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FRANK D. PETRUZELLA

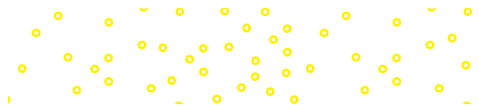
THIRD EDITION

ELECTRICITY

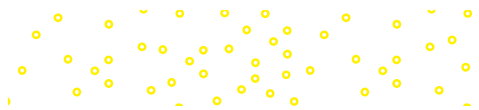
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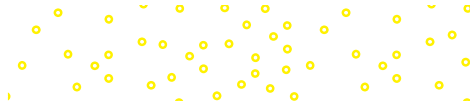


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Electricity for the Trades

Frank D. Petruzella

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ELECTRICITY FOR THE TRADES

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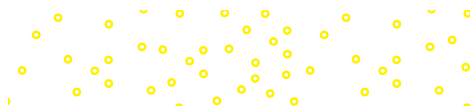
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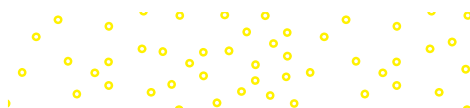
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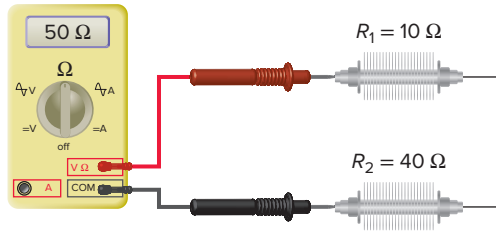
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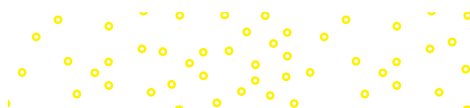


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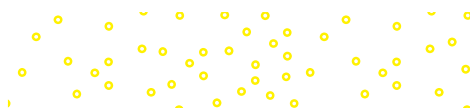
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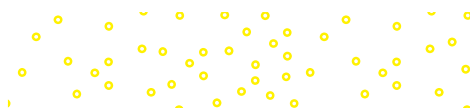
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*Appendix: Multisim Simulation
Lab Manual AP-1*

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The third edition of *Electricity for the Trades* focuses on the understanding of topics required for careers in the electrical industry and associated disciplines. The main objective of this text is to explain, **as simply as possible**, the electrical theory and its applications to related electrical circuits and products.

The textbook is divided into four sections:

Section 1 **Fundamentals of Electricity**

Section 2 **Direct Current (DC) Circuits**

Section 3 **Alternating Current (AC) Circuits**

Section 4 **Electrical Installation and Maintenance**

The organization of the text is designed to distinguish between the major areas of study in order to enhance the text's usability. Each section or combination of sections is available in both **eBook** and customized **McGraw-Hill Create** formats to meet more specific curriculum needs.

In this edition, **all chapters** have been enhanced, as requested by instructors, to provide up-to-date relevant subject matter. Most notable are the **new topics**, which include three-wire circuits, protection relays, DC motor control, and digital logic circuits. The text continues to use:

- **Boldface** fonts to highlight important points.
- **Bulleted** lists to summarize circuit operations.
- Schematic representations of circuits accompanied by **photos** of the devices being studied to increase the student's level of recognition of different electrical devices.

New to this edition is the **Simulation Lab Manual** that accompanies the text. Available through **McGraw-Hill Connect**, it features more than **250 Multisim** simulated lab exercises integrated into each chapter of the text. Features of this new concept of experimental labs assignments include:

- Each Multisim circuit file comes complete with **on-screen** detailed instructions for carrying out circuit simulation problems and exercises.
- All lab components have been **preselected** and with their required values requiring a **minimum of setup**. Students spend more time experimenting

rather than selecting, dragging, and assigning values to components.

- On-screen **formulas and graphics** from the text are designed to integrate the material covered in the text with the simulation assignment.

The lab assignments may require students to:

- Correctly connect and take measurements using a simulated voltmeter, ammeter, ohmmeter, digital multimeter, wattmeter, and oscilloscope.
- Properly record measured data.
- Calculate expected circuit values.
- Troubleshoot components and circuits.
- Modify circuit requirements.

For this edition, Multisim labs have been created to operate using National Instruments' **NI Multisim Student Edition Version 12** or higher.

Note: Multisim software must be purchased separately.

Chapter Changes to This Edition

Chapter 1

- Extended coverage of the National Electrical Code.
- Additional test bank questions.
- Additional chapter review questions.
- New and modified line diagrams and photos.

Chapter 2

- New section on the basic concepts of voltage, current, and resistance.
- Additional test bank questions.
- Additional chapter review questions.
- New and modified line diagrams and photos.

Chapter 3

- Coverage of static electric shock.
- Additional test bank questions.
- Additional chapter review questions.
- New and modified line diagrams and photos.

Chapter 4

- Extended coverage of relationship between the coulomb and the ampere.
- Additional test bank questions.
- Additional chapter review question.
- New and modified line diagrams and photos.

Chapter 5

- New section on short and open circuit faults.
- Additional test bank questions.
- Additional chapter review questions.
- New and modified line diagrams and photos.

Chapter 6

- Extended coverage of digital multimeter measurements.
- Additional test bank questions.
- Additional chapter review questions.
- New and modified line diagrams and photos.

