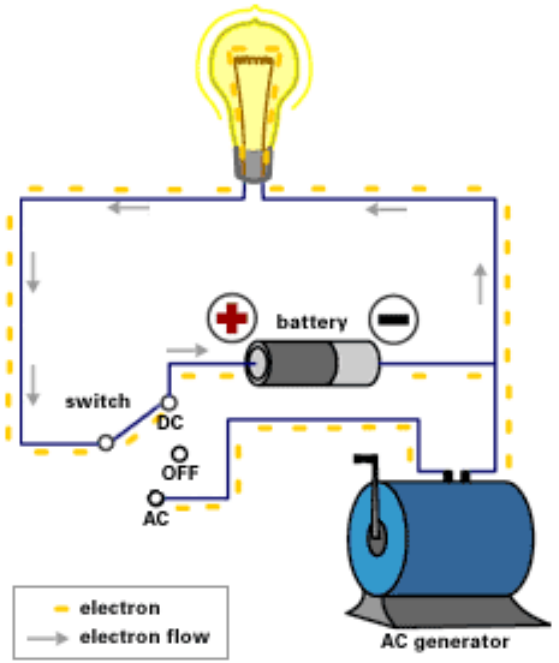
Alternating Current

Direct Current

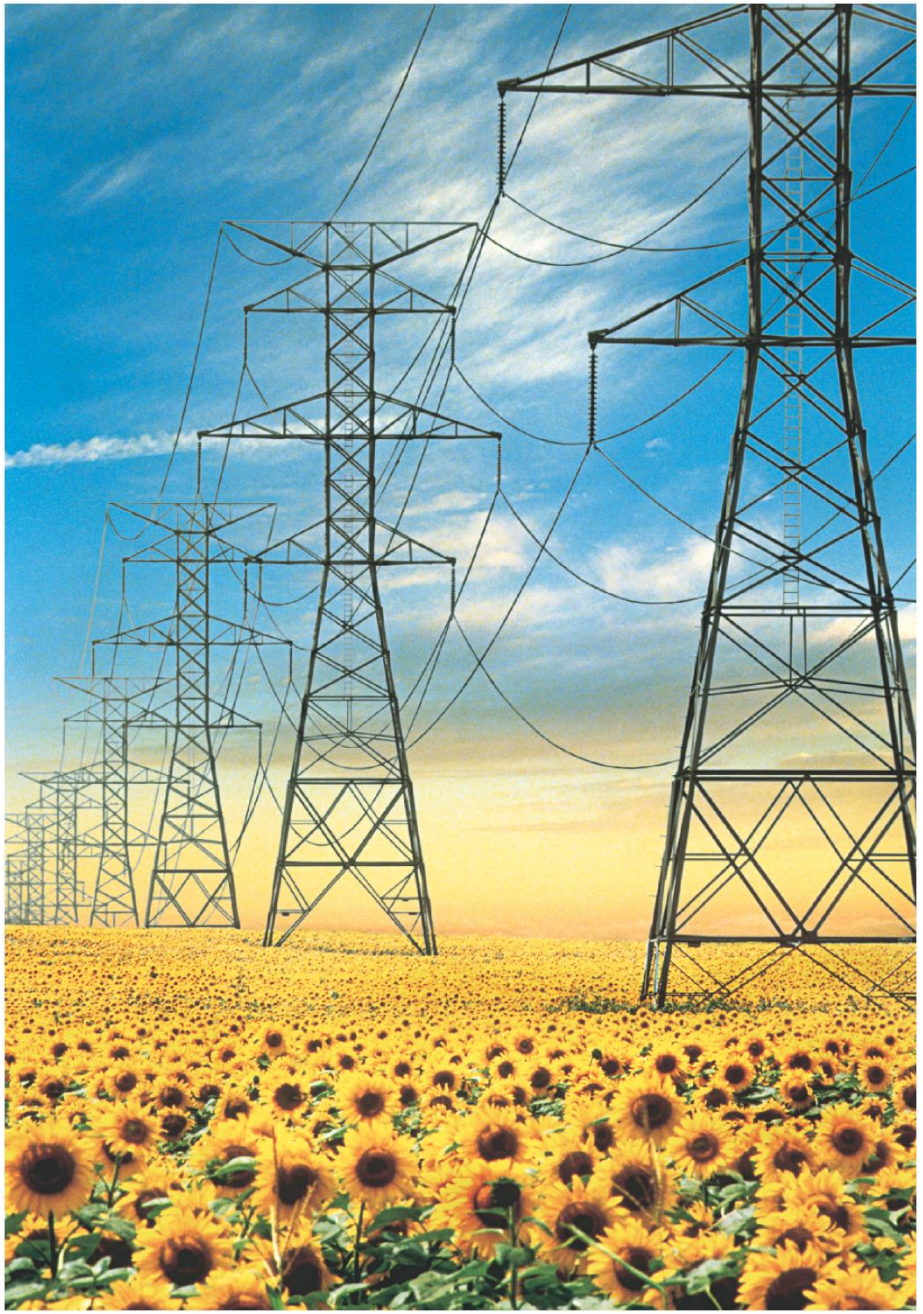
AC - The electrons in alternating current flow in one direction, then in the opposite direction—over and over again. Electricity from a power plant is alternating current.



