Section 1 Topics

Electrical Principles

- Introduction
- Attributes of Electricity
- Voltage
- Current
- Resistance
- Ohm's Law

Introduction

Every year, more and more automotive systems rely on electrical components.

- Transmission
- Steering
- Suspension
- Braking
- Engine Control
- Emission Control
- Navigation

This course will introduce you to the principles used in diagnosing electrical circuits.

Introduction

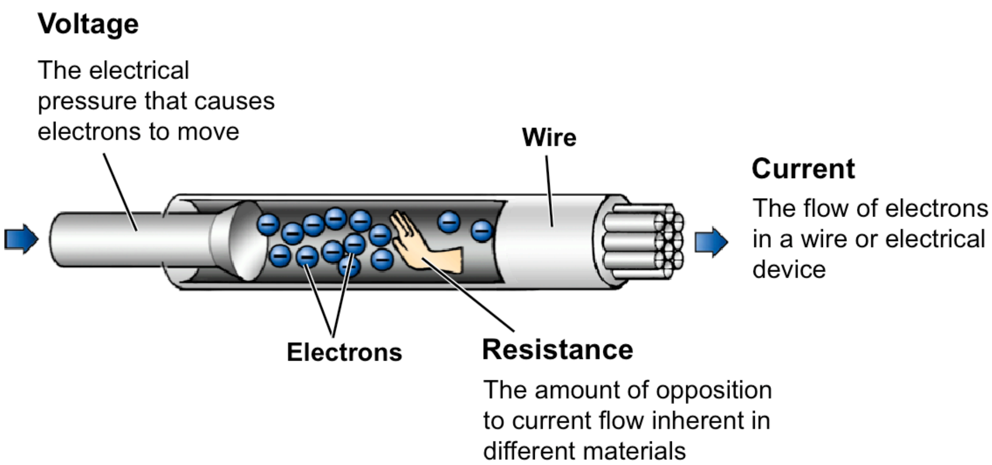
Modern vehicles incorporate many electrical and electronic components and systems: To effectively troubleshoot these and other automotive systems, you need to know how to diagnose electrical circuits.

- Audio
- Lights
- Navigation
- Engine and emission control
- Transmission control
- Braking and traction control
- Steering and suspension

Electrical and electronic system troubleshooting can be straightforward if …

- You know what to look for.
- You know how to select and use the appropriate tools and test equipment.

Attributes of Electricity



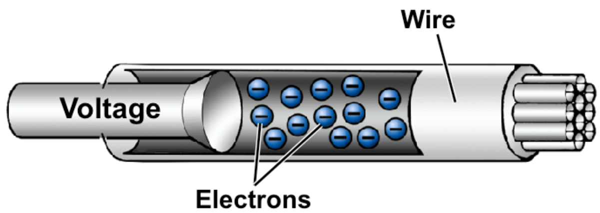
Attributes of Electricity

Electricity is the controlled movement of electrons through a conductor. It is a form of energy. The electrical energy itself cannot be seen, heard, touched, or smelled. However, certain electrical attributes can be detected and measured. The three primary attributes of electricity are:

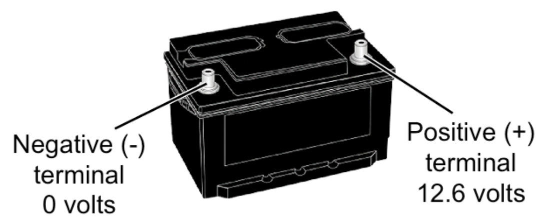
- Voltage (pressure)
- Current (flow)
- Resistance (opposition to flow)

Voltage

Voltage is electrical pressure.