Chapter 7

- Extended coverage of Ohm's law calculations.
- Additional test bank questions.
- Additional chapter review questions.
- New and modified line diagrams and photos.

Chapter 8

- Coverage of alphanumeric resistor code.
- Extended coverage of resistor connections.
- Additional test bank questions.
- Additional chapter review questions.
- New and modified line diagrams and photos.

Chapter 9

- New section on electromagnetic induction.
- Additional test bank questions.
- Additional chapter review questions.
- New and modified line diagrams and photos.

Chapter 10

- New coverage of pumped storage hydroelectric plant.
- Additional test bank questions.
- Additional chapter review questions.
- New and modified line diagrams and photos.

Chapter 11

- Extended coverage of series circuit troubleshooting problems.
- Additional test bank questions.

- Additional chapter review questions.
- New and modified line diagrams and photos.

Chapter 12

- Extended coverage of parallel circuit troubleshooting problems.
- Additional test bank questions.
- Additional chapter review questions.
- New and modified line diagrams and photos.

Chapter 13

- New section on three-wire circuits.
- Additional test bank questions.
- Additional chapter review questions.
- New and modified line diagrams and photos.

Chapter 14

- Additional test bank questions.
- New and modified line diagrams and photos.

Chapter 15

- New coverage of eddy currents and the skin effect.
- Additional coverage of alternator synchronization.
- Additional test bank questions.
- Additional chapter review questions.
- New and modified line diagrams and photos.

Chapter 16

- Additional coverage of Inductors.
- Additional coverage of AC resistive circuits.
- Additional coverage of energy storage versus energy dissipation.
- Additional test bank questions.
- Additional chapter review questions.
- New and modified line diagrams and photos.

Chapter 17

- Additional coverage of inductance.
- Additional coverage of capacitance.
- Additional coverage of series RLC resonance.
- Additional test bank questions.
- Additional chapter review questions.
- New and modified line diagrams and photos.

Chapter 18

- Additional coverage of parallel RLC circuits.
- Additional solved example problems.
- Additional test bank questions.

- Additional chapter review questions.
- New and modified line diagrams and photos.

Chapter 19

- New coverage of the open delta connection.
- Additional coverage of transformer basics.
- Additional test bank questions.
- Additional chapter review questions.
- New and modified line diagrams and photos.

Chapter 20

- Additional coverage of conductor ampacity.
- New coverage of teck cable.
- Additional test bank questions.
- Additional chapter review questions.
- New and modified line diagrams and photos.

Chapter 21

- New section on load centers and circuit breakers.
- Additional coverage of special application circuit breakers.
- Additional test bank questions.
- Additional chapter review questions.
- New and modified line diagrams and photos.

Chapter 22

- New section on protective relays.
- Additional coverage of relay types and applications.

- Additional test bank questions.
- Additional chapter review questions.
- New and modified line diagrams and photos.

Chapter 23

- New coverage of the split receptacle and lighting control devices.
- Additional coverage of LED color light control.
- Additional test bank questions.
- Additional chapter review questions.
- New and modified line diagrams and photos.

Chapter 24

- New chapter title.
- Additional coverage of two-wire and three-wire control.
- New Part 4 coverage of direct current motors.
- Additional test bank questions.
- Additional chapter review questions.
- New and modified line diagrams and photos.

Chapter 25

- New coverage of operational amplifiers.
- New Part 3 coverage of digital logic circuits.
- Additional test bank questions.
- Additional chapter review questions.
- New and modified line diagrams and photos.

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Max Rabiee
University of Cincinnati

I would like to thank Don Pelster of Nashville State Community College, who edited the manuscript, Multisim lab assignments, Test Bank, PowerPoint slides, and created the Instructor's Guide. This textbook would not be possible without the hard work, talent, and thoughtfulness of the editors and reviewers, and I am truly grateful to have worked with you all!

Electricity for the Trades is a practical text for a basic course in electricity. Through clearly written chapters, it focuses on the information students need to be successful in the field. The content is easy to read and is supported by helpful examples, colorful diagrams and illustrations, and review problems that evaluate students' understanding of the material.

LEARNING OUTCOMES give students an idea of what to expect in the following pages and what they should be able to accomplish by the end of the chapter.

LEARNING OUTCOMES

- ▶ Identify the factors that determine the severity of an electric shock.
- ▶ Be aware of general principles of electrical safety including wearing approved protective clothing and using protective equipment.
- ▶ Familiarity with arc flash hazards recognition and prevention.
- ▶ Explain the safety aspect of grounding an electrical installation.
- ▶ Outline the typical steps involved in lockout and tagout procedures.
- ▶ Be aware of the functions of the different organizations responsible for electrical codes and standards.
- ▶ Understand how the National Electrical Code is organized by chapters and article.



DIAGRAMS AND PHOTOS increase the students' recognition of key devices and processes. Dozens of new photos have been added to make this edition more up to date.

EXAMPLES emphasize the importance of using a systematic, step-by-step approach to problem solving.

EXAMPLE 13-5

Conductors carry current from the power supply to the loads. A conductor should have as little resistance as possible for it to carry this current with minimal voltage drop and power loss. All conductors have resistance that in certain instances must be taken into consideration.

Problem: Determine the voltage across the loads, total power of the circuit, wasted power dissipated in the conductors, and the total power delivered to the loads, for the electrical distribution system of Figure 13-25.

