BASIC ELECTRICAL SAFETY

FERMILAB TRAINING COURSE FN000235

CLASSROOM INSTRUCTION MATERIAL

THIS BOOKLET CONTAINS A SUMMARY OF BASIC ELECTRICITY PRINCIPLES AND A HANDOUT OF THE SLIDE PRESENTATION FOR NOTE-TAKING.

REVISED MAY 2014

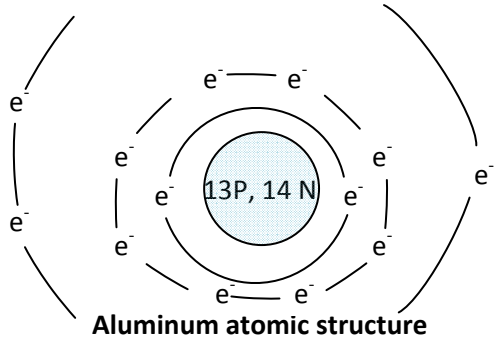
BASIC ELECTRICAL SAFETY HANDOUT

What is electricity?

In the last two centuries, electricity has gone from being a scientific curiosity to an indispensable part of most facets of our lives. Electricity is all about the movement of the electrons that are part of every atom of matter.

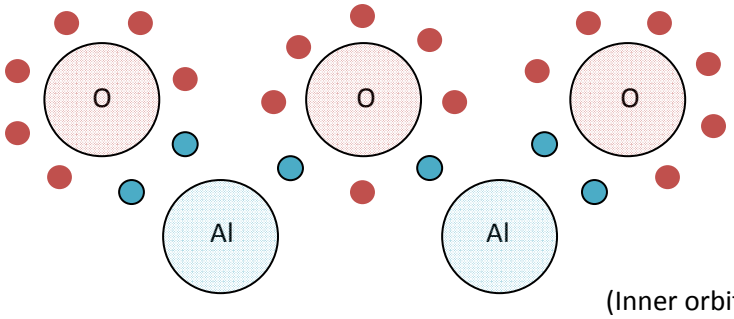
Where are electrons?

As a member of the Fermilab team, you probably have a better knowledge of basic atomic theory than the average person. You know that that every atom is composed of a nucleus composed of protons and neutrons, surrounded by a cloud of electrons, such as in an aluminum atom:



Aluminum atomic structure

Admittedly, this picture is so simplified that we'll have to wait for those with knowledge of quantum mechanics to peel themselves off the ceiling, but it will do for our purposes here. When a large number of aluminum atoms are put together into a solid, we call it a metal. One property of metals that distinguishes them from other substances is that the electrons in the outer shell become mobile, and pushing them from one atom to the next requires very little energy. These are called "free electrons." This ability to easily push electrons through a material makes it a conductor. If we introduce oxygen and let the aluminum and oxygen react, the product is alumina:



(Inner orbits of Al not shown)

Alumina molecule

The oxygen atoms have "captured" the electrons from the outer shell of aluminum atoms to fill out all eight spots in their own outer shells, and all the electrons become tightly bound into the alumina molecules, making it very difficult to bump electrons from one molecule to another. With the addition of some oxygen, our aluminum atoms have become part of a good insulator instead of a good conductor.

GENERATING ELECTRICITY

Electricity is not a source of power. It is a convenient way to transfer power from one place to another and easily control it. Isn't it odd that lightning, the most common natural display of high power electricity has yet to be profitably harnessed, even though it's been over two centuries since Ben Franklin nearly killed himself to prove lightning and electricity were the same? There are many ways to artificially produce electricity. Friction can produce static electricity, batteries are electro-chemical sources, and pressure, heat, and light can produce electricity by piezoelectric effect, thermocouples, and photovoltaic cells, respectively.

Moving electrons produce a magnetic field, a principle which we use to direct our particle beams. Likewise, a conductor moving through a magnetic field produces an electric field. Most electric generation today uses a source of heat (such as coal or nuclear fission) to boil water, which runs a steam turbine that turns a generator, which pushes conductors through a magnetic field to make electricity. A gas turbine, burning oil or natural gas, can skip the boiling water step and turn a generator directly.

DEFINITIONS

Potential measures how hard the electrons are getting "pushed" by the generator or battery. Potential is also known as Electromotive Force. Potential is represented by the letter **E**, and measured in **Volts**, the symbol for which is **V**.

Current measures how many electrons are moving. Just like water in a pipe, it is possible for potential to exist without current, but current cannot exist without potential. Current is represented by the letter **I**, and it is measured in **Amperes**, which has the symbol **A**. When discussing the physiological effects of electricity, milliamperes are used so we don't have to keep track of all those zeroes to the right of the decimal point. 1000 milliamperes equals one ampere. The basic units of electricity were defined before the structure of the atom was known, so the researchers of that time had to guess which way the invisible current was flowing. They guessed wrong. Electrons flow from negative to positive.

Circuit is a path for electricity. Electricity will not flow unless the circuit is a complete, like a circle rather than just an arc.

Direct current (DC) This is current that flows in a single direction on a conductor. This is the kind of current produced by batteries. It is also the kind of power produced by photovoltaic cells. This type of current is used by your car's electrical system and by most computing equipment.

Alternating Current (AC) This is current that periodically reverses direction. This is what is used in nearly all electric power distribution systems. Its primary advantage is that transformers can be used to convert low voltage and high current to high voltage and low current, and vice versa. It also makes it possible to construct motors without brushes, so they are less expensive and require less maintenance than DC motors.

Resistance is the measure of the opposition a material has to letting its electrons get pushed around. Resistance, **R**, is measured in Ohms, represented by the capital Greek letter Omega, Ω.

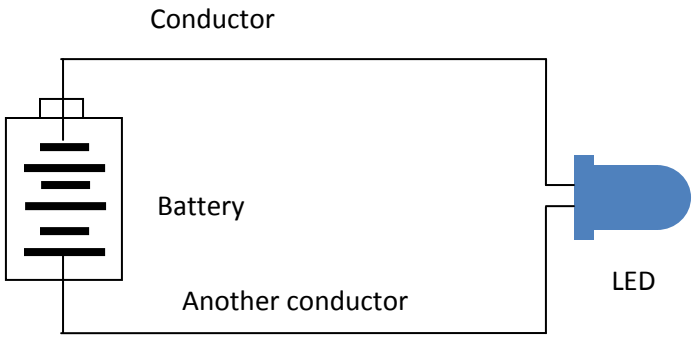
Impedance is the measure of opposition of a circuit to AC current. It is a combination of Resistance with **Inductance (L, measured in Henries, H)**, which measures the opposition to a change in current flow, and **Capacitance (C, measured in Farads, F)**, which measures the opposition to a change in voltage. Other than when a DC circuit is just turned on or off, capacitance and inductance don't affect it. Because the voltage and current are always changing in an AC system, it is always affected by resistance, inductance, and capacitance together. Even a straight length of wire has inductance and capacitance. To make life easier when working on AC power systems, all three are combined into a single property called Impedance, with the symbol **Z**. To make life more difficult and confusing, Impedance is also measured in Ohms, just like resistance, and represented by Omega, Ω, too.