- Voltage is created by a difference in electrical charge between two points
- Voltage is measured in **volts**
- An automobile battery has approximately 12.6 volts difference between its terminals



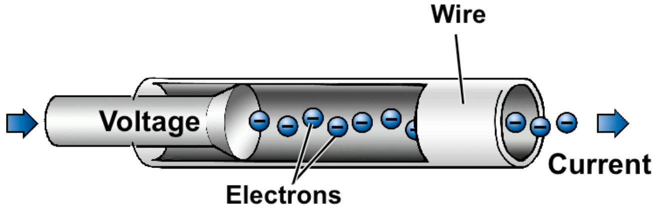
Voltage

Voltage is **electrical pressure** caused by a difference in electrical charge between two points. Voltage (pressure) can exist even when electrons are not flowing. Compare voltage to water pressure. Even when water is not flowing, the pressure is there.

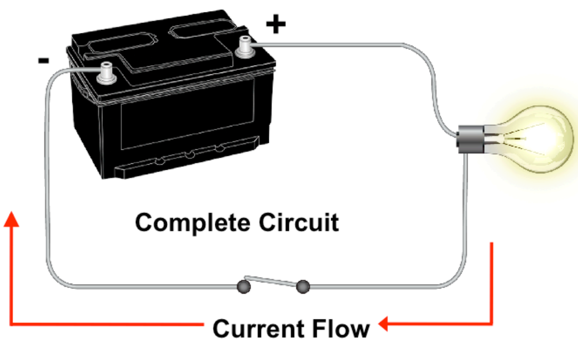
Electrical pressure is created when electrons are freed from their atoms by friction, heat, light, pressure, chemical action, or magnetic forces. It is often called "**potential**," because voltage has the potential to cause electrons to flow (or to do work). Voltage is measured in volts.

Current

Current is the flow of electrons.



- Current flows only if there is a complete path for electron flow **between** a source of higher voltage **(power)** and a lower voltage **(ground)**
- Current is measured in **amperes** (or **amps** for short)