DC - The electrons in direct current flow in one direction. The current produced by a battery is direct current.

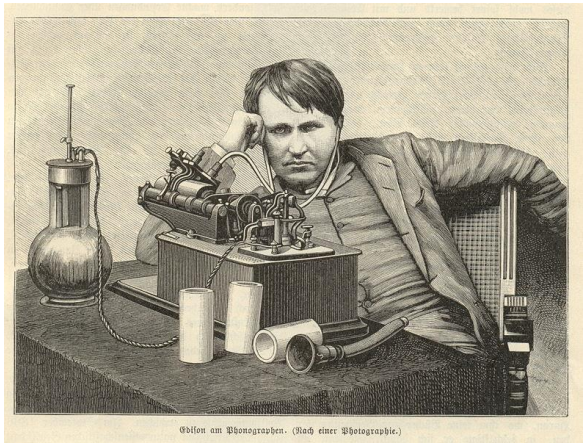


In the United States, the current flow alternates 120 times per second. (In Europe it alternates 100 times per second.) The current supplied to your home by the local utility is alternating current.

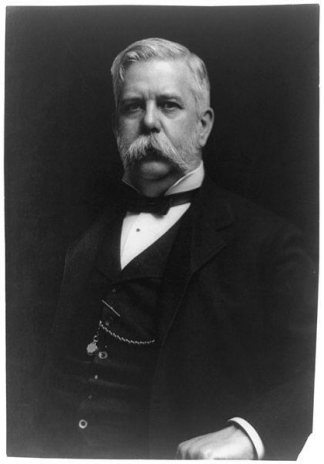


War of Currents
DC vs. AC

EDISON

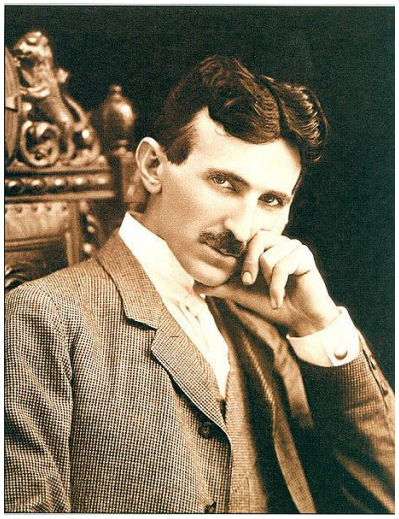


WESTINGHOUSE



Edison carried out a campaign to discourage the use of alternating current, including spreading disinformation on fatal AC accidents, publicly killing animals, and lobbying against the use of AC in state legislatures. Edison directed his technicians to preside over several AC-driven killings of animals, primarily stray cats and dogs but also unwanted cattle and horses. Acting on these directives, they were to demonstrate to the press that alternating current was more dangerous than Edison's system of direct current.

