

RESIDENTIAL  
CONSTRUCTION  
ACADEMY

# HOUSE WIRING

FIFTH EDITION

GREG FLETCHER



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CONSTRUCTION  
ACADEMY

# HOUSE WIRING

FIFTH EDITION



GREG FLETCHER



Australia • Brazil • Mexico • Singapore • United Kingdom • United States

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# PREFACE

## HOME BUILDERS INSTITUTE RESIDENTIAL CONSTRUCTION ACADEMY: HOUSE WIRING, FIFTH EDITION

### ABOUT THE RESIDENTIAL CONSTRUCTION ACADEMY SERIES

One of the most pressing problems confronting the building industry today is the shortage of skilled labor. The construction industry must recruit an estimated 185,000 new craft workers each year to meet future needs. This shortage is expected to continue well into the next decade because of projected job growth and a decline in the number of available workers. At the same time, the training of available labor is becoming an increasing concern throughout the country. The lack of training opportunities resulted in over 200,000 unfilled construction sector jobs in 2016. This challenge is affecting all construction trades and is threatening the ability of builders to construct quality homes.

These challenges led to the creation of the innovative *Residential Construction Academy Series*. The *Residential Construction Academy Series* is the perfect way to introduce people of all ages to the building trades while guiding them in the development of essential workplace skills, including carpentry, electrical wiring, HVAC, plumbing, masonry, and facilities maintenance. The products and services offered through the *Residential Construction Academy* are the result of cooperative planning and rigorous joint efforts between industry and education. The program was originally conceived by the National Association of Home Builders (NAHB)—the premier association of more than 140,000 members—and its affiliate, the Home Builders Institute (HBI), a leading career training provider in the residential construction industry.

For the first time, construction professionals and educators created national skills standards for the construction trades. In the summer of 2001, NAHB, through the HBI, began the process of developing residential craft standards in six trades: carpentry, electrical wiring, HVAC, plumbing, masonry, and facilities maintenance. Groups of employers from across the country met with an independent research and measurement organization to begin the development of new craft training standards. Care was taken to assure representation of builders and remodelers, residential and light commercial, custom single family and high production or volume builders. The guidelines from the National Skills Standards Board were followed in developing the new standards. In addition, the process met or exceeded American Psychological Association standards for occupational credentialing.

Next, through a partnership between HBI and Cengage Learning, learning materials—textbooks, DVDs, and instructor’s curriculum and teaching tools—were created to teach these standards effectively. A foundational tenet of this series is that students *learn by doing*. Integrated into this colorful, highly illustrated text are Procedure sections designed to help students apply information through hands-on, active application. A constant focus of the *Residential Construction Academy Series* is teaching the skills needed to be successful in the construction industry and constantly applying the learning to real-world applications.

In 2009, the Home Builders Institute enhanced the *Residential Construction Academy Series* by adding industry Program Credentialing and Certification for both students and instructors. National Instructor Certification ensures consistency in instructor teaching/training methodologies and knowledge competency when teaching to the industry’s national skills standards. Student Certification is offered for each trade area of the *Residential*

*Construction Academy Series* in the form of rigorous testing. Student Certification is tied to a national database that will provide an opportunity for easy access for potential employers to verify skills and competencies. Instructor and Student Certification serve the basis for Program Credentialing offered by HBI. For more information on HBI Program Credentialing and Instructor and Student Certification, please go to <http://www.hbi.org>.





# ABOUT THIS BOOK

The fifth edition of *House Wiring* covers the basic electrical wiring principles and practices used in the installation of residential electrical wiring systems. It is based on the 2017 *National Electrical Code*<sup>®</sup>. Wiring practices that are commonly used in today's residential electrical market are discussed in detail and presented in a way that not only tells what needs to be done, but also shows how to do it. Both general safety and electrical safety are stressed throughout the textbook.

This textbook provides a valuable resource for the knowledge and skills that are required of an entry-level residential electrician. This includes the basic “hands-on” skills as well as the more advanced theoretical knowledge needed to achieve job proficiency. In addition to important topics such as using the *National Electrical Code*<sup>®</sup>, sizing electrical boxes, sizing circuit conductors, sizing fuses or circuit breakers, and sizing service entrance conductors, this text also focuses on “hands-on” wiring skills. These “hands-on” wiring skills include things like the proper use of hand and power tools, splicing wires together properly, attaching electrical boxes to building framing members, fishing a cable in an existing wall, and installing an overhead service entrance. This edition also includes coverage of green wiring practices, reflecting the *National Green Building Standard ICC 700-2015*, and the installation of photovoltaic solar electric systems. The format is intended to be easy to learn and easy to teach.

## ORGANIZATION

This textbook is organized in the same way that a typical residential wiring project unfolds. The first five sections cover the installation of a residential wiring system from start to finish. The sixth section covers green house wiring practices and the installation of solar photovoltaic (PV) energy systems. It is recommended that the sections be covered in the order that they appear in the textbook; however, all sections and section chapters are designed so that they can be covered in any order an instructor chooses.

- **Section 1: Preparing and Planning a Residential Wiring Job** is designed to show students how to apply common safety practices; how to use materials, tools and testing instruments; and how to read and understand residential building plans. Determining the requirements for branch circuits, feeder circuits, and service entrances are also covered.
- **Section 2: Service Entrances and Equipment** includes material on how to install the necessary equipment to get electrical power from the electric utility to the dwelling unit.
- **Section 3: Residential Electrical System Rough-In** demonstrates how to install electrical boxes and run cable or raceway according to the electrical circuit requirements.
- **Section 4: Residential Electrical System Trim-Out** involves installing all of the switches, receptacles, and luminaires (lighting fixtures) throughout a house. Installing circuit breakers and fuses are also covered.
- **Section 5: Maintaining and Troubleshooting a Residential Electrical Wiring System** explains how to test each circuit to make sure they are installed according to the *NEC*<sup>®</sup> and are in proper working order. It also shows how to troubleshoot and correct problems to ensure a satisfied customer.
- **Section 6: Green House Wiring Techniques** covers the material that every electrician should know so that the home they are wiring has the most up-to-date and efficient green electrical system possible. It also covers the information needed for a good understanding of how a solar photovoltaic (PV) electricity producing system is installed.

## NEW FEATURES

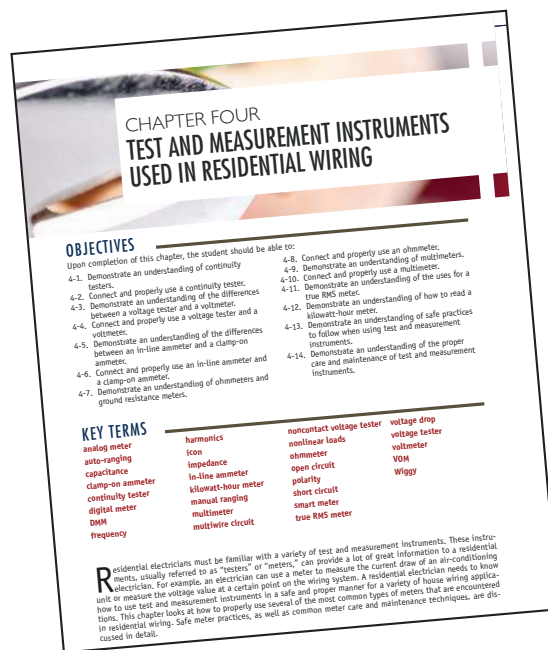
The fifth edition of *Residential Construction Academy: House Wiring* features current information related to the industry and new information to facilitate learning:

- MindTap is available for the fifth edition, including integrated simulations, workbook/lab manual, and more.
- The new Delmar Online Training Simulation: Electricity and Wiring is available with the fifth edition. (The Delmar Online Training Simulation for Residential Wiring and the Delmar Online Training Simulation for Electricity have been updated and combined into this new simulation, which is based on the 2014 *National Electrical Code*®).
- The Delmar Online Training Simulation: Residential Construction Codes 2017 is available with the fifth edition.
- Assessment questions are tied to learning outcomes, helping students demonstrate that they have mastered the outcomes.
- Statistics in the *Introduction* reflect the current state of the construction industry.
- All material has been updated to reflect the requirements of the 2017 *National Electrical Code*®.
- The number of review questions at the end of several chapters has been adjusted. Additional chapter review questions are now located in MindTap and in the instructor’s resource guide.
- The number of illustrations used throughout the textbook has been adjusted to help students better understand the material presented.
- Some procedures have been updated to help students better understand how to do a specific wiring task.
- End of chapter summaries have been adjusted to make it easier for students to quickly review the major topics that were presented in the chapter.

## KEY FEATURES

This innovative series was designed with input from educators and industry and informed by the curriculum and training objectives established by the Standards Committee. The following features aid in the learning process:

**LEARNING FEATURES** such as the **Introduction**, **Objectives**, and **Key Term list** set the stage and help the learner identify key concepts and information. These learning features serve as a road map for the chapter. Learners also may use them as an on-the-job reference.



**CHAPTER 2 Hardware and Materials Used in Residential Wiring 63**

**PROCEDURE 2-1 GANGING METAL DEVICE BOXES**

- Put on safety glasses and observe all applicable safety rules.

- Choose two (or more) metal device boxes that are the same size and can be ganged.
- Using a screwdriver, loosen the screw holding the box side from one of the boxes and remove it.
- Using a screwdriver, loosen the screw holding the box side from the other device box and remove it.
- Align the two boxes together and tighten all screws to hold the boxes securely together.
  - Put all tools and materials away.

**PROCEDURE 2-2 PREPARING ALUMINUM CONDUCTORS FOR TERMINATION USING AN ANTI-OXIDANT**

- Put on safety glasses and observe all applicable safety rules.

- Strip off the required amount of conductor insulation on the end you wish to terminate.
- Apply a liberal amount of antioxidant to the newly exposed aluminum.
- Scrape the conductor end with a wire brush. This breaks down the oxidation layer, and the antioxidant keeps the air from contacting the conductor, preventing further oxidation.
  - Attach the conductor to the termination and tighten to the proper torque requirements.
  - Clean up any excess antioxidant.
  - Put all tools and materials away.

**ACTIVE LEARNING** is a core concept of the *Residential Construction Academy Series*. Information is heavily illustrated to provide a visual of new tools and tasks encountered by learners. In the **Procedures**, various tasks used in residential electrical wiring installation and service are grouped in a step-by-step approach. The overall effect is a clear view of the task, making learning easier.

**SAFETY** is featured throughout the text to instill safety as an “attitude” among learners. Safe jobsite practices by all workers is essential; if one person acts in an unsafe manner, then all workers on the job are at risk of being injured, too. Learners will come to appreciate that safety is a blend of ability, skill, and knowledge that should be continuously applied to all they do in the construction industry.

**CHAPTER 8 Service Entrance Equipment and Installation 243**

In a basement, it is recommended that an air gap of at least 1/2 inch behind the backboard be maintained to allow for moisture to dry out. The backboard must be large enough for the panel and any other items installed on it, such as a surface-mounted box with a duplex receptacle.

**CAUTION** Section 230.70(A)(1) requires the service conductors to terminate at the main disconnecting means as soon as the conductors enter the house from the service panel at a location that you install the least amount of “inside run” of the service entry conductors. Failure to do this will cause your installation.

**CAUTION** Make sure to install the service entrance panel so that the requirements of Section 310.26 are met. In front of the panel that gives you a working space must be provided (762 mm) wide, extends at least 30 inches (762 mm) in front of the panel, and extends from the floor up to a height of 6.5 feet (2.0 m) or more.

**CAUTION** If aluminum wire is being used as service conductors, it may be necessary to use an antioxidant. Instructions that come with the antioxidant.

**FIGURE 8-39** The connections for a 120/240-volt, single-phase, main circuit breaker panel.

- Blind the enclosure to the equipment-grounding bus bar and the neutral bus bar using a main bonding jumper. The main bonding jumper can be a green screw, a short length of wire, or a green screw as the main bonding jumper.
- Attach the service conductors from the meter entrance panel to the main bonding jumper or a service entrance cable. Remember, service entrance cable from the meter socket. The cable will require a split connector to secure it to the enclosure and the raceway will require some type of conduit connector to secure it to the enclosure.
- Connect both ungrounded (“hot”) service entrance conductors to the main circuit breaker terminals. 100-ampere-rated main circuit breakers have slotted set-screws that will need to be tightened, and 150- and 200-ampere-rated and larger main circuit breakers will have hexagonal countersink screws that will require an Allen wrench or a ratchet wrench with a hexagonal socket to tighten them (Figure 8-39). Remember these terminals with a torque wrench or torque panel, along with other information about the panel, inside the panel enclosure on a sticker installed by the panel manufacturer.
- Connect the grounded neutral service entrance conductor to the proper terminal on the neutral bus bar.
- Connect the grounding electrode conductor to the proper terminal on the grounding electrode. If a metal water pipe bringing water to the house is available, it must be used as the grounding electrode. Attach the grounding electrode conductor to the meter pipe at a point that is 5 feet (1.5 m) or less from where the pipe enters the house. Use a water pipe grounding clamp for the attachment (Figure 8-40).