Superconductivity is a property of certain materials that causes them to lose all resistance below certain extremely cold temperatures. This property was exploited to construct the Tevatron, which more than doubled the energy of the accelerated particles over its predecessor, the Main Ring, but actually used less energy, even when you included all the refrigeration equipment.

DIRECT CURRENT (DC) CIRCUITS

DC circuits are discussed before AC circuits because their principles are easier to visualize. Although most electrical distribution is done with AC circuits, DC is widely used at the laboratory, from powering the accelerator magnets, bending particle paths in detectors and running the microprocessor, memory, and video display of your computing resources.

An elementary DC circuit looks like the following figure. It is comprised of a source (the battery), an LED (the load), and conductors to provide a closed loop path between the two. The purpose of this circuit is to convert the chemical potential energy in the battery into visible light radiation emitted by the LED.



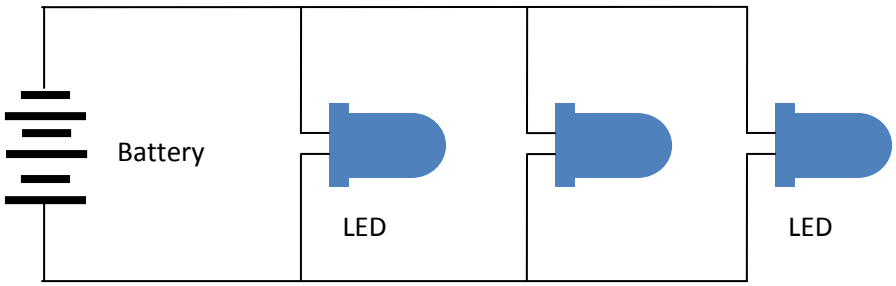
Elementary DC circuit diagram

CIRCUIT TOPOGRAPHY

There are many ways to make circuits. Some of the more common are discussed below.

Parallel Circuit

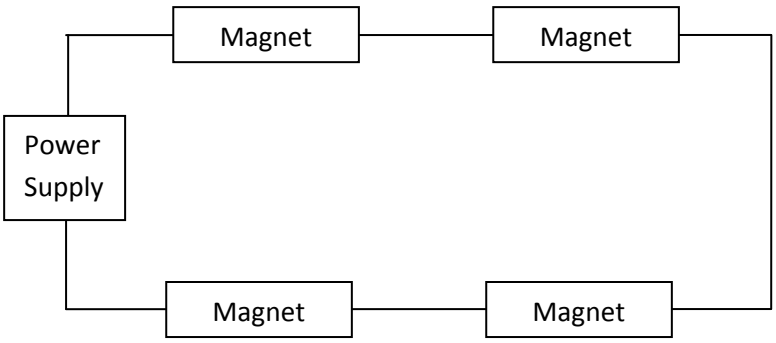
Parallel circuits are the most common type of circuit in most power distribution systems. All loads are designed to accept the voltage produced by the source. Each load draws the amount of current it needs, and the source delivers current equal to the sum of individual load currents. Parallel circuits have several advantages. First, all loads can be designed for one voltage, and moved within the circuit or between circuits operating at the same voltage. Second, the removal of one load will not interrupt the circuit and turn off all the other loads as well. Below our elementary circuit is expanded to power several LEDs.



Parallel circuit diagram

Series Circuit

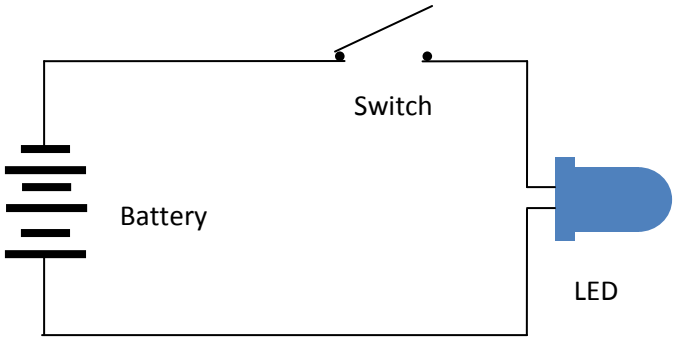
A series circuit consists of two or more loads connected in a string. Unless the conductors between the source and load are superconducting, all circuits, even our elementary DC circuit, is really a series circuit, with the impedance of the two wires in series with the load. Unlike a parallel circuit where the voltage is the same in all the loads and the current may be different, in a series circuit the current is the same in all the loads, though the voltage across them may be different. This can be exploited where it is important to make reasonably identical loads perform the same. We connect dipole and quadrupole magnets in our laboratory's accelerators in series so each one bends and shapes the particle beam almost exactly the same way as its counterparts. A simplified diagram of a magnet power circuit appears below.



Series magnet circuit diagram

Open Circuit

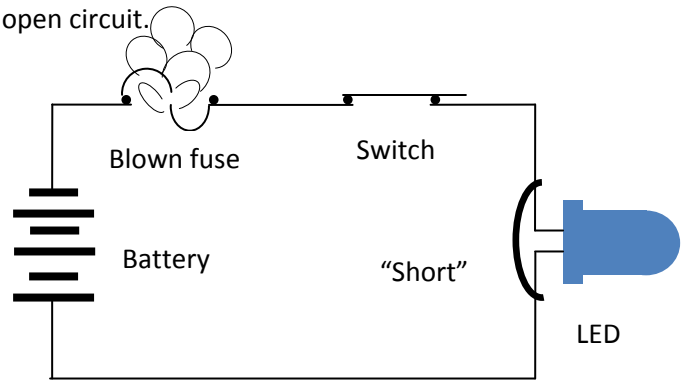
An open circuit is one that has a break in the closed current path. This may be a desirable condition, such as when a switch is opened (turned off), or undesirable, like when a lamp fails or a wiring connection breaks.



Open circuit diagram

Short Circuit

A "short" circuit occurs when a closed path is made that bypasses the intended load of the circuit. The problem with a short circuit is that without the intended load, the conductors alone offer very little resistance to the flow of electricity, so a huge current flows that can rapidly damage the conductors and even start fires because the conductors heat up. Fuses and circuit breakers are used to automatically turn a short circuit into an open circuit.



Short circuit diagram

Potential, Current, Resistance, and Power

The ultimate purpose of an electrical distribution system is to move power from one place to another. The four properties of Potential, Current, Resistance, and Power are related by simple arithmetic for steady-state DC systems. Potential, Current and Resistance are related by a simple formula that can be stated three ways:

$$E = I * R \qquad I = E / R \qquad R = E / I$$

Similarly, **power**, represented by the letter **P** and measured in **Watts**, which are abbreviated **W**, can be calculated from Potential, Current and Resistance. Because the above formulas show how the third property is a function of the other two, we only need to know two of the three to be able to calculate power:

$$P = E * I \qquad P = E^2 / R \qquad P = I^2 * R$$

There is a common misconception that a high power load has high resistance. This can be disproven by restating the middle equation like this: $R = E^2 / P$

So a 100-watt light bulb at 120 volts has a resistance of $(120)^2/100$, which is 14400/100, which is **144** ohms. A 4-watt nightlight draws 14400/4, which is **360** ohms, and a 1500 watt hair dryer is 14400/1500, which is less than **10** ohms. So for a fixed voltage, the higher power the load is, the lower its resistance. This also explains why a short circuit is so dangerous. If the resistance of the wires is an ohm (and often it's less) then by $P = E^2 / R$, the power is 14,400 watts, which is radiated along the length of the wires.