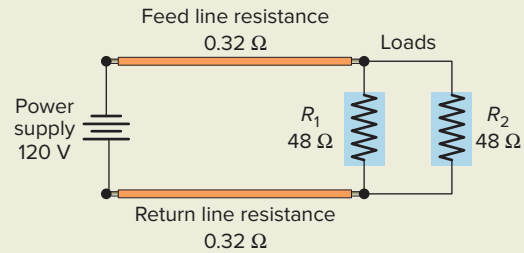


Figure 13-25 Circuit for example 13-5.

Step 1. Simplify the circuit, as shown in Figure 13-26, by representing the line wires as resistive loads.

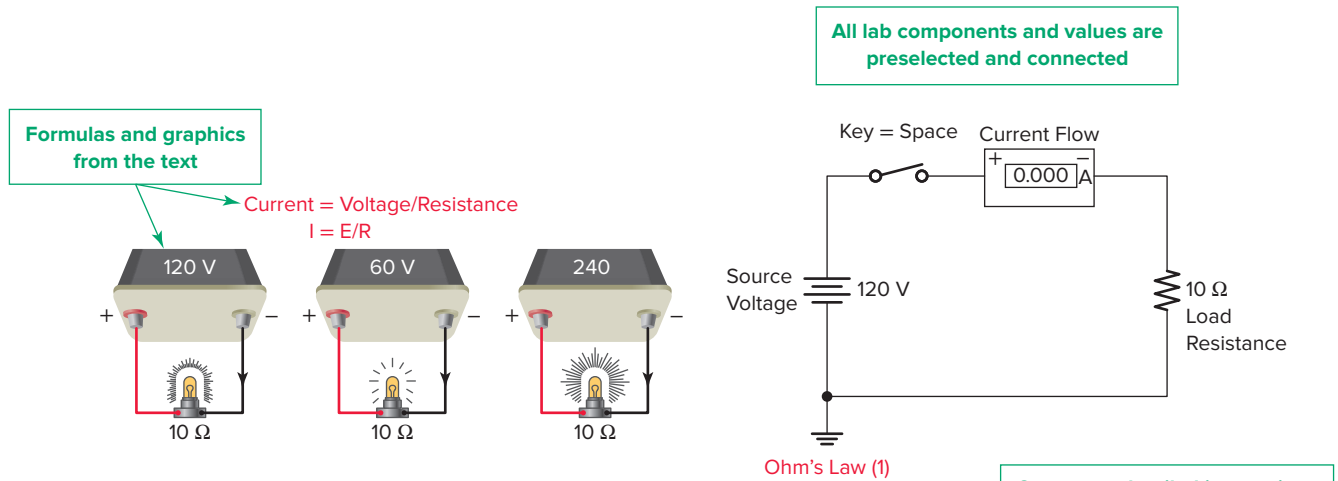
Part 2 Review Questions

1. What does the ampacity rating of a conductor specify?
2. List the factors taken into consideration when determining the ampacity rating of a conductor.
3. Why is a copper conductor rated at a higher ampacity than an aluminum conductor of equivalent gauge size or diameter?
4. State the effect (increase or decrease) of each of the following on the resistance value of a circuit conductor:
 - a. Increasing the length of the conductor.
 - b. Decreasing the diameter of the conductor.
 - c. Increasing the operating temperature of the conductor.
 - d. Using the same-size aluminum conductor in place of a copper one.
5.
 - a. What causes line voltage drop in a circuit?
 - b. Under what condition is the line voltage drop considered to be zero?
 - c. In what type of electrical installation must the resistance of the conductors be taken into account?

REVIEW QUESTIONS appear at the end of each part within each chapter. They test students' knowledge of the material as they read, helping them identify areas that may need further study.

The *Simulation Lab Manual for Electricity for the Trades*, third edition, contains 250 Multisim computer-simulated assignments. Each computer assignment comes

complete with detailed instructions contained within the Multisim circuit file. Instructors can meaningfully integrate these assignments into each chapter of the text.



ASSIGNMENT 4–6

- (a) Calculate the value of the current flow with 120 volts applied to the 10 Ω resistor.
- (b) Turn the simulation on and record the value of the current.
- (c) Calculate the value of the current flow if the source voltage is decreased to 60 volts.
- (d) Double-click on the source voltage icon and change its value to 60 volts. Turn the simulation on and record the value of the current.
- (e) Calculate the value of the current flow if the source voltage is increased to 240 volts.
- (f) Double-click on the source voltage icon and change its value to 240 volts. Turn the simulation on and record the value of the current.

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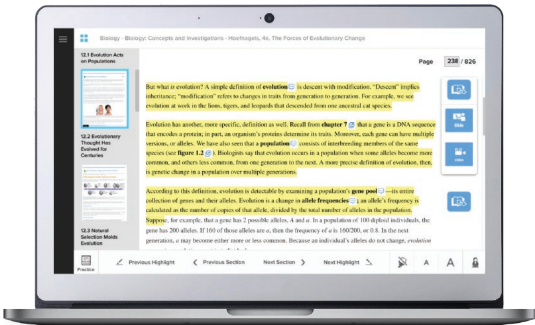
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Fundamentals of Electricity

