This course describes the hazards of electrical work and basic approaches to working safely. You will learn skills to help you recognize, evaluate, and control electrical hazards. This information will prepare you for additional safety training such as hands-on exercises and more detailed reviews of regulations for electrical work. This course is vital, as electrical safety is part of two of OSHA's 10 most frequently cited violations.
OSHAcademy Course 715 Study Guide

Electrical Safety for Technicians & Supervisors

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Contact OSHAcademy to arrange for use as a training document.

This study guide is designed to be reviewed off-line as a tool for preparation to successfully complete OSHAcademy Course 715.

Read each module, answer the quiz questions, and submit the quiz questions online through the course webpage. You can print the post-quiz response screen which will contain the correct answers to the questions.

The final exam will consist of questions developed from the course content and module quizzes.

We hope you enjoy the course and if you have any questions, feel free to email or call:

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Course Introduction

This course describes the hazards of electrical work and basic approaches to working safely. You will learn skills to help you recognize, evaluate, and control electrical hazards. This information will prepare you for additional safety training such as hands-on exercises and more detailed reviews of regulations for electrical work.

Your employer, co-workers, and community will depend on your expertise. Start your career off right by learning electrical safe practices and developing good safety habits while working with electricity. Safety is a very important part of any job. Do it right from the start.

This course will present many topics. There are four main types of electrical injuries: electrocution (death due to electrical shock), electrical shock, burns, and falls. The dangers of electricity, electrical shock, and the resulting injuries will be discussed. The various electrical hazards will be described. You will learn about the 3-STEP Electrical Safety Model, an important tool for recognizing, evaluating, and controlling hazards. Important definitions and notes are shown in the margins. Practices that will help keep you safe and free of injury are emphasized. To give you an idea of the hazards caused by electricity, case studies about real-life deaths will be described.

Note: This is probably our most technically difficult course, so you may want to review the module quizzes first, and then look for the answers as you study the material. If you try to take the exam without studying the material, it's unlikely you will pass.
Module 1: Electricity Is Dangerous

Introduction

Whenever you work with power tools or on electrical circuits, there is a risk of electrical hazards, especially electrical shock. Anyone can be exposed to these hazards at home or at work. Workers are exposed to more hazards because job sites can be cluttered with tools and materials, fast-paced, and open to the weather. Risk is also higher at work because many jobs involve electric power tools.

Electrical workers must pay special attention to electrical hazards because they work on electrical circuits. Coming in contact with an electrical voltage can cause current to flow through the body, resulting in electrical shock and burns. Serious injury or even death may occur.

As a source of energy, electricity is used without much thought about the hazards it can cause. Because electricity is a familiar part of our lives, it often is not treated with enough caution. As a result, an average of one worker is electrocuted on the job every day of every year!

It’s important that you be familiar with OSHA’s electrical standards to help save lives and avoid OSHA citations. Electrical-related violations in OSHA’s Top Ten for 2019 (Oct. 1 to Aug. 15) are related to the control of hazardous energy (Lockout/Tagout).

Quiz Instructions

After each section, there is a quiz question. Make sure to read the material in each section to discover the correct answer to these questions. Circle the correct answer. When you are finished go online to take the final exam. This exam is open book, so you can use this study guide.

1. An electrical shock is received when electrical _____ passes through the body.
   a. current
   b. voltage
   c. resistance
   d. potential
Case Study

A 29-year old male welder was assigned to work on an outdoor concrete platform attached to the main factory building. He wheeled a portable arc welder onto the platform. Since there was not an electrical outlet nearby, he used an extension cord to plug in the welder. The male end of the cord had four prongs and the female end was spring-loaded. The worker plugged the male end of the cord into the outlet. At that instant, the metal case around the power cord plug became energized, electrocuting the worker.

An investigation showed that the female end of the extension cord was broken. The spring, cover plate, and part of the casing were missing from the face of the female connector. Also, the grounding prong on the welder power cord plug was so severely bent that it slipped outside the connection. Therefore, the arc welder was not grounded. Normally, it would have been impossible to insert the plug incorrectly.

To prevent this from happening to you or one of your co-workers, use these safe practices:

- Thoroughly inspect all electrical equipment before beginning to work
- Do not use extension cords as a substitute for fixed wiring. In this case, a weatherproof receptacle should have been installed on the platform.
- Use connectors that are designed to stand up to the abuse of the job. Connectors designed for light-duty should not be used in an industrial environment.

2. Each of the following practices is considered a way to protect against electrocution EXCEPT _____.

   a. using extension cords if fixed wiring is not available
   b. using heavy-duty connectors in an industrial environment
   c. using connectors that can stand up to abuse on the job
   d. using weather-proof receptacles in outside work areas
Terms you need to know

What is a "volt"? A Volt is a measure of the electrical force that seems to push the current along. Think of voltage as a lot of water stored in a high water tank. Because the water tank is high, the water will have more force behind it as it flows down the water pipe to your home. This is why they put water tanks up high! :-) If the same tank was placed at ground level, your water pressure would not be as great. By the way, the symbol for voltage is "V".

What is an "ampere"? An ampere is the unit used to measure the amount of electrical current. Amperage is often referred to as "current" by electrical workers and engineers. Let's go back to our water tank. If diameter of your pipe coming from the water tank is large, a lot of water (amperage) will flow through the pipe. If the pipe's diameter is small, a smaller amount of water will flow through the pipe. If you need a lot of current (many amps) to operate your equipment, you'll need large wires to run the current or they'll burn up! The symbol for amperage is "I".

What is an "ohm"? Think of an ohm as "resistance". An ohm is the unit used to measure the opposition (resistance) to the flow of electrical current. This is pretty easy to understand.

- A small water pipe is going to oppose a lot of water from flowing. Relatively little water will be able to flow through the pipe. So, the pipe offers a high resistance to the flow of water.

- A large pipe would offer little resistance to the flow of water. Big pipe: a lot of water! It's that simple.

In an electrical circuit, components are usually sources of resistance. Any component that heats up due to electrical current is a source of resistance. The symbol for resistance is "R".

What is a "series" circuit? The current in a series circuit takes only one path. For example, water from high in the mountains may flow down one stream (series) into a river that flows to the ocean.

What is a "parallel" circuit? The current in a parallel circuit takes many paths. For example, the water flowing from a water tank up on a hill will flow through many different water pipes (parallel) before it reaches the ocean. The total amount of water will be divided among each path.
3. Which of the following is a measure of the electrical force that seems to push the current along?

a. Amperage  
b. Resistance  
c. Voltage  
d. Reluctance

Case Study

A female assistant manager of a swim club was instructed to add a certain chemical to the pool. She went down into the pump room, barefoot. The room was below ground level and the floor was covered with water. She filled a plastic drum with 35-40 gallons of water, then plugged a mixing motor into a 120-volt wall outlet and turned on the motor. The motor would be used to mix the water and the chemical. Then the solution would be added to the pool. While adding the chemical to the water in the drum, she contacted the mixing motor with her left hand. Apparently, the motor had developed a ground fault. Because of the ground fault, the motor was energized, and she was electrocuted. A co-worker found the victim slumped over the drum with her face submerged in water. The co-worker tried to move the victim but was shocked. The assistant manager was dead on arrival at a local hospital.

An investigation showed that the mixing motor was in poor condition. The grounding pin had been removed from the male end of the power cord, resulting in a faulty ground. The circuit was equipped with a GFCI, but it was not installed properly. A properly wired and functioning GFCI could have sensed the ground fault in the motor and de-energized the circuit.

Take a look at what could have been done to prevent this death:

- The employer should have kept the motor in better condition. Power cords should be inspected regularly, and any missing ground prongs should be replaced.

- All pool-area electrical circuits should be installed by qualified electricians.

- The victim should have worn insulating boots or shoes since she was handling electrical equipment.
• The employer should have followed the law. The NEC requires that all pool-associated motors have a permanent grounding system. In this case, this regulation was not followed. Also, electrical equipment is not permitted in areas without proper drainage.

• OSHA requires employers to provide a work environment free of safety and health hazards.

4. What action is required if the ground prong is missing from the male end of a power cord?

   a. Remove the power cord from service
   b. Replace the ground prong
   c. Use the cord for only two-prong applications
   d. Place a warning sign on the cord

Electrical Shock Causes

An electrical shock is received when electrical current passes through the body. Current will pass through the body in a variety of situations. Whenever two wires are at different voltages, current will pass between them if they are connected. Your body can connect the wires, or what electrical workers call "complete the circuit". If you touch both of them at the same time, current will pass through your body.

In most household wiring in the U.S., the black wires and the red wires are at 120 volts. The white wires are at 0 volts because they are connected to ground. The connection to ground is often through a conducting ground rod driven into the earth.

If you come in contact with an energized black wire- and you are also in contact with the neutral white wire- current will pass through your body. You will receive an electrical shock.

You can even receive a shock when you are not in contact with an electrical ground. Contact with both live wires of a 240-volt cable will deliver a shock. (This type of shock can occur because one live wire may be at +120 volts while the other is at -120 volts during an alternating current cycle-a difference of 240 volts.). You can also receive a shock from electrical components that are not grounded properly. Even contact with another person who is receiving an electrical shock may cause you to be shocked.
5. Whenever two wires are at different voltages, _____ will pass between them if they are connected.

a. electrical potential  
b. electrical resistance  
c. electrical current  
d. electrical impedance

Case Study

A 30-year-old male electrical technician was helping a company service representative test the voltage-regulating unit on a new rolling mill. While the electrical technician went to get the equipment service manual, the service representative opened the panel cover of the voltage regulators control cabinet in preparation to trace the low-voltage wiring in question. (the wiring was not color-coded) The service representative climbed onto a nearby cabinet in order to view the wires. The technician returned and began working inside the control cabinet, near exposed and energized electrical conductors. The technician tugged at the low-voltage wires while the service representative tried to identify them from above. Suddenly, the representative heard the victim making a gurgling sound and looked down to see the victim shaking as though he were being shocked. Cardiopulmonary resuscitation (CPR) was administrated to the victim about 10 minutes later. He was pronounced dead almost two hours later as a result of his contact with an energized electrical conductor.

To prevent an incident like this, employers should take the following steps:

- Establish proper rules and procedures on how to access electrical control cabinets without getting hurt.
- Make sure all employees know the importance of de-energizing (shutting off) electrical systems before preforming repairs.
- Equip voltage-regulating equipment with color-coded wiring.
- Train workers in CPR.
6. To prevent electrocution, what should workers do before performing repair work on electrical systems?

   a. Tell other workers to be careful
   b. Complete a repair request form
   c. Get the manufacturer's manual
   d. Make sure the systems are deenergized
Module 2: The Dangers of Electrical Shock

Severity

The severity of injury from exposure to electricity depends on two factors: the level of electrical current (amperage) and the duration the current passing through the body.

1. The level of current is determined by both the voltage and resistance of an electrical pathway. The higher the voltage and lower the resistance, the greater the current.

2. The next factor determining severity is the duration of exposure to electricity. The longer the employee is exposed, the greater the severity of injury.

OSHA considers all voltages of 50 volts or above to be hazardous because, as we know, electric current, not voltage, passing through the human body causes injury, and the amount of current passing through an object depends on the resistance of the object.

The internal resistance of the human body is about 500 ohms, which is the minimum resistance of a worker with broken skin at the point of contact. The current through 500 ohms from a live part energized at 60 volts would be 120 milliamperes. This level of current, either ac or dc, is sufficient to cause serious injury.

Although OSHA's standards require guarding starting at 50 volts (AC or DC), it is not necessarily the case that voltages below that level are completely safe. Cases in which auto mechanics have sustained serious injuries working with 12-volt or 24-volt (DC) vehicle batteries. For instance, see these two examples of injuries while working around car batteries (NIH/Pubmed):

Real-life Examples

A 34-year-old male auto mechanic who was holding a wrench when his gold ring touched the positive terminal of a 12-volt car battery and the wrench touched both his ring and the negative terminal. He felt instant pain and had a deep partial-thickness circumferential burn at the base of his ring finger. No other soft tissues were injured. The cause of ring burns is most likely electrothermal burns.

A 21-year-old man sustained a band of deep burn around the wrist. A metal watchstrap that the patient was wearing, with evidence of the arching phenomenon on it, short-circuited the
battery of the vehicle. Although the was an electrical accident, the current did not pass through any part of the patient's body, as what happens in an electrical injury.