Alternating Current (AC) Circuits

Across the globe, the electrical distribution system is based on three-phase alternating current (AC) power. The advantages of AC and three-phase power are so overwhelming that other systems only exist either due to the needs of special loads or as isolated remnants of old installations that have not yet been removed from service.

Thomas Edison pioneered electrical distribution in New York City in the early 1890s. He used DC power, which had to be kept to a reasonably low voltage to make the switches and lamps small enough to fit into a house and compete with gas lamps and valves, and to avoid electrocution risks for his customers. A parallel DC power system can operate at only a single voltage from generator to end user. Once wires start to run for several city blocks, they must be made much thicker to prevent the resistance of the wires from using up most of the power generated. It quickly becomes more economical to install many small generating stations a few city blocks apart than to pay for all that extra copper and right-of-way.

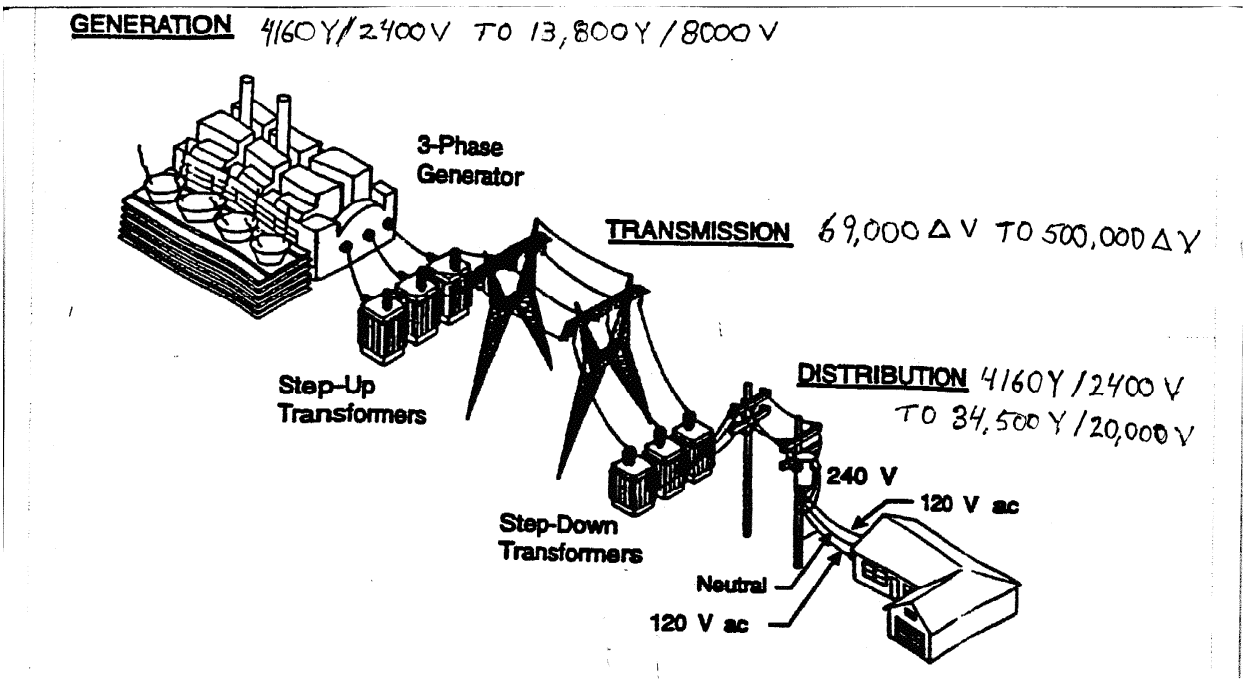
This is where AC's first big advantage over DC comes into play: Transformers work on AC power, but not DC power. A transformer converts electrical energy into magnetic energy in an steel core, and then back into electric energy in a second set of wires. Optimized designs provide conversion efficiencies exceeding 97% for commercial-grade transformers. By changing the ratio of the number wraps of wire of the incoming, or primary windings, to the number of wraps on outgoing, or secondary windings, the voltage and current can be changed. One complete wrap around a transformer core is called a turn. The expressions that govern changes in voltage and current through a transformer are:

$$E_S = E_P * T_S / T_P \quad \text{and} \quad I_S = I_P * T_P / T_S,$$

Where E_P is the primary winding potential, I_P is the primary winding current, and T_P is the number of turns in the primary winding. E_S, I_S, and T_S, are the respective properties for the secondary winding.

If you do a little math, you will also see that $E_P * I_P = E_S * I_S = P$, so the power going in is the same as the power coming out. Really this is not completely true, some energy is lost as heat in the windings and due to magnetic hysteresis is the transformer core, but modern transformers move 97%+ of the incoming power to the outgoing side.

So what good is monkeying around with voltage and current? It allows relatively small conductors to carry prodigious amounts of power by doing so at high voltages. It becomes apparent when we reverse this equation we've seen before: $I^2 * R = P$, except because we're now on an AC system, we'll use impedance instead of just resistance, so we state it as $I^2 * Z = P$. If **Z** is the power line impedance which doesn't change, then **P** is the amount of power lost to the impedance of the power line as heat. If we double the voltage on the power line with a transformer, we halve the current, and we get $(I/2) * Z = P/4$. By doubling the voltage, we halve the current, and cut the power lost in the power line by three quarters. If we consider a typical case, where the 120 volts to a house is supplied by a **7200** volt distribution circuit, that's a **1:60** ratio, so the power loss on the distribution line is 1**/3600** of what it would be without transformers. If we look at the transmission lines that supply Fermilab at **200,000** volts, that's a **1:1662** ratio, which cuts power losses by a factor of **2.7 million**. With that kind of efficiency, we don't need to have a power plant every 10 blocks or so, and those savings will pay for a lot of transmission lines. The net result is our semi-modern electric "grid:"

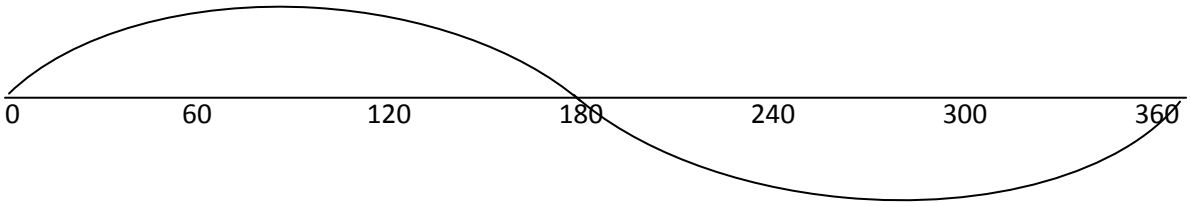


The voltage ranges shown are typical, and do not cover all the strange systems you might find.