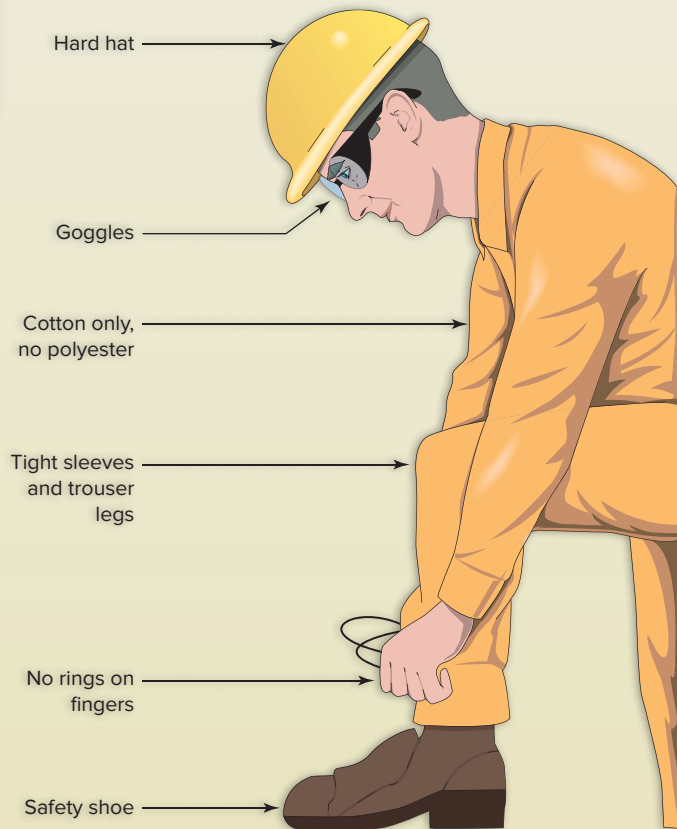
SECTION OUTLINE

- 1 Safety 2
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CHAPTER ONE

Safety

Appropriate attire should be worn for each particular job site.



LEARNING OUTCOMES

- ▶ Identify the factors that determine the severity of an electric shock.
- ▶ Be aware of general principles of electrical safety including wearing approved protective clothing and using protective equipment.
- ▶ Familiarity with arc flash hazards recognition and prevention.
- ▶ Explain the safety aspect of grounding an electrical installation.
- ▶ Outline the typical steps involved in lockout and tagout procedures.
- ▶ Be aware of the functions of the different organizations responsible for electrical codes and standards.
- ▶ Understand how the National Electrical Code is organized by chapters and article.

Safety is the number one priority in any job. Every year, electrical accidents cause serious injury or death. Many of these casualties are young people just entering the workplace. They are involved in accidents that result from carelessness, from the pressures and distractions of a new job, or from a lack of understanding about electricity. This chapter is designed to develop an awareness of the dangers associated with electric power and the potential dangers that can exist on the job or at a training facility.

1.1 Electric Shock

Electric shock occurs when the **body** becomes a part of the electric circuit. The current must enter the body at one point and leave at another. The main factor for determining the severity of an electric shock is the amount of electric **current** that passes through the body. This current is dependent upon the voltage and the resistance of the path it follows through the body.

Resistance (R) is the opposition to the flow of current in a circuit and is measured in **ohms (Ω)**. The lower the body resistance, the greater the current flow and potential electric shock hazard. Body resistance can be divided into external (skin resistance) and internal (body tissues and bloodstream resistance). Dry skin is a good insulator; moisture lowers the resistance of skin, which explains why shock intensity is greater when hands are wet. Internal resistance is low owing to the salt and moisture content of the blood. There is a wide degree of variation in body resistance. Typical body resistance values are:

- Dry skin—100,000 to 600,000 Ω
- Wet skin—1,000 Ω
- Internal body (hand to foot)—400 to 600 Ω
- Ear to ear—100 Ω

Voltage (E) is the pressure that causes the flow of electric current in a circuit and is measured in units called **volts (V)**. The amount of voltage that is dangerous to life varies with each individual because of differences in body resistance and heart conditions. *Generally, any voltage above 30 volts is considered dangerous.*

Current (I) is the rate of flow of electricity and is measured in **amperes (A)** or **milliamperes (mA)**. A milliampere is equal to one-thousandth (1/1000) of an ampere, or 0.001 A. In other words it takes 1,000 milliamperes to equal 1 ampere. The amount of current flowing through a person's body depends on the voltage and resistance. Current flow can be calculated using the following Ohm's law formula:

$$\text{Current } (I) = \frac{\text{Voltage } (E)}{\text{Resistance } (R)}$$

Voltage is not as reliable an indication of shock intensity because the body's resistance varies so widely that it is impossible to predict how much current will result from a given voltage. The three most reliable criteria of shock intensity are:

- Amount of current flowing through the body.
- Path of the current through the body.
- Length of time the body is in the circuit.

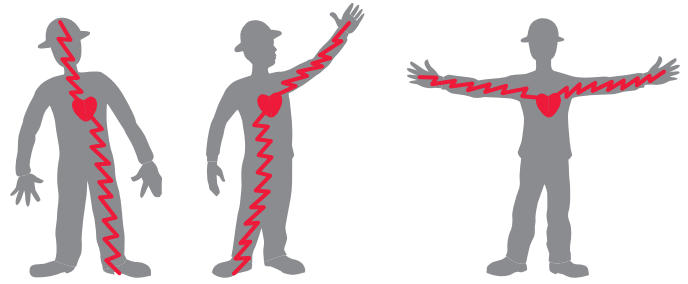


Figure 1-1 Pathways that can stop normal pumping of the heart.

