



## Electrical Safety in Laboratories: Essential Terminology and Practices

The water hose analogy offers a simple way to visualize three key electrical concepts: voltage, current, and resistance.

In the image below:

The hose represents a wire, while

- **Water pressure = voltage**
- **Water flow = electric current**
- **A kink or narrow section = resistance**

Since electricity is invisible, this analogy helps make sense of how electricity behaves in a circuit. The following sections will define these terms and introduce other important electrical safety terminology.

### Electricity is like a water hose

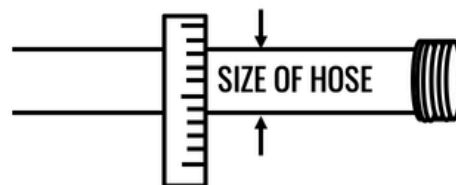
**Voltage**

Volts (V)



**Current**

Amps (A or I)



**Resistance**

Ohms (R or  $\Omega$ )



FREEING  
ENERGY

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**Voltage (Volt)** - The fundamental force or “pressure” that causes electricity to flow through a conductor. Measured in volts. If electricity flowing through a wire or conductor was represented by water flowing through a hose, the water pressure in the hose would be the equivalent of the voltage.

**Hazard Contribution:** High voltage increases the potential for electric shock or electrocution. The greater the voltage, the more likely it is that injury or death could occur if a person comes into accidental contact with electricity. Voltage is the driving force behind the flow of current, so high-voltage systems present significant risk. Typical residential and commercial outlets supply 120 volts. In most cases, “high voltage” refers to systems operating at or above 600 volts.

**Safety:** Proper insulation, grounding, and circuit protection are essential when working with all electrical systems, especially high-voltage systems.

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**Current (Ampere)** - The unit by which the flow of current through a conductor is measured. If electricity flowing through a wire or conductor was represented by water flowing through a hose, the amount of water flowing in the hose would be the equivalent of the current.

**Hazard Contribution:** The higher the current (measured in amps), the more dangerous the electrical system becomes. Current is directly related to the severity of electric shock. A current as low as 100 mA (milliamps) can be lethal to humans if combined with sufficient voltage and resistance. Most common residential and commercial electrical service panels are 100-amp to 200 amp with 15-amp or 20-amp branch circuits supplying lighting and outlet receptacle loads.

**Safety:** Devices like fuses and circuit breakers limit current flow, which helps prevent fatal shocks or burns.

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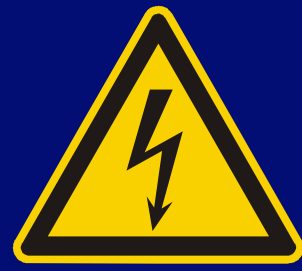


**Resistance** - The opposition to the flow of electric current in a conductor, which slows down electron movement and can generate heat. Resistance depends on the material, length, cross-sectional area, and conductor temperature. If electricity flowing through a wire or conductor were represented by water flowing through a hose, the diameter of the hose would be the equivalent of the resistance; a narrow hose has high resistance, while a larger hose offers lower resistance to the flow of water within.

**Hazard Contribution:** High resistance in electrical components can lead to excessive heat buildup, increasing the risk of burns, equipment failure, and electrical fires. Low resistance in unintended areas, such as the human body, can result in severe electrical shocks or electrocution. Moisture reduces resistance, in general.

**Safety:** Understanding and controlling resistance helps regulate current flow, preventing overheating and ensuring safe voltage levels for laboratory equipment. Proper selection of wiring materials, circuit design, and environmental controls (e.g., avoiding moisture) can minimize resistance-related hazards.

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**Circuit** - The complete path through which electric current flows, including a power source (generator or battery), conductive wiring, and electrical devices. If any part of the circuit is removed or interrupted, the current stops, creating an open or broken circuit.

**Hazard Contribution:** A damaged or incomplete circuit can cause unintended current flow, potentially leading to short circuits, overheating, or electrical fires. If a person contacts an exposed wire or faulty equipment, they may become part of the circuit, increasing the risk of electric shock or electrocution.

**Safety:** Proper insulation, grounding, and regular inspection of electrical components help maintain a safe circuit. Using circuit protection devices such as circuit breakers and ensuring wires and tools are in good condition reduces the risk of unintended current flow and electrical hazards.



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**Circuit Breaker** - A protective device which automatically opens, or trips, a circuit, without damage to itself, when the current exceeds a predetermined level.

**Hazard Contribution:** A lack of a functioning circuit breaker can allow a dangerous current to flow, potentially causing overheating, fires, or electric shocks.

**Safety:** Circuit breakers automatically cut off the electrical supply when current exceeds safe levels, reducing the risk of electrical fires or injuries. Laboratory devices which draw high current may require a dedicated circuit breaker to ensure uninterrupted operation.