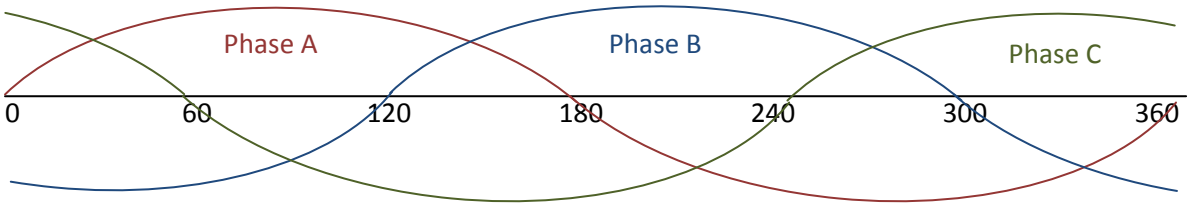
THREE PHASE MAGIC

Three phase AC power is an idea that is so incredibly useful no one has improved on it in a century. It does two things incredibly well. The first is make efficient use of conductors.

One phase power:

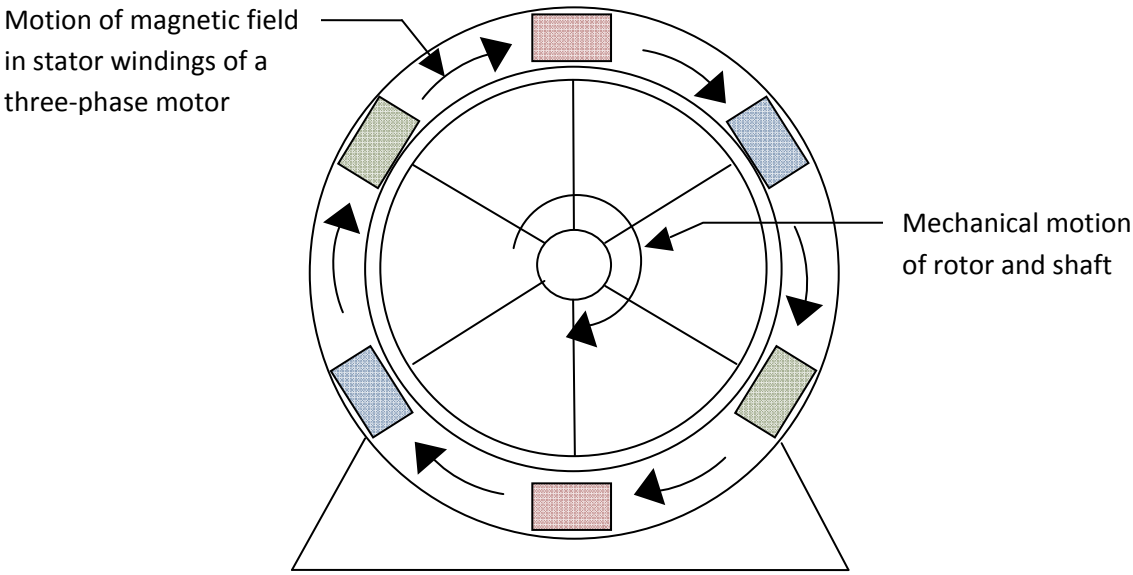


Three phase power



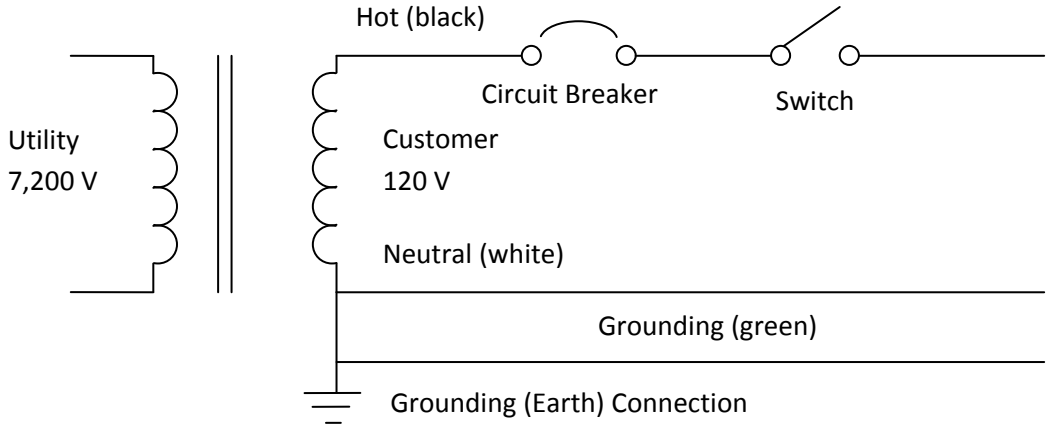
A two- wire circuit at 208 volts, with 10 amperes in each wire, provides 2080 watts. A three- wire, three phase circuit at 208 volts, with 10 amperes in each wire, provides 2080 * 1.73, or 3600 watts. That's 1.73 (really the square root of 3) times the power for only 1.5 times the number of wires. That's the kind of innovation that makes accountants really happy.

The second part is more likely to make engineers happy. If you build a motor with one phase windings, the magnetic field pulsates. If you build a motor with three phase windings, the magnetic field is a constant strength, and it ***rotates***. That's what motors are supposed to do, right?