Although it is not known the exact injuries that result from any given amperage, it doesn't take much current to cause a painful or even fatal shock. A current of 1 mA (1/1000 of an ampere) can be felt. A current of 10 mA will produce a shock of sufficient intensity to prevent voluntary control of muscles, which explains why, in some cases, the victim of electric shock is unable to release grip on the conductor while the current is flowing. A current of 100 mA passing through the body for a second or longer can be fatal. *Generally, any current flow above 0.005 A, or 5 mA, is considered dangerous.*

A 1.5-V flashlight cell can deliver more than enough current to kill a human being, yet it is safe to handle. This is because the resistance of human skin is high enough to limit greatly the flow of electric current. In lower-voltage circuits, resistance restricts current flow to very low values. Therefore, there is little danger of an electric shock. Higher voltages, on the other hand, can force enough current through the skin to produce a shock. *The danger of harmful shock increases as the voltage increases.*

Figure 1-1 illustrates electric current pathways that can stop normal pumping of the heart. For example, a current from hand to foot, which passes through the heart and part of the central nervous system, is far more dangerous than a shock between two points on the same arm.

1.2 Arc Flash Hazards

An **arc flash** is the ball of fire that explodes from an electrical **short circuit** resulting from one exposed live conductor to another conductor or to ground. The arc flash creates an enormous amount of energy, as shown in Figure 1-2, that can damage equipment and cause severe injury or loss of life. An arc flash can be caused by dropped tools, unintentional contact with electrical systems, or the buildup of conductive dust, dirt, corrosion, and particles.

Electrical short circuits are either bolted faults or arcing faults. A **bolted fault** is current flowing through bolted bus bars or other electric conductors. An **arcing fault** is current flowing through the air. Because air offers opposition to



Figure 1-2 Arc flash.

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electric current flow, the arc fault current is always lower than the bolted fault current. An **arc blast** is a flash that causes an explosion of air and metal that produces dangerous pressure waves, sound waves, and molten steel.

In order to understand the hazards associated with an arc flash incident, it's important to understand the difference between an arcing short circuit and a bolted short circuit. A bolted short circuit occurs when the normal circuit current bypasses the load through a very low conductive path, resulting in current flow that can be hundreds or thousands of times the normal load current. In this case, assuming all equipment remains intact, the fault energy is contained within the conductors and equipment, and the power of the fault is dissipated throughout the circuit from the source to the short. All equipment needs to have adequate interrupting ratings to safely contain and clear the high fault currents associated with bolted faults.

In contrast, an arcing fault is the flow of current through a higher-resistance medium, typically the air, between phase conductors or between phase conductors and neutral or ground. Arcing fault currents can be extremely high in current magnitude approaching the bolted short-circuit current but are typically between 38 and 89 percent of the bolted fault. The inverse characteristics of typical overcurrent protective devices generally results in substantially longer clearing times for an arcing fault due to the lower fault values.

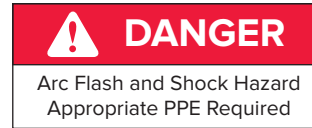


Figure 1-3 An arc flash hazard exists when a person interacts with equipment.

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Eighty percent of electrical workplace accidents are associated with arc flash and involve burns or injuries caused by intense heat or showers of molten metal or debris. In addition to toxic smoke, shrapnel, and shock waves, the creation of an arc flash produces an intense flash of blinding light. This flash is capable of causing immediate vision damage and can increase a worker's risk of future vision impairment.

An arc flash hazard exists when a person interacts with equipment in a way that could cause an electric arc. Such tasks may include testing or troubleshooting, application of temporary protective grounds, or the racking in or out of power circuit breakers as illustrated in Figure 1-3. **Arcs can produce temperature four times hotter than the surface of the sun.** To address this hazard, safety standards such as National Fire Protection Association (NFPA) 70E have been developed to minimize arc flash hazards. The NFPA standards require that any panel likely to be serviced by a worker be **surveyed** and **labeled**. Injuries can be avoided with training, proper work practices, and using protective face shields, hoods, and clothing that are NFPA-compliant.

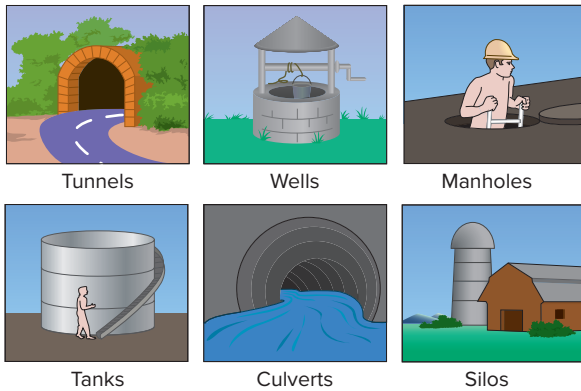


Figure 1-4 Confined spaces.

1.3 Confined Spaces

Confined spaces can be found in almost any workplace. Figure 1-4 illustrates examples of typical confined spaces. In general, a **confined space** is an enclosed or partially enclosed space that:

- Is not primarily designed or intended for human occupancy.
- Has a restricted entrance or exit by way of location, size, or means.
- Can represent a risk for the health and safety of anyone who enters, because of its design, construction, location, or atmosphere; the materials or substances in it; work activities being carried out in it; or the mechanical, process, and safety hazards present.