TESLA



Resistance

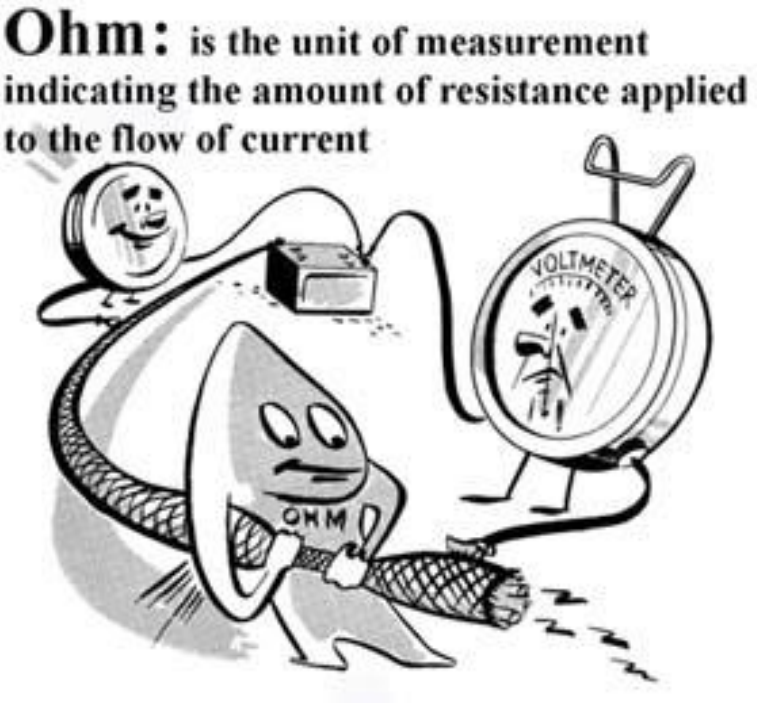
(V) Electric potential difference (voltage- like a battery) is necessary for current to flow.
(Electric Pressure).

(I) Current is the flow of electrons through a circuit.

(R) Resistance discourages or controls the flow.
It is caused by “things” that get in the way of a direct path.

The resistance of a conductor (like a wire) is the ratio of the potential difference applied to the circuit and the current that flows through it…

This is Ohm's Law…

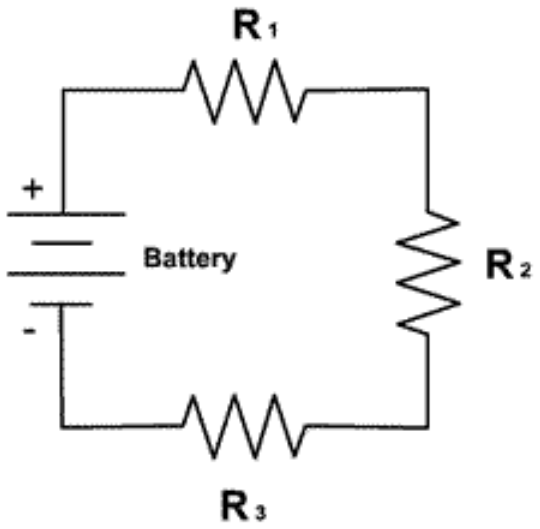


$$R = \frac{V}{I}$$

$$R = \frac{\text{Volts}}{\text{Amps}}$$

R = ohm (Ω)

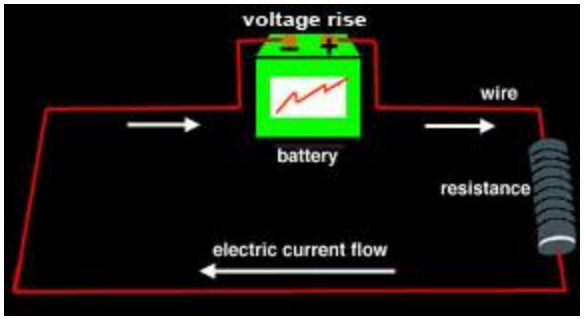
Resistors are “things” in a circuit that limit current flow. They can be controlled resistors or electrical devices like light bulbs or lamps.