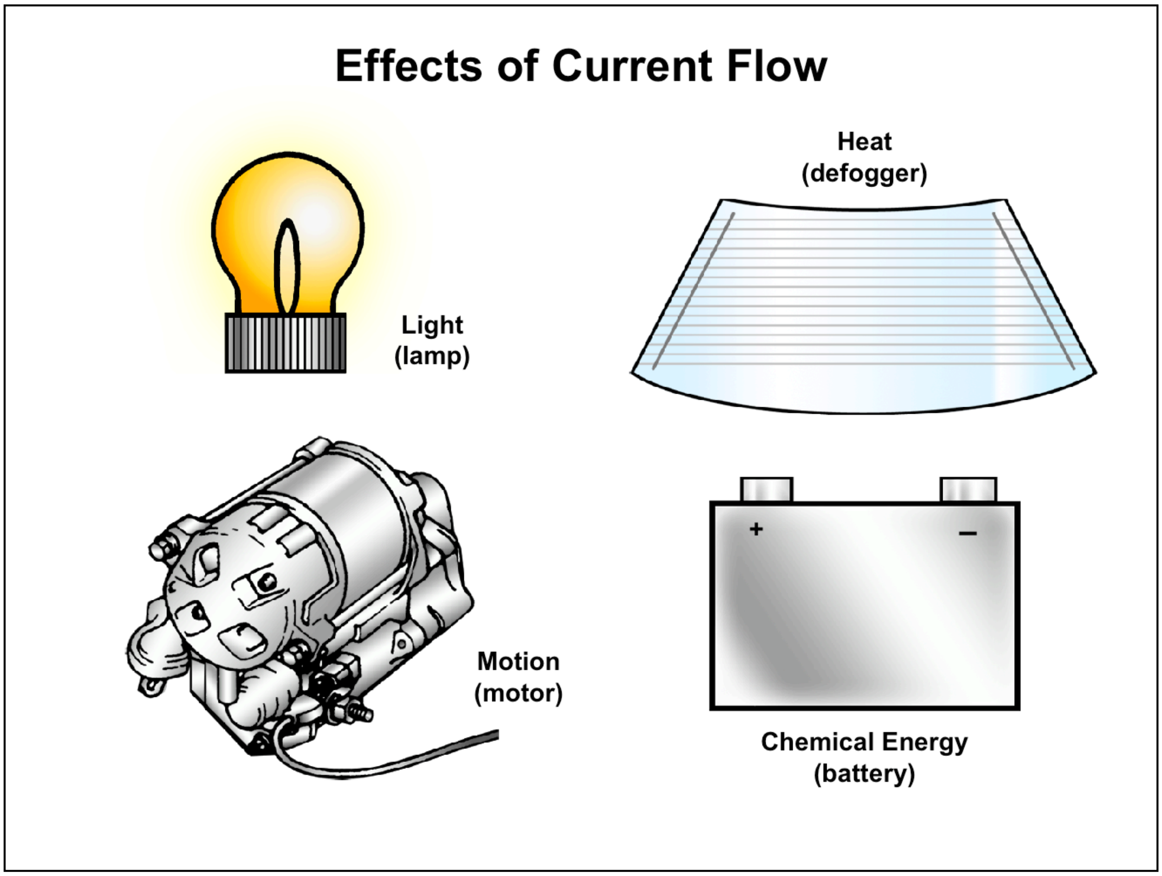


Current Current is the **flow of electrons** caused by electrical pressure.

Voltage (electrical pressure) can exist without current flow. However, current cannot flow without voltage.

Compare current to water flow. When a faucet is opened, water flows if there is water pressure. Without water pressure, there is no water flow.

Current is measured in **amperes**, or “**amps**” for short. Current may also be referred to as “amperage.”



Effects of Current Flow

Electrical current flowing through a device can be converted into motion, light, heat, chemical energy, or electromagnetic force.

Motion – Current flowing through an electric motor is converted to rotary motion.

Light – Resistance to current flow causes the filament to glow in an electric light bulb.

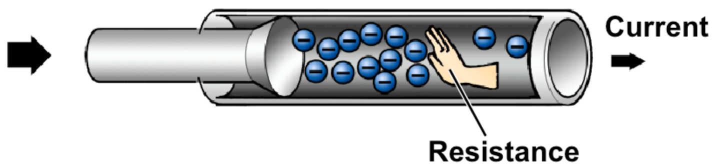
Heat – In a cigarette lighter or a rear window de-fogger, electrical energy is converted to thermal energy (heat). High current can also melt the metal strip in a fuse, causing it to blow.

Chemical Energy – When charging a battery, electrical current causes a chemical reaction in the battery resulting in it building up a stored charge.

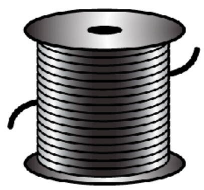
Electromagnetic Force – Current flowing through a coil of wire creates an electromagnetic field that can activate a relay or a solenoid.

Resistance

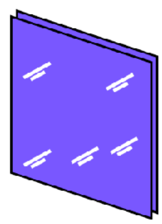
Resistance is the opposition to current flow.



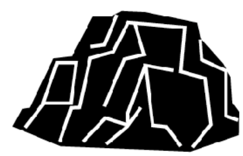
- All materials have some resistance to current flow
- Resistance is measured in **ohms** (abbreviated Ω)



Conductors. Have very low resistance to current flow.



Insulators. Have very high resistance to current flow.