**CAUTION** features highlight safety issues and urgent safety reminders for the trade.

**156 SECTION 1 Preparing and Planning a Residential Wiring Job**

**TABLE 200.12** General Lighting Loads by Occupancy

TYPES OF OCCUPANCY	VOLTS-AMPERES/100	VOLTS-AMPERES/100
	AMPERES/100	AMPERES/100
Residential and auditoriums	11	11
Barber shops and beauty parlors	30 <sup>a</sup>	30 <sup>a</sup>
Churches	33	3
Clubs	11	1
Court rooms	22	2
Dwelling Units <sup>b</sup>	22	2
Garages—commercial (Storage)	33	3
Hospitals	6	1/2
Hotels and motels, including apartment houses without provision for cooking by tenant <sup>c</sup>	22	2
Industrial commercial (off)	22	2
Lodge rooms	17	1 1/2
Office buildings	30 <sup>a</sup>	30 <sup>a</sup>
Restaurants	22	2
Schools	33	3
Stores	33	3
Warehouses (storage)	3	1/2
In any of the preceding occupancies except one-family dwellings and individual dwelling units of two-family and multifamily dwellings:		
Assembly halls and auditoriums	11	1
Halls, corridors, closets, stairways	6	1/2
Storage spaces	3	1/2

<sup>a</sup>See 220.14(C).  
<sup>b</sup>See 220.14(D).

**FIGURE 6-3** NEC Table 200.12 provides the minimum general lighting load per square foot for a variety of building types, including 3 VA per square foot for dwelling units.

The minimum number of 15-ampere general lighting branch circuits. In our example, if we were installing a minimum of three 20-ampere general lighting branch circuits would be required: 50 amperes/20 amperes = 2.5, then round up to 3.

The following formulas can be used to determine cuts in a dwelling:

$$3 \text{ volt-amperes} \times \text{calculated square-foot area} = 120 \text{ volts}$$

$$= \text{Total general lighting load in amps}$$

$$= 15 \text{ amp}$$

$$= \text{Minimum number of 15-amp general lighting branch circuits}$$

$$= 20 \text{ amp}$$

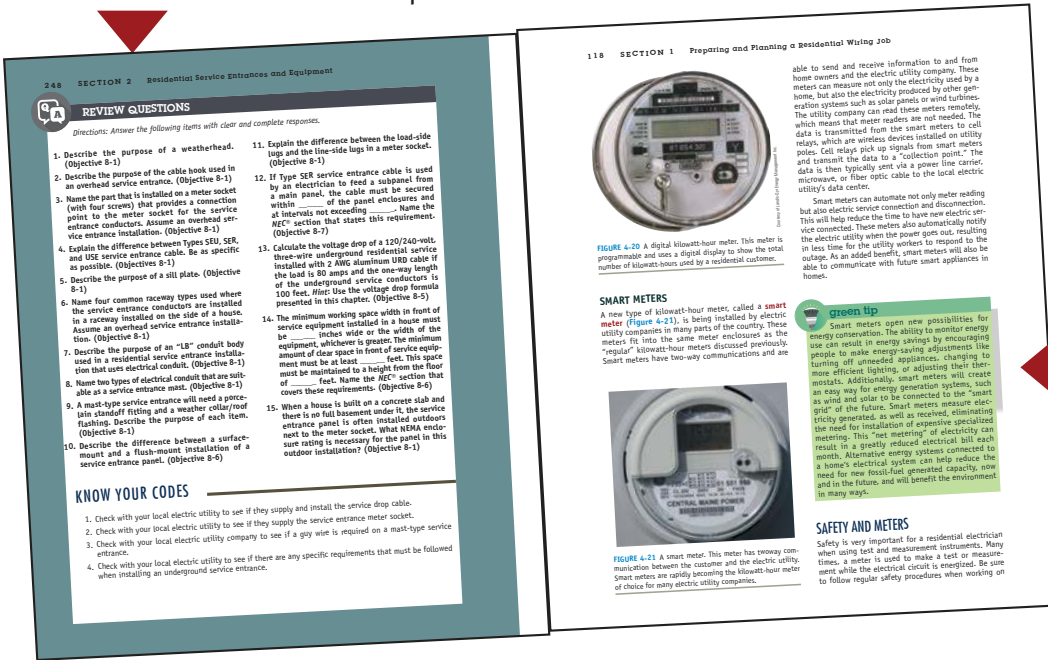
$$= \text{Minimum number of 20-amp general lighting branch circuits}$$

**FROM EXPERIENCE:** Most residential general lighting branch circuits are wired with 14 AWG wire and protected by 15-ampere fuses or circuit breakers, although there are many applications where 12 AWG wire is installed and 20-ampere overcurrent protection devices are used. Make sure to check the building plans, especially the electrical specifications, to determine whether the general lighting branch circuits are rated 15 amperes or 20 amperes.

**FROM EXPERIENCE:** Another way to determine the minimum number of general lighting branch circuits is to determine the total floor area in square feet for the house using the outside dimensions and assign one general lighting branch circuit for every 600 square feet. If you are using 20-ampere-rated general lighting branch circuits, assign one general lighting branch circuit for every 800 square feet. For example, a 2400-square-foot house would require a minimum of four 15-ampere general lighting branch circuits (2400 square feet/600 = 4) or three 20-ampere general lighting branch circuits (2400 square feet/800 = 3).

**FROM EXPERIENCE** provides tricks of the trade and practical advice that make a particular task a little easier for the novice to accomplish.

**REVIEW QUESTIONS** tagged to learning objectives complete each chapter. They are designed to reinforce the information learned in the chapter and to review what was accomplished.



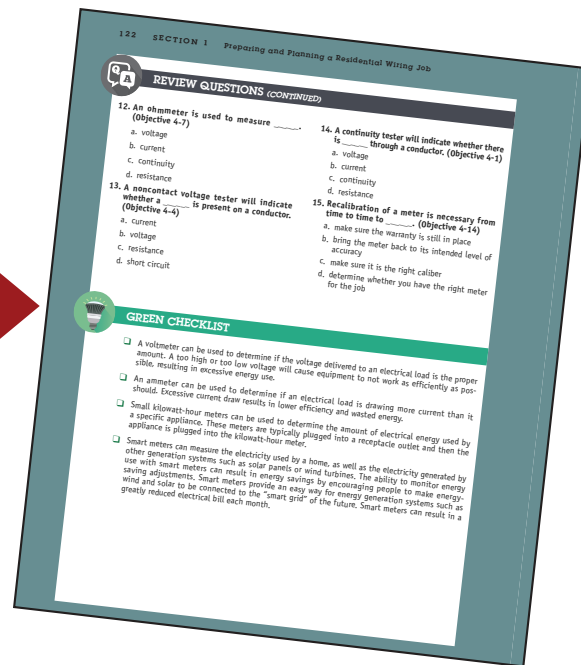
**GREEN TIPS** are included throughout the book to highlight existing or new information pertaining to environmentally-friendly and sustainable wiring practices.

**KNOW YOUR CODES** feature is included in many chapters allowing students to research their local codes. This teaches code book use and strengthens the knowledge of local codes and research capabilities required on a job site.

**CONSIDER AND COMPARE** feature illustrates and describes various practices being demonstrated on actual jobsites, leaving it up to the learner to evaluate the situation and determine if the practices are smart and safe—or not. This feature is an excellent tool to reinforce the lessons learned in the chapter and promote critical thinking skills.



**GREEN CHECKLISTS** located at the end of chapters highlight the chapter's environmentally friendly and sustainable wiring practices coverage and provide a quick reference tool for students.



## TURNKEY CURRICULUM AND TEACHING MATERIAL PACKAGE

We understand that a text is only one part of a complete, turnkey educational system. We also understand that Instructors want to spend their time on teaching, not preparing to teach. The *Residential Construction Academy Series* is committed to providing thorough curriculum and preparatory materials to aid Instructors and alleviate some of their heavy preparation commitments. An integrated teaching solution is provided with the text, including MindTap, the instructor resources, a printed Instructor's Resource Guide, and a Workbook/Lab Manual.

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Ask your instructor if these materials are available for your course:

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MindTap is a platform that propels you from memorization to mastery. Build confidence with engaging content provided in a logical learning path. Access everything you need in one place: the core text, interactive multimedia, assignments, quizzes, and more. You have the power to read, listen, and study on your phone, so you can learn on your terms.

MindTap for Residential Construction Academy: House Wiring, 5th edition includes the core text, workbook and lab manual, Delmar Online Training Simulation: Residential Wiring 2017, Delmar Online Training Simulation: Residential Construction Codes 2017 (Electrical 1 and Electrical 2 modules), interactive quizzes, flashcards, and more.

### DELMAR ONLINE TRAINING SIMULATION: ELECTRICITY AND WIRING 2017

Immerse yourself in a realistic 3D learning experience like no other as *Delmar Online Training Simulation: Electricity and Wiring 2017* guides you from understanding the basics of residential wiring through mastering and practicing room-by-room wiring installation.

This engaging digital simulation provides essential practice within a captivating, lifelike, yet safe, environment. The simulation is divided into three clear sections.

You initially focus on understanding and mastering wiring basics, including the single-pole switch, three-way switches, GFCI outlets, and other essentials. In the second section, you practice wiring a full 3D house, room-by-room—from the initial wire diagrams through completing the installation. In the final section, you learn how to effectively apply the National Electric Code® 2014 (NEC® 2014) to lifelike situations and possible challenges, which deepens your understanding of the code and gives you a strong command of the industry's best practices. Each section features dynamic feedback reports on your performance that encourage your advancement and ensure mastery of the skills you need.

## DELMAR ONLINE TRAINING SIMULATION: RESIDENTIAL CONSTRUCTION CODES 2017

Developed in partnership with the International Code Council (ICC) and the National Fire Protection Association (NFPA), this highly interactive environment allows students to interpret and apply the 2015 International Residential Code (IRC®) and the 2014 *National Electric Code (NEC®)*. Choose your challenge level and decide whether you'd like helpful hints from a building inspector, or to move along alone.

## PRINT RESOURCES FOR STUDENTS

### WORKBOOK/LAB MANUAL

Designed to accompany Residential Construction Academy: House Wiring fifth edition, the Workbook/Lab Manual is an extension of the core text and provides additional review questions, problems, and hands-on activities designed to challenge and reinforce the student's comprehension of the content presented in the core text. The Workbook section includes study outlines linked to the chapter objectives, key term reviews, chapter quizzes, and troubleshooting exercises. The Lab Manual section contains more than 50 hands-on labs developed by the text author to build practical house wiring skills. Instructors will find a Lab Grading Competency List in the Instructor's Guide and on the Instructor's Resource CD that can help students track their progress and build a record of achievement for prospective employers.

## DIGITAL RESOURCES FOR INSTRUCTORS

### INSTRUCTOR COMPANION SITE

The instructor companion site to accompany *Residential Construction Academy: House Wiring* offers a FREE and secure online option for accessing the Instructor Resource Guide, PowerPoint® Presentations, Computerized Test Banks, and an Image Gallery.

The **Instructor's Guide** contains lecture outlines, notes to instructors with teaching hints, cautions, and answers to review questions and other aids for the instructor using this Series. These features are available for each chapter of the book. Designed as a complete and integrated package, the instructor is also provided with suggestions for when and how to use the accompanying **PowerPoint®** and **Computerized Test Bank**. There are also print and pdf versions of the Instructor's **Resource Guide** available, as well as other aids for the instructor using this Series.

Customizable **PowerPoint® Presentations** focus on key points for each chapter through lecture outlines that can be used to teach the course. Instructors may teach from this outline or make changes to suit individual classroom needs.

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MindTap isn't just a tool, it's backed by a personalized team eager to support you. We can help set up your course and tailor it to your specific objectives, so you'll be ready to make an impact from day one. Know we'll be standing by to help you and your students until the final day of the term.

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## ABOUT THE AUTHOR

The author of this textbook, Greg Fletcher, has over 40 years of experience in the electrical field as both a practicing electrician and as an electrical instructor. His practical experience has been primarily in the residential and commercial electrical construction field. He has been a licensed electrician since 1976; first as a Journeyman Electrician and then as a Master Electrician. He has taught electrical wiring practices at both the secondary level and the post-secondary level. He has taught apprenticeship electrical courses and has facilitated many workshops on topics such as Using the *National Electrical Code*®, Fiber Optics for Electricians, Understanding Electrical Calculations, and Introduction to Photovoltaics. The knowledge gained over those years, specifically on what works and what does not work to effectively teach electrical wiring practices, was used as a guide to help determine the focus of this textbook.