1. The severity of injury from electrical shock depends on which two factors below?
   - a. resistance and voltage
   - b. current and duration
   - c. duration and voltage
   - d. resistance and current

**Low voltage - 600 Volts or Less**

The table below summarizes what usually happens for a range of currents with a duration of one second at typical household voltages. Longer exposure times increase the danger to the shock victim. For example, a current of 100 mA applied for 3 seconds is as dangerous as a current of 900 mA applied for a fraction of a second (0.03 seconds).

<table>
<thead>
<tr>
<th>Current</th>
<th>Reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 milliamp</td>
<td>Just a faint tingle.</td>
</tr>
<tr>
<td>5 milliamps</td>
<td>Slight shock felt. Disturbing, but not painful. Most people can &quot;let go.&quot; However, strong involuntary movements can cause injuries.</td>
</tr>
<tr>
<td>6-25 milliamps (women)†</td>
<td>Painful shock. Muscular control is lost. This is the range where &quot;freezing currents&quot; start. It may not be possible to &quot;let go.&quot;</td>
</tr>
<tr>
<td>9-30 milliamps (men)</td>
<td></td>
</tr>
<tr>
<td>Current (milliamps)</td>
<td>Description</td>
</tr>
<tr>
<td>--------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>50-150 milliamps</td>
<td>Extremely painful shock, respiratory arrest (breathing stops), severe muscle contractions. Flexor muscles may cause holding on; extensor muscles may cause intense pushing away. Death is possible.</td>
</tr>
<tr>
<td>1,000-4,300 milliamps (1-4.3 amps)</td>
<td>Ventricular fibrillation (heart pumping action not rhythmic) occurs. Muscles contract; nerve damage occurs. Death is likely.</td>
</tr>
<tr>
<td>10,000 milliamps (10 amps)</td>
<td>Cardiac arrest and severe burns occur. Death is probable.</td>
</tr>
<tr>
<td>15,000 milliamps (15 amps)</td>
<td>Lowest overcurrent at which a typical fuse or circuit breaker opens a circuit!</td>
</tr>
</tbody>
</table>

*Effects are for voltages less than about 600 volts. Higher voltages also cause severe burns.
†Differences in muscle and fat content affect the severity of shock.

2. **Cardiac arrest, severe burns, and death is probable if a worker receives an electrical shock of _____**.
   a. 1 microamp
   b. 5 milliamps
   c. 2 amps
   d. 10 amps

**High Voltage - Over 600 Volts**

The U.S. Department of Energy (DOE) Electrical Safety Guidelines classify high voltage as over 600 volts. Also, OSHA classifies any use of electrical service over 600 volts as high voltage.
Sometimes high voltages lead to additional injuries. High voltages can cause violent muscular contractions. You may lose your balance and fall, which can cause injury or even death if you fall into machinery that can crush you. High voltages can also cause severe burns.

At 600 volts, the current through the body may be as great as 4 amps, causing damage to internal organs such as the heart. High voltages also produce burns. In addition, internal blood vessels may clot. Nerves in the area of the contact point may be damaged. Muscle contractions may cause bone fractures from either the contractions themselves or from falls.

3. OSHA classifies any use of electrical service _____ as high voltage.
   a. 50 volts or greater
   b. above 120 volts
   c. between 50 and 480 volts
   d. over 600 volts

Current

The amount of internal current a person can withstand and still be able to control the muscles of the arm and hand can be less than 10 milliamperes (milliamps or mA).

Currents above 10 mA can paralyze or "freeze" muscles. When this "freezing" happens, a person is no longer able to release a tool, wire, or other object. In fact, the electrified object may be held even more tightly, resulting in longer exposure to the shocking current. For this reason, hand-held tools that give a shock can be very dangerous.

If you can’t let go of the tool, current continues through your body for a longer time, which can lead to respiratory paralysis (the muscles that control breathing cannot move). You stop breathing for a period of time.

People have stopped breathing when shocked with currents from voltages as low as 49 volts. Usually, it takes about 30 mA of current to cause respiratory paralysis.

Currents greater than 75 mA may cause ventricular fibrillation (very rapid, ineffective heartbeat). This condition will cause death within a few minutes unless a special device called a defibrillator is used to save the victim.

Heart paralysis occurs at 4 amps, which means the heart does not pump at all. Tissue is burned with currents greater than 5 amps.
4. Electrical currents above _____ milliamperes may have a paralyzing or "freezing" effects on muscles.

a. 1  
   b. 10  
   c. 100  
   d. 1000

Factors that Determine Current Levels

As we know, the severity of an electrical shock in the body is determined by several factors that influence the amount of current and the duration of exposure. These factors include:

- **Voltage.** Greater voltages produce greater currents.
- **Resistance.** Resistance hinders current. The lower the resistance (or impedance in AC circuits), the greater the level of current.
- **Body type.** Muscle structure also makes a difference. People with less muscle tissue are typically affected at lower current levels. Even
- **Duration.** If the shock is short in duration, it may only be painful. A longer shock (lasting a few seconds) could be fatal if the level of current is high enough to cause the heart to go into ventricular fibrillation. Duration is important when you realize that a small power drill uses 30 times as much current required to cause death. However, if the shock is of short duration and the heart has not been damaged, a normal heartbeat may resume after contact with the electrical is eliminated. (This type of recovery is rare.)
- **Moisture.** Dry skin may have a resistance of 100,000 ohms or more. Wet skin may have a resistance of only 1,000 ohms. Wet working conditions or broken skin will drastically reduce resistance. The low resistance of wet skin allows current to pass into the body more easily and give a greater shock.
- **Force.** When more force is applied to the contact point or when the contact area is larger, the resistance is lower, causing stronger shocks.
5. Which of the following will result in lower resistance and greater risk of injury when shocked?

- a. Dirty skin
- b. Dry skin
- c. Wet skin
- d. Thick skin

**Real-Life Example**

A male service technician arrived at a customer’s house to perform pre-winter maintenance on an oil furnace. The customer then left the house and returned 90 minutes later. She noticed the service truck was still in the driveway. After 2 more hours, the customer entered the crawl space with a flashlight to look for the technician but could not see him. She then called the owner of the company, who came to the house. He searched the crawl space and found the technician on his stomach, leaning his elbows on the front of the furnace.

The assistant county coroner was called and pronounced the technician dead at the scene. The victim had electrical burns on his scalp and right elbow. After the incident, an electrician inspected the site. A toggle switch that supposedly controlled electrical power to the furnace was in the “off” position. The electrician described the wiring as “haphazard and confusing.”

Two weeks later, the county electrical inspector performed another inspection. He discovered that incorrect wiring of the toggle switch allowed power to flow to the furnace even when the switch was in the “off” position. The owner of the company stated that the victim was a very thorough worker. Perhaps the victim performed more maintenance on the furnace than previous technicians, exposing himself to the electrical hazard.

This death could have been prevented!

- The victim should have tested the circuit to make sure it was de-energized.
- Employers should provide workers with appropriate equipment and training. Using safety equipment should be a requirement of the job. In this case, a simple circuit tester may have saved the victim’s life.
Residential wiring should satisfy the National Electrical Code (NEC). Although the NEC is not retroactive, all homeowners should make sure their systems are safe.

6. What should you do to verify an electrical circuit is deenergized prior to working on it?

a. Ask someone if the electricity is off
b. Test the circuit to verify that it is deenergized
c. Flip the wall switch to make sure power is off
d. Work on the circuit live if it's under 50 volts
Module 3: Electrical Burns

Common Injuries

The most common shock-related, nonfatal injury is a burn. Burns caused by electricity may be of three types:

1. Electrical burns. Electrical burns can result when a person touches electrical wiring or equipment that is used or maintained improperly. Typically, such burns occur on the hands. Electrical burns are one of the most serious injuries you can receive. They need to be given immediate attention. Additionally, clothing may catch fire and a thermal burn may result from the heat of the fire.

2. Burns from arc blasts and arcing. Arc-blasts occur when powerful, high-amperage currents arc through the air. Arcing is the luminous electrical discharge that occurs when high voltage exists across a gap between conductors and current travels through the air. This situation is often caused by equipment failure due to abuse or fatigue. Temperatures as high as 35,000°F have been reached in arc-blasts.

3. Thermal contact burns. Thermal burns may result if an explosion occurs when electricity ignites an explosive mixture of material in the air. This ignition can result from the buildup of combustible vapors, gases, or dusts. OSHA standards, National Fire Protection Association (NFPA) standards, and other safety standards give precise safety requirements for the operation of electrical systems and equipment in such dangerous areas. Ignition can also be caused by overheated conductors or equipment, or by normal arcing at switch contacts or in circuit breakers.

1. Which of the following is a luminous electrical discharge occurs when high voltages exist across a gap between conductors and current travels through the air?
   
   a. Arc blast
   b. Arcing
   c. Arc-metal blast
   d. Lightning
Arc Blast Hazards

There are three primary hazards associated with an arc-blast.

1. **Thermal radiation**. Arcing during an arc blast gives off thermal radiation (heat) and intense light, which can cause burns. Several factors affect the degree of injury, including skin color, area of skin exposed, and type of clothing worn. Proper clothing, work distances, and overcurrent protection can reduce the risk of such a burn.

2. **High pressure blast**. A high-voltage arc can produce a considerable pressure wave blast. A person 2 feet away from a 25,000-amp arc feels a force of about 480 pounds on the front of the body. In addition, such an explosion can cause serious ear damage and memory loss due to concussion. Sometimes the pressure wave throws the victim away from the arc-blast. While this may reduce further exposure to the thermal energy, serious physical injury may result. The pressure wave can propel large objects over great distances. In some cases, the pressure wave has enough force to snap off the heads of steel bolts and knock over walls.

3. **Molten metal blast**. A high-voltage arc can also cause many of the copper and aluminum components in electrical equipment to melt. These droplets of molten metal can be blasted great distances by the pressure wave. Although these droplets harden rapidly, they can still be hot enough to cause serious burns or cause ordinary clothing to catch fire, even if you are 10 feet or more away.

2. Each of the following is a primary hazard associated with an arc blast EXCEPT _____.
   a. bleve forces
   b. thermal radiation
   c. explosive blast wave
   d. molten metal

Case Study

Five technicians were performing preventive maintenance on the electrical system of a railroad maintenance facility. One of the technicians was assigned to clean the lower compartment of an electrical cabinet using cleaning fluid in an aerosol can. But, he began to clean the upper compartment as well. The upper compartment was filled with live circuitry. When the cleaning spray contacted the live circuitry, a conductive path for the current was created. The current passed through the stream of fluid, into the technician’s arm, and across his chest. The current caused a loud explosion. Co-workers found the victim with his clothes on fire. One worker put
out the fire with an extinguisher and another pulled the victim away from the compartment with a plastic vacuum cleaner hose. The paramedics responded in five minutes. Although the victim survived the shock, he died 24 hours later because of the burns.

This death could have been prevented if the following precautions had been taken:

• Before doing any electrical work, de-energize all circuits and equipment. Perform lockout/tagout, and test circuits and equipment to make sure they are de-energized.

• The company should have trained the workers to perform their jobs safely.

• Proper personal protective equipment (PPE) should always be used.

• Never use aerosol spray cans around high-voltage equipment.

3. Before initiating electrical work, each of the following should be accomplished EXCEPT _____.

a. de-energize all circuits and equipment
b. perform lock-out/tag-out
c. test for voltage by touching wires together
d. test circuits and equipment

Extinguishing the fire

Defective or misused electrical equipment is a major cause of electrical fires. Different types of fire extinguishers are designed to fight different types of fire. The three most common types of fire extinguishers are: air pressurized water, CO2 (carbon dioxide), and dry chemical. The following table provides information regarding the type of fire and which fire extinguisher should be used.

If there is a small electrical fire, be sure to use only a Class C or multipurpose (ABC) fire extinguisher, or you might make the problem worse. All fire extinguishers are marked with letter(s) that tell you the kinds of fires they can put out. Some extinguishers contain symbols, too.

The letters and symbols are explained below (including suggestions on how to remember them):
A (think: Ashes) = paper, wood, etc.

B (think: Barrel) = flammable liquids

C (think: Circuits) = electrical fires

Do not try to put out fires unless you have received proper training. If you are not trained, the best thing you can do is evacuate the area and call for help.

4. Which class of fire extinguisher would you use to extinguish a small electrical fire?
   a. Class A or ABC
   b. Class C or ABC
   c. Class B or C
   d. Class C or D

Case Study

A 29-year-old male maintenance worker was found at 3:45 am lying on his back and convulsing. An overturned cart and an electric welding machine were next to him and lying in a pool of water on the concrete floor. Arcing was visible between the welding machine and the floor. The worker was transported to the closest hospital, where he was pronounced dead.