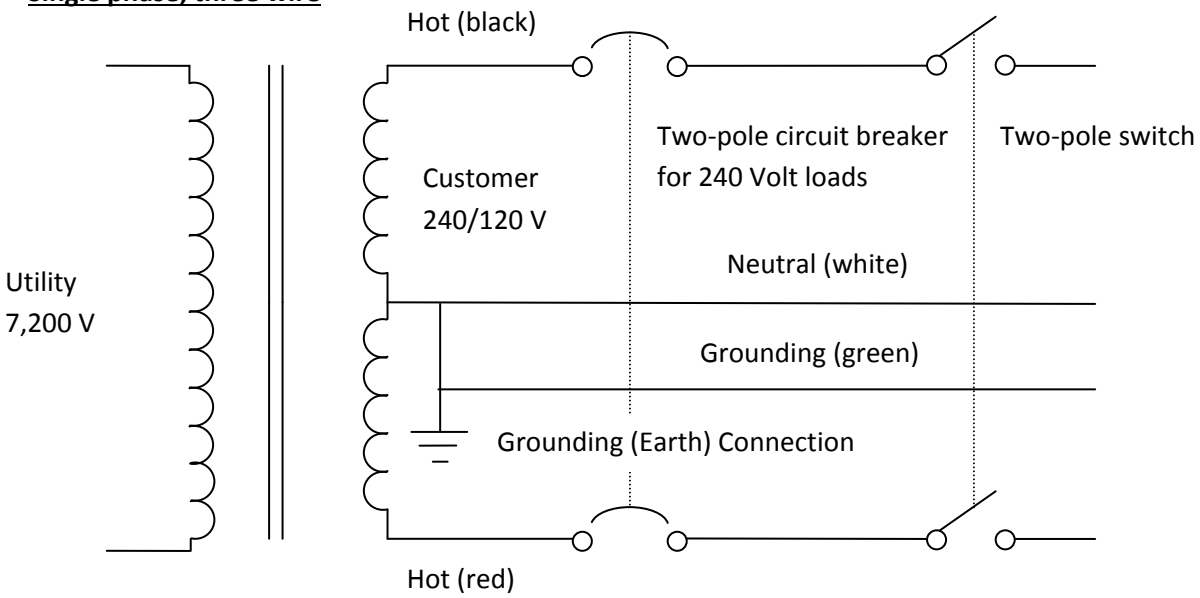


COMMON AC POWER CIRCUITS AND VOLTAGES

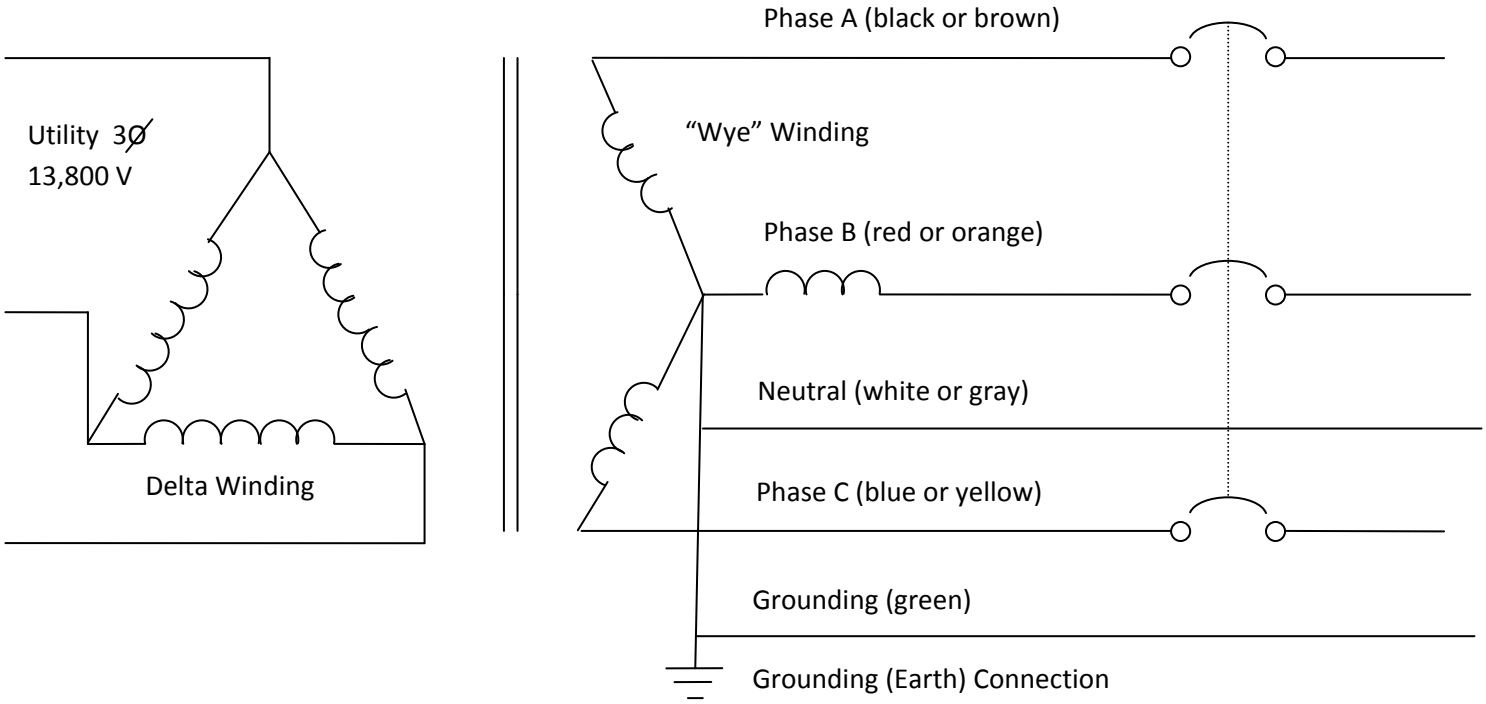
Single phase, two wire



Single phase, three wire

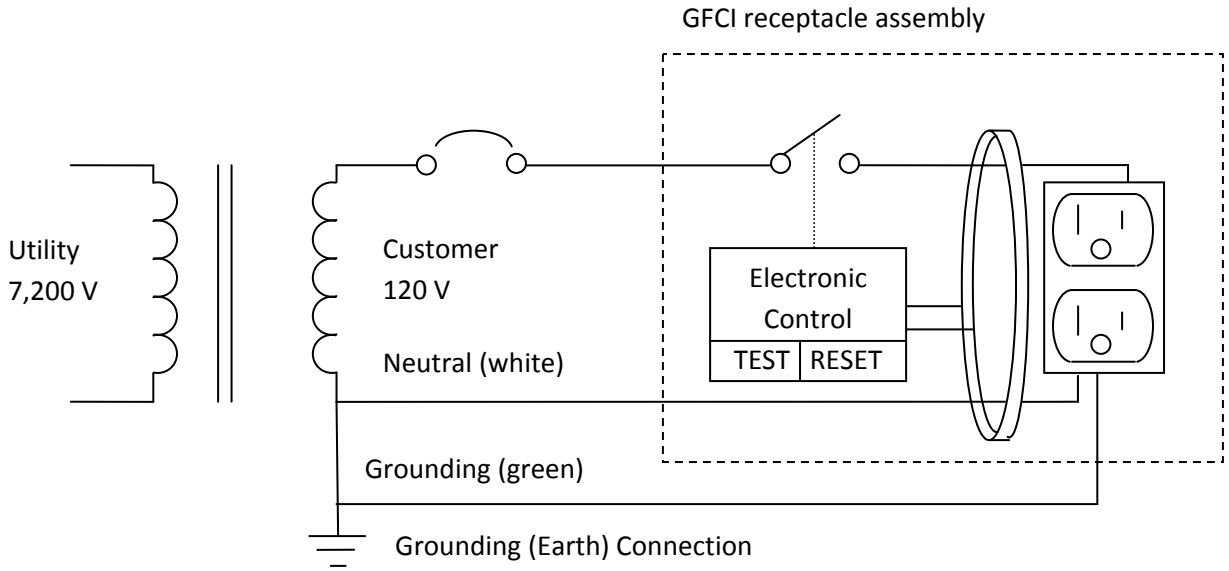


Three phase, four wire



Insulation colors shown are present Fermilab standard for 208Y120 and 408Y277 volt systems, respectively. Due to varying practices prior to the standard's development, insulation color is not a reliable indicator of voltage.