**Fuse** - A protective device that allows a piece of metal to become part of a circuit. The metal melts under heat created by excessive current, interrupting the circuit and preventing the flow of electricity from exceeding the circuit's current-carrying capacity.

**Hazard Contribution:** Fuses are a key safety component. If a fuse is not properly rated or fails, excessive current can flow, leading to overheating, fire, or equipment damage.

**Safety:** Fuses interrupt current flow when it exceeds safe levels, preventing dangerous overcurrent situations from escalating.



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**Conductor** - A substance or body that allows a current of electricity to pass continuously along it. Metals such as copper or aluminum are good conductors and are commonly used in wiring for this reason. Poor conductors include rubber, glass, plastic, or wood.

**Hazard Contribution:** Conductors are materials that allow current to flow, and they can be dangerous when exposed. Unprotected conductors or damaged wiring can result in shock, electrocution or fire.

**Safety:** Proper insulation and protection of conductors help prevent accidental contact or short circuits.

**Insulation** - Non-conductive materials, such as rubber or plastic, used to cover or surround a conductor, permitting it to be handled without danger of electric shock.

**Hazard Contribution:** Insulation failure or damage increases the risk of direct contact with live conductors, leading to electric shock.

**Safety:** Insulation prevents accidental contact with electrical currents and minimizes the chance of electric shock, especially in high-voltage equipment. Always ensure insulation on wires and other conductive electrical components is intact before operating.

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**Grounding** - A method that prevents the buildup of hazardous voltages in a circuit by creating a low-resistance path to earth or some other ground plane. Typically, this is accomplished by connecting a wire to a conductor – such as a metal rod - which is in contact with the earth.

**Hazard Contribution:** Without proper grounding, electrical systems may build up hazardous voltages, posing a risk of electrocution or electrical fires.

**Safety:** Grounding provides a safe path for stray electrical currents, directing them harmlessly to the earth and reducing shock hazards. This is commonly seen in the grounding pin of three-prong power cords, which helps prevent electric shock by safely diverting excess current to ground. Never attempt to remove the grounding pin from a three-prong cord or use an appliance if the pin has been removed or damaged.

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**Overcurrent** - Any current in excess of the rated capacity of equipment or of a conductor.

**Hazard Contribution:** Overcurrent (excessive current) can lead to overheating of wires, equipment, and even cause fires. It can also damage electrical components and lead to system failures.

**Safety:** Overcurrent protection devices like circuit breakers or fuses ensure that the current in a system does not exceed safe levels, preventing damage and potential harm. Always verify that equipment is plugged into a properly rated outlet to prevent overcurrent.

**GFCI (Ground-fault Circuit Interrupter)** - A device that detects an insulation failure by comparing the amount of current flowing to electrical equipment with the amount of current returning from the equipment. Whenever the difference is greater than 5 milliamps, the GFCI trips and interrupts the flow of electricity. GFCIs are required to be installed on outlets in wet locations, such as near sinks, to prevent accidental shock due to water contacting electricity.

**Hazard Contribution:** Without a GFCI, electrical faults that cause an imbalance in current flow may go undetected, increasing the risk of electric shock.

**Safety:** GFCIs quickly detect ground faults and shut off the power, preventing potential electrocution or electrical hazards.

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**Lockout/Tagout** - A system used to prevent the unplanned activation of an electrical system. To lock a switch in the "off" position by means of a padlock, or to lock electrified equipment behind a locked door, to which only qualified persons have the key.

**Hazard Contribution:** If electrical equipment is not properly locked out during maintenance or repair, workers can accidentally energize the equipment and cause injury.

**Safety:** Lockout/tagout procedures ensure that equipment is de-energized and cannot be inadvertently turned on while being worked on, greatly reducing the risk of shock or electrocution. Plug-operated devices do not require LOTO protection during maintenance, however lockable plug covers can be used for added protection. Never attempt to remove a lock from a locked-out device if not authorized.

**Impedance** - Opposition to the flow of alternating (AC) electric current. It includes both resistance and reactance.

**Hazard Contribution:** High impedance can restrict current flow, making it harder for the circuit to react to unsafe conditions. Low impedance (in some cases) can lead to higher currents, which can be hazardous.

**Safety:** Proper impedance ensures safe current flow, especially in AC circuits, and helps balance electrical loads to avoid overloading systems.



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**Fault** - An insulation failure that exposes electrified conductors, causing current to leak and possibly resulting in electric shock.

**Hazard Contribution:** A fault in an electrical system (such as a short circuit or grounding issue) exposes live parts and may result in electric shock, fire, or equipment damage.

**Safety:** Identifying and isolating faults quickly helps prevent unsafe conditions like electrical shock or fire hazards.

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