An examination of the welding machine showed there were exposed conductors in the machine’s cables. There were numerous cuts and scrapes in the cables’ insulation. On other parts of the machine, insulation was damaged or missing. Also, the machine didn’t have a ground connection.

Investigators concluded the maintenance worker was electrocuted when he tried to turn off the welding machine, which was sitting on the cart. The metal frame of the machine had become energized due to the damaged insulation. When he touched the energized frame, he
completed the conducting path to ground. The current travelled through his body to ground. Since he was probably standing in water, the risk of a ground fault was even greater.

You must take steps to decrease such hazards in your workplace:

- Ground circuits and equipment.
- Keep all equipment in good operating condition with a preventive maintenance program.
- Never use electrical equipment or work on circuits in wet areas. If you find water or dampness, notify your supervisor immediately.

5. What is recommended to keep electrical equipment in good working order?

   a. A corrective maintenance program
   b. A "just-in-time" maintenance program
   c. A preventive maintenance program
   d. An as-needed maintenance program
Module 4: The Electrical Safety Model

Three Step Process

To make sure all employees are safe before, during and after electrical work is performed, electrical workers should follow the three-step process of the Electrical Safety Model:

1. recognize hazards
2. evaluate risk
3. control hazards

To be safe, you must think about your job and plan for hazards. To avoid injury or death, you must understand and recognize hazards. You need to evaluate the situation you are in and assess your risks. You need to control hazards by creating a safe work environment, by using safe work practices, and by reporting hazards to a supervisor or teacher.

If you do not recognize, evaluate, and control hazards, you may be injured or killed by the electricity itself, electrical fires, or falls. If you use the safety model to recognize, evaluate, and control hazards, you will be much safer at work.

Use the safety model to:

- Recognize, evaluate, and control hazards.
- Identify electrical hazards.
- Don’t listen to reckless, dangerous people.
- Evaluate your risk.
- Take steps to control hazards
1. Each of the following is one of the steps in the Electrical Safety Model EXCEPT _____.
   a. recognizing hazards
   b. organizing hazards
   c. evaluating risk
   d. controlling hazards

Recognize Hazards

The first step of the safety model is recognizing the electrical hazards around you. Only then can you avoid or control the hazards. It is best to discuss and plan hazard recognition tasks with your co-workers. Sometimes we take risks ourselves, but when we are responsible for others, we are more careful. Sometimes others see hazards that we overlook. Of course, it is possible to be talked out of our concerns by someone who is reckless or dangerous. Don't take a chance. Careful planning of safety procedures reduces the risk of injury. Decisions to lock out and tag out circuits and equipment need to be made during this part of the safety model. Plans for action must be made now.

2. Before you can avoid and control electrical hazards you must first _____.
   a. recognize them
   b. mitigate them
   c. list them
   d. understand them

Evaluate Risks

Evaluation is a judgment call, and it's based on the perceived level of risk of injury. Risk is determined by analyzing the probability of an injury occurring and the severity of the injury if it occurs. The greater the probability and higher the severity, the greater the risk.

When evaluating risk, it is best to identify all possible hazards first, then evaluate the risk of injury from each hazard. Do not assume the risk is low until you evaluate the hazard. It is dangerous to overlook hazards.
Job sites are especially dangerous because they are always changing in construction and electrical work. Many people are working at different tasks and job sites are frequently exposed to bad weather. A reasonable place to work on a bright, sunny day might be very hazardous in the rain. The risks in your work environment need to be evaluated all the time. Then, whatever hazards are present need to be controlled.

3. **Risk is determined by analyzing which two factors?**
   
   a. Awareness and likelihood  
   b. Probability and awareness  
   c. Severity and distance  
   d. Probability and severity

**Control Hazards**

Once electrical hazards have been recognized and evaluated, they must be controlled. You control electrical hazards in two main ways:

1. create a safe work environment and

2. use safe work practices.

One way to implement this safety model is to conduct a job hazard analysis (JHA). This involves development of a chart:

1. Column 1, breaking down the job into its separate task or steps;

2. Column 2, evaluating the hazard(s) of each task, and

3. Column 3, developing a control for each hazard. See the example below.
4. **Once electrical hazards have been recognized and evaluated, they must be _____**.

   a. Reported  
   b. Controlled  
   c. managed  
   d. removed

**Helpful Information**

Controlling electrical hazards (as well as other hazards) reduces the risk of injury or death.

OSHA regulations, the NEC, and the National Electrical Safety Code (NESC) provide a wide range of safety information. Although these sources may be difficult to read and understand at first, with practice they can become very useful tools to help you recognize unsafe conditions and practices.

Knowledge of OSHA standards is an important part of training for electrical apprentices. Check out the following OSHA publications for more information:

- **1910 Subpart S - Electrical**
- **1910 Subpart R - Electric Power Generation, Transmission, and Distribution**
- **1910.137 - Electrical Protective Equipment**
- **OSHA Fact Sheet - Working Safely with Electricity**
5. Electrical safety training should include which of the following topics for apprentices?

a. NIOSH research studies  
b. MSHA regulations  
c. OSHA standards  
d. ANSI standards

Case Study

A maintenance man rode 12 feet above the floor on a motorized lift to work on a 227-volt light fixture. He did not turn off the power supply to the lights. He removed the line fuse from the black wire, which he thought was the “hot” wire. But, because of a mistake in installation, it turned out the white wire was the “hot” wire and not the black one. The black wire was neutral. He began to strip the white wire using a wire stripper in his right hand. Electricity passed from the “hot” white wire to the stripper, into his hand and through his body, and then to the ground through his left index finger. A co-worker heard a noise and saw the victim lying face-up on the lift. She immediately summoned another worker, who lowered the platform. CPR was performed, but the maintenance man could not be saved. He was pronounced dead at the scene.

You can prevent injuries and deaths by remembering the following points:

- If you work on an electrical circuit, test to make sure the circuit is de-energized. (shut-off)
- Never attempt to handle any wires or conductors until you are absolutely positive their electrical supply has been shut off.
- Be sure to lock out and tag out circuits so they cannot be re-energized.
- Always assume a conductor is dangerous.
6. Which of the following is a safe work practice when working with electricity?

   a. It is safe to work on live low-voltage circuits
   b. Assume you are safe if properly grounded
   c. It's safe to work with circuits after switching the equipment off
   d. Always assume a conductor is dangerous
Module 5: Recognizing Hazards

Introduction
The first step toward protecting yourself is recognizing the many hazards you face on the job. To do this, you must know which situations can place you in danger. Knowing where to look helps you to recognize hazards.

- Inadequate wiring is dangerous.
- Exposed electrical parts are dangerous.
- Overhead power lines are dangerous.
- Wires with bad insulation can shock you.
- Electrical systems and tools that are not grounded or double-insulated are dangerous.
- Overloaded circuits are dangerous.
- Damaged power tools and equipment are electrical hazards.
- Using the wrong PPE is dangerous.
- Using the wrong tool is dangerous.
- Some on-site chemicals are harmful.
- Defective ladders and scaffolding are dangerous
- Ladders that conduct electricity are dangerous.
- Electrical hazards can be made worse if the worker, location, or equipment is wet.
Case Study

An electrician was removing a metal fish tape from a hole at the base of a metal light pole. (A fish tape is used to pull wire through a conduit run.) The fish tape became energized, electrocuting him. As a result of its inspection, OSHA issued a citation for three serious violations of the agency’s construction standards.

If the following OSH requirements had been followed, this death could have been prevented.

- De-energize all circuits before beginning work.
- Always lock out and tag out de-energized equipment.
- Companies must train workers to recognize and avoid unsafe conditions associated with their work.

1. All of the following are examples of hazardous situations when working with electricity EXCEPT _____.
   a. exposed electrical parts
   b. dry or low humidity work conditions
   c. working on metal ladders
   d. ungrounded electrical systems and tools

Inadequate wiring hazards

Some definitions:

- **Wire gauge:** wire size or diameter (technically, the cross-sectional area.)
- **Ampacity:** the maximum amount of current a wire can carry safely without overheating.

Heads up: Inadequate or improper electrical wiring was one of OSHA’s top 10 most commonly cited violations during 2011!! An electrical wiring hazard exists when the wire is too small for the current it will carry or is not connected properly. Normally, the circuit breaker in a circuit is matched to the wire size. However, in older wiring, branch lines to permanent ceiling light fixtures could be wired with a smaller gauge than the supply cable. Let's say a light fixture is replaced with another device that uses
more current. The current capacity (ampacity) of the branch wire could be exceeded. When a wire is too small for the current it is supposed to carry, the wire will heat up. The heated wire could cause a fire.

When you use an extension cord, the size of the wire you are placing into the circuit may be too small for the equipment. The circuit breaker could be the right size for the circuit but not right for the smaller-gauge extension cord. A tool plugged into the extension cord may use more current than the cord can handle without tripping the circuit breaker. The wire will overheat and could cause a fire.

The kind of metal used as a conductor can cause an electrical hazard. Special care needs to be taken with aluminum wire. Since it is more brittle than copper, aluminum wire can crack and break more easily. Connections with aluminum wire can become loose and oxidize if not made properly, creating heat or arcing.

You must recognize that inadequate wiring is a hazard.

Case Study

A worker was attempting to correct an electrical problem involving two non-operational lamps. He examined the circuit in the area where he thought the problem was located. He had not shut off the power at the circuit breaker panel and didn’t test the wires to see if they were live. He was electrocuted when he grabbed the two live wires with his left hand. He collapsed to the floor and was found dead.

- Employers should not allow work to be done on electrical circuits unless an effective lock-out/tag-out program is in place.

- No work should be done on energized electrical circuits. Circuits must be shut off, locked out, and tagged out. Even then, you must test the circuit before beginning work to confirm that it is de-energized. (“dead”)
2. Electrical wiring may become hazardous and cause arcing or fires if the wires _____.
   a. have too much insulation
   b. are too long for the load
   c. are too small for the load
   d. do not have in-line GFCIs

Exposed electrical parts hazards

Electrical hazards exist when wires or other electrical parts are exposed. If you contact exposed live electrical parts, you will be shocked.

- Wires and parts can be exposed if a cover is removed from a wiring or breaker box.
- The overhead wires coming into a home may be exposed.
- Electrical terminals in motors, appliances, and electronic equipment may be exposed.
- Older equipment may have exposed electrical parts.

Guarding. Guarding involves locating or enclosing electric equipment to make sure people don’t accidentally come into contact with its live parts. Effective guarding requires equipment with exposed parts operating at 50 volts or more to be placed where it is accessible only to authorized people qualified to work with it. Recommended guarding solutions include:

- A room, vault, or similar enclosure
- A balcony, gallery, or elevated platform
- A site elevated 8 feet (2.44 meters) or more above the floor
- A sturdy, permanent screen

Warning. Conspicuous signs must be posted at the entrances to electrical rooms and similarly guarded locations to alert people to the electrical hazard and to forbid entry to unauthorized people. Signs may contain the word "Danger," "Warning," or "Caution," and beneath that, appropriate concise wording that alerts people to the hazard or gives an instruction, such as "Danger/High Voltage/Keep Out."
3. Effective guarding requires equipment with exposed parts operating at _____ to be placed where it is accessible only to authorized people qualified to work with it.

   a. 50 volts or more  
   b. 120 volts or more  
   c. 600 volts or more  
   d. 1000 volts or more

Case Study

Five workers were constructing a chain-link fence in front of a house, directly below a 7,200-volt energized power line. As they prepared to install 21-foot sections of metal top rail on the fence, one of the workers picked up a section of rail and held it up vertically. The rail contacted the 7,200-volt line, and the worker was electrocuted. Following inspection, OSHA determined the employee who was killed had never received any safety training from his employer and no specific instruction on how to avoid the hazards associated with overhead power lines.

In this case, the company failed to obey these regulations:

- Employers must train their workers to recognize and avoid unsafe conditions on the job.
- Employers must not allow their workers to work near any part of an electrical circuit unless the circuit is de-energized (shut-off) and grounded or guarded in such a way it cannot be contacted.
- Ground-fault protection must be provided at construction sites to guard against electrical shock.
4. **What must be provided at construction sites to guard against electrical shock?**
   
   a. OSHA safety bulletin board  
   b. Ground-fault protection  
   c. Tested two-prong extension cords  
   d. Leather or other fabric gloves

**Approach boundaries**

The risk from exposed live parts depends on your distance from the parts. Three "boundaries" are key to protecting yourself from electric shock and one to protect you from arc flashes or blasts. These boundaries are set by the [National Fire Protection Association](https://www.nfpa.org) (NFPA 70E) and the [Canadian Standards Association](https://www.csa.ca) (CSA Z462).