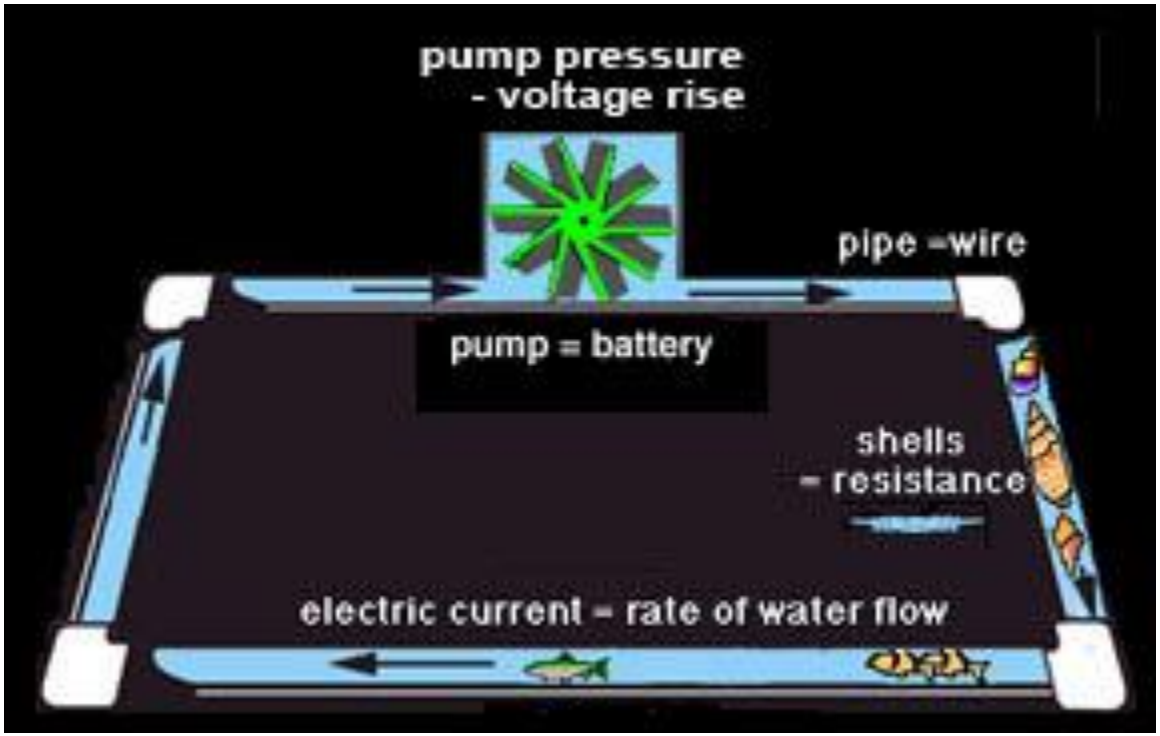


Circuit Analogy

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

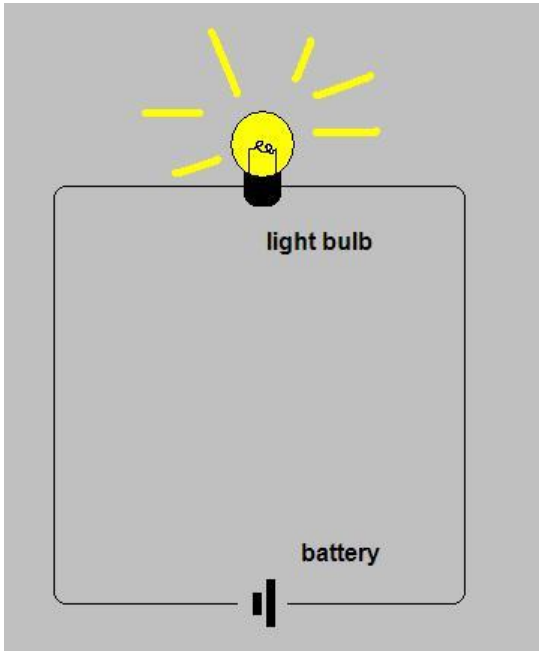
- The pipe is the counterpart of the wire in the electric circuit.
- The pump is the mechanical counterpart of the battery.
- The pressure generated by the pump, that drives the water through the pipe, is like the voltage generated by the battery to drive the electrons through the circuit.
- The seashells plug up the pipe and constrict the flow of the water creating a pressure difference from one end to the other. In a similar manner the resistance in the electric circuit resists the flow of electricity and creates a voltage drop from one end to the other. Energy is lost across the resistor and shows up as heat.





Try this…

A student measures a current of .10 A flowing through a light bulb connected by short wires to a 12 V battery.
What is the resistance of the light bulb?



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

$$R = \frac{12\ V}{.10\ A}$$

$$R = 120\ \Omega$$

Try this…

A lamp with a resistance of 20 Ω is in a circuit that has a current of .05 A flowing through it. What is the potential difference across the lamp?