Since 1988 he has been Department Chairman of the Trades and Technology Department and Program Director/Instructor in the Electrical Technology program at Kennebec Valley Community College in Fairfield, Maine. He holds an Associate of Applied Science Degree in Electrical Construction and Maintenance, a Bachelor of Science Degree in Applied Technical Education, and a Master of Science Degree in Industrial Education.

Mr. Fletcher is a member of the International Association of Electrical Inspectors and The National Fire Protection Association. He lives in Waterville, Maine with his wife. When not teaching or writing textbooks he enjoys reading, golfing, motorcycling, and spending time with his family.

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# INTRODUCTION

## ORGANIZATION OF THE INDUSTRY

The residential construction industry is one of the biggest sectors of the American economy. According to the U.S. Department of Labor, construction is one of the nation's largest industries, employing 6 million workers nationwide. About 62% of wage and salary jobs in construction were in the specialty trade contractors sector, primarily plumbing, heating and air-conditioning, electrical, and masonry. The National Association of Home Builders (NAHB) reports that home building traditionally accounts for 50–55% of the construction industry. Opportunities are available for people to work at all levels in the construction industry, from those who handle the tools and materials on the job site to the senior engineers and architects who spend most of their time in offices. Few people spend their entire lives in a single occupation, and even fewer spend their lives working for one employer. You should be aware of all the opportunities in the construction industry so that you can make career decisions in the future, even if you are sure of what you want to do at this time.

## CONSTRUCTION PERSONNEL

The occupations in the construction industry can be divided into four categories:

- Unskilled or semiskilled labor
- Skilled trades or crafts
- Technicians
- Design and management

## UNSKILLED OR SEMISKILLED LABOR

Construction is labor-intensive. That means it requires a lot of labor to produce the same dollar value of end products by comparison with other industries, in which labor may be a smaller part of the picture. Construction workers with limited skills are called

laborers. Laborers are sometimes assigned the tasks of moving materials, running errands, and working under the close supervision of a skilled worker. Their work is strenuous, and so construction laborers must be in excellent physical condition.

Construction laborers are construction workers who have not reached a high level of skill in a particular trade and are not registered in an apprenticeship program. These laborers often specialize in working with a particular trade, such as mason's tenders or carpenter's helpers ([Figure I-1](#)). Although the mason's tender may not have the skill of a bricklayer, the mason's tender knows how to mix mortar for particular conditions, can erect scaffolding, and is familiar with the bricklayer's tools. Many laborers go on to acquire skills and become skilled workers. Laborers who specialize in a particular trade are often paid slightly more than completely unskilled laborers.



**FIGURE I-1** Mason.

## SKILLED TRADES

A *craft* or *skilled trade* is an occupation working with tools and materials and building structures. The

building trades are the crafts that deal most directly with building construction (see Figure I-2).

Carpenter
Framing carpenter
Finish carpenter
Cabinetmaker
Plumber
New construction
Maintenance and repair
Roofer
Electrician
Bricklayer (also lays concrete blocks)
Cement finisher
HVAC technician
Plasterer
Finish plaster
Stucco plaster
Tile setter
Equipment operator
Drywall installer
Installer
Taper
Painter

FIGURE I-2 Building Trades.

The building trades are among the highest paying of all skilled occupations. However, work in the building trades can involve working in cold conditions in winter or blistering sun in the summer. Also, job opportunities will be best in an area where a lot of construction is being done. The construction industry is growing at a high rate nationwide. Generally, plenty of work is available to provide a comfortable living for a good worker.

### Apprenticeship

The skill needed to be employed in the building trades is often learned in an apprentice program. Apprenticeships are usually offered by trade unions, trade associations, technical colleges, and large employers. *Apprentices* attend class a few hours a week to learn the necessary theory. The rest of the week they work on a job site under the supervision of a *journeyman* (a skilled worker who has completed the apprenticeship and has experience on the job). The term “journeyman” is a gender neutral term that has been used for decades. It is worth noting that many highly skilled building trades’ workers are women. Apprentices receive a much lower salary than journeymen, often about 50% of what a journeyman receives. The apprentice wage usually increases as stages of the apprenticeship are

successfully completed. By the time the apprenticeship is completed, the apprentice can be earning as much as 90% of what a journeyman earns. Many apprentices receive college credit for their training. Some journeymen receive their training through school or community college and on-the-job training. In one way or another, some classroom training and some on-the-job supervised experience are usually necessary to reach journeyman status. Not all apprentice programs are the same, but a typical apprenticeship lasts between two and four years and requires a minimum of 144 hours of classroom training per year, along with 2000 hours of supervised work experience per year.

### TECHNICIANS

*Technicians* provide a link between the skilled trades and the professions. Technicians often work in offices, but their work also takes them to construction sites. Technicians use mathematics, computer skills, specialized equipment, and knowledge of construction to perform a variety of jobs. Figure I-3 lists several technical occupations.

Technical Career	Some Common Jobs
Surveyor	Measures land, draws maps, lays out building lines, and lays out roadways
Estimator	Calculates time and materials necessary for project
Drafter	Draws plans and construction details in conjunction with architects and engineers
Expeditor	Ensures that labor and materials are scheduled properly
Superintendent	Supervises all activities at one or more job sites
Inspector	Inspects project for compliance with local building codes at various stages of completion
Planner	Plans for best land and community development

FIGURE I-3 Technicians.

Most technicians have some type of college education, often combined with on-the-job experience, to prepare them for their technical jobs. Community colleges often have programs aimed at preparing people to work at the technician level in construction. Some community college programs are intended especially for preparing workers for the building trades, while others have more of

a construction management focus. Construction management courses give the graduate a good overview of the business of construction. The starting salary for a construction technician is about the same as for a skilled trade, but the technician can be more certain of regular work and will have better opportunities for advancement.

## DESIGN AND MANAGEMENT

Architecture, engineering, and contracting are the design and management professions. The *professions* are those occupations that require more than four years of college and a license to practice. Many contractors have less than four years of college, but they often operate at a very high level of business, influencing millions of dollars, and so they are included with the professions here. These construction professionals spend most of their time in offices and are not frequently seen on the job site.

Architects usually have a strong background in art, so they are well-prepared to design attractive, functional buildings. A typical architect's education includes a four-year degree in fine art, followed by a master's degree in architecture. Most of their construction education comes during the final years of work on the architecture degree.

Engineers generally have more background in math and science, so they are prepared to analyze conditions and calculate structural characteristics. There are many specialties within engineering, but civil engineers are the ones most commonly found in construction. Some civil engineers work mostly in road layout and building. Other civil engineers work mostly with structures in buildings. They are sometimes referred to as structural engineers.

*Contractors* are the owners of the businesses that do most of the building. In larger construction firms, the principal (the owner) may be more concerned with running the business than with supervising construction. Some contractors are referred to as general contractors and others as *subcontractors* (Figure I-4). The general contractor is the principal construction company hired by the owner to construct the building. A general contractor might have only a skeleton crew, relying on subcontractors for most of the actual construction. The general contractor's superintendent coordinates the work of all the subcontractors.

It is quite common for a successful journeyman to start his or her own business as a contractor, specializing in the field in which he or she was a

journeyman. These are the subcontractors that sign on to do a specific part of the construction, such as framing or plumbing. As the contractor's company grows and the company works on several projects at one time, the skilled workers with the best ability to lead others may become foremen. A foreman is a working supervisor of a small crew of workers in a specific trade. All contractors have to be concerned with business management. For this reason, many successful contractors attend college and get a degree in construction management. Most states require contractors to have a license to do contracting in their state. Requirements vary from state to state, but a contractor's license usually requires several years of experience in the trade and a test on both trade information and the contracting business.

*Construction managers* or project managers are those professionals who work for the owner to oversee the entire construction process. Their main objective is to see that the construction process flows efficiently without delay or slowdown and the resources are used to best advantage. Their goal is to see that the job is completed on time, on budget, and is of the desired quality. They coordinate and control when the various trades will need to complete their portions of the job and what standards will guide the work performed. They estimate materials and budget when payments can be made to material suppliers and trades. They serve to make sure everyone on the job works together.

## An Overall View of Design and Construction

To understand the relationships between some of the design and construction occupations, we shall look at a scenario for a typical housing development. The first people to be involved are the community planners and the real estate *developer*. The real estate developer has identified a 300-acre tract on which he would like to build nearly 1000 homes, which he will later sell at a good profit. The developer must work with the city planners to ensure that the use he has planned is acceptable to the city. The city planner is responsible for ensuring that all building in the city fits the city's development plan and zoning ordinances. On a project this big, the developer might even bring in a planner of his own to help decide where parks and community buildings should be located and how much parking space they will need.

As the plans for development begin to take shape, it becomes necessary to plan streets and to start designing houses to be built throughout the development. A civil

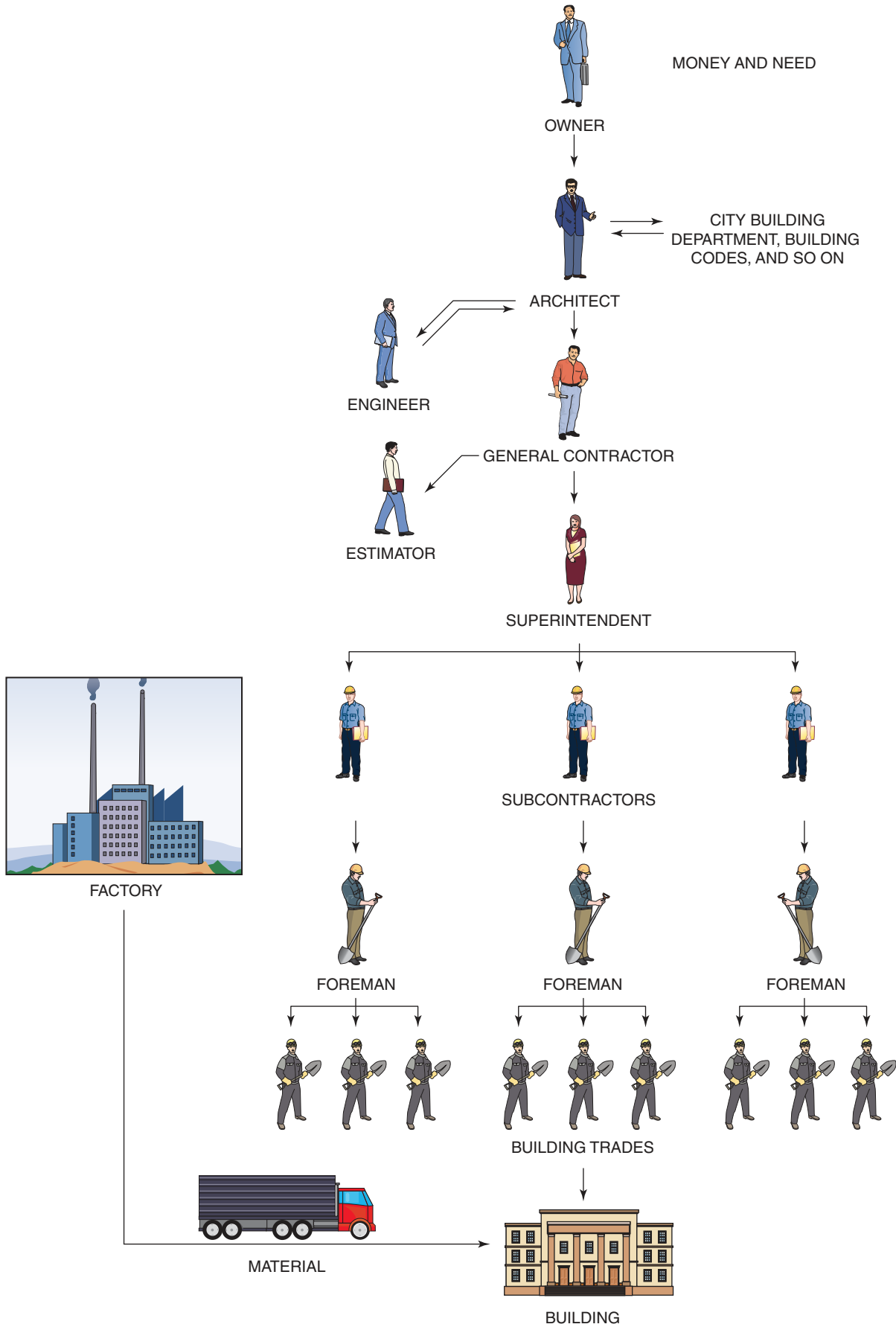


FIGURE I-4 Organization of the construction industry.

engineer is hired to plan and design the streets. The civil engineer will first work with the developer and planners to lay out the locations of the streets, their widths, and drainage provisions to get rid of storm water. The civil engineer also considers soil conditions and expected traffic to design the foundation for the roadway.