**The Restricted Approach Boundary.** This boundary may only be crossed by a Qualified Person wearing appropriate PPE, as determined by the Shock Risk Assessment.

- The Qualified Person must also have an Energized Electrical Work Permit (EEWP).
- The use of shock protection techniques and equipment are required.
- To cross into the Restricted Space, the qualified person must wear appropriate PPE.
- The Qualified Person must have a written approved plan for the work to be performed and plan the work to keep all parts of the body out of the Prohibited Space.

**1. The Limited Approach Boundary.** NFPA 70 defines the limited approach boundary as a shock protection boundary to be crossed by only qualified persons (at a distance from a live part), which is not to be crossed by unqualified persons unless escorted by a qualified person.

- This boundary is the minimum distance from the energized item where unqualified personnel may safely stand.
- No untrained personnel may approach any closer to the energized item than this boundary.
• A qualified person must use appropriate PPE and be trained to perform the required work to cross the limited approach boundary and enter the limited space.

2. **Flash Protection Boundary (FPB)**. The FPB is the farthest established boundary from the energy source and is considered a safe approach distance from energized equipment or parts.

• Only Persons wearing appropriate personal protective clothing and equipment for the Arc Flash Boundary, as determined by an Arc Flash Risk Assessment, may approach closer than the FPB.

5. **When working around high voltage components, no untrained personnel may approach any closer to the energized item than the _____.**

   a. Prohibited Approach Boundary  
   b. Restricted Approach Boundary  
   c. Limited Approach Boundary  
   d. Flash Protection Boundary

**Overhead powerline hazards**

Overhead power lines are not insulated and can carry tens of thousands of volts, making them extremely dangerous to employees who work in their vicinity. Powerline workers must be especially aware of the dangers of overhead lines.

More than half of all electrocutions are caused by direct worker contact with energized powerlines because workers fail to maintain proper work distance. Fatal electrocution is the main risk but burns and falls from elevations are also hazards. Using tools and equipment that can contact power lines increases the risk.

Examples of equipment that can contact overhead power lines include:

• Aluminum paint rollers  
• Backhoes  
• Concrete pumpers  
• Cranes
• Long-handled cement finishing floats
• Metal building materials
• Metal ladders
• Raised dump truck beds
• Scaffolds

Avoid overhead power line hazards by following these best practices:

• Look for overhead power lines and buried power line indicators. Post warning signs.
• Contact utilities for buried power line locations.
• Stay at least 10 feet away from overhead power lines.
• Unless you know otherwise, assume that overhead lines are energized.
• De-energize and ground lines when working near them. Other protective measures include guarding or insulating the lines.
• Use non-conductive wood or fiberglass ladders when working near power lines.

6. What is the cause of more than half of all electrocutions?
   a. Direct worker contact with energized powerlines
   b. Improper transformer wiring
   c. Defective power tools
   d. Improperly grounded equipment

Defective Insulation Hazards

Insulation that is defective or inadequate is an electrical hazard. Usually, a plastic or rubber covering insulates wires. Insulation prevents conductors from coming in contact with each other. Insulation also prevents conductors from coming in contact with people.
Extension cords may have damaged insulation. Sometimes the insulation inside an electrical tool or appliance is damaged. When insulation is damaged, exposed metal parts may become energized if a live wire inside touches them. Electric hand tools that are old, damaged, or misused may have damaged insulation inside. If you touch damaged power tools or other equipment, you will receive a shock. You are more likely to receive a shock if the tool is not grounded or double-insulated. (Double-insulated tools have two insulation barriers and no exposed metal parts.)

You must recognize that defective insulation is a hazard.

Improper Grounding Hazards

When an electrical system is not grounded properly, a hazard exists. The most common OSHA electrical violation is improper grounding of equipment and circuitry. The metal parts of an electrical wiring system that we touch (switch plates, ceiling light fixtures, conduit, etc.) should be grounded and at 0 volts. If the system is not grounded properly, these parts may become energized. Metal parts of motors, appliances, or electronics that are plugged into improperly grounded circuits may be energized. When a circuit is not grounded properly, a hazard exists because unwanted voltage cannot be safely eliminated. If there is no safe path to ground for fault currents, exposed metal parts in damaged appliances can become energized.

Extension cords may not provide a continuous path to ground because of a broken ground wire or plug. If you contact a defective electrical device that is not grounded, (or grounded improperly) you will be shocked.

You must recognize that an improperly grounded electrical system is a hazard.

7. Double-insulated equipment must meet which of the following two criteria?
   a. Two safety switches, guarded parts
   b. Two insulation barriers, no exposed parts
   c. No insulation barriers, two exposed parts
   d. No exposed parts or insulation barriers
Ground Fault Circuit Interrupters (GFCI)

A ground fault circuit interrupter, or GFCI, is an inexpensive life-saver. GFCI’s detect any difference in current between the two circuit wires (the black wires and white wires). This difference in current could happen when electrical equipment is not working correctly, causing leakage current. If leakage current (a ground fault) is detected in a GFCI-protected circuit, the GFCI switches off the current in the circuit, protecting you from a dangerous shock. GFCI’s are set at about 5 mA and are designed to protect workers from electrocution. GFCI’s are able to detect the loss of current resulting from leakage through a person who is beginning to be shocked. If this situation occurs, the GFCI switches off the current in the circuit. GFCI’s are different from circuit breakers because they detect leakage currents rather than overloads.

Circuits with missing, damaged, or improperly wired GFCI’s may allow you to be shocked.

You must recognize that a circuit improperly protected by a GFCI is a hazard.

8. GFCIs detect any difference in _____ between the two circuit wires (the black wires and white wires).
   a. impedance
   b. voltage
   c. current
   d. resistance

Overload hazards

Overloads in an electrical system are hazardous because they can produce heat or arcing. Wires and other components in an electrical system or circuit have a maximum amount of current they can carry safely. If too many devices are plugged into a circuit, the electrical current will heat the wires to a very high temperature. If any one tool uses too much current, the wires will heat up.

The temperature of the wires can be high enough to cause a fire. If their insulation melts, arcing may occur. Arcing can cause a fire in the area where the overload exists, even inside a wall.

In order to prevent too much current in a circuit, a circuit breaker or fuse is placed in the circuit. If there is too much current in the circuit, the breaker "trips" and opens like a switch. If an overloaded circuit is equipped with a fuse, an internal part of the fuse melts, opening the circuit. Both breakers and fuses do the same thing: open the circuit to shut off the electrical current.
If the breakers or fuses are too big for the wires they are supposed to protect, an overload in the circuit will not be detected and the current will not be shut off. Overloading leads to overheating of circuit components (including wires) and may cause a fire.

*You must recognize that a circuit with improper overcurrent protection devices—or one with no overcurrent protection devices at all—is a hazard.*

Overcurrent protection devices are built into the wiring of some electric motors, tools, and electronic devices. For example, if a tool draws too much current or if it overheats, the current will be shut off from within the device itself. Damaged tools can overheat and cause a fire.

*You must recognize that a damaged tool is a hazard.*

9. All of the following may happen if the circuit breakers or fuses are too big for the wires they are supposed to protect EXCEPT _____.

   a. the circuit may blow a fuse too soon
   b. it may cause a fire
   c. an overload will not be detected
   d. the current may not be shut off

**Wet conditions hazards**

Working in wet conditions is hazardous because you may become an easy path for electrical current. For instance, if you touch a live wire while standing in even a puddle of water, you will probably receive a shock.

Damaged insulation, equipment, or tools can expose you to live electrical parts. A damaged tool may not be grounded properly, so the housing of the tool may be energized, causing you to receive a shock. Improperly grounded metal switch plates and ceiling lights are especially hazardous in wet conditions. If you touch a live electrical component with an un-insulated hand tool, you are more likely to receive a shock when standing in water.

Remember: you don’t have to be standing in water to be electrocuted. Wet clothing, high humidity, and perspiration also increase your chances of being electrocuted.

*You need to recognize that all wet conditions are hazards.*

**Additional hazards**
In addition to electrical hazards, other types of hazards are present at job sites. Remember that all of these hazards can be controlled.

- There may be chemical hazards. Solvents and other substances may be poisonous or cause disease.

- Frequent overhead work can cause tendinitis (inflammation) in your shoulders.

Intensive use of hand tools that involve force or twisting can cause tendinitis of the hands, wrists, or elbows. Use of hand tools can also cause carpal tunnel syndrome, which results when nerves in the wrist are damaged by swelling tendons or contracting muscles.

10. If you touch a live electrical component with an uninsulated hand tool, you are more likely to receive a shock in all of the following situations EXCEPT _____.

   a. when perspiring
   b. when wearing wet clothing
   c. when working in an open field
   d. when standing in water
Module 6: Evaluating Risk

How Do You Evaluate Your Risk?

After you recognize a hazard, your next step is to evaluate your risk from the hazard. The closer you work to the "danger zone," the more likely you'll be exposed to the electrical hazard. For instance, exposed wires should be recognized as a hazard. If the exposed wires are 15 feet off the ground, you are not close to the danger zone so the risk is low. However, if you are going to be working on a roof near those same wires, your risk is high. The risk of shock is greater if you will be carrying metal conduit that could touch the exposed wires. It's important that as you work throughout the day, you must constantly evaluate your risk.

Another factor increasing your risk of injury is working around combinations of hazards. Improper grounding and a damaged tool greatly increase your risk. Wet conditions combined with other hazards also increase your risk. You will need to make decisions about the nature of hazards in order to evaluate your risk and do the right thing to remain safe.

There may be important clues that electrical hazards exist. For example, if a GFCI keeps tripping while you are using a power tool, that's a clue that there is a problem. Don't keep resetting the GFCI and continue to work. You must evaluate the "clue" and decide what action should be taken to control the hazard.

Any of these conditions, or "clues," tells you something important: there is a risk of fire and electrical shock. The equipment or tools involved must be avoided. You will frequently be caught in situations where you need to decide if these clues are present. A maintenance electrician, supervisor, or instructor needs to be called if there are signs of overload and you are not sure of the degree of risk. Ask for help whenever you are not sure what to do. By asking for help, you will protect yourself and others.

1. Working with a defective electrical tool on wet ground would be an example of increased risk due to _____.
   a. work on a construction site
   b. location to the hazard
   c. a combination of hazards
   d. a single hazard type
Case Study

An 18-year-old male worker had just completed mopping the floor 10 minutes earlier and was plugging a toaster into a floor outlet when he received a shock. The restaurant manager and another employee heard the victim scream and investigated. The victim was found with one hand on the plug and the other hand grasping the metal receptacle box. His face was pressed against the top of the outlet.

By the time the circuit was turned off, the victim had been exposed to the current for 3 to 8 minutes. The manager and the employee left the victim to unlock the front door and call for help. Another employee found that the victim no longer had a pulse. The employee began administering CPR, which was continued by the rescue squad for 90 minutes, but unfortunately the victim was dead on arrival at a local hospital.

The investigation showed that the victim's hand slipped forward when he was plugging in the toaster. His index finger made contact with an energized prong in the plug. His other hand was on the metal receptacle box, which was grounded. Current entered his body through his index finger, flowed across his chest, and exited through the other hand, which was in contact with the grounded receptacle.

To prevent death or injury, you must recognize hazards and take the right action.

- If the circuit had been equipped with a GFCI, the current would have been shut off before injury occurred.
- The recent mopping increased the risk of electrocution. Never work in wet or damp areas.
- Know the location of circuit breakers for your work area.
2. What would prevent an electrocution should a worker be exposed to electrical current while working in a damp location?

a. Circuits equipped with GFCI protection
b. Circuit breakers removed
c. Warning signs in wet areas
d. Use of extension cords

Conditions that point to electrical hazards

There are a number of other conditions that indicate an electrical hazard.

- Tripped circuit breakers and blown fuses show that too much current is flowing in a circuit. This condition could be due to several factors, such as malfunctioning equipment or a short between conductors. You need to determine the cause in order to control the hazard.

- An electrical tool, appliance, wire, or connection that feels warm may indicate too much current in the circuit or equipment. You need to evaluate the situation and determine your risk.

- An extension cord that feels warm may indicate too much current for the wire size of the cord. You must decide when action needs to be taken.