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

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

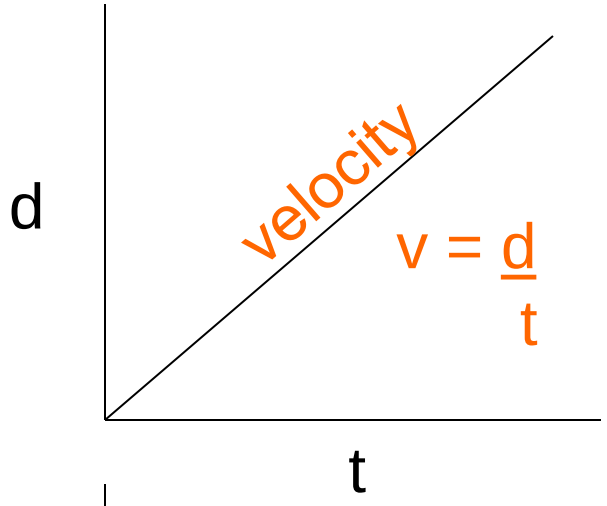
$V = I R$

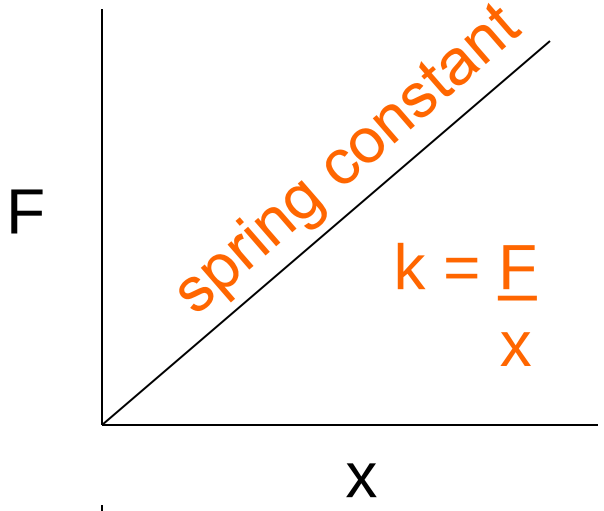
$V = I R$

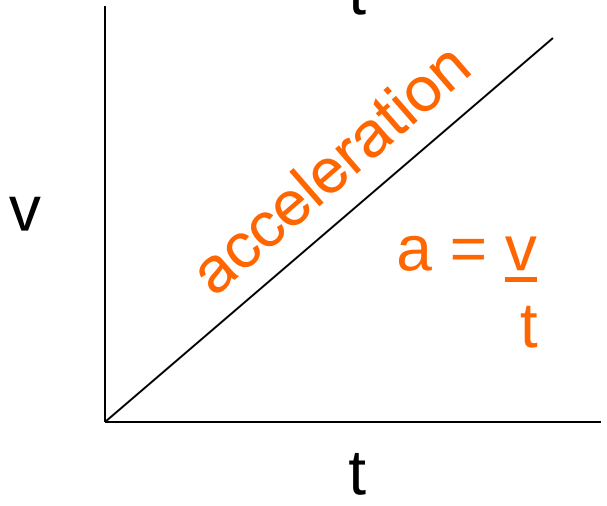
$V = (.05\ A)(20\ \Omega)$

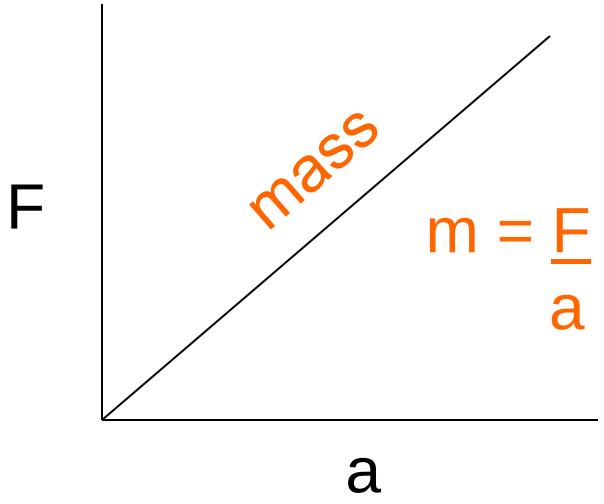
$V = 1\ V$

Recall slope…What are the slopes for the following graphs?

