13th Edition

Grob's BASIC ELECTRONICS

McGraw Hill

Mitchel E. Schultz

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Some ancillaries, including electronic and print components, may not be available to customers outside the United States.

This book is printed on acid-free paper.

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Dedication

This book is dedicated to all of the students I have had the honor of teaching over the span of my career. Your passion and level of commitment to learning has truly been inspiring.

Brief Contents

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Preface

The thirteenth edition of ***Grob's Basic Electronics*** provides students and instructors with complete and comprehensive coverage of the fundamentals of electricity and electronics. The book is written for beginning students who have little or no experience and/or knowledge about the field of electronics. A basic understanding of algebra and trigonometry is helpful since several algebraic equations and right-angle trigonometry problems appear throughout the text.

The opening material in the book, titled **"Introduction to Powers of 10,"** prepares students to work with numbers expressed in scientific and engineering notation as well as with the most common metric prefixes encountered in electronics. Students learn how to add, subtract, multiply, divide, square, and take the square root of numbers expressed in any form of powers of 10 notation.

Chapters 1 through 12 cover the basics of atomic structure, voltage, current, resistance, the resistor color code, Ohm's law, power, series circuits, parallel circuits, series-parallel (combination) circuits, voltage and current dividers, analog and digital meters, Kirchhoff's laws, network theorems, wire resistance, switches, insulators, primary and secondary cells, battery types, internal resistance, and maximum transfer of power. The first 12 chapters are considered DC chapters because the voltages and currents used in analyzing the circuits in these chapters are strictly DC.

Chapters 13 through 27 cover the basics of magnetism, electromagnetism, relays, alternating voltage and current, capacitance, capacitor types, capacitive reactance, capacitive circuits, inductance, transformers, inductive reactance, inductive circuits, *RC* and *L/R* time constants, real power, apparent power, power factor, complex numbers, resonance, filters, and three-phase AC power systems. Chapters 13–27 are considered the AC chapters since the voltages and currents used in analyzing the circuits in these chapters are primarily AC.

Chapters 28 through 34 cover the basics of electronic devices, which include semiconductor physics, diode characteristics, diode testing, half-wave and full-wave rectifier circuits, the capacitor input filter, light-emitting diodes (LEDs), zener diodes, bipolar junction transistors, transistor biasing techniques, the common-emitter, common-collector, and common-base amplifiers, JFET and MOSFET characteristics, JFET amplifiers, MOSFET amplifiers, class A, class B and class C amplifiers, diacs, SCRs, triacs, UJTs, op-amp characteristics, inverting amplifiers, noninverting amplifiers, and nonlinear op-amp circuits. ***These seven additional chapters covering electronic devices may qualify this text for those who want to use it for DC fundamentals, AC fundamentals, as well as electronic devices.***

Appendixes **A** through **G** serve as a resource for students seeking additional information on topics that may or may not be covered in the main part of the text. Appendix A provides a comprehensive list of electrical quantities and their symbols. It also includes a listing of the most popular multiple and submultiple units encountered in electronics as well as a listing of all the Greek letter symbols and their uses. Appendix B provides students with a comprehensive overview of solder and the soldering process. Appendix C provides a list of preferred values for resistors. The list of preferred values shows the multiple and submultiple values available for a specified tolerance. Appendix D provides a complete listing of electronic components and their respective schematic symbols. Appendix E provides students with an introduction on how to use an oscilloscope. Both analog and digital scopes are covered. Appendix F provides an extensive overview on the use of **Multisim,** which is an interactive circuit simulation software package that allows students to create and test electronic circuits. Appendix F introduces students to the main features of Multisim that directly relate to their study of DC circuits, AC circuits, and electronic devices. Appendix G provides thorough coverage of the damaging effects of electrostatic discharge (ESD). It also discusses the proper techniques and procedures to follow to prevent ESD from damaging sensitive electronic components and assemblies.

What's New in the Thirteenth Edition of *Grob's Basic Electronics?*

The thirteenth edition continues to provide complete and comprehensive coverage of the basics of electricity and electronics. Several sections throughout the book have been updated to reflect the latest changes in the field of electronics, and new photos and illustrations have been added and/or replaced throughout the book, giving it a fresh, new look. Significant changes are outlined below.