- A cable, fuse box, or junction box that feels warm may indicate too much current in the circuits.

- A burning odor may indicate overheated insulation.

- Worn, frayed, or damaged insulation around any wire or other conductor is an electrical hazard because the conductors could be exposed. Contact with an exposed wire could cause a shock. Damaged insulation could cause a short, leading to arcing or a fire. Inspect all insulation for scrapes and breaks. You need to evaluate the seriousness of any damage you find and decide how to deal with the hazard.

- A GFCI that trips indicate there is current leakage from the circuit. First, you must decide the probable cause of the leakage by recognizing any contributing hazards. Then, you must decide what action needs to be taken.
3. Tripped circuit breakers and blown fuses show that _____.
   a. the voltage is high
   b. too little resistance
   c. too much current is flowing
   d. the a.c. frequency is too high

Case Study

A 20-year-old male laborer was carrying a 20-foot piece of iron from a welding shop to an outside storage rack. As he was turning a corner near a bank of electrical transformers, the top end of the piece of iron struck an uninsulated supply wire at the top of a transformer. Although the transformers were surrounded by a 6-foot fence, they were about 3 feet taller than the fence enclosure. Each transformer carried 4,160 volts.

When the iron hit the supply wire, the laborer was electrocuted. A forklift operator heard the iron drop to the ground at about 8:46 am and found the victim five minutes later. He was pronounced dead on arrival at a local hospital.

- According to OSHA, the enclosure around the transformers was too low. The fence should have been at least 8 feet tall.
- The company in this case didn’t offer any formal safety training to its workers. All employers should develop safety and health training programs, so their employees know how to recognize and avoid life-threatening hazards.

4. A wall, screen, or fence around electrical installations must provide a degree of isolation equivalent to _____.
   a. a distance of 6 feet (1.8 m)
   b. at least an 8-foot (2.44 m) fence
   c. a GFCI-protected isolation of 600 v
   d. a lock and key mechanism
Module 7: Safe Work Environments

How Do You Control Hazards?

In order to control hazards, you must first create a safe work environment, then work in a safe manner. Generally, it is best to remove the hazards altogether and create an environment that is truly safe. When OSHA regulations and the NEC are followed, safe work environments are created.

But, you never know when materials or equipment might fail. Prepare yourself for the unexpected by using safe work practices. Use as many safeguards as possible. If one fails, another may protect you from injury or death.

How Do You Create a Safe Work Environment?

A safe work environment is created by controlling contact with electrical voltages and the currents they can cause. Electrical currents need to be controlled so they do not pass through the body. In addition to preventing shocks, a safe work environment reduces the chance of fires, burns, and falls.

You need to guard against contact with electrical voltages and control electrical currents in order to create a safe work environment. Make your environment safer by doing the following:

- Treat all conductors—even "de-energized" ones—as if they are energized until they are locked out and tagged.
- Lock out and tag out circuits and machines.
- Prevent overloaded wiring by using the right size and type of wire.
- Prevent exposure to live electrical parts by isolating them.
- Prevent exposure to live wires and parts by using insulation.
- Prevent shocking currents from electrical systems and tools by grounding them.
- Prevent shocking currents by using GFCI's.
- Prevent too much current in circuits by using overcurrent protection devices.
1. In order to create a safe electrical work environment treat all conductors _____.
   a. as if they are de-energized
   b. as if they are energized
   c. as if they are grounded
   d. as if they are connected

Case Study

At about 1:45 a.m., two journeyman electricians began replacing bulbs and making repairs on light fixtures in a spray paint booth at an automobile assembly plant. The job required the two electricians to climb on top of the booth and work from above. The top of the booth was filled with pipes and ducts that restricted visibility and movement. Flashlights were required.

The electricians started at opposite ends of the booth. One electrician saw a flash of light, but continued to work for about 5 minutes, the climbed down for some wire. While cutting the wire, he smelled a burning odor and called to the other electrician. When no one answered, he climbed back on top of the booth. He found his co-worker in contact with a single-strand wire from one of the lights. Needle-nose wire strippers were stuck in the left side of the victim’s chest. Apparently, he had been stripping insulation from an improperly grounded 530-volt, single-strand wire when he contacted it with the stripper. In this case, the electricians knew they were working on energized circuits. The breakers in both the booth’s control panel were not labeled, and the lock used for lock-out/tag-out was broken. The surviving electrician stated that locating the means to de-energize a circuit often takes more time than the actual job.

The electrician would be alive to if the following rules had been observed:

- Always shut off circuits-then test to confirm they are de-energized- before starting a job.

- Switchgear that shuts off a circuit must be clearly labeled and easy to access.

- Lock-out/tag-out materials must always be provided, and lock-out/tag-out procedures must always be followed.

- Always label circuit breakers.
2. To ensure the electrical safety of employees, it is important to follow each of the following rules EXCEPT _____.

a. using lockout/tagout procedures
b. clearly labeling switchgear
c. ensuring circuits are energized
d. always shutting off circuits

Lock Out and Tag Out Circuits and Equipment

Lockout/tagout is an essential safety procedure that protects workers from injury while working on or near electrical circuits and equipment. Lock-out involves applying a physical lock to the power source(s) of circuits and equipment after they have been shut off and de-energized. The source is then tagged out with an easy-to-read tag that alerts other workers in the area that a lock has been applied.

In addition to protecting workers from electrical hazards, lock-out/tag-out prevents contact with operating equipment parts: blades, gears, shafts, presses, etc. Read more about Lockout/Tagout by taking OSHAcademy Course 710.

Real-World Accidents

A worker was replacing a V-belt on a dust collector blower. Before beginning work, he shut down the unit at the local switch. However, an operator in the control room restarted the unit using a remote switch. The worker's hand was caught between the pulley and belts of the blower, resulting in cuts and a fractured finger.

Remember, when performing lockout/tagout on machinery, you must always lockout and tagout ALL energy sources to the machinery.

An employee was cutting into a metal pipe using a blowtorch. Diesel fuel was mistakenly discharged into the line and was ignited by his torch. The worker burned to death at the scene.

All valves along the line should have been locked out, blanked out, and tagged out to prevent the release of fuel. Blanking is the process of inserting a metal disk into the space between two
pipe flanges. The disk, or blank, is then bolted in place to prevent passage of liquids or gases through the pipe.

3. Which procedure can protect workers against injury due to the unexpected equipment and machinery startup or shutdown?
   
   a. Confined space entry
   b. Lockout/Tagout
   c. Electrical safety permits
   d. Competent person approval

Control Inadequate Wiring Hazards

Electrical hazards result from using the wrong size or type of wire. You must control such hazards to create a safe work environment. You must choose the right size wire for the amount of current expected in a circuit. The wire must be able to handle the current safely. The wire's insulation must be appropriate for the voltage and tough enough for the environment. Connections need to be reliable and protected.

Fixed Wiring

The wiring methods and size of conductors used in a system depend on several factors:

- Intended use of the circuit system
- Building materials
- Size and distribution of electrical load
- Location of equipment (such as underground burial)
- Environmental conditions (such as dampness)
- Presence of corrosives
• Temperature extremes

Fixed, permanent wiring is better than extension cords, which can be misused and damaged more easily. NEC requirements for fixed wiring should always be followed. A variety of materials can be used in wiring applications, including nonmetallic sheathed cable (Romex®), armored cable, and metal and plastic conduit. The choice of wiring material depends on the wiring environment and the need to support and protect wires.

Aluminum wire and connections should be handled with special care. Connections made with aluminum wire can loosen due to heat expansion and oxidize if they are not made properly. Loose or oxidized connections can create heat or arcing. Special clamps and terminals are necessary to make proper connections using aluminum wire. Antioxidant paste can be applied to connections to prevent oxidation.

Flexible Wiring

Electrical cords supplement fixed wiring by providing the flexibility required for maintenance, portability, isolation from vibration, and emergency and temporary power needs.

Flexible wiring can be used for extension cords or power supply cords. Power supply cords can be removable or permanently attached to the appliance.

DO NOT use flexible wiring in situations where frequent inspection would be difficult, where damage would be likely, or where long-term electrical supply is needed. Flexible cords cannot be used as a substitute for the fixed wiring of a structure. Flexible cords must not be:

• Run through holes in walls, ceilings, or floors;

• Run through doorways, windows, or similar openings (unless physically protected);

• Attached to building surfaces (except with a tension take-up device within 6 feet of the supply end);

• Hidden in walls, ceilings, or floors; or

• Hidden in conduit or other raceways.
4. Why is fixed, permanent wiring preferred over the use of extension cords?

a. It is cheaper to use fixed wiring
b. It is better for connecting equipment long-term
c. It is easier to work with
d. It is less likely to be misused or damaged

Use the Right Extension Cord

The size of wire in an extension cord must be compatible with the amount of current the cord will be expected to carry. The amount of current depends on the equipment plugged into the extension cord. Current ratings (how much current a device needs to operate) are often printed on the nameplate. If a power rating is given, it is necessary to divide the power rating in watts by the voltage to find the current rating. For example, a 1,000-watt heater plugged into a 120-volt circuit will need almost 10 amps of current. Be sure to choose a wire size that can handle the total current expected to be used by all tools and equipment.

**American Wire Gauge (AWG).** American wire gauge (AWG) is a standardized wire gauge system used in North America for the diameters of round, solid, nonferrous, electrically conducting wire.

- #10 AWG - 30 amps max.
- #12 AWG - 25 amps max.
- #14 AWG - 18 amps max.
- #16 AWG - 13 amps max.

The length of the extension cord also needs to be considered when selecting the wire size. Voltage drops over the length of a cord. If a cord is too long, the voltage drop can be enough to damage equipment. Many electric motors only operate safely in a narrow range of voltages and will not work properly at voltages different than the voltage listed on the nameplate. Even though light bulbs operate (somewhat dimmer) at lowered voltages, do not assume electric motors will work correctly at less-than-required voltages. Also, when electric motors start or operate under load, they require more current. The larger the size of the wire, the longer a cord can be without causing a voltage drop that could damage tools and equipment.

The grounding path for extension cords must be kept intact to keep you safe. A typical extension cord grounding system has four components:
• a third wire in the cord, called a ground wire;

• a three-prong plug with a grounding prong on one end of the cord;

• a three-wire, grounding-type receptacle at the other end of the cord; and

• a properly grounded outlet.

Also, when electric motors start or operate under load, they require more current. The larger the size of the wire, the longer a cord can be without causing a voltage drop that could damage tools and equipment.

5. The size of wire in an extension cord must be compatible with the _____.

   a. size of the equipment that will be serviced
   b. amount of current the cord will be expected to carry
   c. type of electrical outlet - American or European
   d. voltage of the equipment being used

Control Hazards of Exposed Live Electrical Parts: Isolate Energized Components

Electrical hazards exist when wires or other electrical parts are exposed. These hazards need to be controlled to create a safe work environment. Isolation of energized electrical parts makes them inaccessible unless tools and special effort are used.

Isolation

Isolation can be accomplished by placing the energized parts at least 8 feet high and out of reach, or by guarding. Guarding is a type of isolation that uses various structures-like cabinets, boxes, screens, barriers, covers, and partitions-to close-off live electrical parts.

Take the following precautions to prevent injuries from contact with live parts:

• Immediately report exposed live parts to a supervisor or teacher. As a student, you should never attempt to correct the condition yourself without supervision.
• Use covers, screens, or partitions for guarding that require tools to remove them.

• Replace covers that have been removed from panels, motors, or fuse boxes.

• Even when live parts are elevated to the required height (8 feet), care should be taken when using objects (like metal rods or pipes) that can contact these parts.

• Close unused conduit openings in boxes so that foreign objects (pencils, metal chips, conductive debris, etc.) cannot get inside and damage the circuit.

6. Isolating energized components can be accomplished by placing the energized parts at least _____ feet high and out of reach, or by guarding.

   a. 5
   b. 8
   c. 10
   d. 12

Insulation

Insulation is made of material that does not conduct electricity (usually plastic, rubber, or fiber). The purpose of insulation is to prevent conductors from coming in contact with each other or any other conductors which creates a short circuit. It also prevents live wires from touching people and animals, thus protecting them from electrical shock. Insulation also does the following:

• It helps protect wires from physical damage and conditions in the environment.

• It is used on almost all wires, except some ground wires and some high-voltage transmission lines.

• Insulation is used internally in tools, switches, plugs, and other electrical and electronic devices.