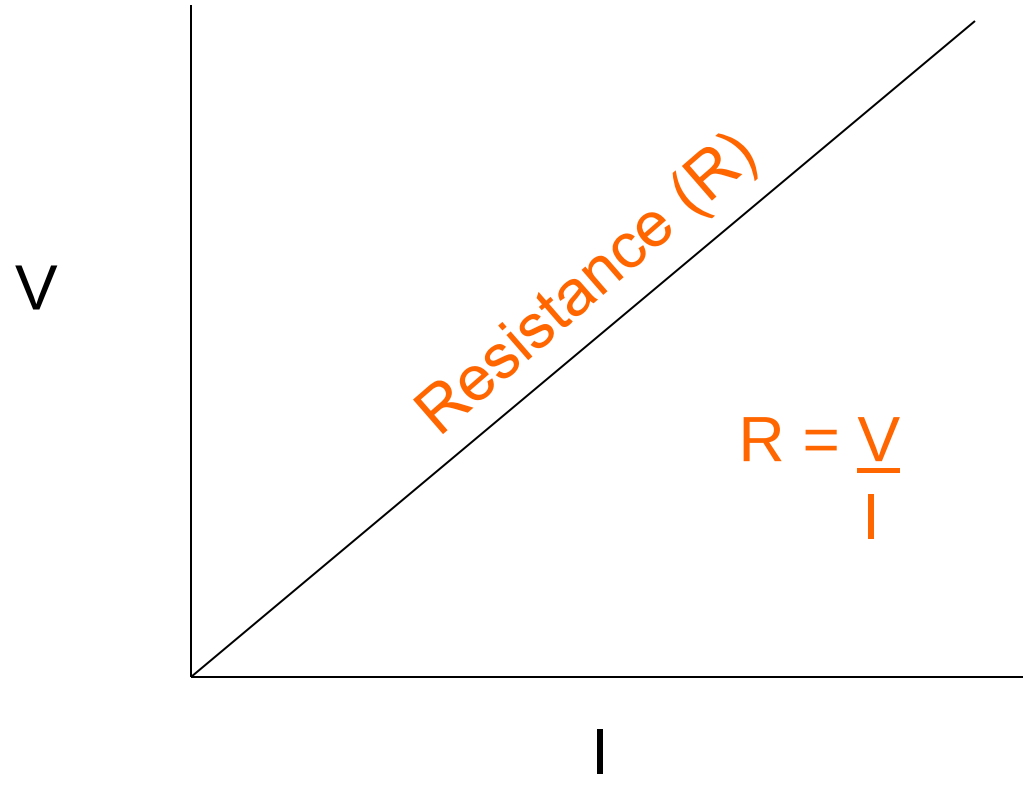




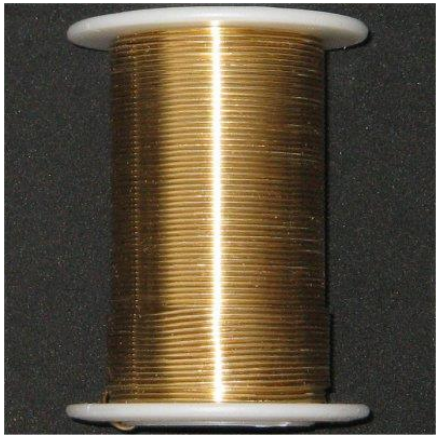




Guess what the slope is for this graph:



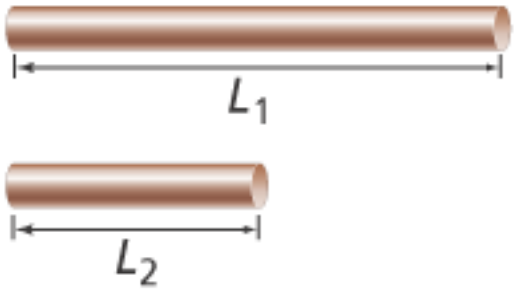
Wires made of a certain types of metals are used in circuits because they are good conductors and allow the electrons within them to move relatively freely.



Although wires allow current to flow through a circuit they also control the current or have some resistance.

Factors that affect the resistance of a wire:

1. **LENGTH**: Increasing the length (L) of the wire will increase the resistance of the wire.



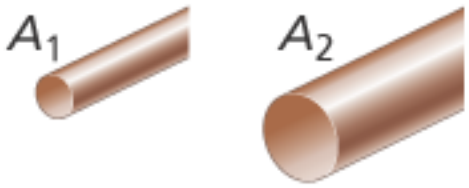
$R_{L1} > R_{L2}$

This is because the current (electrons) will now have further to travel and will encounter and collide with an increasing number of atoms.