An architectural firm, or perhaps a single architect, will design the houses. Typically, several stock plans are used throughout a development, but many home owners wish to pay extra to have a custom home designed and built. In a custom home, everything is designed for that particular house. Usually the home owner, who will eventually live in the house, works with the architect to specify the sizes, shapes, and locations of rooms, interior and exterior trim, type of roof, built-in cabinets and appliances, use of outdoor spaces, and other special features. Architects specialize in use of space, aesthetics (attractive appearance), and livability features. Most architectural features do not involve special structural considerations, but when they do, a structural engineer is employed to analyze the structural requirements and help ensure that the structure will adequately support the architectural features.

One part of construction that almost always involves an engineer is the design of roof trusses. Roof trusses are the assemblies that make up the frame of the roof. Trusses are made up of the top chords, bottom chords, web members, and gussets. The engineer considers the weight of the framing materials, the weight of the roof covering, the anticipated weight of any snow that will fall on the roof in winter, and the span (the distance between supports) of the truss to design trusses for a particular purpose. The architect usually hires the engineer for this work, and so the end product is one set of construction drawings that includes all the architectural and engineering specifications for the building. Even though the drawings are sometimes referred to as architectural drawings, they include work done by architects, engineers, and their technicians. Building codes require an architect's seal on the drawings before work can begin. The architect will require an engineer to certify certain aspects of the drawings before putting the architect's seal on them.

## FORMS OF OWNERSHIP

Construction companies vary in size from small, one-person companies to very large international organizations that do many kinds of construction. However, the size of the company does not necessarily

indicate the form of ownership. Three types of ownership and the advantages and disadvantages of each are shown in [Figure I-5](#).

## UNIONS AND CONTRACTORS' ASSOCIATIONS

The construction industry contains thousands of organizations of people with common interests and goals. Whole directories of these organizations are available in libraries and on the Internet. Two categories of construction organizations are of particular importance to construction students: craft unions and contractors' associations.

### UNIONS

A *craft union*, usually just called a "union," is an organization of workers in a particular building trade. Workers' unions were first formed in the 1800s when factory workers were being forced to work extreme hours under unsafe conditions—and for very low wages. Although working conditions in both factories and construction have improved dramatically, unions continue to serve a valuable role in the construction industry. [Figure I-6](#) lists several national construction craft unions.

Union members pay dues to be members of the union. Dues money pays for the benefits the union provides for its members. Most unions have an apprenticeship program that includes both classroom instruction and on-the-job supervised work experience. Some of the members' dues pay for instructors, classroom space, and training supplies. Unions usually provide a pension for members who have worked in the trade. Because they represent a large block of members, unions can be a powerful force in influencing government to do such things as pass worker safety laws, encourage more construction, and support technology that is good for construction. Unions negotiate with employers (contractors) to establish both a pay rate and working conditions for their members. It is quite typical to find that union members enjoy a higher hourly pay rate than nonunion workers in the same trade.

### CONTRACTORS' ASSOCIATIONS

Associations of contractors include just about every imaginable type of construction contractor. [Figure I-7](#) lists only a small number of the largest associations

Forms of Ownership	What it Means	Advantages	Disadvantages
<b>Sole Proprietorship</b>	A sole proprietorship is a business whose owner and operator are the same person.	The owner has complete control over the business and there is a minimum of government regulation. If the company is successful, the owner receives high profits.	If the business goes into debt, the owner is responsible for that debt. The owner can be sued for the company, and the owner suffers all the losses of the company.
<b>Partnership</b> (General and Limited Liability Partnership (LLP))	A partnership is similar to a sole proprietorship, but there are two or more owners.  <i>General:</i> In a general partnership, each partner shares the profits and losses of the company in proportion to the partner's share of investment in the company.  <i>LLP:</i> A limited liability partner is one who invests in the business, receives a proportional share of the profit or loss, but has limited liability.	<i>General Partnership:</i> The advantage is that the partners share the expense of starting the business and partnerships are not controlled by extensive government regulations.  <i>LLP:</i> A limited liability partner can only lose his or her investment	<i>General Partnership:</i> Each partner can be held responsible for all the debts of the company.  <i>LLP:</i> Every LLP must have one or more general partners who run the business. The general partners in an LLP have unlimited liability and they can be personally sued for any debts of the company
<b>Corporation</b>	In a corporation a group of people own the company. Another, usually smaller, group of people manage the business. The owners buy shares of stock. A share of stock is a share or a part of the business. The value of each share increases or decreases according to the success of the company.	In a corporation, no person has unlimited liability. The owners can only lose the amount of money they invested in stock. The owners of a corporation are not responsible for the debts of the corporation. The corporation itself is the legal body and is responsible for its own debts.	The government has stricter regulations for corporations than for the other forms of ownership. Also, corporations are more expensive to form and to operate than are proprietorships and partnerships.

**FIGURE I-5** Three types of ownership.

that have apprenticeship programs. Some contractors' associations are formed to represent only nonunion contractors; a few represent only union contractors; and others represent both. Many associations of nonunion contractors were originally formed because the contractor members felt a need to work together to provide some of the benefits that union contractors receive—such as apprentice training and a lobbying voice in Washington, D.C.

## BUILDING CODES

Most towns, cities, and counties have *building codes*. A building code is a set of regulations (usually in the form of a book) that ensure that all buildings in that jurisdiction (area covered by a certain government agency) are of safe construction. Building codes specify such things as minimum size and spacing of lumber



International Association of Bridge, Structural, Ornamental and Reinforcing Iron Workers ([www.ironworkers.org/](http://www.ironworkers.org/))

International Association of Heat and Frost Insulators and Asbestos Workers ([www.insulators.org/](http://www.insulators.org/))

International Brotherhood of Boilermakers, Iron Ship Builders, Blacksmiths, Forgers and Helpers ([www.boilermakers.org/](http://www.boilermakers.org/))

International Brotherhood of Electrical Workers ([www.ibew.org/](http://www.ibew.org/))

International Brotherhood of Teamsters ([www.teamster.org/](http://www.teamster.org/))

International Union of Bricklayers and Allied Craftworkers ([www.bacweb.org/](http://www.bacweb.org/))

International Union of Elevator Constructors ([www.iuec.org/](http://www.iuec.org/))

International Union of Operating Engineers ([www.iuoe.org/](http://www.iuoe.org/))

International Union of Painters and Allied Trades ([www.iupat.org/](http://www.iupat.org/))

Laborers' International Union of North America ([www.liuna.org/](http://www.liuna.org/))

Operative Plasterers' and Cement Masons' International Association of the United States and Canada ([www.opcmia.org/](http://www.opcmia.org/))

Sheet Metal Workers' International Association ([www.smwia.org/](http://www.smwia.org/))

United Association of Journeymen and Apprentices of the Plumbing and Pipefitting Industry of the United States and Canada ([www.ua.org/](http://www.ua.org/))

United Brotherhood of Carpenters and Joiners of America ([www.carpenters.org/](http://www.carpenters.org/))

United Union of Roofers, Waterproofers and Allied Workers ([www.unionroofers.com/](http://www.unionroofers.com/))

Utility Workers Union of America ([www.uwua.org/](http://www.uwua.org/))

**FIGURE I-6** Construction craft unions.

Air Conditioning Contractors of America (<http://www.acca.org>)

Air Conditioning Heating and Refrigeration Institute (<http://www.ahrinet.org/>)

Associated Builders and Contractors (<http://www.abc.org>)

National Association of Home Builders (<http://www.nahb.org>)

Home Builder's Institute (<http://www.hbi.org>)

Independent Electrical Contractors Association (<http://www.ieci.org>)

National Electrical Contractors Association (<http://www.necanet.org>)

National Utility Contractors Association (<http://www.nuca.com>)

Plumbing-Heating-Cooling Contractors Association (<http://www.phccweb.org>)

The Associated General Contractors (AGC) of America (<http://www.agc.org>)

**FIGURE I-7** These are only a few of the largest construction associations.

for wall framing, steepness of stairs, and fire rating of critical components. The local building department enforces the local building codes. States usually have

their own building codes, and state codes often require local building codes to be at least as strict as the state code. Most small cities and counties adopt the state

code as their own, meaning that the state building code is the one enforced by the local building department.

Until recently, three major model codes were published by independent organizations. (A model code is a suggested building code that is intended to be adopted as is or with revisions to become a government's official code.) Each model code was widely used in a different region of the United States. By themselves model codes have no authority. They are simply a model that a government agency can choose to adopt as their own or modify as they see fit. For 2015, the International Code Council released new editions of the *International Building Code* and the *International Residential Code* to cover home construction (Figure I-8). The next edition of the International Residential Code comes out in 2018. Since publication of the first *International Building Code*, states have increasingly adopted it as their building code.

Other than the building code, many codes govern the safe construction of buildings: plumbing codes, fire protection codes, and electrical codes. Most workers on the job site do not need to refer to the codes much during construction. It is the architects and engineers who design the buildings that usually see that the code requirements are covered by their designs. Plumbers and electricians do, however, need to refer to their respective codes frequently. Especially in residential construction, it is common for the plans to indicate where fixtures and outlets are to be located, but the plumbers and

electricians must calculate loads and plan their work so it meets the requirements of their codes. The electrical and plumbing codes are updated frequently, so the workers in those trades spend a certain amount of their time learning what is new in their codes.

## WORKING IN THE INDUSTRY

Often success in a career depends more on how people act or how they present themselves to the world than it does on how skilled they are at their job. Most employers would prefer to have a person with modest skills but a great work ethic than a person with great skills but a weak ethic.

## ETHICS

*Ethics* are principles of conduct that determine which behaviors are right and wrong. The two aspects of ethics are values and actions. *Values* have to do with what we believe to be right or wrong. We can have a very strong sense of values, knowing the difference between right and wrong, but not act on those values. If we know what is right but we act otherwise, we lack ethics. To be ethical, we must have good values and act accordingly.

We often hear that someone has a great work ethic. That simply means that the person has good ethics in



FIGURE I-8 The International Residential Code and the International Building Code.

matters pertaining to work. Work ethic is the quality of putting your full effort into your job and striving to do the best job you can. A person with a strong work ethic has the qualities listed in [Figure I-9](#). Good work ethics become habits, and the easiest way to develop good work ethics is to consciously practice them.

#### A person with a strong work ethic:

- Shows up to work a few minutes early instead of a few minutes late
- Looks for a job to do as soon as the previous one is done (This person is sometimes described as a self-starter.)
- Does every job as well as possible
- Stays with a task until it is completely finished
- Looks for opportunities to learn more about the job
- Cooperates with others on the job
- Is honest with the employer's materials, time, and resources

**FIGURE I-9** Characteristics of a good work ethic.

## COMMON RATIONALIZATIONS

We judge ourselves by our best intentions and our best actions. Others judge us by our last worst act. Conscientious people who want to do their jobs well often fail to consider their behavior at work. They tend to compartmentalize ethics into two parts: private and occupational. As a result, sometimes good people think it is okay to do things at work that they know would be wrong outside of work. They forget that everyone's first job is to be a good person. People can easily fall prey to rationalizations when they are trying to support a good cause. "It is all for a good cause" is an attractive rationale that changes how we see deception, concealment, conflicts of interest, favoritism, and violations of established rules and procedures. In making tough decisions, do not be distracted by rationalizations.

Good work ethics yield great benefits. As little children, most of us learned the difference between right and wrong. As adults, when we do what we know is right, we feel good about ourselves and what we are doing. On the other hand, doing what we know is wrong is depressing. We lose respect for ourselves, knowing that what we have done is not something we would want others to do to us. Employers recognize

people with a good work ethic. They are the people who are always doing something productive, their work turns out better, and they seem cheerful most of the time. Which person do you think an employer will give the most opportunities to: a person who is always busy and whose work is usually well done or a person who seems glum and must always be told what to do next?

## WORKING ON A TEAM

Constructing a building is not a job for one person acting alone ([Figure I-10](#)). The work at the site requires cooperative effort by carpenters, masons, plumbers, painters, electricians, and others. Usually several workers from each of these trades collaborate. A construction project without teamwork would have lots of problems. For example, one carpenter's work might not match up with another carpenter's work. There could be too much of some materials and not enough of others. Walls may be enclosed before the electrician runs the wiring in them.

Teamwork is very important on a construction site, but what does being a team player on a construction team mean? Effective team members have the best interests of the whole team at heart. Each team member has to carry his or her own load, but it goes beyond that. Sometimes a team member might have to carry more than his or her own load, just because that is what is best for the team. If you are installing electrical boxes and the plumber says one of your boxes is in the way of a pipe, it might be in the best interests of the project to move the electrical box. That would mean you would have to undo work you had just completed and then redo it. It is, after all, a lot easier to relocate an outlet box than to reroute a sink drain.

The following are six traits of an effective team:

- **Listening.** Team members listen to one another's ideas. They build on teammates' ideas.
- **Questioning.** Team members ask one another sincere questions.
- **Respect.** Team members respect one another's opinions. They encourage and support the ideas of others.
- **Helping.** Team members help one another.
- **Sharing.** Team members offer ideas to one another and tell one another what they have learned.
- **Participation.** Team members contribute ideas, discuss them, and play an active role together in projects.