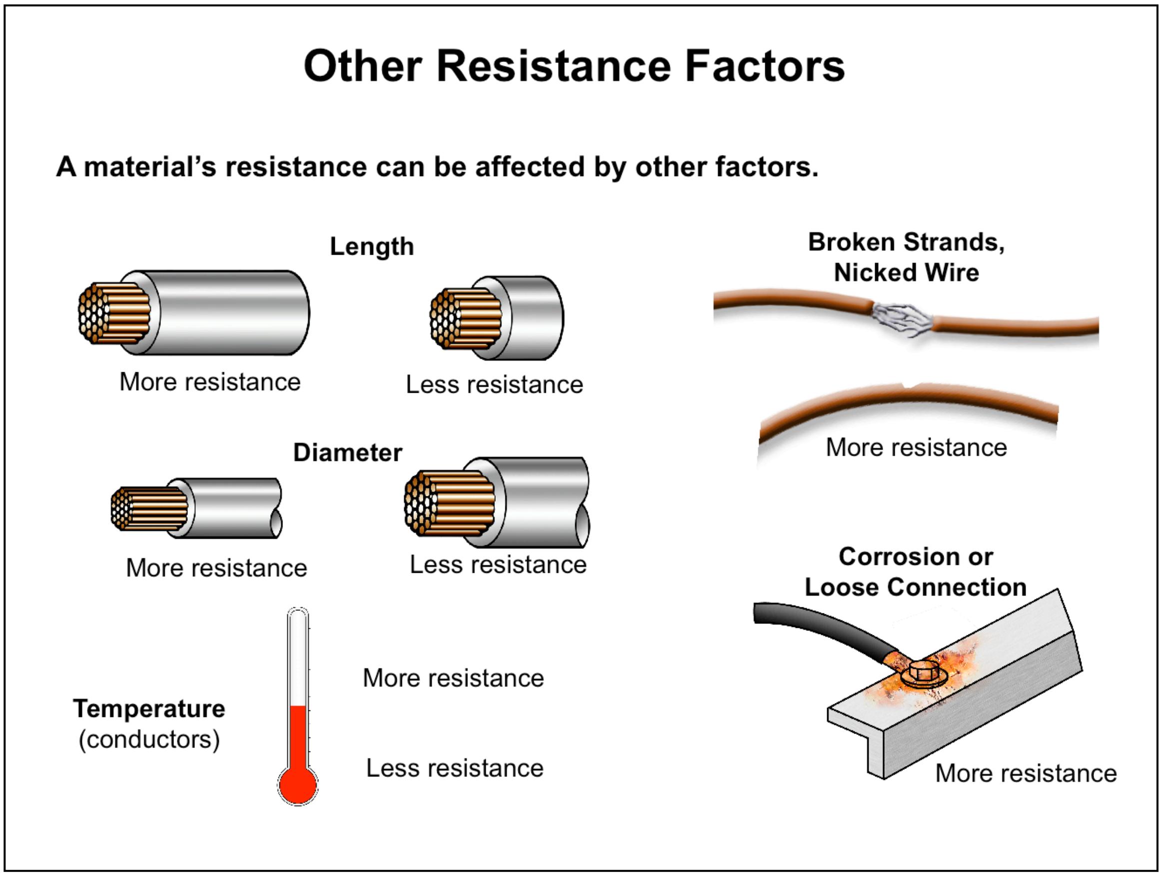
Semiconductors. Can take on the properties of either a conductor or insulator.

Resistance

Every electrical component or circuit has resistance. **Resistance** opposes electron flow. It does not slow down the flow of electrons, but rather reduces the number of electrons flowing. Resistance changes electrical energy into another form of energy, such a heat or light, etc..

- Some materials have a **low resistance** to current flow. These are called **conductors** and include **copper, aluminum, silver and gold**.
- Some materials have a **high resistance** to current flow. These are called **insulators** and include **rubber, glass, paper, ceramics, plastics and air.**
- Materials that can take on the properties of **either a conductor or insulator** are called **semiconductors**. These include **carbon and silicon**.

Resistance is measured in ohms, abbreviated with the omega symbol – **Ω.**



Resistance Factors

Length – A longer wire has more resistance than a shorter one.

Diameter – A small gauge wire has more resistance than a larger gauge wire.

- Wire diameters are rated by **gauge**.
- Gauges 1, 2, 3 are thicker with less resistance and more current capacity.
- Gauges 18, 20, 22 are thinner with more resistance and less current capacity.

Temperature – Changes in temperature affect resistance differently in different materials.

- For most conductors, resistance increases as the temperature increases. For example, the resistance of a lamp's filament increases as it heats up.
- Insulators, on the other hand, have less resistance at higher temperatures.
- Certain semiconductor devices called thermistors exhibit decreasing resistance as temperature increases.