All hazards found in a regular workspace can also be found in a confined space. However, they can be even more hazardous in a confined space than in a regular work site. Hazards in confined spaces can include poor air quality, fire hazard, noise, moving parts of equipment, temperature extremes, poor visibility, and barrier failure resulting in a flood or release of free-flowing solid.

A **permit-required** confined space is a confined space that has specific health and safety hazards associated with it. Permit-required confined spaces require assessment of procedures in compliance with Occupational Safety and Health Administration (OSHA) standards prior to entry.

1.4 Personal Protective Equipment

Construction and manufacturing work sites, by nature, are potentially hazardous places. For this reason, safety has become an increasingly large factor in the working environment. *The electrical industry, in particular, regards safety to be unquestionably the most single important priority because of the hazardous nature of the business.*



Figure 1-5 Typical safety signs.

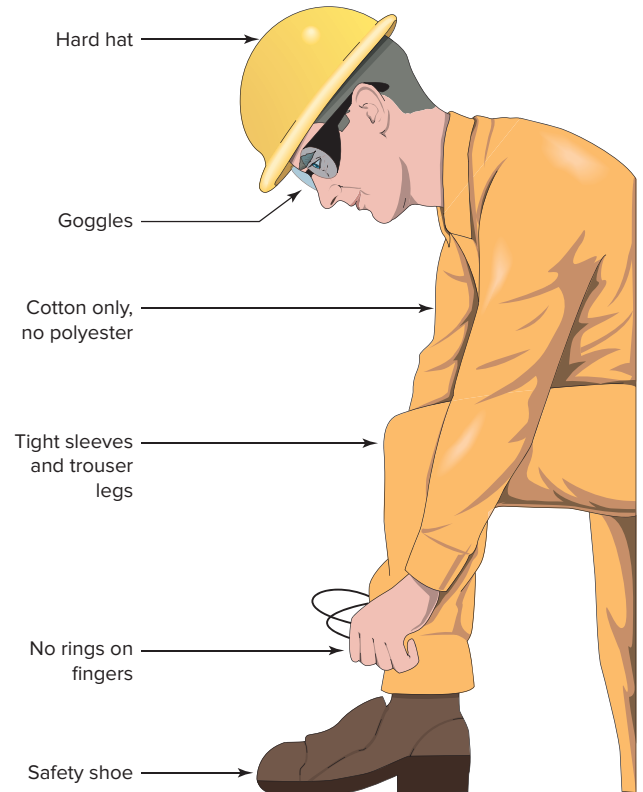


Figure 1-6 Appropriate attire should be worn for each particular job site.

A safe operation depends largely upon all personnel being informed and aware of potential hazards. Safety signs, such as those shown in Figure 1-5, indicate areas or tasks that can pose a hazard to personnel and/or equipment. Signs and tags may provide warnings specific to the hazard, or they may provide safety instructions.

Personal protective equipment (PPE) is equipment worn by a worker to minimize exposure to specific occupational hazards. Appropriate attire should be worn for each particular job site and work activity as illustrated in Figure 1-6 and summarized as follows:

- Hard hats, safety shoes, and goggles are normally required on almost any work site. In addition, non-conductive plastic hard hats must be of the approved type for the purpose of the electrical work being performed. *Metal hats are not acceptable!*
- Safety earmuffs or earplugs must be worn in noisy areas.



Figure 1-7 Rubber glove protection.

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- Clothing should fit snugly to avoid the danger of becoming entangled in moving machinery.
- Avoid wearing synthetic-fiber clothing such as polyester material as these types of materials may melt or ignite when exposed to high temperatures and may increase the severity of a burn. Instead always wear cotton clothing.
- Remove all metal jewelry when working on energized circuits; gold and silver are excellent conductors of electricity.

Rubber gloves are used to prevent the skin from coming into contact with energized circuits. A separate outer leather cover is used to protect the rubber glove from punctures and other damage, as shown in Figure 1-7.

Rubber blankets are used to prevent contact with energized conductors or circuit parts when working near exposed energized circuits. All rubber protective equipment must be marked with the appropriate voltage rating and the last inspection date. It is important that the insulating value of both rubber gloves and blankets have a voltage rating that matches that of the circuit or equipment they are to be used with. ***Insulating gloves must be given an air test, along with inspection.*** Twirl the glove around quickly, or roll it down to trap air inside. Squeeze the palm, fingers, and thumb to detect any escaping air. If the glove does not pass this inspection, you must dispose it.

The type of safety **eye protection** you should wear depends on the hazards in your workplace. If you are working in an area that has particles, flying objects, or dust, you must at least wear safety glasses with side protection (side shields). If you are working with chemicals, you should wear goggles. Approved listed **face shields**, such as shown in Figure 1-8, should be worn during all electrical switching operations where there is a possibility of



Figure 1-8 Typical face shield.

©Elvex Corporation

injury to the eyes or face from electric arcs or flashes, or from flying or falling objects that may result from an electrical explosion.

1.5 Fall Protection

Fall arrest systems are designed, not to necessarily prevent a fall, but to stop a fall once initiated. At a minimum, they must be rigged so that the workers will not free-fall more than **6 feet**, nor contact any lower level. They include personal fall arrest systems, such as the safety harness shown in Figure 1-9, and safety nets.