• Is it used on wires and cables in harsh environments to protect against heat, moisture, fungus, and corrosion?

In all situations, you must be careful not to damage insulation while installing it.
• Do not allow staples or other supports to damage the insulation.

• Bends in a cable must have an inside radius of at least 5 times the diameter of the cable so that insulation at a bend is not damaged.

• Because extension cords often receive rough handling, and are often used near combustible materials, a short in an extension cord could easily cause arcing and a fire.

**NEC U.S. Wiring Color Codes**

Insulation on individual wires is often color-coded. In general:

• Insulated wires used as equipment grounding conductors are either continuous green or green with yellow stripes.

• The grounded conductors that complete a circuit are generally covered with continuous white or gray insulation.

• The ungrounded conductors, or "hot" wires, may be any color other than green, white, or gray. They are usually black or red.

7. Ungrounded, or "hot" electrical conductors are usually colored _____.
   a. blue or pink
   b. black or blue
   c. black or red
   d. red or blue

**Ground circuits and equipment**

When an electrical system is not grounded properly, a hazard exists. This is because the parts of an electrical wiring system that a person normally touches may be energized, or live, relative to ground. Parts like switch plates, wiring boxes, conduit, cabinets, and lights need to be at 0 volts relative to ground. If the system is grounded improperly, these parts may be energized. The metal housings of equipment plugged into an outlet need to be grounded through the plug.
Grounding is connecting an electrical system to the earth with a wire. Excess or stray current travels through this wire to a grounding rod (commonly called a "ground") buried in the earth. Rods used for grounding should be:

- made of 5/8th inch copper or steel
- at least 2 feet from a foundation wall
- located at least 6 feet apart
- driven into the ground to an 8-foot depth

Sometimes an electrical system receives a higher voltage than it is designed to handle, or a defect occurs in a device that allows exposed metal parts to become energized. Grounding will help protect the person working on a circuit, and others using tools or operating equipment connected to the circuit.

**Leakage current.** Leakage current occurs when an electrical current escapes from its intended path. Leakages are sometimes low-current faults that can occur in all electrical equipment because of dirt, wear, damage, or moisture. A good grounding system should be able to carry off this leakage current.

**Ground faults.** A ground fault occurs when current passes through the housing of an electrical device to ground. Ground faults are usually caused by misuse of a tool or damage to its insulation that allows a bare conductor to touch metal parts or the tool housing.

Equipment needs to be grounded under any of these circumstances:

- The equipment is within 8 feet vertically and 5 feet horizontally of the floor or walking surface.
- The equipment is within 8 feet vertically and 5 feet horizontally of grounded metal objects you could touch.
- The equipment is located in a wet or damp area and is not isolated.
- The equipment is connected to a power supply by cord and plug and is not double-insulated.
8. Parts like switch plates, wiring boxes, conduit, cabinets, and lights need to be at _____ relative to ground.

   e. 0 volts
   a. 5+ volts
   b. 10+ volts
   c. 120 volts

**Use Ground Fault Circuit Interrupters (GFCI's)**

The use of GFCI's has lowered the number of electrocutions dramatically. A GFCI is a fast-acting switch that detects any difference in current between two circuit conductors. If either conductor comes in contact—either directly or through part of your body—with a ground (a situation known as a ground fault), the GFCI opens the circuit in a fraction of a second. If a current as small as 4 to 6 mA does not pass through both wires properly, but instead leaks to the ground, the GFCI is tripped. The current is shut off.

There is a more sensitive kind of GFCI called an isolation GFCI. If a circuit has an isolation GFCI, the ground fault current passes through an electronic sensing circuit in the GFCI. The electronic sensing circuit has enough resistance to limit current to as little as 2 mA, which is too low to cause a dangerous shock.

GFCI's are usually in the form of a duplex receptacle. They are also available in portable and plug-in designs and as circuit breakers that protect an entire branch circuit. GFCI's can operate on both two- and three-wire ground systems. For a GFCI to work properly, the neutral conductor (white wire) must (1) be continuous, (2) have low resistance, and (3) have sufficient current-carrying capacity.

GFCI's help protect you from electrical shock by continuously monitoring the circuit. However, a GFCI does not protect a person from line-to-line hazards such as touching two "hot" wires (240 volts) at the same time or touching a "hot" and neutral wire at the same time. Also be aware that instantaneous currents can be high when a GFCI is tripped. A shock may still be felt. Your reaction to the shock could cause injury, perhaps from falling.

Test GFCI's regularly by pressing the "test" button. If the circuit does not turn off, the GFCI is faulty and must be replaced.

The NEC requires that GFCI's be used in these high-risk situations:
• Electricity is used near water.

• The user of electrical equipment is grounded (by touching grounded material).

• Circuits are providing power to portable tools or outdoor receptacles.

• Temporary wiring or extension cords are used.

• Specifically, GFCI's must be installed in bathrooms, garages, out-door areas, crawl spaces, unfinished basements, kitchens, and near wet bars.

9. For a GFCI to work properly, the neutral white wire must be continuous, have low resistance, and have _____.
   
a. a connection to the red wire  
b. a connection to ground  
c. sufficiently high reluctance  
d. sufficient current-carrying capacity

Bonding

In order to assure a continuous, reliable electrical path to ground, a bonding jumper wire is used to make sure electrical parts are connected. Some physical connections, like metal conduit coming into a box, might not make a good electrical connection because of paint or possible corrosion. To make a good electrical connection, a bonding jumper needs to be installed.

Bonding Jumper

A bonding jumper is a conductor used to connect parts to be bonded. Bonding assures electrical continuity between electrical components. Any fault current will be conducted along the bonded metal to ground.

Additionally, interior metal plumbing must be bonded to the ground for electrical service equipment in order to keep all grounds at the same potential (0 volts). Even metal air ducts should be bonded to electrical service equipment.
10. Which of the following methods assures electrical continuity between electrical components?

a. Connecting  
b. Bonding  
c. Jumping  
d. Grounding

Control Overload Current Hazards

When a current exceeds the current rating of equipment or wiring, a hazard exists. The wiring in the circuit, equipment, or tool cannot handle the current without heating up or even melting. Not only will the wiring or tool be damaged, but the high temperature of the conductor can also cause a fire.

Overcurrent Protection Devices

To prevent this from happening, an overcurrent protection device (circuit breaker or fuse) is used in a circuit. These devices open a circuit automatically if they detect current in excess of the current rating of equipment or wiring. This excess current can be caused by an overload, short circuit, or high-level ground fault.

Circuit Breakers

A circuit breaker is one kind of overcurrent protection device. It is a type of automatic switch located in a circuit. A circuit breaker trips when too much current passes through it. A circuit breaker should not be used regularly to turn power on or off in a circuit, unless the breaker is designed for this purpose and marked "SWD" (stands for "switching device").

Fuses

A fuse is another type of overcurrent protection device. A fuse contains a metal conductor that has a relatively low melting point. When too much current passes through the metal in the fuse, it heats up within a fraction of a second and melts, opening the circuit. After an overload is found and corrected, a blown fuse must be replaced with a new one of appropriate amperage.
Not Allowed in Hazardous Environments

Overcurrent protection devices are not allowed in areas where they could be exposed to physical damage or in hazardous environments. Overcurrent protection devices can heat up and occasionally arc or spark, which could cause a fire or an explosion in certain areas. Hazardous environments are places that contain:

- flammable or explosive materials such as flammable gasses or vapors (Class I Hazardous Environments),
- finely pulverized flammable dusts (Class II Hazardous Environments), or
- fibers or metal filings that can catch fire easily (Class III Hazardous Environments).

11. What type of overcurrent protection device contains a metal conductor that melts when too much current passes through the metal?

   a. Circuit breakers
   b. Fuses
   c. Capacitors
   d. Resistors
Module 8: Working on Live Circuits

When You Must Work on or Near Live Circuits

When you must work on or near live circuits means actually touching energized parts. Working near live circuits means working close enough to energized parts to put you at risk even though you may be working on de-energized parts.

Common tasks where you need to work on or near live circuits include:

- taking voltage and current measurements,
- opening and closing disconnects and circuit breakers,
- racking circuit breakers on and off the bus,
- removing panels and dead fronts, and
- opening electric equipment doors for inspection.

There should be standard written procedures and training for these common tasks. For instance, when opening and closing disconnects, use the left-hand rule when possible (stand to the right side of equipment with a disconnect on the right, and operate the disconnect with your left hand). For other situations where you might need to work on or near live circuits, your employer should institute a written live-work permit system, which must be authorized by a qualified supervisor.

1. Taking voltage and current measurements is an example of _____.
   a. working on locked-out circuits
   b. working near live circuits
   c. working on deenergized circuits
   d. work near locked-out circuits

Case Study

A 40-year-old male meter technician had just completed a 7-week basic lineman training course. He worked as a meter technician during normal working hours and as a lineman during unplanned outages. One evening, he was called to repair a residential power outage. By the
time he arrived at the site of the outage, he had already worked 2 hours of overtime and worked 14 straight hours the day before. At the site, a tree limb had fallen across an overhead powerline. The neutral wire in the line was severed, and the two energized 120-volt wires were disconnected. The worker removed the tree limb and climbed up a power pole to reconnect the three wires. He was wearing insulated gloves, a hard hat, and some safety goggles.

He prepared the wires to be connected. While handling the wires, one of the energized wires caught the cuff of his left glove and pulled the cuff down. The conductor contacted the victim’s forearm near the wrist. He was electrocuted and fell backwards. He was wearing a climbing belt, which left him hanging upside down from the pole. Paramedics arrived 5 minutes after the contact. The power company lowered his dead body 30 minutes later.

Several factors may have contributed to this incident. Below are some ways to eliminate these risk factors:

- Ask for assistance when you are assigned tasks that cannot be safely completed alone. The task assigned to the victim could not have been done safety by only one person.

- Do not work overtime performing hazardous tasks that are not part of your normal assignments.

- Employees should only be given tasks they are qualified to perform. All employees below the journeyman level should be supervised.

2. Employees below journeyman level that are assigned to perform hazardous electrical tasks _____.

   a. should be properly supervised
   b. must check in every 15 minutes
   c. may work alone if allowed
   d. may work overtime a maximum of two hours
**Live-work permit system**

A live-work permit should, at least, contain this information:

- a description of the circuit and equipment to be worked on and the location,
- explanation why the work must be done "live"
- date and time covered by the permit
- a description of the safe work practices to be used
- results of shock hazard analysis and determination of shock protection boundaries
- results of flash hazard analysis and determination of the flash protection boundary
- PPE needed to safely perform the job
- who will do the work and how unqualified persons will be kept away
- evidence of completion of job briefing, including discussion of job-specific hazards
- energized-work approval signatures (authorizing or approving management, safety officer, owner, etc.)

3. For situations where you may need to work on or near live circuits, your employer should _____.
   
   a. make sure employees perform full lockout/tagout procedures
   b. ensure the local electrical company is notified
   c. institute a written live-work permit system
   d. authorize ensure a safety manager approves the task
Case Study

A company was contracted to install wiring and fixtures in a new office complex. The third floor was being prepared in a hurry for a new tenant, and daily changes to the electrical system blueprints were arriving by fax. The light fixtures in the office were mounted in a metal grid that was fastened to the ceiling and properly grounded.

A 23-year-old man apprentice electrician was working on a light fixture when he contacted an energized conductor. He came down from the fiberglass ladder and collapsed. Apparently, he had contacted the “hot” conductor while also in contact with the metal grid. Current passed through his body and into the grounded grid. Current always takes a path to the ground. In this case, the worker was part of that path.

He was dead on arrival at a nearby hospital. Later, an investigation showed the victim had cross-wired the conductors in the fixture by mistake. This incorrect wiring allowed electricity to flow from the live circuit on the completed section of the building to the circuit on which the victim was working.

Below are some safety procedures that should have been followed in this case. Because they were ignored, the job ended in death.

- Before work beings, all circuits in the immediate work area must be shut off, locked out, and tagged out- then tested to confirm they are de-energized.

- Wiring done by apprentice electricians should be checked by a journeyman.

- Supervisors should always review changes to an original blueprint in order to identify any new hazards the changes might create.
4. Wiring done by apprentice electricians should _____.
   a. follow written installation procedures
   b. be checked by a journeyman
   c. be reviewed by a coworker
   d. documented using a wiring permit

Safe Work Practices

To work on or near live parts, you must do the following:

- Have a written live-work permit for the work to be done.