Condition – The condition of a wire or connector can increase resistance.

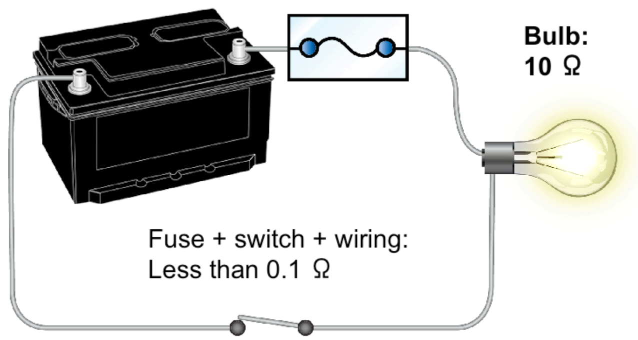
- A **nicked wire** or a wire with **broken wire strands** has higher resistance than an undamaged wire because the wire's diameter is effectively diminished.
- **Corrosion** can increase resistance because the conducting material is replaced by higher-resistance corrosion by-products.
- **Loose connections** are like wires with broken wire strands. Fewer contact points between the connecting components result in higher resistance.

HINT When replacing a wire in a circuit, do not use a thinner wire or a longer wire because this will increase the resistance in the circuit.

Component Resistances

All of the components in a circuit have resistance, including wiring, switches, and fuses.

The load(s) in a circuit have the most resistance of all the circuit components.



Component Resistances

All materials have some resistance, even conductors. The resistance of conductors, however, is very low. Wiring, fuses and switches in a circuit normally have less than 1/10 of an ohm (0.1 Ω) resistance.

Loads

Loads are the devices in a circuit that use electricity to **perform work**. The purpose of the circuit is to deliver the electrical current necessary to operate the load. Typical loads include:

- Lamps
- Motors
- Horn
- Defogger
- Audio speakers
- Cigarette lighter

Other devices that can act as a load in a circuit are **resistors**. Resistors are electronic devices that add resistance to a circuit to **control current flow**. A blower motor control switch is an example. It has several resistance levels to control current flow to the blower motor and thus control blower speed.

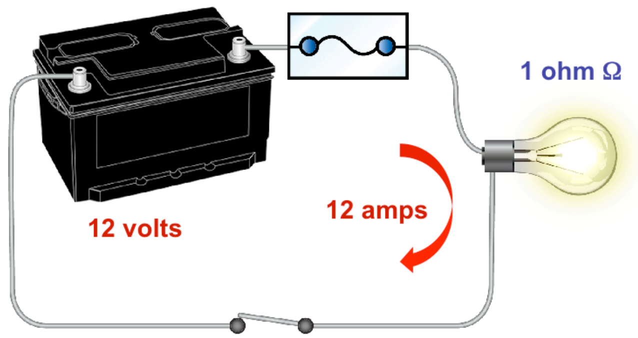
The loads in a circuit – whether working loads or resistors – will have the most resistance of all the components in the circuit.

Ohm's Law

According to Ohm's Law:

In a circuit with **1 ohm resistance**,
a **1 volt power** source causes
1 amp of current to flow.

If resistance doesn't change:
- **Higher voltage** produces **more current**
- **Lower voltage** produces **less current**