The misuse of ladders and scaffolds accounts for a high percentage of injuries in the workplace. Important rules for **all ladder** usage and safety include:

- Select the right ladder for the job; when performing electrical work, always use ladders made of **nonconductive material**.
- Inspect the ladder before you use it; inspect it for damaged rungs, steps, rails, or braces and traces of oil, grease, or other slippery substances.
- Never place the legs of a ladder on anything but a firm level surface.
- Never place a ladder in front of a door that swings open toward the ladder, unless the door is fastened open, locked, or guarded.
- Face the ladder when going up or down.
- Do not allow more than one person at a time on the ladder.
- Hold the ladder with both hands while climbing or descending. Use a tool belt or bucket attached to a



Figure 1-9 Typical safety harness.

Courtesy of Miller Fall Protection/Honeywell

hand line for raising and lowering the tools and materials you need.

- Make sure the ladder is clear of any power lines.
- Never climb higher than the second step from the top on a stepladder or the third from the top on a straight ladder.

Important rules for **stepladder** usage and safety include:

- Always open a stepladder to its fullest extent.
- Always lock both braces before climbing the ladder.
- Never use a stepladder as a straight ladder.
- Do not leave tools or materials on a stepladder.

Important rules for **extension ladder** usage and safety include:

- Always place a straight ladder at the proper angle; straight ladders should be placed at a **4-to-1** ratio. This means the base of the ladder should be 1 foot away from the wall or other vertical surface for every 4 feet of height to the point of support, as illustrated in Figure 1-10. When a person has to step off the ladder, it should extend about 3 feet above the roof, scaffold, or other kind of raised platform.
- Do not extend an extension ladder beyond the point where there is less than 3 feet of overlapping sections.

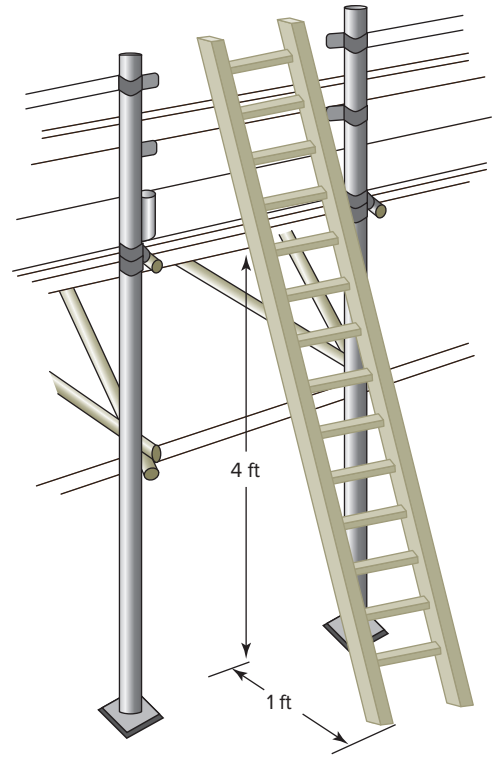


Figure 1-10 Ladder 4-to-1 placement rule.

- When possible, secure the top of the ladder to the structure.
- When working on a ladder, hold a rung or rail with one hand at all times. Use a safety belt when it is absolutely necessary to work with both hands.
- Never add more extensions or fasten two ladders together to make a longer one.

At times it may be necessary to work in an elevated location. When this is the case, **scaffolds** provide the safest elevated working platforms. Important rules for scaffold usage and safety include:

- Scaffolds must be erected on rigid footing that can carry the maximum intended load using only materials designed and marked for this purpose.
- Guardrails and toe boards must be installed on the open sides and ends of platforms that are higher than 6 feet above the ground or floor.
- Work platforms must be completely decked with scaffold planks extended over their end supports not less than 6 inches nor more than 12 inches and must be properly blocked.
- Keep scaffold platforms clear of unnecessary material.

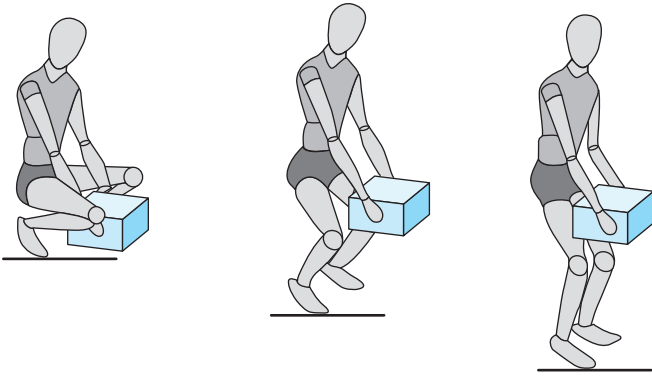


Figure 1-11 Lifting and moving loads.

1.6 Lifting and Moving Loads

When lifting, it is better to take small loads if possible. Lift only what you can handle, and get help if you need it. The basics steps for safe lifting and moving loads are illustrated in Figure 1-11 and summarized as follows:

- First stand close to the load.
- Then, squat down and keep your back straight.
- Get a firm grip on the load, and keep the load close to your body.
- Lift by straightening your legs. Make sure that you lift with your legs and not your back.
- Avoid lifting and twisting at the same time.
- Bend your knees rather than your back when putting a load down.
- If you bend from the waist to pick up a 50-pound object, you are applying **10 times the amount of pressure** (500 pounds) to your lower back.