**FIGURE I-10** Work on the job requires cooperative efforts by different individuals from different trade areas.

## COMMUNICATION

How could members function as a team without communication? Good communication is one of the most important skills for success in any career. Employers want workers who can communicate effectively; but more importantly, you must be able to communicate with others to do your job well and to be a good team member. How many of the six traits of an effective team require communication?

Many forms of communication exist, but the most basic ones are speaking, listening, writing, reading,

and body language. If you master those five forms of communication, you will probably succeed in your career.

### Speaking

To communicate well through speech, you need a reasonably good vocabulary. It is not necessary, or even desirable, to fill your speech with a lot of flowery words that do not say much or that you do not really understand. What is necessary is to know the words that convey what you want the listener to hear, and it is equally necessary to use good enough grammar so those words can be communicated properly. Using

the wrong word or using it improperly can cause two serious problems: For one thing, if you use the wrong word, you will not be saying what you intended to say. This is also often true if you use a great word wrong because you still might not be saying what you thought you were saying. For another thing (the second serious problem), using a poor choice of words or using bad grammar gives the listener the impression that you are poorly educated or that maybe you just do not care about good communication skills. As a businessperson, you will find that communicating is critical to earning respect as a professional as well as to gaining people's business. Three important steps of effective communication are:

- Looking your listeners in the eye.
- Asking yourself if you think they understand what you are saying. If it is important, ask them if they understand.
- Trying a different approach if they do not understand.

## Listening

Good listening is an important skill. Have you ever had people say something to you, and after they were finished and gone, you wondered what they said or you missed some of the details? Perhaps they were giving you directions or telling you about a school assignment. If only you could listen to them again! If possible, try paraphrasing. Paraphrasing means to repeat what they said but in different words. If someone gives you directions, wait until the person is finished. Then, repeat the directions to the person, so he or she can tell you if you are correct. Look at the speaker and form a mental picture of what the speaker is saying. Make what the speaker is saying important to you. Good listening can mean hearing and acting on a detail of a job that will result in giving a competitive edge in bidding.

## Writing

Writing is a lot like speaking, except you do not have the advantage of seeing if the person seems to understand or of asking if the person understands. That means you really have to consider your reader. If you are giving instructions, keep them as simple as possible. If you are reporting something to a supervisor, make your report complete, but do not take up his or her time with unrelated trivia. Penmanship, spelling, and grammar count. Always use good grammar to ensure that you are saying what you intend and that your reader will take you seriously. Use standard penmanship, and make it as neat as

possible. Do not invent new ways of forming letters, and do not try to make your penmanship ornate. You will only make it harder to read. If you are unsure of how to spell a word, look it up in a dictionary. Next time, you will know the word and will not have to look it up. After you write something—read it, thinking about how your intended reader will take it. Make changes if necessary. Your writing is important! Sole proprietors have to demonstrate good writing skills in proposals and contracts. If either of these is poorly written, it can cost the business a lot of money.

## Reading

You will have to read at work. That is a fact no matter what your occupation. You will have to read building specifications, instructions for use of materials and tools, safety notices, and notes from the boss (**Figure I-11**). To develop reading skills, find something you are interested in and spend at least 10 or 15 minutes every day reading it. You might read the sports section of the newspaper, books about your hobby, hunting and fishing magazines, or anything else that is interesting to you. What is important is that you read. Practicing reading will make you a better reader. It will also make you a better writer and a better speaker. When you come across a word you do not know how to pronounce or you do not know the meaning of, look it up or ask someone for help. You will find that you learn pronunciation and meaning very quickly, and your communication skills will improve faster than you expect. In practically no time, you will not need help very often.



**FIGURE I-11** Copies of material data safety sheets.

## Electronic and Digital

Personal electronic devices are being used more and more everywhere and the job site is no exception. Cell phones allow workers to be in continual communication

with suppliers and supervisors. Smart phones make it easy to research any hazards of a particular material or best a method of installation. Hand held tablets allow workers to instantly view updated or corrected drawings from the architect. Laptop computers bring office work into the field via word processing, spreadsheets, and scheduling software. All these digital enhancements have changed job site expectations. Workers must be savvy in and able to use new technology while at the same time use them safely. Distracted workers are a hazard to everyone around them.

## Body Language

Body language is an important form of communication. How you position your body and what you do with your hands, face, and eyes all convey a lot of information to the person you are communicating with. Whole books are written about how body language is used to communicate and how to read body language. We will only discuss a couple of key points here.

When you look happy and confident, the message you convey is that you are honest (you have nothing to hide or to worry about) and you probably know what you are talking about. If you look unhappy, unsure of yourself, or uninterested, your body language tells the other person to be wary of what you are saying—something is wrong. The following are a few rules for body language that will help you convey a favorable message:

- Look the other person in the eye. Looking toward the floor makes you look untrustworthy. Looking off in space makes you seem uninterested in the other person.
- Keep your hands out of your pockets, and do not wring your hands. Just let your hands rest at your sides or in your lap if you are sitting. An occasional hand gesture is okay, but do not overdo it.
- Dress neatly. Even if you are wearing work clothes, you can be neat. Faddish clothes, extra baggy or extra tight fitting clothes, and T-shirts with offensive messages on them all distract from the real you.
- Speak up. How loudly you speak might not seem like body language, but it has a lot to do with how people react to you. If they have to strain to hear what you are saying, they will think that either you are not confident in what you are saying or you are angry and not to be trusted. If you see your listeners straining to hear you or if they frequently ask you to repeat what you are saying, speak a little louder.

## CUSTOMER SERVICE

In any industry, you will only be as successful as you are good at building your reputation for doing quality work and to the degree that your customers are happy with you and your job. On the job site, your customer might be a crew chief, a foreman, a subcontractor, or a contractor. If you are the contractor or subcontractor, the customer will be whoever hired you. It does not actually matter who hired you, though—your role will always be to do the very best job you can for whomever it is that you are working.

Good customer service also includes providing a good value for your fees, being honest, communicating clearly, being cooperative, and looking to provide the best possible experience your customer can have in working with you. Just as when you practice good ethics, when you provide great customer service you will enjoy your job much more. You will be proud of your work, others will want to hire you more often, and your career will be much easier to build. Think about how you like being treated when you are a customer—and always try to treat your customers at least as well.

## LIFELONG LEARNING

Lifelong learning refers to the idea that we all need to continue to learn throughout our entire lives. We have greater opportunities to learn and greater opportunities to move up a career ladder today. Our lives are filled with technology, innovative new materials, and new opportunities. People change not only jobs, but entire careers several times during their working life. Those workers who do not understand the new technology in the workplace, along with those who do not keep up with the changes in how their company is managed, are destined to fall behind economically. There is little room in a fast-paced company of this century for a person whose knowledge and skills are not growing as fast as the company. To keep up with new information and to develop new skills for the changing workplace, everyone must continue to learn throughout life.

## CONSTRUCTION TRENDS

Every industry has innovations, and construction is no exception. As a construction professional, it is important to be aware of new technologies, new methods, and new ways of thinking about your work. This is as important for a worker's future employment

as being aware of safety and ethical business practices. Some of the key technological trends include disaster mitigation, maintenance, building modeling, and green building.

## DISASTER MITIGATION

Both new and existing buildings need to be strengthened and improved to deal with earthquakes, floods, hurricanes, and tornados. Actions like improving wall bracing or preparing moisture management reduces damage and improves safety when these events occur. These actions are increasingly required by building regulations (especially in disaster-prone areas) and requested by property owners and insurers.

## MAINTENANCE

Besides single natural disasters, preventing long-term wear and tear is also an important industry trend. Property owners are more concerned about the costs, effort, and time required to repair and to maintain their homes and buildings. So, there has been significant research into materials that are more durable, construction assemblies that manage moisture, air and elements better, and overall higher quality construction work.

## BUILDING MODELING

One of the biggest new trends in construction technology does not include construction materials at all: it includes being able to design, simulate, and manage buildings with the use of computer and information technology. Some of these tools, like Computer-Aided Drafting (CAD) and Computer-Aided Manufacturing (CAM), have been around for decades. Others, like energy modeling and simulation software or project management tools, are being used more and more. Still others, like Building Information Modeling (BIM) are gathering many of these previous tools into single computing platforms. In all cases, the ability to use computers and professional software is becoming mandatory among workers.

## GREEN BUILDING

Probably the biggest trend in the construction industry over the last decade has been *green building*—that is, planning, design, construction, and maintenance practices that try to minimize a building's impact on the environment throughout its use. Although a set definition of green building is still evolving, everyone

agrees on a few key concepts that are important and that in themselves are also major construction trends.

## Energy Efficiency and Renewable Energy Sources

The most widely known of all green building trends involves the kind and amount of energy that buildings use. New buildings should consume as little energy as possible while at the same time improving the personal comfort level of their occupants. The boundary between inside and outside air, the insulation layer, is the number one area of concern for a builder to reduce operating costs. Buildings must be designed and constructed to maximize the use of building materials. These materials must be installed according to the proper standards. This equates to all building trades. People must know their trade well and perform each installation with great care.

The use of renewable energy sources (like solar photovoltaics) or passive solar orientation is a smart way to reduce the net energy demand of buildings. Then, the combination of good building envelope construction and efficient equipment and appliances can all reduce utility costs for property owners, much like the maintenance trend reduces repair costs ([Figure I-12](#)).



**FIGURE I-12** Duct insulation increases system energy efficiency.

## Material Efficiency

Builders are becoming more aware of the amount of waste coming from construction sites and inefficiency in the amount of materials (like structural members) that they install in buildings. Many of the materials that are used in construction also do not come from

naturally renewable sources or from recycled content materials. Using materials from preferred sources, using them wisely, and then appropriately recycling what is left is a big industry trend (Figure I-13).



**FIGURE I-13** Construction site waste recycling. Courtesy of Carl Seville.

## Occupant Health and Safety

The quality of indoor air is influenced by the kinds of surface paints and sealants that are used as well as the management of moisture in plumbing lines, HVAC equipment, and fixtures. Long-term maintenance and care by home owners and remodelers also can shape the prevalence of pests, damage, and mold. Builders and remodelers are becoming more aware of the products and assemblies they use that could have an effect on indoor environments.

## Water Conservation and Efficiency

Many builders and property owners are attempting to collect, efficiently use, and reuse water in ways that save the overall amount being used. From using collectors of rainwater to irrigate lawns, to installing low-flow toilets and water-conserving appliances, to feeding used “greywater” from sinks and showers into secondary non-occupant water needs, water efficiency is a trend in all green building but especially where water shortages or droughts are prevalent.

## Low-Impact Development

Builders concerned with the effect of the construction site on the land, soil, and water underneath are incorporating storm water techniques, foundation and pavement treatments, and landscaping preservation

methods to minimize disturbances to the land and surrounding natural environments.

There are many ways to keep track of the latest trends in the construction industry. Trade or company journals, online resources and blogs, and the latest research coming out of government and university laboratories are several ways to keep informed and up-to-date on the latest industry trends.

## JOB OPPORTUNITIES

Because of the widespread need for electrical services, jobs for residential electricians are found in all parts of the country. Most states and localities require electricians to be licensed. Although licensing requirements differ from area to area, residential electricians generally have to pass an examination that tests their knowledge of electrical theory, the *National Electrical Code*<sup>®</sup>, local electrical codes, and the various types of wiring methods and materials. Experienced electricians can advance to jobs as estimators, supervisors, project managers, or even electrical inspectors. They may also decide to start their own electrical contracting business.

## EMPLOYMENT

As key members of the residential construction industry, residential electricians install, maintain, and troubleshoot electrical wiring systems in a house. A residential electrician’s job requires skills and knowledge in the following areas:

- Understanding and following both general and electrical safety procedures.
- Knowing the common hardware and materials used in a residential electrical system.
- Knowing how to read and understand residential building plans.
- Knowing how to use hand tools, power tools, and testing equipment.
- Understanding and applying the *National Electrical Code*<sup>®</sup> as well as state and local codes when installing electrical wiring.
- Installing service entrances so that electrical power can be provided from the electric utility to a building’s electrical system.
- Installing branch and feeder circuits with various types of cable and conduit.



- Installing metal or nonmetallic electrical boxes to the framing members of a house.
- Connecting conductors to circuit breakers, lighting fixtures, receptacles, switches, paddle fans, electric motors, and other electrical equipment.
- Installing video, voice, and data wiring and equipment.
- Rewiring a home or replacing an old fuse box with a new circuit breaker loadcenter.
- Going on “service calls” to identify and then fix electrical problems.
- Installing, maintaining, and troubleshooting photovoltaic renewable energy systems.