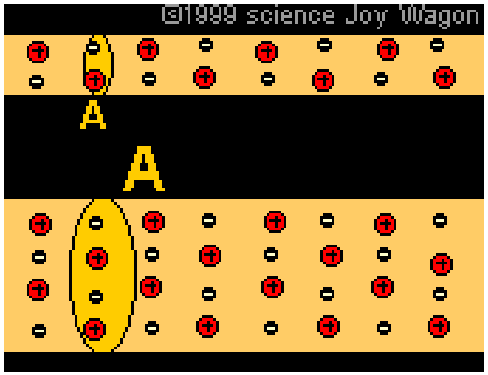
Factors that affect the resistance of a wire:

2. **AREA**: Increasing the cross-sectional area (A) of a wire will decrease the wires resistance.

$$A = \pi r^2$$



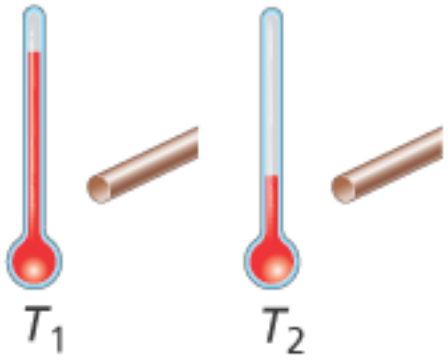
$R_{A1} > R_{A2}$



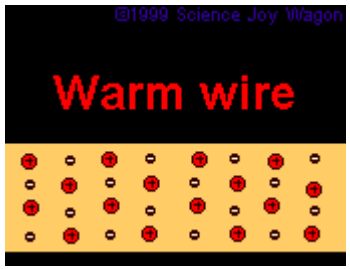
This occurs because in making the wire thicker there is now more spaces between atoms through which the electrons can travel and thus flow easier. The wire isn't resisting the flow as much.

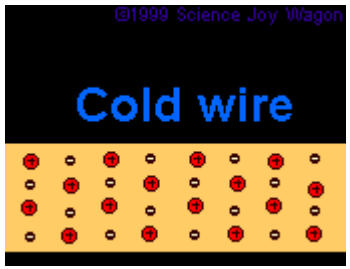
Factors that affect the resistance of a wire:

3. RESISTIVITY (ρ) – this is a characteristic of a material that depends on its electronic structure and temperature. If a wire is made of a material that has a high resistivity then it will have a high resistance.



$R_{T1} > R_{T2}$



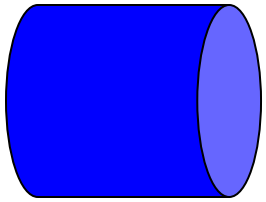


Resistivities at 20°C	
Material	**Resistivity** (Ω•m)
Aluminum	2.82×10^{-8}
Copper	1.72×10^{-8}
Gold	2.44×10^{-8}
Nichrome	$150. \times 10^{-8}$
Silver	1.59×10^{-8}
Tungsten	5.60×10^{-8}

Combining all these factors gives us the following equation for the resistance of a wire:

$$R = \frac{\rho L}{A}$$

Short/thick/cold wires = low resistance (easy for electrons to flow)

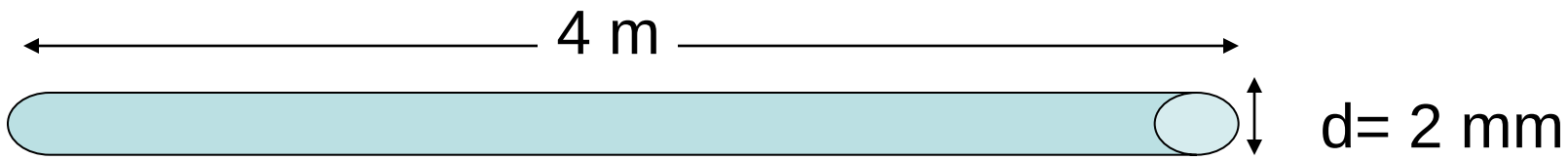


Long/thin/hot wires = high resistance (hard for electrons to flow)

http://phet.colorado.edu/sims/resistance-in-a-wire/resistance-in-a-wire_en.html

Try this…

Determine the resistance of a 4.00 m length of copper wire having a diameter of 2 mm. Assume the temperature of 20°C.