Ground fault circuit Interrupter, two wire



NOTES

NOTES

Electrical Safety

Basic Electrical Safety

Course FN000235/CR
Basic Electrical Safety

Fermi Nat'l Accelerator Laboratory
Environment Safety and Health Section

Occupational Health Group

Electrical Safety

Course Objectives

- Identify how electricity can injure and kill.
- Illustrate common electrical hazards.
- Demonstrate safe practices that reduce or eliminate electrical hazards.
- Provide instructions for safely responding to an electrical emergency.

Electrical Safety

Course Limitations

√ **This course is not designed to teach you to work on electrical equipment.**

√ **This course will not qualify you to work on electrical equipment.**

√ **If you spot problems with electrical equipment you should report it to your supervisor.**

Introduction

- Electrical accidents are responsible for a disproportionate number of fatalities.
- One worker is electrocuted every day.
- Four physiological effects of electricity are:
  - Electric Shock
  - Electrical Burns
  - Arc flash and arc blast
  - Indirect injuries such as falls
- Four fifths of direct electrical injuries are from arc-flash and blast, not shock

Electrical Terminology

- Potential: Electrical force, measured in Volts
- Current: Movement of Electric Charge, measured in Amperes
- Impedance: Resistance to flow of electric current, measured in Ohms
- Power: Volts multiplied by Amperes, measured in Watts

Electrical Terminology

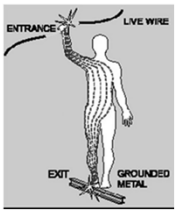
- Conductor: substance with little resistance to the flow of electric current, includes metals and impure water (you!)
- Insulator: substance with high resistance to the flow of electric current, includes rubber, glass, some plastics.
- Circuit: closed path for current.
- Fault: unintended closed path for current.

Electrical Terminology

- Grounding: Making a low-resistance path from conductive material to the earth.
- Bonding: Making *one* low-resistance path from an electrical power source to the earth and to conductive objects
- Combined, grounding and bonding help prevent electric shock.

Electric Shock

- Electric shock is current passing through the body.
- Shock severity depends on:
  - Path through the body
  - Amount of Current passing through the body
  - Length of Time current passes through the body



Electrical Shock Effects

- √ **Under 1 ma:** may not be perceived
- √ **More than 3 ma:** painful shock
- √ **More than 5 ma:** could interrupt pulse
- √ **More than 10 ma:** “no-let-go” danger
- √ **More than 30 ma:** respiratory paralysis
- √ **More than 50 ma:** likely ventricular fibrillation
- √ More than **100 ma:** certain ventricular fibrillation
- √ **Over 4,000 ma:** heart and lung paralysis, severe burns, musculo-skeletal damage.
- √ √ **Over 15,000 ma:** 15 amp fuse blows

Sources of Electrical Shock

- 50 volts is all that is needed to generate a potentially fatal current in an adult.
- 12% of electrocutions are caused by 120 volt sources like common office and home circuits.

Electrical Burns

- Most common non-fatal shock-related injury.
- Typically occurs on hands
- Produces unusually deep tissue damage that requires immediate medical care to avoid complications than can result in amputation.

Arc Flash and Arc Blast

- Cause of 80% of electrical injuries
- Electric current passing through air produces conductive ionized gas at up to 35,000° Fahrenheit (19,500° Celsius)
- An arc flash produces:
  - Intense light that can cause blindness and cataracts
  - Intense heat that can burn flesh and ignite clothing.
  - Shrapnel that can cause impact injuries
  - Supersonic shock wave (arc blast) that can pierce eardrums and shred internal organs

Electrical Safety

Arc Flash Scene

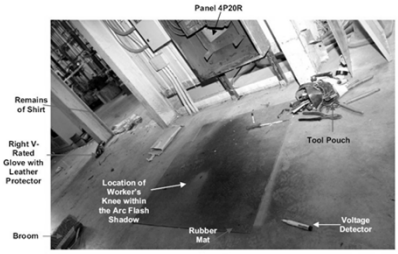


Figure 2-3. The insulating mat with the outline of BSE-1's knee in the arc flash shadow

Electrical Safety

Arc Flashed Clothing

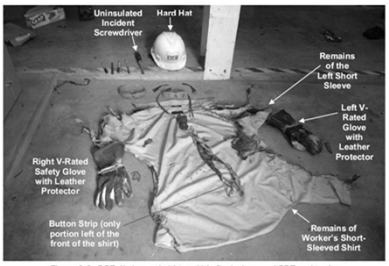


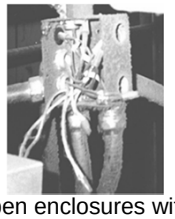
Figure 2-6. BSE-1's burned shirt and his flash-damaged PPE and tools

Electrical Safety

Hazard Recognition

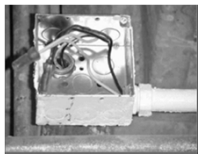
- Working Space and Exit from Working Space
  - Four yardstick (or meterstick) guideline
  - Exit path is 2 feet wide by 6-1/2 feet high

Hazard Recognition



- Open enclosures with exposed energized parts
  - Missing doors, covers, and “knockouts”
  - Holes in panelboards where circuit breakers used to be

Hazard Recognition



- Exposed Electrical **Wiring**
  - Assume all exposed electrical wiring is energized
  - Report exposed wiring to supervision

Hazard Recognition

- Physical Damage
  - Protect electrical equipment from damage
  - Report damaged electrical equipment to supervision

Hazard Recognition

- Tripping and Abrasion Hazards
  - Don't create or permit tripping and abrasion points
  - Do not cover cords with rugs or carpet. This traps heat, increases the odds the cord will be damaged, and decreases the odds the damage will be seen.

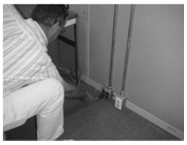
Hazard Recognition

- Frayed and damaged cords
  - If you can see anything inside the outer jacket, remove the cord from service promptly
  - Wrapping the cord with tape is not an adequate repair

Hazard Recognition

- Plug and receptacle damage
  - Never use a cord with a damaged grounding prong
  - A plug must have a good mechanical connection to the cord jacket so the wires are not under tension
  - Promptly remove damaged cords from service

Hazard Recognition



- Plug and receptacle damage
  - Grasp the plug body to remove it from a receptacle. Never pull on the cord.
  - Never use a damaged receptacle. Report it instead.

Hazard Recognition

- Overhead electrical hazards
  - Pole-mounted utility wires are not insulated. Stay at least 10 feet (3 m) away, including poles and ladders not marked for high voltage applications
  - Bare bus bars for overhead cranes are also present in many of the industrial and experimental buildings

Hazard Recognition

- Electrical work areas
  - Stay outside of work areas where marked and when verbally instructed.
  - Keep well clear when workers are wearing personal protective equipment (and you're not!).