Working as a residential electrician can be very rewarding and is usually a lot of fun. There are many positive aspects about the job, such as:

- Residential electricians have a great sense of accomplishment once a house has been wired and everything works correctly.
- Residential electricians work on different sizes and types of houses that make the job very interesting and never boring.
- Residential electricians often work outdoors.
- Being a residential electrician requires a higher level of technical skill than many other construction trades.
- Residential electricians receive higher pay than many other construction trade jobs.

Like any job or career, there are challenges as well. Some of the challenges of being a residential electrician are:

- The work is sometimes strenuous and may require standing or kneeling for long periods of time.
- Residential electricians may be subject to bad weather conditions when working outdoors.
- Residential electricians may have to travel long distances to job sites.
- The work may involve frequently working on ladders and scaffolding.
- There is a risk of injury from electrical shock, burns, falls, and cuts.

Residential electricians should be in good health and have decent physical strength. It also helps to have good agility and manual dexterity. Good color vision is a requirement because electricians often must identify electrical wires by color. It is also important that residential electricians have good people and communication skills.

## JOB OUTLOOK

Employment for residential electricians is projected to increase by at least 14% through the year 2024 according to the Bureau of Labor Statistics, U.S. Department of Labor *Occupational Outlook Handbook, 2016-17 Edition*. This is very encouraging because the average increase for all occupations is only 7%. As the population and the economy grow, more residential electricians will be needed to install and maintain electrical equipment in homes. Also, new technologies are expected to continue to spur demand for residential electricians. Efforts to increase conservation of energy in existing homes and in new home construction will boost demand for residential electricians because electricians are key to installing some of the latest energy savers, such as solar panels and motion sensors for turning on lights.

Because of their training and relatively high earnings, a smaller proportion of electricians than other trade workers leave their occupation each year. In addition to jobs created by the increased demand for electrical work, many openings are expected to occur over the next two decades as a large number of older electricians retire. The median hourly wage for all electricians as of 2016 (the newest data available) was \$25.35, or around \$53,000 per year. The lowest 10% earned less than \$31,800 per year, and the highest 10% earned more than \$90,420 per year. Residential electricians may earn more or less per hour, depending on a number of factors such as experience, education, licenses, and worker demand. Beginning electricians usually start at between 40% to 50% of the rate paid to fully licensed and trained electricians.



## CAREER PROFILE

### CHARLES MARTZ

#### TITLE

Master Electrician, Electrical Inspector, SME (Subject Matter Expert) and Theatre Master Electrician for Iraq and Chief of Electrical Training

#### EDUCATION

Associate of Applied Science degree in Industrial Electrical/Electronics Technology from Kennebec Valley Community College in Fairfield, Maine.

#### HISTORY

Charles had always been fascinated by electricity and he needed a way to provide for his family. Becoming an electrician was an ideal career path for Charles to pursue.

#### ON THE JOB

Since becoming an electrician his responsibilities have varied greatly. Charles spent 2009 in Iraq as an electrical inspector and eventually the SME/Theatre Master Electrician. It was there that he had the opportunity to brief Generals and Colonels on electrical issues in Iraq. Charles also had the opportunity to train third country nationals, electricians, and soldiers on proper grounding and bonding. Since coming home, he has worked for a company where he travels around the country working on various electrical installations, such as federal prisons and most recently a clean coal production plant.

#### CHALLENGES

According to Charles, the most difficult challenge for an electrician is staying up-to-date with the newest technologies, latest equipment, and the most recent National Electrical Code changes.



#### IMPORTANCE OF EDUCATION

Charles believes that a proper education is essential to becoming an electrician and working in the electrical industry. His knowledge of electricity and how it works has not only aided him in the proper installation of electrical equipment, but it has also kept him safe from electric shock.

#### FUTURE OPPORTUNITIES

Charles currently has two job offers in Afghanistan as an Electrical Inspector and one working here in the United States doing electrical inspections for the FBI.

#### WORDS OF ADVICE

“Learn all that you possibly can and ask lots of questions. Do not just take what you hear from another electrician as being gospel, but take the initiative to find out if it is the truth ... do not be afraid to challenge and question! Go above and beyond. Do not be satisfied with ‘good enough.’ Soak up all the knowledge you can when you have the opportunity.”



## CAREER PROFILE

### CHRISTOPHER MORGAN

#### TITLE

Journeyman Wireman

#### EDUCATION

Chris received his electrical pre-apprenticeship certificate through HBI's Electrical Wiring program. He also completed a three-year apprenticeship program with Helix Electric and an additional four-year apprenticeship to become a journeyman wireman.

#### HISTORY

Chris knew he didn't have the money to pay for college out of high school, but he wanted to become an electrician. After high school, Chris enrolled in Golconda Job Corps Center in 2005, where he began his journey to become a wireman. Chris credits his HBI instructor for teaching him all of the basic fundamentals that has helped him become successful as an electrician. Chris also treasures the interpersonal skills he learned through his HBI training to help him communicate well with customers and peers.

#### ON THE JOB

Chris has worked on commercial and residential projects. As a Journeyman Wireman with his current company, he was given his own service van and the opportunity to run some big jobs, including a new dental building at Southern Illinois University and a new train station in Chicago.

#### CHALLENGES

Chris says there are always challenges as an electrician. But, having a support system through his former HBI instructor has helped him overcome



those challenges. Reaching out to others for help can make the daily challenges easier.

#### IMPORTANCE OF EDUCATION

Chris expresses that education comes in different ways. Whether through school, certification programs, apprenticeship programs or from his new or long-time peers, everyone can learn new things every day. Although Chris says he was a fast learner as a student, he notes that other students also took him under their wings to help guide him. In turn, he was able to help others. Helping each other learn is very important.

#### FUTURE OPPORTUNITIES

In the next 3–5 years, Chris plans to run a shop truck and manage major electrical jobs. I want to be a foreman and manage a team of workers on a construction site.

#### WORDS OF ADVICE

"Be willing to learn and realize that you can learn from anybody whether they have one year of experience or 30 years. However, test everything and never take someone else's advice on the status on different things. Find out yourself to be safe. Anyone who likes working with their hands and working outside in different climates should consider learning a construction trade."



## CAREER PROFILE

### TODD NOEL

#### TITLE

Maine Licensed Master Electrician and business owner of Wire Guys Electric

#### EDUCATION

Todd received his Certificate in Electrical Construction Technology and earned an Associate of Applied Science Degree in Industrial Electrical/Electronic Technology from Kennebec Valley Community College in Fairfield, Maine.

#### HISTORY

Having an electrician for a father meant that Todd had an early introduction into the electrical trade at the age of 13. After high school Todd enrolled at Kennebec Valley Community College where he received his certificate and Associates Degree. Following college he spent the next 10 years working in various aspects of the electrical industry while still working part-time for his father doing primarily residential electric construction. In 2004, after he was laid off by his then current employer, Todd decided to start his own business: Wire Guys Electric. He has been self-employed now for six years and has established a solid and ever-expanding client base.

#### ON THE JOB

A typical day for Todd starts in his office checking and replying to emails, returning phone calls, ordering parts, and so on. By 8:00 a.m., he is typically at the job site and, depending upon the job, may have a helper/journeyman with him. He meets with the home owner or general contractor about job specifics for that day, assigns tasks and supervises while working on his own wiring job.



By mid-afternoon he is usually moving on to look at new jobs and returning phone calls. At the end of his work day and in the evening, Todd works on estimates and invoicing.

#### CHALLENGES

Todd finds there are many challenges as a self-employed electrical contractor. It can be difficult to juggle efficiency with the different job requirements, customer schedules, and employee's schedules. In addition, finding time for continuing education, meeting with advertisers, meeting with inspectors, and handling all of the paperwork can also be challenging.

#### IMPORTANCE OF EDUCATION

Todd's education proved to be very important for many reasons. He needed an education to take the tests to get his licenses, but it has also prepared him for other opportunities and challenges he had no idea he would face. Todd's education has given him the knowledge and foundation to act and react in difficult and unfamiliar circumstances, while still completing jobs on schedule. Todd truly believes that he would not have gotten any of the jobs he has had since college if he did not have his education.

## **FUTURE OPPORTUNITIES**

Since he graduated Todd has taken his continuing education seriously. He has continued his education by taking more CAD courses, a supervisory management course, PLC programming courses, servo programming courses, a pneumatic course, an alternative energy course, and a lead smart course. Todd even attended and graduated from a Radon Mitigation program. Taking these

courses and keeping up-to-date on developments in the field is the best way, he believes, to be prepared for future opportunities.

## **WORDS OF ADVICE**

“It is important to treat everyone you deal with with respect. You never know who is going to get the opportunity to say something good or bad about you. Make sure you leave a positive impression.”

## **LOOKING FORWARD**

Before you can start a career in the residential construction industry as a residential electrician, you must acquire the knowledge, skills, and work attitudes required for the job. The chapters that follow in this textbook cover all of the areas needed for you to

become proficient as a residential electrician. Your job now is to be a student and study the material presented in this textbook to the best of your ability. Your instructor will guide you through the process. To a large degree, the better you do your job now as a student will determine how well you eventually do your job as an electrician in the residential construction industry.





## SECTION ONE

# PREPARING AND PLANNING A RESIDENTIAL WIRING JOB

CH 1: Residential Workplace Safety

CH 2: Hardware and Materials Used in Residential Wiring

CH 3: Tools Used in Residential Wiring

CH 4: Test and Measurement Instruments Used in Residential Wiring

CH 5: Understanding Residential Building Plans

CH 6: Determining Branch Circuit, Feeder Circuit, and Service Entrance Requirements







# CHAPTER ONE

## RESIDENTIAL WORKPLACE SAFETY

### OBJECTIVES

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Upon completion of this chapter, the student should be able to:

- 1-1. Demonstrate an understanding of the electrical hazards associated with electrical work.
- 1-2. Demonstrate an understanding of the purpose of the *National Electrical Code*<sup>®</sup>.
- 1-3. Demonstrate an understanding of the arrangement of the *National Electrical Code*<sup>®</sup>.
- 1-4. Identify examples of rules from the *National Electrical Code*<sup>®</sup> that apply to common residential electrical safety hazards.
- 1-5. Demonstrate an understanding of the purpose of NFPA 70E Standard for Electrical Safety in the Workplace.
- 1-6. Identify common electrical hazards and how to avoid them on the job.
- 1-7. Demonstrate an understanding of the purpose of OSHA.
- 1-8. Identify examples of OSHA requirements that apply to various general and electrical safety hazards associated with residential wiring.
- 1-9. Demonstrate an understanding of the personal protective equipment used by residential electricians.
- 1-10. List several safety practices pertaining to general and electrical safety.
- 1-11. Demonstrate an understanding of safety data sheets (SDS).
- 1-12. Demonstrate an understanding of various classes of fires, the types of extinguishers used on them, and the fire triangle.

### KEY TERMS

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aerial lift	electrical shock	Occupational Safety and Health Administration (OSHA)	Safety Data Sheet (SDS)
ampere	grounding	ohm	scaffolding
arc	ground fault circuit interrupter (GFCI)	Ohm's law	shall
arc-blast	hazard	personal protective equipment (PPE)	ventricular fibrillation
arc-flash	insulator	polarized plug	volt
circuit	load	power source	voltage
conductor	<i>National Electrical Code</i> <sup>®</sup> (NEC) <sup>®</sup>	resistance	

**S**afety should be the main concern of every worker. Each person on the job should work in a safe manner, no matter what the occupation. Too often, failure on the part of workers to follow recommended safe practices results not only in serious injury to themselves and fellow workers but also in costly damage to equipment and property. The electrical trades, perhaps more than most other occupations, require constant awareness of the hazards associated with the occupation. The difference between life and death is a very fine line. There is no room for mistakes or mental lapses. Trial-and-error practices are not acceptable! Electricity plays a big part in our lives and serves us well. Being able to control electricity allows us to make it do the things we want it to do. Control comes with a good understanding of how electricity works and an appreciation of the hazards and

consequences involved when this control is not present. A good residential electrician will possess and display respect for the hazards associated with the occupation. Residential electrical workers must realize from the beginning of their training that if they do not observe safe practices when installing, maintaining, and troubleshooting an electrical system, there will be a good chance that they could be injured on the job. Both general and electrical safety is serious business. It is very important that you make workplace safety a part of your everyday life.

## UNDERSTANDING ELECTRICAL HAZARDS

There are three general categories of electrical hazards that a residential electrician could be exposed to. They are electrical shock, arc-flash, and arc-blast. It is very important for an electrician to understand these hazards and learn how to avoid them.