$\rho_{copper} = 1.72 \times 10^{-8}\ \Omega \cdot m$

$$R = \frac{\rho L}{A} = \frac{(1.72 \times 10^{-8}\ \Omega \cdot m)(4m)}{\pi(.001m)^2} = .0219\ \Omega$$

Determine the length of a copper wire that has a resistance of .172 Ω and cross-sectional area of 1×10^{-4} m^2. The resistivity of copper is 1.72×10^{-8} Ω•m.

$$AR = \frac{\rho L \cancel{A}}{\cancel{A}}$$

$$\frac{AR}{\rho} = \frac{\cancel{\rho} L}{\cancel{\rho}}$$

$$L = \frac{AR}{\rho}$$

$$L = \frac{AR}{\rho}$$

$$L = \frac{(.001 m^2)(.172 \Omega)}{(1.72 \times 10^{-8} \Omega \cdot m)}$$

$$L = 10{,}000 \text{ m}$$

Wire	Material	Length	Diameter
A	iron	2 m	6.4×10^{-4} m
B	copper	2 m	6.4×10^{-4} m
C	copper	2 m	1.2×10^{-3} m
D	copper	1 m	1.2×10^{-3} m
E	Iron	2 m	1.2×10^{-3} m

$\rho_{iron} = 9.7 \times 10^{-8}\ \Omega\cdot m$ $\rho_{copper} = 1.7 \times 10^{-8}\ \Omega\cdot m$

- Which one of the five wires has the largest resistance?

High resistance = long/thin/hot wires

Wire A

Wire	Material	Length	Diameter
A	iron	2 m	6.4×10^{-4} m
B	copper	2 m	6.4×10^{-4} m
C	copper	2 m	1.2×10^{-3} m
D	copper	1 m	1.2×10^{-3} m
E	Iron	2 m	1.2×10^{-3} m

$\rho_{iron} = 9.7 \times 10^{-8}\ \Omega\cdot m$ $\rho_{copper} = 1.7 \times 10^{-8}\ \Omega\cdot m$

- Of the five wires, which one has the smallest resistance?

Small resistance = short/thick/cold

Wire D

Wire	Material	Length	Diameter
A	iron	2 m	6.4×10^{-4} m
B	copper	2 m	6.4×10^{-4} m
C	copper	2 m	1.2×10^{-3} m
D	copper	1 m	1.2×10^{-3} m
E	Iron	2 m	1.2×10^{-3} m

$\rho_{iron} = 9.7 \times 10^{-8}\ \Omega\cdot m$ $\rho_{copper} = 1.7 \times 10^{-8}\ \Omega\cdot m$

Which of the wires carries the smallest current when they are connected to identical batteries?

How does current (I) relate to resistance (R)?

$R = \frac{V}{I}$ When current is low, resistance is high.

Wire A

High resistance = long/thin/hot wires

Electric Power (Watts): 3 different ways

Power is the rate at which electrical energy is supplied to a circuit or consumed by a load.

$P = V\ I$

$P = V\ I$

From Ohm's Law $V = I\ R$

$P = I\ R\ I$

$P = I^2\ R$

$P = V\ I$

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

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

$P = \frac{V^2}{R}$

Remember:
1 W = 1 J/s

Try this…

A potential difference of 60 V is applied across a 15 Ω resistor. What is the power dissipated in the resistor?

$$P = \frac{V^2}{R}$$

$$P = \frac{(60\ V)^2}{15\ \Omega}$$

$$P = \frac{3600\ V^2}{15\ \Omega}$$

$$P = 240\ W$$

Try these…

Determine the ...

a. ... current in a 60-watt bulb plugged into a 120-volt outlet.

$I = P / V = (60\ W) / (120\ V) =$ **0.5 A**

b. ... current in a 120-watt bulb plugged into a 120-volt outlet.

$I = P / V = (120\ W) / (120\ V) =$ **1.0 A**

c. ... power of a saw that draws 12 amps of current when plugged into a 120-volt outlet.

$P = V \cdot I = (120\ V) \cdot (12\ A) =$ **1440 W**

d. ... power of a toaster that draws 6 amps of current when plugged into a 120-volt outlet.

$P = V \cdot I = (120\ V) \cdot (6\ A) =$ **720 W**

e. ... current in a 1000-watt microwave when plugged into a 120-volt outlet

$I = P / V = (1000\ W) / (120\ V) =$ **8 A**

Electrical Energy (J)

$W = Pt$

$P = I^2R$ or $P = \frac{V^2}{R}$

$W = I^2Rt$

$W = \frac{V^2t}{R}$

Remember:

1 J = 1 N•m = 1 kg •m^2/s^2

Try this…

A current of.4 A is measured in a 150 Ω resistor. How much energy is expended by the resistor in 30 seconds?

$W = I^2Rt$

$W = (.4)^2(150\ \Omega)(30s)$

$W = (.16)(150\ \Omega)(30s)$

$W = 720\ J$