- Wear the right PPE to protect against electric shock and arc flash. Never wear clothing made from synthetic materials, such as acetate, nylon, polyester, polypropylene, or rayon - alone or combined with cotton. Such clothing is dangerous because it can burn and melt into your skin.

The PPE that is needed depends on the type of electric work being done. The minimum PPE required while working on live circuits would be an untreated natural fiber long-sleeve shirt and long pants plus safety glasses with side shields. Depending on the voltage and the electric task to be done, different types of PPE are required. Fire-resistant protective clothing can include multi-layer flash suit jacket and pants, wraparound face shield, double-layer switching hood, voltage-rated gloves with leather protectors, electrically rated hard hats, and so forth. [(See Table 130.7(C)(15)(A)(b) Arc-Flash Hazard PPE Categories for A/C systems, Table 130.7(C)(15)(B) Arc-Flash Hazard PPE Categories for D/C Systems, and Table 130.7(C)(16) Personal Protective Equipment (PPE)) NFPA 70E, 2015 Edition]

- Use the proper type of protective equipment, such as insulated tools and/or handling equipment that is rated for the voltage. These can include insulated fuse or fuse holding equipment, nonconductive ropes and handlines, fiberglass-reinforced plastic rods, nonconductive portable ladders (such as, fiberglass), protective shields, rubber insulating equipment, voltage-rated plastic guards, and so forth.
5. Synthetic clothing is dangerous when working on live parts because _____.
   a. synthetics can conduct electrical energy
   b. it can cause overheating, sweating and shock
   c. it can burn and melt into your skin
   d. synthetics do not adequately insulate the worker

Case Study

A lineman (the victim) was killed after contacting a 17,400-volt charge switch. The victim was part of a three-man crew replacing cables under a switch cabinet. At the time of the accident, the crew was feeding a new cable under the concrete foundation pad below the cabinet. As one worker pushed the cable under the foundation, the victim looped the cable inside the foundation under the cabinet. The victim was using a hot stick to loop the cable but was not wearing his hard hat when his head came either in close proximity to or contacted the charged switch. Crewmembers saw a flash and came around the switch cabinet to where the victim was located. He was found slumped partially in the cabinet. A crewmember used a hot stick to move the victim away from the cabinet and then began CPR. Emergency medical services transported the victim to a nearby hospital where he was declared dead from injuries associated with high-voltage electrocution.

Based on the findings in the investigation, to prevent similar incidents, employers should:

- Ensure workers use personal protective equipment and enforce its use.
- Ensure workers are capable of recognizing and avoiding hazardous situations.
- Emphasize de-energizing, isolating, or cover energized work areas whenever personnel need to work within high voltage danger zones.
6. When personnel need to work within high voltage danger zones, it important to do all of the following EXCEPT _____.

   a. isolating high voltage equipment and circuits
   b. covering energized work areas
   c. properly de-energizing high-voltage equipment
   d. wearing lifelines to remove injured workers
Module 9: Safe Work Practices

How Do You Work Safely?

A safe work environment is not enough to control all electrical hazards. You must also work safely. Safe work practices help you control your risk of injury or death from workplace hazards. If you are working on electrical circuits or with electrical tools and equipment, you need to use safe work practices.

Before you begin a task, ask yourself:

- What could go wrong?
- Do I have the knowledge, tools, and experience to do this work safely?

All workers should be very familiar with the safety procedures for their jobs. You must know how to use specific controls that help keep you safe. You must also use good sense.

Note: So, why did we strike through "common sense" above? That's because there's no such thing as common sense! We harp on this all the time. You've got to use good sense, and in order to do that, you need to be educated, trained, and experienced. There is no way to get around it. Do not assume anyone has common sense: That will get you in trouble and possibly hurt.

Control electrical hazards through safe work practices.

- Plan your work and plan for safety.
- Avoid wet working conditions and other dangers.
- Avoid overhead powerlines.
- Use proper wiring and connectors.
- Use and maintain tools properly.
- Wear correct PPE.
1. For accidents to occur _____ must interact with _____.
   a. unsafe actions, existing conditions
   b. hazardous conditions, unsafe behaviors
   c. people, unsafe situations
   d. unsafe conditions, lack of common sense

Plan Your Work and Plan for Safety

Take time to plan your work, by yourself and with others. Safety planning is an important part of any task. It takes effort to recognize, evaluate, and control hazards. If you are thinking about your work tasks or about what others think of you, it is hard to take the time to plan for safety. But, YOU MUST PLAN.

Planning with others is especially helpful. It allows you to coordinate your work and take advantage of what others know about identifying and controlling hazards. The following is a list of some things to think about as you plan.

- Work with a buddy-Do not work alone. Both of you should be trained in CPR. Both of you must know what to do in an emergency.

- Know how to shut off and de-energize circuits-You must find where circuit breakers, fuses, and switches are located. Then, the circuits that you will be working on (even low-voltage circuits) MUST BE TURNED OFF! Test the circuits before beginning work to make sure they are completely de-energized.

- Plan to lock out and tag out circuits and equipment - Make certain all energy sources are locked out and tagged out before performing any work on an electrical circuit or electrical device. Working on energized ("hot") circuits is one of the most dangerous things any worker could do. If someone turns on a circuit without warning, you can be shocked, burned, or electrocuted. The unexpected starting of electrical equipment can cause severe injury or death.

Before ANY work is done on a circuit, shut off the circuit, lock out and tag out the circuit at the distribution panel, then test the circuit to make sure it is de-energized.

Before ANY equipment inspections or repairs-even on so-called low-voltage circuits-the current must be turned off at the switch box, and the switch must be padlocked in the OFF position. At the same time,
the equipment must be securely tagged to warn everyone that work is being performed. Again, test circuits and equipment to ensure they are de-energized.

No two locks should be alike. Each key should fit only one lock, and only one key should be issued to each worker. If more than one worker is working on a circuit or repairing a piece of equipment, each worker should lock out the switch with his or her own lock and never permit anyone else to remove it. At all times, you must be certain that you are not exposing other workers to danger. Workers who perform lock-out/tag-out must be trained and authorized to repair and maintain electrical equipment. A locked-out switch or feeder panel prevents others from turning on a circuit. The tag informs other workers of your action.

- Remove jewelry and metal objects - Remove jewelry and other metal objects or apparel from your body before beginning work. These things can cause burns if worn near high currents and can get caught as you work.

- Plan to avoid falls - Injuries can result from falling off scaffolding or ladders. Other workers may also be injured from equipment and debris falling from scaffolding and ladders.

- DO not do any tasks that you are not trained to do or that you do not feel comfortable doing!

2. When working on electrical circuits, even low-voltage circuits, the circuits must be

   - de-energized
   a. turned on
   b. tagged
   c. energized

Case Study

A crew of 7 workers was painting a 33-foot sign at a shopping mall. The crew used tubular welded frame scaffolding that was 31 feet tall and made up of several tiers. The sign was partially painted when the crew was instructed to move the scaffolding so the concrete could be poured for an access road. The crew moved the scaffolding 30 feet without disassembling it. An overhead powerline was located about 10 feet away from the scaffolding. After the concrete was hardened, the workers lifted the scaffolding to move it back to the sign. The top
tier came loose, fell, and contacted the powerline. All seven workers were knocked away from the scaffolding. Two died; five were hospitalized.

You must take certain precautions when working with scaffolding.

- Scaffolding should not be moved until all potential safety hazards are identified and controlled. In this case, the scaffolding should have taken apart before it was moved.

- Locking pins must be used to secure tiers to one another.

- Always make sure you have enough time to complete your assignment safely. If you are rushed, you may be more likely to take deadly shortcuts. (such as failing to dismantle scaffolding before moving it)

- Employers must have a written safety program that includes safe work procedures and hazard recognition.

3. Unless you are authorized to work on energized circuits, you must do each of the following prior to working on electrical circuits EXCEPT _____.

   a. shut off the circuit
   a. lock/tag out the circuit as required
   b. check the circuit's drawing (schematic)
   c. test the circuit to make sure it's dead

**Overhead and Underground Powerlines**

**Overhead Powerlines**

Be very careful not to contact overhead powerlines or other exposed wires. More than half of all electrocutions are caused by contact with overhead lines. When working in an elevated position near overhead lines, avoid locations where you (and any conductive object you hold) could contact an unguarded or uninsulated line. You should be at least 10 feet (3.05 meters) away from high-voltage transmission lines.
Vehicle operators should also pay attention to overhead wiring. Dump trucks, front-end loaders, and cranes can lift and make contact with overhead lines. If you contact equipment that is touching live wires, you will be shocked and may be killed. If you are in the vehicle, stay inside. Always be aware of what is going on around you.

**Underground Powerlines**

Underground powerlines present a different set of hazards. Workers digging with heavy equipment or using power tools are injured most frequently by inadvertent exposure to live underground powerlines. Be sure that you call the local utility company to submit a "locate request" before digging. The federally-regulated *call before you dig* number is 811. Locate crews will mark your dig site within a few days so that you know where to avoid digging. Always dig around the marks/flags, not on them.

<table>
<thead>
<tr>
<th>4. When performing hoisting operations, keep at least _____ away from high-voltage transmission lines.</th>
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</thead>
<tbody>
<tr>
<td>a. 3 feet</td>
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<tr>
<td>b. 10 feet</td>
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<tr>
<td>c. 12 feet</td>
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<tr>
<td>d. 20 feet</td>
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**Use Proper Wiring and Connectors**

- Avoid overloads - Do not overload circuits.
- Test GFCI's - Test GFCI's monthly using the "test" button.
- Check switches and insulation - Tools and other equipment must operate properly. Make sure that switches and insulating parts are in good condition.
- Use three-prong plugs - Never use a three-prong grounding plug with the third prong broken-off. When using tools that require a third-wire ground, use only three-wire extension cords with three-prong grounding plugs and three-hole electrical out-lets. Never remove the grounding prong from a plug! You could be shocked or expose someone else to a hazard. If you see a cord without a grounding prong in the plug, remove the cord from service immediately.
Use extension cords properly - If an extension cord must be used, choose one with sufficient ampacity for the tool being used. An undersized cord can overheat and cause a drop-in voltage and tool power. Check the tool manufacturer's recommendations for the required wire gauge and cord length. Make sure the insulation is intact. To reduce the risk of damage to a cord's insulation, use cords with insulation marked "S" (hard service) rather than cords marked "SJ" (junior hard service). Make sure the grounding prong is intact. In damp locations, make sure wires and connectors are waterproof and approved for such locations. Do not create a tripping hazard.

5. What should you do if you see an extension cord with the ground prong missing?
   a. Connect it only to two-prong outlets
   b. Stick another prong into the plug and continue using it
   c. Remove the extension cord from service
   d. Nothing, it's not a hazard if the prong is missing

Use the following best practices when working with wiring and connectors:

- Check power cords and extensions - Electrical cords should be inspected regularly using the following procedure:
  1. Remove the cord from the electrical power source before inspecting.
  2. Make sure the grounding prong is present in the plug.
  3. Make sure the plug and receptacle are not damaged.
  4. Wipe the cord clean with a diluted detergent and examine for cuts, breaks, abrasions, and defects in the insulation.
  5. Coil or hang the cord for storage. Do not use any other methods. Coiling or hanging is the best way to avoid tight kinks, cuts, and scrapes that can damage insulation or conductors.

- You should also test electrical cords regularly for ground continuity using a continuity tester as follows:
  1. Connect one lead of the tester to the ground prong at one end of the cord.
2. Connect the second lead to the ground wire hole at the other end of the cord.

3. If the tester lights up or beeps (depending on design), the cord's ground wire is okay. If not, the cord is damaged and should not be used.

- Do not pull on cords - Always disconnect a cord by the plug.

- Use correct connectors - Use electrical plugs and receptacles that are right for your current and voltage needs. Connectors are designed for specific currents and voltages so that only matching plugs and receptacles will fit together. This safeguard prevents a piece of equipment, a cord, and a power source with different voltage and current requirements from being plugged together. Standard configurations for plugs and receptacles have been established by the National Electric Manufacturers Association (NEMA).

6. Which of the following is a safe work practice when using electrical wiring and connectors?

   a. Inspect the cord while energized to ensure continuity
   b. If the ground prong is missing, insert a new one
   c. Never coil or hang cords for storage
   d. Always disconnect a cord by the plug

**Use and Maintain Tools Properly**

Hand and power tools are a common part of our everyday lives and are present in nearly every industry. These tools help us to easily perform tasks that otherwise would be difficult or impossible. However, these simple tools can be hazardous and have the potential for causing severe injuries when used or maintained improperly. Special attention toward hand and power tool safety is necessary in order to reduce or eliminate these hazards.