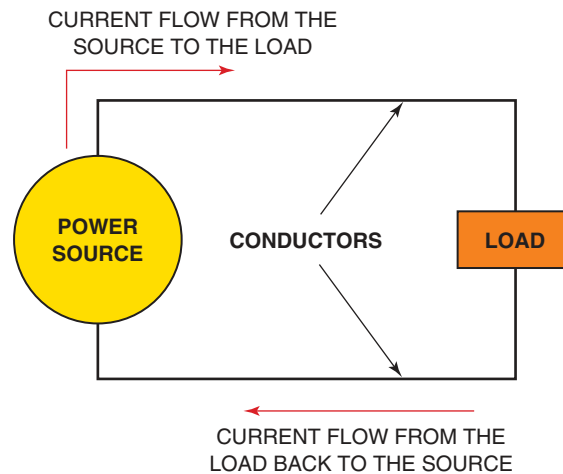
### ELECTRICAL SHOCK

**Electrical shock** is considered the biggest safety hazard associated with doing electrical work. Approximately 30,000 nonfatal electrical shock accidents happen each year. According to the U.S. Bureau of Labor Statistics, there were almost 2000 workers killed during the 10-year period from 2005 to 2015 from electrical shock. Roughly half of those killed were working in the construction trades. Many of the construction trades workers who were killed by electrical shock were electricians.

A lot of residential electricians think that the voltages encountered in residential work will not really hurt them. Others think that residential wiring just does not present the same opportunities for an electrical shock that commercial or industrial electrical work does. They are wrong. The shock hazard exists in residential wiring just as much as it exists in other wiring areas. To help you understand and appreciate the shock hazard in residential wiring, a review of basic electrical theory is provided in the following paragraphs.

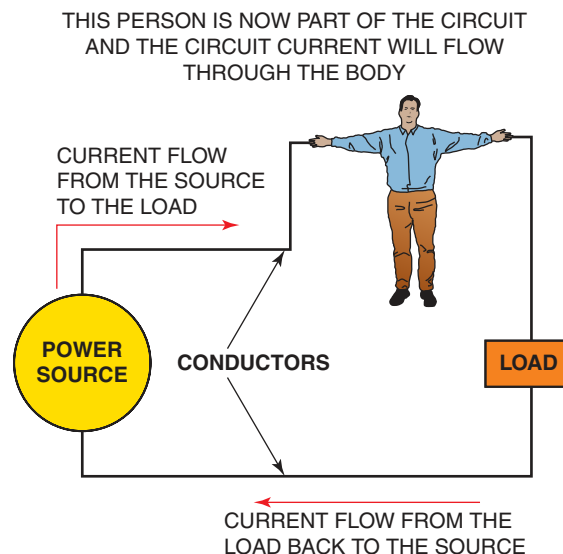
Electricity refers to the flow of electrons through a material. The force that drives the electrons and makes electron flow possible is known as the **voltage**. Any material or substance through which electricity flows is called a **conductor**. Examples of conductors used in electrical work include copper and aluminum. These substances offer very little resistance to electron flow. Some materials offer very high resistance to electron flow and are classified as **insulators**. Examples are plastic, rubber, and porcelain. Electricity flows along a path or **circuit**. Typically, this path begins with a **power source** and follows through a conductor

to a **load**. The path then flows back along another conductor to the power source (**Figure 1-1**).



**FIGURE 1-1** A basic electrical circuit showing the location of the power source, the conductors, and the load.

A very important point to consider at this time is that the human body can, under certain conditions, readily become a conductor and a part of the electrical circuit (**Figure 1-2**). When this happens, the result is often fatal. Electrons flowing in the circuit have no way of detecting the difference between human beings and electrical equipment.



**FIGURE 1-2** An electrical circuit that includes a human body as part of the circuit. Because of the way the body is in the circuit, current will flow into the right hand and travel through the right arm, through the heart and lungs, through the left arm, and back into the circuit through the left hand. The amount of current that flows through the body depends on the body's resistance and the voltage of the power source.

There is a relationship among the **current**, voltage, and **resistance** in an electrical circuit. Georg Simon Ohm discovered this relationship many years ago. His discovery resulted in a mathematical formula that became known as **Ohm's law**:

$$\text{Current} = \text{Electrical Force}/\text{Resistance}$$

Current flow is measured in **amperes**, electrical force (voltage) is measured in **volts**, and electrical resistance is measured in **ohms**. Remember that the lower the circuit resistance, the greater the current that a voltage can push through a circuit.

**Table 1-1** shows some common resistance values for the human body. Dry skin offers much more opposition to current flow through the human body than does a perspiring or wet body. Remember that the higher the ohm value, the more opposition to current flow there is.

SKIN CONDITION	RESISTANCE
Dry skin	100,000 to 500,000 ohms
Perspiring (sweaty hands)	1000 ohms
In water (completely wet)	150 ohms

**TABLE 1-1** Human Body Resistance under Wet and Dry Conditions

The human body reacts differently to the level of current flowing through it. **Table 1-2** shows some typical reactions when a body is subjected to various amounts of current. Remember that a milliamper (mA) is 1/1000 (0.001) of an ampere. It is a very small amount of current.

Consider a situation in which a residential electrician is operating a faulty 120-volt electric-powered drill to bore holes through 2 x 6-inch wall studs. It is a hot and humid day in the middle of the summer. Like many of us, the electrician will perspire heavily and end

up using the drill with wet, sweaty hands. According to **Table 1-1**, the electrician's body resistance would be reduced to about 1000 ohms. If the electrician becomes part of the electrical circuit because of using a faulty drill, the amount of current flowing through the electrician's body could be dangerously high. The current flowing through the electrician's body can be calculated with Ohm's law using the drill's operating voltage of 120 volts and a body resistance of 1000 ohms:

$$\begin{aligned} \text{Current in Amperes} &= 120 \text{ volts}/1000 \text{ ohms} \\ &= 0.12 \text{ ampere, or } 120 \text{ mA} \end{aligned}$$

With this amount of current, the electrician could receive a shock that is sufficient to cause his or her breathing to stop. The electrician may not survive without proper medical treatment.

**CAUTION** A high-voltage electrical shock is more likely to cause death than a low-voltage electrical shock. However, many electrocution deaths occur from low-voltage electrical shocks because electrical workers are exposed more often to low voltages and they do not usually use the same level of caution around low voltage that they do around high voltages.

Let's look at another situation. This time a residential electrician is using a faulty 120-volt hammer drill and masonry anchors to install an electrical box on the outside brick wall of a house. The home's nearest outside receptacle is not close enough for the electrician's extension cord to reach, so he opens a nearby window and runs the extension cord inside the house and plugs it into a receptacle located in a bedroom. The bedroom receptacle does not have ground fault circuit interrupter (GFCI) protection like an outside

CURRENT FLOW	EFFECT ON THE HUMAN BODY
Less than 1 milliamper	No sensation
1 milliamper	Possibly a tingling sensation
5 milliamperes	Slight shock felt; not painful, but disturbing; most people can let go; strong involuntary reactions may lead to injuries
6 to 30 milliamperes	Can definitely feel the shock; it may be painful and you could experience muscular contraction (which could cause you to hold on)
50 to 150 milliamperes	Painful shock, breathing could stop, severe muscle contractions; death is possible
1000 to 4300 milliamperes	Heart convulsions ( <b>ventricular fibrillation</b> ), paralysis of breathing; usually means death
10,000 milliamperes	Cardiac arrest and severe burns; death is probable

<sup>1</sup>The effects are for currents lasting one second at the voltage levels found in residential wiring systems. Higher voltages will cause severe burns.

**TABLE 1-2** Effect of Current on the Human Body<sup>1</sup>

receptacle would have. As the electrician begins to use the hammer drill it starts to rain hard and water begins to puddle around the electrician's feet. He needs to get this job done so he continues using the hammer drill in these conditions. If the electrician becomes part of the electrical circuit because of a faulty hammer drill, the amount of current flowing through the electrician's body could be dangerously high. Body resistance in this case is down to approximately 150 ohms, and the current amount is well in excess of the shock required to cause paralysis of breathing (see [Tables 1-1](#) and [1-2](#)):

$$\begin{aligned} \text{Current in Amperes} &= 120 \text{ volts}/150 \text{ ohms} \\ &= 0.800 \text{ ampere or } 800 \text{ mA} \end{aligned}$$

Do not become a shock victim like the electricians described in the preceding paragraphs. By understanding the shock hazard and following electrical safety procedures at all times, your chance of becoming another victim is greatly reduced.



**The longer a human body is in an electrical circuit, the greater the severity of the injury.**



### FROM EXPERIENCE:

Current that flows from one finger to another on the same hand will not pass through vital organs such as the heart. For this reason, it is recommended that electricians try to use only one hand when using instruments to take measurements on "live" circuits. Current flowing from one hand to the other would pass through the heart or lungs.

## ARC-FLASH

Burns caused by electricity are another hazard encountered by electricians. An **arc-flash** is defined as a dangerous condition associated with the possible release of energy caused by an electric **arc**. When an electric current arcs through the air, the temperature can reach as high as 35,000 degrees Fahrenheit. If you are exposed to these temperatures, direct burns to the skin will occur. Also, unless you are wearing the proper clothing, your clothes could catch on fire.

Usually the severity of the burn depends on the voltage of the circuit. While the chance of an arc-flash burn in residential electrical work is certainly present, the chances for burn injuries tend to be greater on commercial and industrial electrical job sites, where the voltages are typically higher.

An electrical burn is sometimes a result of getting an electrical shock. Burns occur whenever electrical

current flows through bone or tissue. This is a very serious type of injury because it happens inside the body. It may not look that severe from the outside, but you need to be aware that severe tissue damage could have taken place under the skin where you cannot see it. Seek medical help whenever you get an electrical shock, especially if it could result in internal burning.

## ARC-BLAST

Another hazard associated with an arc is the **arc-blast**. When an arc occurs, the extremely high temperature causes an explosive expansion of both the surrounding air and the metal in the arc path. This explosive expansion causes molten metal to be thrown through the air and onto the skin or into the eyes of an electrical worker. The speed of the molten metal flying through the air is estimated to be around 700 mph, which is fast enough for the metal pieces to completely penetrate the human body. Also, the high pressure that results from the arc-blast can rupture eardrums and knock people off ladders and scaffolding. Poor electrical connections or insulation that has failed are the usual causes of arcing that can result in personal injury. Proper personal protective equipment (PPE) must be used where the possibility of arcing exists. This type of protection is covered later in this chapter.



**Always wear the proper personal protective equipment (PPE) and test the electrical equipment for voltage before working on it. Never work on energized equipment unless it is absolutely necessary and you have permission from your supervisor!**

## NATIONAL ELECTRICAL CODE®

The *National Electrical Code*® (*NEC*®) is the guide for safe wiring practices in the electrical field. Every three years the *NEC*® is updated to reflect the latest changes and trends in the electrical industry. It contains specific rules to help safeguard people and property from the hazards arising from the use of electricity. Its content should become very familiar to all individuals involved with the design, installation, or maintenance of electrical wiring in residential buildings. It is used in all fifty states of the United States, all U.S. territories, and in many other countries around the world.

## HISTORY AND DEVELOPMENT OF THE *NEC*®

Knowing a little bit about the history of the *NEC*® will help you understand why it is structured the way it is

and ultimately will help you in understanding how to use the Code in an effective manner. The first edition of the *National Electrical Code*<sup>®</sup> was published in 1897 and came about primarily because of the many electrical fires that were being caused by electric lighting systems installed during the latter part of the nineteenth century. By 1881, sixty-five textile mills in the New England area had been destroyed or badly damaged from fires that were started by faulty electric lighting systems. Because the electrical construction and operation field was relatively new, updates and revisions occurred on a regular basis during the early years of the *NEC*<sup>®</sup>. Starting after the 1975 *NEC*<sup>®</sup>, new editions containing additions, revisions, and deletions began to come out in a three-year cycle that continues to this day. The *National Electrical Code*<sup>®</sup> is considered to be among the finest building code standards in use today.