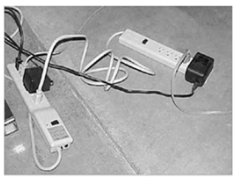
Hazard Recognition

- Other electrical “red flags”
  - Blown fuses, tripped circuit breakers and GFCIs
  - Utilization equipment, tools cords, or connections are warmer than ambient temperatures
  - Plugs, receptacles, or equipment are discolored or distorted.
  - Odor of burning plastic or rubber
  - Sizzling, buzzing, or rattling sounds (“hum” is OK)
  - Loose-feeling receptacles and switches
  - Dim or flickering lights, “flaky” equipment operation

Safe Practices and Bad Examples

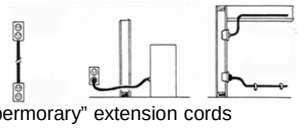
- Extension Cords and Power Strips
  - The image on the left is not a “listed” use for the box.
  - Most extension cords and power strips are not designed for large loads. Check the fine print and do not put heavy loads (heaters and kitchen appliances) on power strips

Safe Practices and Bad Examples



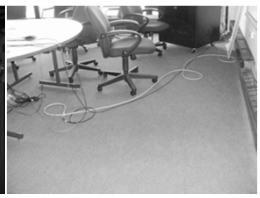
- Extension Cord and Power Strip “Daisy Chains”
  - Only one multi-outlet device is permitted from a building receptacle.
  - Provide a secure place for power strips

Safe Practices and Bad Examples



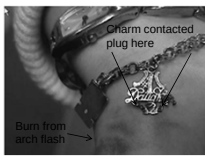
- No “permorary” extension cords
- No flexible cords to or between outlet boxes.
- No flexible cords in concealed areas or under carpet
- No flexible cords fastened to structure
- No flexible cords on hot or sharp objects
- No flexible cord plugs inaccessible behind furniture
- No plugs supporting excessive weight

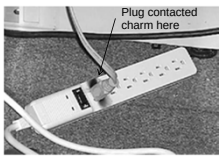
Safe Practices and Bad Examples



- No “clotheslines” or “tripwires”

Safe Practices and Bad Examples





- Conductive Apparel Hazards
  - Cover or remove loose conductive apparel when handing energized electrical equipment.
  - Tight conductive apparel has it own hazards

Safe Practices

- Ground Fault Circuit Interrupters
  - GFCIs measure the difference between current on the two conductors and trip when the difference is over 4-6 mA.
  - Required for cord-connected tools and receptacles in exterior locations and within 6' of water.
  - Verify operation with the test button prior to use.
  - Correct deficient condition if GFCI trips repeatedly.

Safe Practices

- Electricity and water
  - Cords must be rated for wet use (Text embossed or printed on the cord will have a "W" in it.)
  - Flat receptacle covers are only for temporary use while the operator remains present. Otherwise a "weatherproof-in-use" cover is required.

Safe Practices

- Electricity and Water
  - Water reduces the resistance of many objects – including you!
  - Do not operate, connect, or disconnect electrical equipment with wet hands or when you are in contact with wet surfaces.
  - Even if electrical equipment is submerged in water, assume it is still energized.
  - Any electrical loads in or within 6 feet (2 m) of water must be protected by a GFCI.

Safe Practices

- Utilization Equipment
  - Read the fine print on the equipment and in the instructions. Use equipment only as intended. Keep equipment out of wet or damp areas or high or low temperatures unless it is listed for use there.
  - No power strips may be used to supply high-current equipment. Only a single appliance-duty extension cord may be used to supply a high-current load High current loads include all heaters, microwave ovens, coffeemakers, toasters and toaster ovens, hair dryers, refrigerators, copiers, and multi-user laser-type printers.

Safe Practices

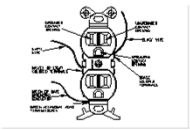
- "Listed" Equipment
  - Consumer electrical equipment must be listed and labeled by a Nationally Recognized Testing Lab. Seal must be UL, ETL, or include "US" or "NRTL."

  - Be wary of any "too good to be true" deals or merchandise that appears deficient. It may be counterfeit. Even genuine equipment may be cheaply made, especially if it was inexpensive.

Safe Practices

- Miscellaneous
  - Turn off electrical loads before unplugging cords
  - Do not reset circuit breakers or replace fuses until the cause of the trip has been corrected. Common circuit breakers are only listed to interrupt a short circuit twice.
  - Do not replace switch plates unless the circuit is off.
  - Verify the absence of concealed wiring before drilling into walls, ceilings, or floors. This is particularly true for residential construction where non-metallic sheathed cable ("romex") is used.

Safe Practices



Stockroom # 1145-500000

- Receptacle wiring
  - Proper receptacle wiring is essential to safely operate utilization equipment.
  - A plug-in tester similar to the one shown is a safe, accurate device for use by unqualified personnel. This tester is available through the stockroom.

Safe Practices

- You may operate a switch or breaker if:
  - It powers utilization equipment, not more electrical distribution equipment like a transformer or panel
  - Your supervisor or job description authorizes you to operate the switch or circuit breaker
  - The enclosure is not damaged or heavily corroded
  - All of the covers are held in place with all the screws and latches provided by the manufacturer

Safe Practices

- When you have turned a switch or breaker off:
  - Verify the power has been removed by attempting to operate the load.
  - Place LOTO locks and tags, if required.
- Before turning a switch or breaker on:
  - Verify that any guards or other protections are in place and other personnel are clear of hazards that might result from energizing the circuit.
  - Follow LOTO and/or JHA procedures for re-energizing the circuit.

Safe Practices

- Switch and circuit breaker operation
  - Step to the side – present as little of your body to the potential arc flash as possible.
  - Face away – don't place your eyes at risk.
  - You should follow this procedure at home as well.

Safe Practices

- Switch and circuit breaker operation PPE:
  - Long sleeve shirt and full-length pants made of natural fibers (cotton, wool, linen, etc.) No blends.
  - Safety glasses and in-the-ear hearing protection.
  - Leather gloves.

Safe Practices

- Do not operate a switch or breaker if:
  - The enclosure is damaged, corroded, or has loose or missing fasteners.
- Report deficiency to your supervisor if:
  - The enclosure is damaged, corroded, or has loose or missing fasteners.
  - The switch or circuit breaker mechanism is does not operate correctly or fails to turn the load on or off.
  - A circuit breaker trips when it is turned to "ON."

Safe Practices

- For the homeowner
  - Exercise circuit breakers annually. A convenient occasion and good reminder is the year's first power outage.
  - Homeowners with screw shell fuses should tighten fuses annually.
  - Pre-1960 houses may have 2-wire electrical systems. These may not have a grounding conductor.

    - Do not use "cheater" plugs
    - Do not replace 2-prong receptacles with 3-prong type
    - Install GFCI receptacles and apply the "no ground" sticker
    - Double-insulated tools are highly recommended

Battery Hazards

- What? Batteries can be dangerous?
  - Batteries are made of highly reactive chemicals that are stable until the energy is desired. So are bombs.
  - Batteries present three types of hazards:
    - Energy Release. Through manufacturing defects or damage while in storage or use, energy is released suddenly.
    - Flammability: Chemicals used to construct certain battery types, like Lithium Ion, are flammable and may ignite if released.
    - Physiological Hazard: The strong reactivity that makes certain chemicals so valuable for battery construction also makes them react with our bodies in undesirable ways, such as the sulfuric acid in vehicle lead-acid batteries.