Your tools are at the heart of your craft. Tools help you do your job with a high degree of quality. Tools can do something else, too. They can cause injury or even death! You must use the right tools for the job. Proper maintenance of tools and other equipment is very important. Inadequate maintenance can cause equipment to deteriorate, creating dangerous conditions. You must take care of your tools so they can help you and not hurt you.
• Inspect tools before using them - Check for cracked casings, dents, missing or broken parts, and contamination (oil, moisture, dirt, corrosion). Damaged tools must be removed from service and properly tagged. These tools should not be used until they are repaired and tested.

• Use the right tool correctly - Use tools correctly and for their intended purposes. Follow the safety instructions and operating procedures recommended by the manufacturer. When working on a circuit, use approved tools with insulated handles.

Note: DO NOT USE THESE TOOLS TO WORK ON ENERGIZED CIRCUITS. ALWAYS SHUT OFF AND DE-ENERGIZE CIRCUITS BEFORE BEGINNING WORK ON THEM.

• Protect your tools - Keep tools and cords away from heat, oil, and sharp objects. These hazards can damage insulation. If a tool or cord heats up, stop using it! Report the condition to a supervisor or instructor immediately. If equipment has been repaired, make sure that it has been tested and certified as safe before using it. Never carry a tool by the cord. Disconnect cords by pulling the plug-not the cord!

• Use double-insulated tools - Portable electrical tools are classified by the number of insulation barriers between the electrical conductors in the tool and the worker. The NEC permits the use of portable tools only if they have been approved by Underwriter's Laboratories (UL Listed). Equipment that has two insulation barriers and no exposed metal parts is called double-insulated. When used properly, double-insulated tools provide reliable shock protection without the need for a third ground wire. Power tools with metal housings or only one layer of effective insulation must have a third ground wire and three-prong plug.

• Use multiple safe practices - Remember: A circuit may not be wired correctly. Wires may contact other "hot" circuits. Someone else may do something to place you in danger. Take all possible precautions.
7. When used properly, double-insulated tools provide reliable shock protection without the need for a _____.

a. third ground wire  
b. lockout device  
c. GFCI  
d. insulation test

**Be Sure Neutral Wires Are Not Open**

An open neutral is the most dangerous and unknown hazard a worker can encounter when it's line is not de-energized. It’s important to understand that in a 3-phase electrical system, all three phases must be verified as de-energized or there may be the potential for a shock. The neutral circuit wire (usually white) is grounded but is under a load and the source of the neutral current cannot always be identified.

If a grounded (neutral) service conductor which serves as the effective ground-fault current path is opened, a ground fault cannot be cleared and the metal parts of electrical equipment, as well as metal piping and structure steel will become and remain energized providing the potential for electric shock.

Potential hazards include:

- Breaking a neutral under load can create a shock hazard.
- Workers contacting a lifted neutral potentially provide an alternative path to ground.
- A broken neutral of lifted neutral can result in a shock or an arc.

For instance, in 2005 a worker received a shock after lifting a neutral from its bus bar. The neutral received its power through an emergency light that received power from another distribution panel.
Case Study

An employee was climbing a metal ladder to hand an electrical drill to the journeyman installer on a scaffold about 5 feet above him. When the victim reached the third rung of the ladder, he received an electrical shock that killed him. An investigation showed the grounding prong was missing from the extension cord attached to the drill. Also, the cord’s green grounding wire was, at times, contacting the energized black wire. Because of this contact with the “hot” wire, the entire length of the grounding wire and the drill’s frame became energized. The drill was not double-insulated.

To avoid deadly incidents like this one, take these precautions:

- Make certain that approved GFCI’s or equipment grounding systems are used at construction sites.
- Use equipment that provides a permanent and continuous path to ground. Any fault current will be safely diverted along this path.
- Inspect electrical tools and equipment daily and remove damaged or defective equipment from use right away.

8. If you see a loose white wire on an energized circuit, what does it mean?
   a. A possible short circuit of the hot wire: possible problem
   b. An open neutral wire: could be very dangerous
   c. An open ground wire: not a problem
   d. It's a one phase circuit: not a problem

Wear Correct PPE

OSHA requires that you be provided with personal protective equipment. This equipment must meet OSHA requirements and be appropriate for the parts of the body that need protection and the work performed. There are many types of PPE: rubber gloves, insulating shoes and boots, face shields, safety glasses, hard hats, etc. Even if laws did not exist requiring the use of PPE, there would still be every
reason to use this equipment. PPE helps keep you safe. It is the last line of defense between you and the hazard.

- Wear safety glasses - Wear safety glasses to avoid eye injury.

- Wear proper clothing - Wear clothing that is neither floppy nor too tight. Loose clothing will catch on corners and rough surfaces. Clothing that binds is uncomfortable and distracting.

- Contain and secure loose hair - Wear your hair in such a way that it does not interfere with your work or safety.

- Wear proper foot protection - Wear shoes or boots that have been approved for electrical work. (Tennis shoes will not protect you from electrical hazards.) If there are non-electrical hazards present (nails on the floor, heavy objects, etc.), use footwear that is approved to protect against these hazards as well.

- Wear a hard hat - Wear the proper class of hard hat to protect your head from bumps, falling objects and electrical hazards. Hard hats should be worn with the bill forward to protect you properly.

- Wear hearing protectors - Wear hearing protectors in noisy areas to prevent hearing loss.

- Follow directions - Follow the manufacturer's directions for cleaning and maintaining PPE.

- Make an effort - Search out and use any and all equipment that will protect you from shocks and other injuries.

9. **Which of the following is considered electrical protective equipment?**

   a. R23 hearing protection  
   b. Class C Hard hat  
   c. Rubber insulating gloves  
   d. UL-approved safety glasses
Module 10: Electrical Protective Equipment

Electrical Personal Protective Equipment (PPE)

Employees working in areas where there are potential electrical hazards must be provided with, and use, electrical protective equipment that is appropriate for the specific parts of the body protected and for the work performed. Personal Protective Equipment refers to items typically worn by a worker to provide protection from recognized hazards. PPE for the electric power industry generally includes:

- safety glasses,
- face shields,
- hard hats,
- safety shoes,
- insulating (rubber) gloves with leather protectors,
- insulating sleeves, and
- flame-resistant (FR) clothing.

To prevent injury from exposure to electrical conductors, it’s important that all electrical protective equipment be maintained in a safe and reliable condition. All electrical protective equipment made of rubber should meet the established safety standards and specifications discussed in the next few sections.

1. Electrical Personal Protective Equipment (PPE) includes all of the following EXCEPT ________.
   a. rubber blankets  
   b. safety shoes  
   c. face shields  
   d. hard hats
**Electrical Protective Gloves**

Protector gloves must be worn over insulating gloves. An exception is when using Class 0 gloves, under limited-use conditions, where small equipment and parts manipulation necessitate unusually high finger dexterity. But, it's important to note that extra care must be taken while visually examining the glove. Also, make sure to avoid handling sharp objects.

Any other class of glove may be used for similar work without protector gloves if the employer can demonstrate that the possibility of physical damage to the gloves is small and if the class of glove is one class higher than that required for the voltage involved. Insulating gloves that have been used without protector gloves may not be used at a higher voltage until they have been tested.

2. While wearing electrical protective gloves make sure to avoid handling _____.
   a. dull objects
   b. sharp objects
   c. electrical equipment
   d. power tools

**Insulating Protective Equipment (IPE)**

Electric power workers working on high voltage circuits (600 V and above) often use Insulating Protective Equipment (IPE). Since IPE is not worn, it is technically not considered to be electrical PPE.

To prevent injury from exposure to electrical conductors, it's important that all IPE be maintained in a safe and reliable condition. IPE includes the following:

- line hoses,
- rubber hoods,
- rubber blankets, and
- insulating live-line tools (for example, hotsticks, switchsticks, or shotgun sticks) for protection.
3. Insulating Protective Equipment (IPE) includes all of the following EXCEPT _____.

   a. hot sticks
   b. rubber gloves
   c. rubber blankets
   d. line hoses

Inspecting Equipment

To make sure electrical protective equipment actually performs as designed, it must be inspected for damage at the following times:

1. before each day’s use, and

2. immediately following any incident that can reasonably be suspected of having caused damage.

Insulating gloves must be given an air test, along with the inspection.

Defects

Insulating equipment must not be used if any of the following defects are detected:

- a hole, tear, puncture, or cut;

- ozone cutting or ozone checking (the cutting action produced by ozone on rubber under mechanical stress into a series of interlacing cracks);

- an embedded foreign object;

- changes in the texture including, swelling, softening, hardening, or becoming sticky or inelastic; or

- any other defect that damages the insulating properties.

Insulating equipment found to have other defects that might affect its insulating properties must be removed from service and returned for testing. It must be cleaned as needed to remove foreign substances. It must be stored in such a location and in such a manner to protect it from:
• light;
• temperature extremes;
• excessive humidity;
• ozone; and
• other injurious substances and conditions.

4. To make sure electrical protective equipment actually performs as designed, it must be inspected for damage _____.

   a. prior to the beginning of a work shift and monthly
   b. before each use and quarterly thereafter
   c. monthly and following any incident causing damage
   d. before each day's use and when damage is suspected

**Testing**

Rubber insulating equipment is tested for maximum intervals between electrical testing according the schedule below:

**Rubber Insulating Equipment and When to Test**

- **Rubber insulating line hose** - Upon indication that insulating value is suspect and after repair.
- **Rubber insulating covers** - Upon indication that insulating value is suspect and after repair.
- **Rubber insulating blankets** - Before first issue and every 12 months thereafter\(^1\) upon indication that insulating value is suspect; and after repair.
- **Rubber insulating gloves** - Before first issue and every 6 months thereafter\(^1\) upon indication that insulating value is suspect; after repair; and after use without protectors.
- **Rubber insulating sleeves** - Before first issue and every 12 months thereafter\(^1\) upon indication that insulating value is suspect; and after repair.
Footnote (1): If the insulating equipment has been electrically tested but not issued for service, it may not be placed into service unless it has been electrically tested within the previous 12 months.

The test method used must reliably indicate whether the insulating equipment can withstand the voltages involved. Repaired insulating equipment must be retested before it may be used by employees.

**Certification**

The employer must certify that equipment has been tested in accordance with the requirements of the standard, and the certification must identify the equipment that passed the test and the date it was tested.

Marking equipment and entering the results of the tests and the testing dates onto logs are two acceptable ways to meet this requirement.

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5. When must all rubber insulating gloves be tested?

- a. Before first issue and every 12 months thereafter
- b. Upon indication that insulating value is suspect
- c. Before first issue and every 6 months thereafter
- d. Before first issue and after repair

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**General Electrical Protective Equipment and tools**

**Tools and handling equipment.** When working near exposed energized conductors or circuit parts, use insulated tools or handling equipment if the tools or handling equipment might make contact with such conductors or parts. If the insulating capability of insulated tools or handling equipment is subject to damage, protect the insulating material.

**Fuse handling equipment.** Use fuse handling equipment, insulated for the circuit voltage, to remove or install fuses when the fuse terminals are energized.

**Ropes and landlines.** Make sure ropes and handlines used near exposed energized parts are nonconductive.

**Shields, barriers, and materials.** Use protective shields, protective barriers, or insulating materials to protect employees from shock, burns, or other electrically related injuries while they are working near exposed energized parts which might be contacted or where dangerous electric heating or arcing might
occur. When normally enclosed live parts are exposed for maintenance or repair, guard them to protect unqualified persons from contact with the live parts.

**Alerting techniques.** The following alerting techniques shall be used to warn and protect employees from hazards which could cause injury due to electric shock, burns, or failure of electric equipment parts:

- **Safety signs and tags.** Safety signs, safety symbols, or accident prevention tags shall be used where necessary to warn employees about electrical hazards which may endanger them, as required by 1910.145.

- **Barricades.** Barricades shall be used in conjunction with safety signs where it is necessary to prevent or limit employee access to work areas exposing employees to uninsulated energized conductors or circuit parts. Conductive barricades may not be used where they might cause an electrical contact hazard.

- **Attendants.** If signs and barricades do not provide sufficient warning and protection from electrical hazards, an attendant shall be stationed to warn and protect employees.

6. If signs and barricades do not provide sufficient warning and protection from electrical hazards, what alerting technique must be used?

   a. Orange cones
   b. Work schedules
   c. Announcements
   d. Attendants