A new section, "*Electric Shock—Dangers, Precautions and First Aid*," has been added. Detailed coverage of the dangers associated with electricity and electronic circuits is provided in this section. A guideline of safe practices for students to follow in a laboratory setting has also been included. This section also outlines the first aid and medical treatment procedures a person should follow if assisting someone who has experienced an electric shock.

Real-World Applications* appearing throughout the book have been increased**. These ***Real-World Applications validate the importance of the topics discussed within a given chapter.

- ***Chapter 1, Electricity:*** A new section, "***Application in Understanding Alternative and Renewable Energy***," has been added. This section defines alternative and renewable energy and discusses the basics of two common types, wind and solar energy. It also discusses the benefits and limitations of solar and wind energy.
- ***Chapter 2, Resistors:*** A new section, "***Application in Understanding Varistors and Surge Protectors***," has been added. In this section, the characteristics and ratings of ***metal-oxide varistors (MOVs)*** are thoroughly examined. Furthermore, this section explains how MOVs are used in ***surge protectors*** to prevent voltage spikes (power surges) from damaging sensitive electronic equipment plugged into the 120 V AC power line.
- ***Chapter 8, Analog and Digital Multimeters:*** A new section, "***Application in Understanding Clamp-On Ammeters***," has also been added. In this section, the ***controls, keys***, and ***features*** of a typical clamp-on ammeter are discussed. Also discussed is the technique for using an ***AC line-splitter*** to measure the AC current in a power cord without splitting the conductors and/or breaking open the circuit.
- ***Chapter 15, Alternating Voltage and Current:*** New information on ***ground-fault circuit interrupters (GFCIs)*** has been added to the section "***Application in Understanding the 120-V Duplex Receptacle***." The basic operation, methods of testing, and safety benefits of GFCIs are thoroughly covered.

A new chapter, "*Three Phase AC Power Systems*," has been added. This chapter provides in-depth coverage of both wye (Y)- and delta (Δ)-connected three-phase AC generators. In this chapter, the relationship between the phase voltages and line voltages as well as the phase currents and line currents are thoroughly explained for a typical three-phase AC circuit. Also included are the four possible source/load configurations in three-phase AC power systems. The voltage, current, and power calculations for these configurations are thoroughly covered in this chapter. And finally, the advantages of using three-phase AC power versus single-phase AC power are explained in detail.

New appendix covering electrostatic discharge, abbreviated ESD. ***"Appendix G—Electrostatic Discharge (ESD)"*** provides detailed coverage of the causes of ESD as well as its damaging effects. Most importantly, this appendix provides detailed information on how to prevent the build-up of ESD and in turn how to prevent ESD from damaging sensitive electronic components and assemblies.

Other Significant Changes:

- ***Chapter 1, Electricity:*** A small section has been added regarding the magnetic field surrounding a current-carrying conductor.
- ***Chapter 11, Conductors and Insulators:*** A new section has been added on fuse ratings.
- ***Chapter 33, Thyristors:*** Several additions and/or clarifications were made regarding DIACs, SCRs, and TRIACs.

Many of the features from the previous editions have been retained for this edition. For example, the ***"Lab Application Assignments"*** at the end of each chapter and the ***MultiSim*** activities embedded within each chapter still remain. These features have and will continue to be a benefit to those students and instructors using the book.

Ancillary Package

The following supplements are available to support *Grob's Basic Electronics*, thirteenth edition.

Problems Manual for Use with Grob's Basic Electronics

This book, written by Mitchel E. Schultz, provides students and instructors with hundreds of additional practice problems for self-study, homework assignments, tests, and review. The book is organized to correlate with the first 27 chapters of the textbook, including the Introduction to Powers of 10 chapter. Each chapter contains a number of solved illustrative problems demonstrating step-by-step how representative problems on a particular topic are solved. Following the solved problems are sets of problems for the students to solve. The changes in the thirteenth edition include a new section on switches and switch applications in chapter 11, Conductors and Insulators. Also new to this edition is a brand-new chapter (chapter 27) on three-phase AC power systems. Included at the end of each chapter is a brief true/false self-test. The *Problems Manual* is a must-have for students requiring additional practice in solving both DC and AC circuits. It is important to note that this book can be used as a supplement with any textbook covering DC and AC circuit theory.