Battery Safety

- Safe battery use practices
  - Do not expose batteries to high heat.
  - Wear gloves and safety glasses when working on or near a car battery, including jump starting a car.
  - If a battery seems unusually warm, stop using or charging it.
  - Do not use a damaged battery.
    - If you damage a battery powered device, inspect the battery before using the device. Look for leaks, cracks or swelling.
  - Dispose of batteries properly – not in the trash
    - Fermilab provides used battery collection so we can keep the hazardous battery chemicals out of the environment.

Electrical Emergencies

- Your safety comes first
  - If you are aware that there is an electrical problem, you are safe – at least temporarily
  - If you are not in imminent danger, your best response is to summon trained help: x 3131 or 630-840-3131.
  - If you are in imminent danger and can determine where the hazard is, move to a safer location.
  - If you don't know where the hazard is, stay put. You can just as easily run toward problems as away from them if you're just guessing.

Electrical Emergencies

- Lights, switches, receptacles, or plug-ins
  - Know where the electrical disconnect switches and panelboards are in your work area.
  - If you observe a non-life-threatening condition, such as light smoke, buzzing, or arcing, follow the steps given previously to remove power from the problematic device. All light switches and receptacles are labeled with the panelboard and circuit numbers that serve them to help you do this. Call your supervisor or building manager.
  - If you think there is even a remote threat to your safety, move to safety and call 3131.

Electrical Emergencies

- Arc-flash emergency
  - If victim is clear of electrical equipment, start CPR if indicated. If victim is not clear, proceed as for electric shock emergency.
  - Summon trained help: x 3131 or 630-840-3131.
  - Provide information to, and follow directions from, the emergency response operator.

Electrical Emergencies

- Electric shock emergency (under 600 volts)
  - If victim is not clear, DO NOT touch them. You could become another crispy critter. Call 3131.
  - Unplug portable equipment, if that is the source of the shock hazard.
  - Turn off any switch or circuit breaker that might de-energize fixed equipment.
  - If power cannot be disconnected and area is dry, use a wood pole, leather belt, or similar insulating object to pull person from the energy source.
  - Once free of energy source, start CPR if indicated.

Electrical Emergencies

- Downed power line emergency
  - Do not move unless in imminent danger. If you must move, see the slides about step potential.
  - Summon trained help: x 3131 or 630-840-3131.
  - Warn others to stay away from the downed line. You cannot tell if a downed line is de-energized.
  - If someone is disabled near or in direct contact with the power line, DO NOT even approach them. You do not have the tools or training to be able to help them. You will only add to the body count. Scream if it helps.

Electrical Emergencies

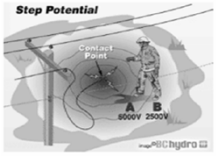
- Power line contact emergency
  - Holley, New York, September 13, 2008, as reported by Time-Warner Cable News:
  - Stephen Annucci, 39, of Rochester had just finished unloading concrete at a produce processing warehouse. Annucci was cleaning his truck after the delivery when the boom on the truck hit a power line.

    Responders could not help Annucci right away because of the live power lines. It took the power company about an hour to shut the power off.

    "Very frustrating. We could not even extinguish the portions of the trucks that were burning because of the chance of the electrical hazard with our responders. So, we just had to sit and wait. As they gave us the go ahead, we were there in seconds," said Holley Fire Chief Roland Nenni.

    Annucci was transported to Lakeside Memorial Hospital where he later died.

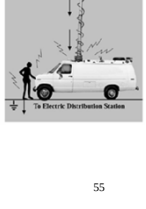
Electrical Emergencies



- Downed power line: Step Potential
  - Step potential can and will kill you.
  - Keep feet together and shuffle away from the line. Cross curbs and other obstacles by “bunny hopping,” keeping your feet together.

Electrical Emergencies

- Downed power line: Touch Potential
  - Touch potential can and will kill you.
  - Keep at least 50 feet away from any object in contact with the downed line, including vehicles, buildings, fences, and people.
  - Qualified electrical workers use “hot sticks” to avoid touch potential risks and increase distance from electrical hazards.



Electrical Emergencies

- Downed power line: In a Vehicle
  - If you are in a vehicle in contact with a downed line, you are a “bird on a wire.” You can touch the vehicle or the earth, but not both.
  - Summon help and stay in the vehicle. If the vehicle is an immediate hazard, climb out onto vehicle to the place you can most safely jump to the ground. Keep your feet together! Shuffle away from the vehicle. Don’t close the door!

Electrical Emergencies

- Distance and Electrical Hazards
  - Most electrical hazards, whether shock or arc-flash, are a “point source.” If you double your distance from the hazard, you reduce your exposure to the hazard by 75%.
  - For a downed line, keep shuffling until you get not less 50 feet (17 meters) away.
  - For low voltage hazards, 10 feet (3 m) is a good guideline, as long as you’re not on metal floorplate or grating. Follow specific directions from emergency responders.

Myths and Misconceptions

- **Electricity takes the path of least resistance.**
- **Electricity wants to go to ground.**
- **If an electric tool falls into a sink or tub of water, the item will short out.**

Myths and Misconceptions

- **Electricity takes *every* conductive path it can find.**
- **Electricity wants to go to ground.**
- **If an electric tool falls into a sink or tub of water, it will short out and kill the circuit.**

Electrical Safety

Myths and Misconceptions

- Electricity takes *every* conductive path it can find.
- Electricity wants to go back to its source, which is usually connected to the earth.
- If an electric tool falls into a sink or tub of water, it will short out and kill the circuit.

Electrical Safety

Myths and Misconceptions

- Electricity takes *every* conductive path it can find.
- Electricity wants to go back to its source, which is also connected to ground.
- If an electric tool falls into a sink or tub of water, the water will become energized and can electrocute you if you are in contact with anything that is grounded.

Electrical Safety

Myths and Misconceptions

- AC reverse polarity is not hazardous.
- It takes high voltage to kill; 120 volts is not dangerous.
- Extension cords and power strips are just as good as regular receptacles.

Electrical Safety

Myths and Misconceptions

- AC reverse polarity can energize the external metal of utilization equipment; it can electrocute you.
- It takes high voltage to kill; 120 volts is not dangerous.
- Extension cords and power strips are just as good as regular receptacles.

Electrical Safety

Myths and Misconceptions

- AC reverse polarity can energize the external metal of utilization equipment; it can electrocute you.
- Common household voltage can kill; 120 volts is responsible for 12% of deaths by electrocution.
- Extension cords and power strips are just as good as regular receptacles.

Electrical Safety

Myths and Misconceptions

- AC reverse polarity can energize the external metal of utilization equipment; it can electrocute you.
- Common household voltage can kill; 120 volts is responsible for 12% of electrocutions.
- Extension cords and power strips are meant for temporary use only.

For More Information

- Contact your Supervisor.
- Contact your Senior Safety Officer.
- Electrical Safety Foundation, Inc.: www.esfi.org