1.7 Fire Prevention

Fire prevention is a very important part of any safety program. The fire triangle of Figure 1-12 illustrates the ingredients necessary for most fires, namely, **fuel**, **heat**, and **oxygen**. The fire is prevented or extinguished by removing any one of them.

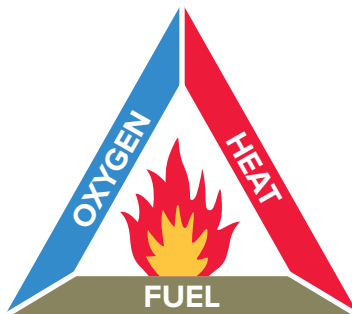


Figure 1-12 Fire triangle.



Figure 1-13 Multipurpose fire extinguisher.

Using the correct type of fire extinguisher is vital to safely combating fires. Fires are divided into four classes: A, B, C, and D. Each class designates the fuel involved in the fire, as follows, and thus the most appropriate extinguishing agent:

Class A fires involve common combustible materials such as wood or paper. They are often extinguished by lowering the temperature of the fuel below the combustion temperature. Class A fire extinguishers often use water to extinguish a fire and as such **should never be used on an electrical fire**.

Class B fires involve flammable liquids such as gasoline, solvents, oil, paint, and varnish. A class B fire extinguisher generally employs carbon dioxide, which greatly lowers the temperature of the fuel and deprives the fire of oxygen.

Class C fires involve energized electrical equipment. A class C fire extinguisher uses a dry powder to smother the fire. **Under no circumstances use water, as the stream of water may conduct electricity through your body and give you a severe shock.**

Certain multipurpose dry-chemical extinguishers may be used on multiple types of fires. For example, an extinguisher labeled A/B/C, as shown in Figure 1-13, could be used on any of the three classes of fire listed.

Class D fires consist of burning metal. Class D extinguishers contain a sodium chloride or graphite metal-based powder. When discharged on a fire, the powder reacts to the heat, causing the powder to cake and form a crust which excludes air and dissipates the heat.

1.8 Hazardous Waste

Many products contain hazardous substances, which if not used and disposed of properly can result in the production of hazardous waste. A hazardous material is defined as any substance or material that could adversely affect the safety of the public, handlers, or carriers during transportation. Recognizing hazardous substances and the type of hazardous waste they produce is the first step in learning how to properly handle and dispose of them. One or more of the following dangerous properties



Figure 1-14 Hazardous properties or characteristics.

or characteristics, illustrated in Figure 1-14, identify most common hazardous waste:

- **Corrosives** are materials that can attack and destroy human tissue, clothes, and other materials including metals on contact. For example, acids found in batteries are corrosive.
- A **flammable** material is one that is capable of bursting into flames. For example, gasoline and paint are flammable substances.
- **Toxic** materials can poison people and other life. Pesticides, weed killers, and many household cleaners are all examples of toxic materials.
- A **reactive** material can explode or create poisonous gas when mixed with another substance or chemical. For example, chlorine bleach and ammonia are reactive. When they come into contact with each other, they produce a poisonous gas.

Hazardous materials are required to be listed as such. A **material safety data sheet (MSDS)** is a form with data regarding the properties of a particular substance. MSDSs are a widely used system for cataloging information on chemicals, chemical compounds, and chemical mixtures. MSDS information may include instructions for the safe use and potential hazards associated with a particular material or product. These data sheets can be found anywhere where chemicals are being used.

Part 1 Review Questions

1. Does the severity of an electric shock increase or decrease with each of the following changes?
 - a. A decrease in the source voltage.
 - b. An increase in body current flow.
 - c. An increase in body resistance.
 - d. A decrease in the length of time of exposure.
2. In general, voltage levels above what value are considered dangerous?
3. In general, current levels above what value are considered dangerous?
4. What circuit fault can result in an arc flash?

5. Define each of the following terms associated with an arc flash:
 - a. *Bolted fault*
 - b. *Arcing fault*
 - c. *Arc blast*
6. Explain why an arc flash is so potentially dangerous.
7. What is a permit-required confined space?
8. What does the term personal protective equipment (PPE) refer to?
9. What personal protective attire is required when taking measurements on energized circuits?
10. When should face shields be worn?
11. A fall arrest system must be rigged so that workers cannot free-fall more than how many feet?
12. A ladder is used to reach the top of a building 16 feet tall. According to the 4-to-1 ratio rule, what distance should the bottom of the ladder be placed from the side of the building?
13. What are the deck requirements for a scaffold work platform?
14. When lifting a load, why is it important to lift with your legs and not your back?
15. List the three ingredients required to sustain a fire.
16. Which classes of fire are multipurpose dry-chemical fire extinguishers approved for?
17. List four hazardous properties or characteristics.

PART 2 GROUNDING-Fault Protection-LOCKOUT-CODES

1.9 Grounding and Bonding

Proper grounding practices protect people from the hazards of electric shock and ensure the correct operation of overcurrent protection devices. Intentional grounding is required for the safe operation of electrical systems and equipment. Unintentional or accidental grounding is considered a fault in electrical wiring systems or circuits.

Grounding is the intentional connection of a current-carrying conductor to the earth. The prime reasons for grounding are:

- To limit the voltage surges caused by lightning, utility system operations, or accidental contact with higher-voltage lines.
- To provide a ground reference that stabilizes the voltage under normal operating conditions.