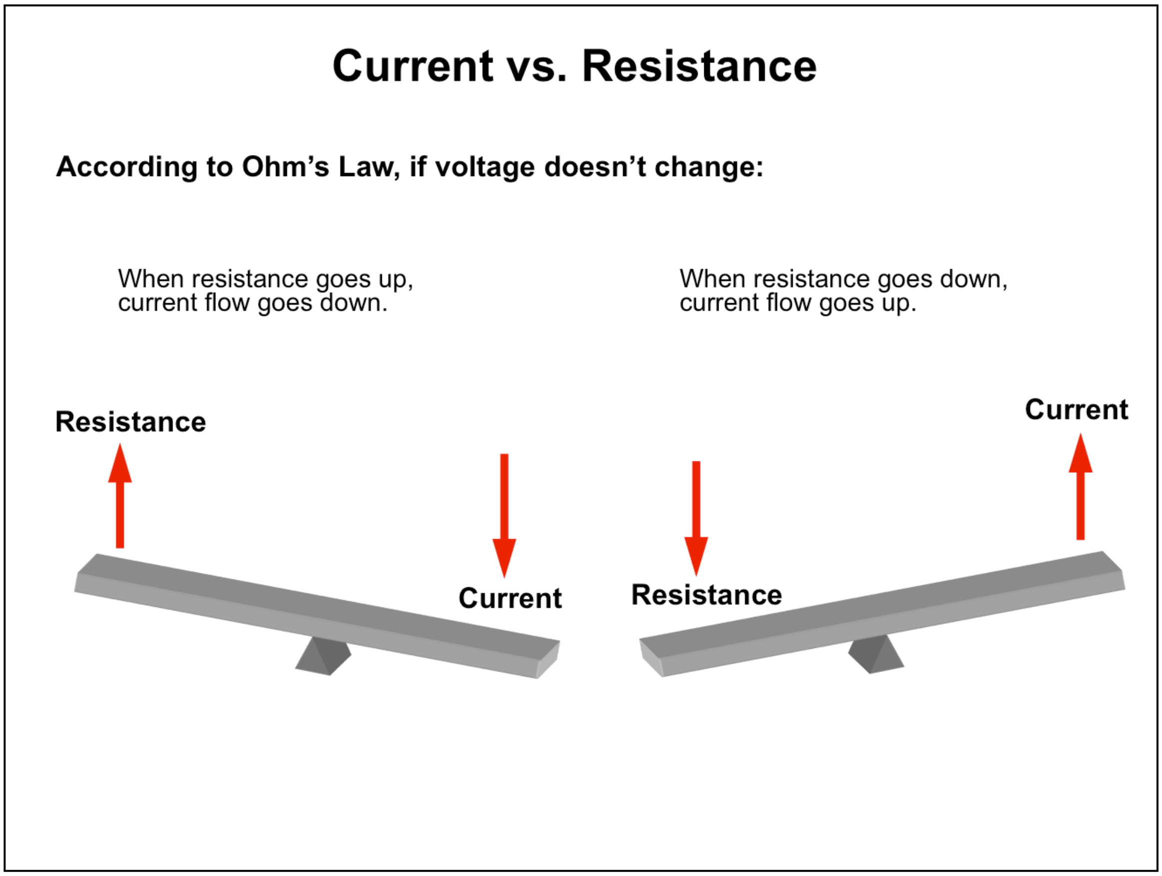


Ohm's Law

Ohm's Law explains the relationship between voltage, current, and resistance. One part of Ohm's Law states:

> The current in a circuit is directly proportional to the applied voltage.

According to Ohm's Law, when resistance stays the same:
- If applied voltage increases, current flow increases.
- If applied voltage decreases, current flow decreases.



Current vs. Resistance

Ohm's Law also states:

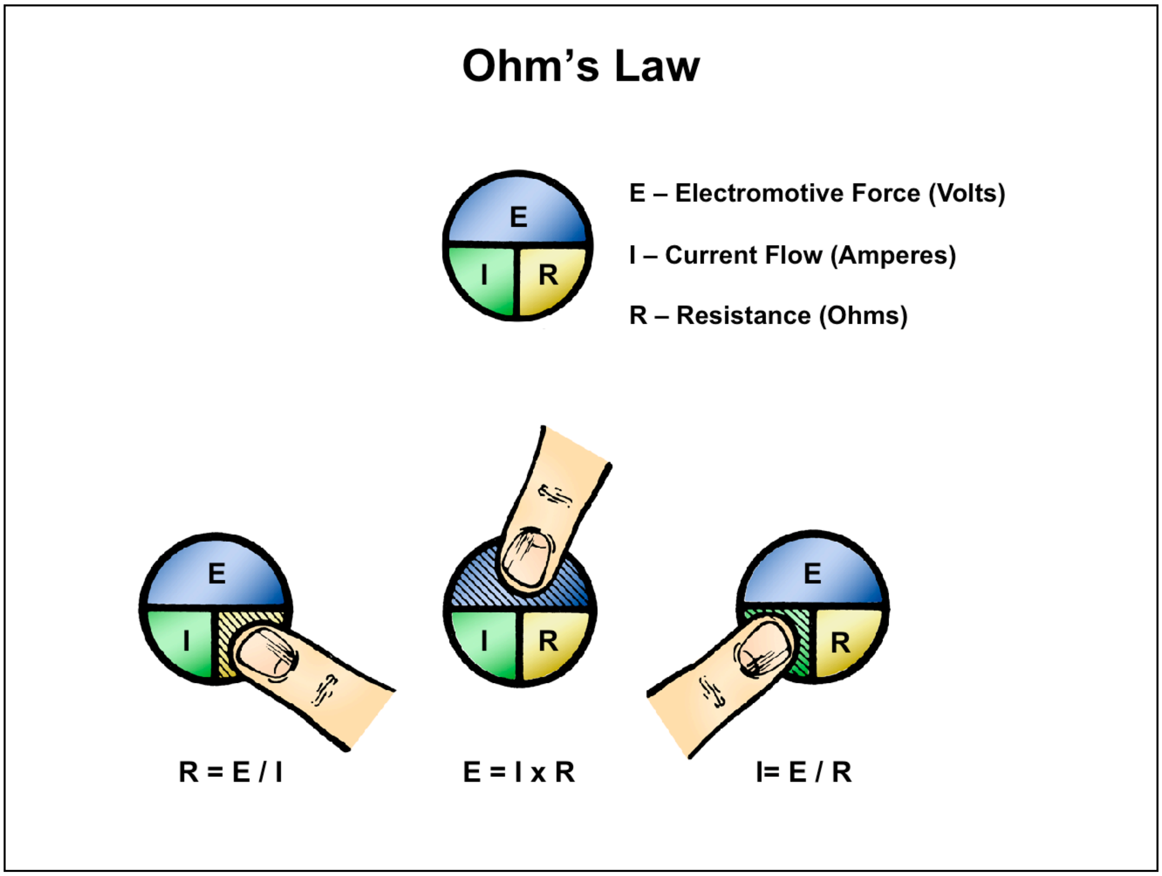
The current in a circuit is inversely proportional to the amount of resistance.

According to Ohm's Law, when voltage stays the same:

- If circuit resistance increases, current flow decreases.
- If circuit resistance decreases, current flow increases.

Resistance is not affected by either voltage or current. It is a characteristic of the combination of conductors and loads in the circuit. Resistance can be OK, too low, or too high.

- If resistance is too low, current will be higher than normal.
- If resistance is too high, current will be low if there is sufficient voltage, or there will be no current if the voltage is not enough to overcome the resistance.



Calculating Volts, Amps, or Ohms

The formula for Ohm's Law is E = I x R where:

- E = Electromotive force (in volts)
- I = inductance, or current flow (in amps)
- R = Resistance (in ohms)

If you know any two values in a circuit, you can calculate the third value using Ohm's law.

Examples

If you know the voltage in a circuit is 12 volts and the current is 2 amps, you can calculate the circuit resistance:

R = E / I
R = 12 volts / 2 amps
R = 6 ohms

If you know the resistance in a circuit is 3 ohms and the current is 4.2 amps, you can calculate the circuit voltage:

E = I x R
E = 4.2 amps x 3 ohms
E = 12.6 volts

If you know the voltage in a circuit is 12 volts and the resistance is 4 ohms, you can calculate the circuit current:

I = E / R
I = 12 volts / 4 ohms
I = 3 amps