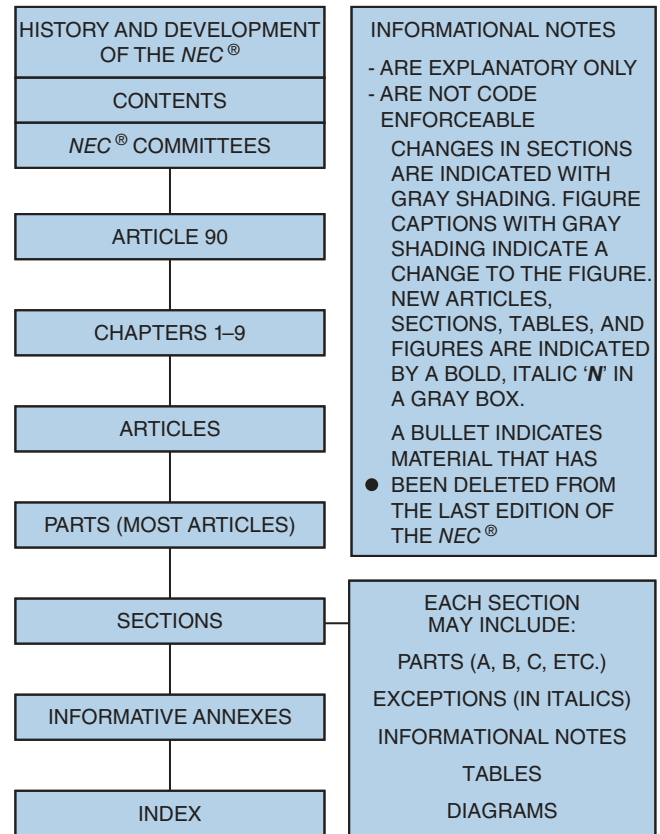
The *National Electrical Code*<sup>®</sup> is developed and published by the National Fire Protection Association (NFPA). The NFPA develops and publishes many different codes and standards, not just the *NEC*<sup>®</sup>. As a matter of fact, the NFPA develops and publishes around 300 safety codes and standards that deal with a range of subjects related to fire, building, life safety, and of course, electrical safety. The *NEC*<sup>®</sup> is document number 70 out of all of the NFPA safety codes and standards and is actually titled *NFPA 70: National Electrical Code*. Other NFPA codes of interest to residential electrical system installers include *NFPA 70A Electrical Code for One-and Two-Family Dwellings and Mobile Homes* and *NFPA 70E Standard for Electrical Safety in the Workplace*. To learn more about the National Fire Protection Association and the various codes and standards it develops and publishes, visit <http://www.nfpa.org>.

## THE ORGANIZATION OF THE *NEC*<sup>®</sup>

When new electricians first take a look at the *National Electrical Code*<sup>®</sup>, they are usually intimidated. It is not the easiest book to read, and it even tells us in the introduction that it is not intended as a “how-to” book or a book to use for someone who has no electrical training. The best way for a new electrician to learn how to use the *NEC*<sup>®</sup> is to use it in conjunction with a textbook. However, the first step in learning how to use the *NEC*<sup>®</sup> is to understand how it is organized (**Figure 1-3**). The following sections cover how the *NEC*<sup>®</sup> is organized and written.

### Chapters

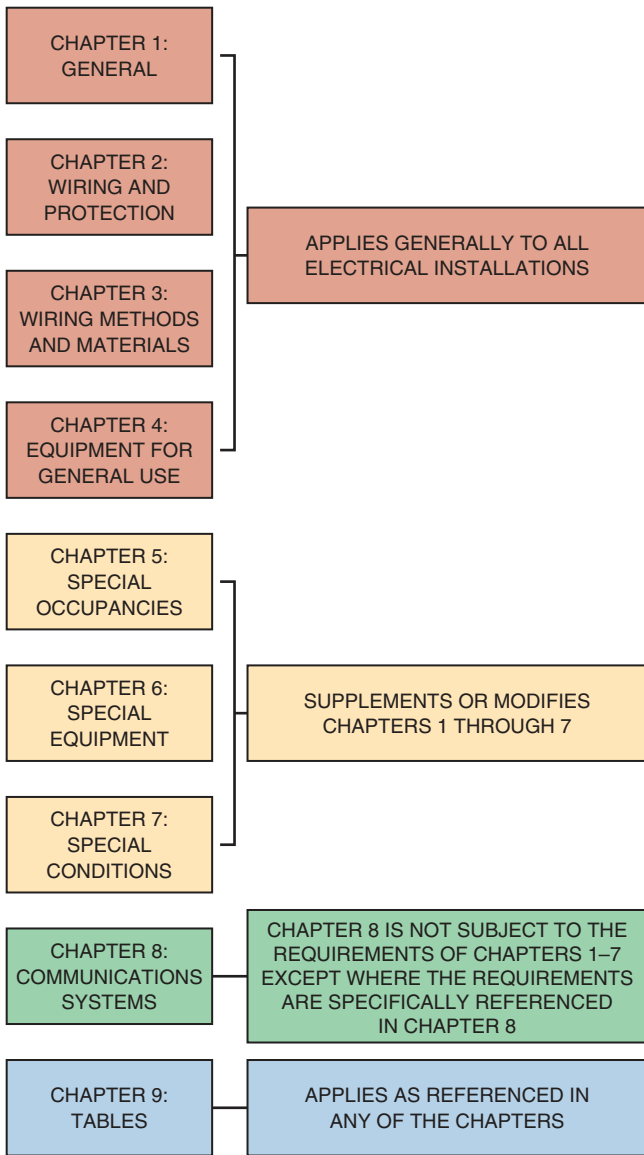
The *National Electrical Code*<sup>®</sup> is divided into nine chapters (**Figure 1-4**). Chapters 1 through 4 consist of rules that apply generally to all electrical installations. **Chapter 1: General** contains definitions and rules covering the basic requirements for electrical



**FIGURE 1-3** The organization of the National Electrical Code<sup>®</sup>.

wiring installations. **Chapter 2: Wiring and Protection** contains rules that apply to the installation of things such as branch circuits, feeders, services, fuses, circuit breakers, and grounding. **Chapter 3: Wiring Methods and Materials** contains rules that apply to various wiring methods, such as nonmetallic sheathed cable, metal-clad cable, rigid metal conduit, and electrical metallic tubing. **Chapter 4: Equipment for General Use** contains rules that apply to the installation of equipment and materials such as receptacles, panelboards, lighting fixtures, electric motors, and transformers.

Chapters 5, 6, and 7 apply to special occupancies and equipment and other special wiring conditions. **Chapter 5: Special Occupancies** contains rules that apply to wiring in special areas such as gas stations, aircraft hangers, hospitals, movie theaters, agricultural buildings, and mobile homes. **Chapter 6: Special Equipment** contains rules that apply to the installation of special equipment such as electric signs, cranes, elevators, electric welders, swimming pools, and solar photovoltaic systems. **Chapter 7: Special Conditions** contains rules that apply to special wiring installations such as emergency power systems, fire alarm systems, and optical fiber cables. Chapters 5,



**FIGURE 1-4** The arrangement of the chapters in the *National Electrical Code*®.

6, and 7 often amend the rules found in Chapters 1 through 4. For example, in Chapter 2, Article 250 Grounding and Bonding permits an equipment grounding conductor to be insulated, covered, or bare, but in Chapter 6, Article 680 Swimming Pools requires an *insulated* equipment grounding conductor. Whenever the requirements of Chapters 5, 6, and 7 differ from Chapters 1 through 4, the requirements in Chapters 5, 6, and 7 apply. For example, in Chapter 2, Articles 210 and 220 contain requirements for branch circuits and service entrance calculations for dwelling units, but in Chapter 5, Article 550 contains branch circuit and service entrance calculation requirements that must be applied to mobile home dwellings.

**Chapter 8: Communications Systems** contains rules for the installation of wiring for communication systems such as cable television and telephones. It is a standalone chapter. As an independent chapter, it is not subject to the requirements of Chapters 1 through 7 unless material in those chapters is specifically referenced in Chapter 8. For example, in Chapter 8, Article 800 refers an installer to Chapter 3, Article 300 when installing telephone wiring in a building through metal or wood framing members.

**Chapter 9: Tables** has only tables. The tables contain information such as conduit fill and properties of conductors. For example, **Table 8: Conductor Properties** in Chapter 9 can be used to find information on the different sizes of conductors recognized by the *NEC*®. Tables are discussed in detail later in this chapter.

### Articles

Chapters 1 through 8 are broken down into a series of articles. Each chapter heading describes the general subject area covered in the chapter. Articles cover specific subjects that fall under the general subject area of a chapter. For example, “Chapter 2, Wiring and Protection” is a general subject area. The articles within this chapter cover topics such as branch circuits, load calculations, grounding and bonding, services, and overcurrent protection. Articles are very specific in their coverage. The article number will always start with the number of the chapter in which it is found. For example, “Article 250, Grounding and Bonding” is found in Chapter 2; and “Article 422, Appliances” is found in Chapter 4 (**Figure 1-5**).

#### Examples of Article Locations in Specific Chapters

- Article 110 Requirements for Electrical Installations is located in Chapter 1 General.
- Article 230 Services is located in Chapter 2 Wiring and Protection
- Article 330 Metal Clad Cable: Type MC is located in Chapter 3 Wiring Methods and Materials.
- Article 422 Appliances is located in Chapter 4 Equipment for General Use.
- Article 517 Health Care Facilities is located in Chapter 5 Special Occupancies.
- Article 680 Swimming Pools, Fountains, and Similar Installations is located in Chapter 6 Special Equipment.
- Article 760 Fire Alarm Systems is located in Chapter 7 Special Conditions.
- Article 810 Radio and Television Equipment is located in Chapter 8 Communications Systems.

**FIGURE 1-5** The first digit of the article number indicates the chapter in which it is located.

Article 90, Introduction is the only article that is not actually located in a chapter. It stands alone at the beginning of the *NEC*® and contains information on such things as the purpose of the *NEC*®, what kind

of electrical installation the *NEC*<sup>®</sup> covers and doesn't cover, and how the rules listed in the *NEC*<sup>®</sup> are to be enforced. Article 90 clearly points out that it is the authority having jurisdiction (AHJ) who will inspect the electrical system installation to make sure that all electrical materials and wiring techniques used are acceptable. It is usually the local or state electrical inspector who inspects the electrical work and who is considered to be the AHJ.

## Parts

Most articles are divided into parts. The parts of an article are indicated by Roman numerals. Part I: General discusses general rules that apply to all the following parts in that article. The rest of the parts are independent and apply to very specific topics. For example, Part III of Article 250, Grounding and Bonding covers grounding electrode system and grounding electrode conductor. The *only* rules covered in Part III are those addressing the grounding electrode system and the grounding electrode conductor. There are no rules covering topics such as equipment grounding or equipment grounding conductors. The rules for these topics are found in Part IV: Equipment Grounding and Equipment Grounding Conductors.

It is important to understand which part of the article you may be looking at in the *NEC*<sup>®</sup>. Rules that apply under one specific part may not apply under another part. An example of this occurs in Article 230, Services where Part II covers Overhead Service Conductors and Part III covers Underground Service Conductors. If you are installing an underground service entrance the rules in Part II will not apply. Only the rules found in Part III would apply to your underground service installation.

## Sections

Each rule found in the *National Electrical Code*<sup>®</sup> is called a section. Articles contain the *NEC*<sup>®</sup> rules covering a specific electrical area. As a result, articles (except Article 100, Definitions) consist of many sections. Sections are identified by a number that consists of the article number, a dot, and then the section number. For example, Section 110.3 is located in Chapter 1, Article 110, and is Section 3. Some sections are further divided into parts identified by uppercase letters in parentheses: (A), (B), (C), and so on. For example, Section 110.3(B) is located in Part (B) of Section 110.3. Sections may further be divided into numbers in parentheses: (1), (2), (3), and so on. There is even a third level of division, which is identified with lowercase letters: (a), (b), (c), and so on.

Many residential electricians who use the *NEC*<sup>®</sup> make the mistake of using the term "article" when they are actually referring to a "section." For example, it

should be said that standard sizes of fuses and nonadjustable circuit breakers are found in *Section 240.6(A)*, not in *Article 240.6(A)*.

## Tables

There are numerous tables found in the *NEC*<sup>®</sup>, and a lot of important information is contained in them. Many tables include numerical data that can be applied to a particular wiring installation. Make sure you read the title of each table very carefully so that you can understand completely what the table actually contains, where its information can be applied, and what its limitations are. When a table is used, make sure to read all footnotes and notes to the tables, because the material there must also be applied.

## Figures

You have most likely heard the old saying that "a picture is worth a thousand words." Unfortunately, the *NEC*<sup>®</sup> does not include many pictures to help us understand how to apply the code rules. However, there are a few basic illustrations used, and they are intended to help explain a section that may be somewhat confusing. A good example is in Article 410. Section 410.2 defines storage space in a clothes closet and Figure 410.2 illustrates the storage space in a clothes closet. Knowing what is considered storage space in a clothes closet is important for an electrician to know because Section 410.16 lists certain installation requirements that apply to luminaires (light fixtures) located in clothes closets, and they include minimum mounting distances from the storage space.

## Exceptions

When an *Exception* to a code rule is used, it is printed in italics. *Exceptions* always follow the rule that they amend, and they only apply to the code rule that they follow. They are in the *NEC*<sup>®</sup> to provide an alternate method to a specific requirement. Two types of *Exceptions* are found in the *NEC*<sup>®</sup>. A mandatory *Exception* is identified by the use of the terms "**shall**" or "shall not" and means that you *must* apply the rule in a specific way. A permissive *Exception* is identified by a phrase like "is permitted." This means that you could apply the rule as written but you may decide not to. Sometimes there is more than one *Exception* to a rule. When this is the case, they are shown as *Exception No. 1*, *Exception No. 2*, and so on.

## Informational Notes

Informational notes provide explanatory material and are found following the section or table to which they apply. They often refer the reader to other *NEC*<sup>®</sup> sections that give additional information on the same subject. Informational notes may also refer the reader