Experiments Manual for Grob's Basic Electronics

This lab manual provides students and instructors with easy-to-follow laboratory experiments. The experiments range from an introduction to laboratory equipment to experiments dealing with operational amplifiers. New to this edition is an experiment involving the Y-Y configuration in three-phase AC power systems. All experiments have been student tested to ensure their effectiveness. The lab book is organized to correlate with the topics covered in the text, by chapter.

All experiments have a Multisim activity that is to be done prior to the actual physical lab activity. Multisim files are part of the Instructor's Resources on Connect. This prepares students to work with circuit simulation software, and also to do "pre-lab" preparation before doing a physical lab exercise. Multisim coverage also reflects the widespread use of circuit simulation software in today's electronics industries.

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Mitchel E. Schultz

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Before you read . . .

Chapter Introductions briefly outline the main chapter topics and concepts.

1

Introduction to Powers of 10

The electrical quantities you will encounter while working in the field of electronics are often extremely small or extremely large. For example, it is not at all uncommon to work with extremely small decimal numbers such as 0.000000000056 or extremely large numbers such as 1,296,000,000. To enable us to work conveniently with both very small and very large numbers, powers of 10 notation is used. With powers of 10 notation, any number, no matter how small or

Chapter Outlines guide you through the material in the chapter ahead. The outlines breakdown the individual topics covered, and each outline is tied to a main heading to emphasize important topics throughout the chapter.

Chapter Outline

Chapter Objectives

After studying this chapter, you should be able to

- *List* the two basic particles of electric charge.
- *Describe* the basic structure of the atom.
- *Define* the terms *conductor, insulator,* and *semiconductor* and give examples of each term.
- *Define* the coulomb unit of electric charge.
- *Define* potential difference and list its unit of measure.
- *Define* current and list its unit of measure.
- *Describe* the difference between voltage and current.
- *Define* resistance and conductance and list the unit of each.
- *List* three important characteristics of an electric circuit.
- *Define* the difference between electron flow and conventional current.
- *Describe* the difference between direct and alternating current.

Chapter Objectives organize and highlight the key concepts covered within the chapter text.

Important Terms

alternating current (AC)
ampere
atom
atomic number
circuit
compound
conductance
conductor
conventional current
coulomb
current
dielectric
direct current (DC)
electron
electron flow
electron valence
element
free electron
insulator
ion
molecule
neutron
nucleus
ohm
potential difference
proton
resistance
semiconductor
siemens
static electricity
volt

Important Terms help students identify key words at the beginning of each chapter. They are defined in the text, at the end of the chapter, and in the glossary.

While you read . . .

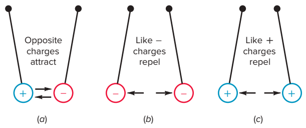
Pioneers in Electronics offer background information on the scientists and engineers whose theories and discoveries were instrumental in the development of electronics.

Bettmann/Getty Images

PIONEERS IN ELECTRONICS

French natural philosopher *Charles-Augustin Coulomb (1736–1806)* developed a method for measuring the force of attraction and repulsion between two electrically charged spheres. Coulomb established the law of inverse squares and defined the basic unit of charge quantity, the coulomb.

Figure 1–5 Physical force between electric charges. (*a*) Opposite charges attract. (*b*) Two negative charges repel each other. (*c*) Two positive charges repel.



repel in Fig. 1–5*b*, and two positive charges of the same value repel each other in Fig. 1–5*c*.

Polarity of a Charge

An electric charge must have either negative or positive polarity, labeled $-Q$ or $+Q$, with an excess of either electrons or protons. A neutral condition is considered zero charge. On this basis, consider the following examples, remembering that the electron is the basic particle of charge and the proton has exactly the same amount, although of opposite polarity.

Good to Know boxes provide additional information in the margins of the text.

GOOD TO KNOW

As an aid for determining the added charge ($\pm Q$) to a neutral dielectric, use the following equation:

$$\pm Q = \frac{\text{Number of electrons added or removed}}{6.25 \times 10^{18}\ \text{electrons/C}}$$

Example 1-1

A neutral dielectric has 12.5×10^{18} electrons added to it. What is its charge in coulombs?

ANSWER This number of electrons is double the charge of 1 C. Therefore, $-Q = 2$ C.

Section Self-Reviews allow students to check their understanding of the material just presented. They are located at the end of each section within a chapter, with answers at the end of the chapter.

Examples throughout the text expand on key concepts and offer students a deeper understanding of complex material.

GOOD TO KNOW

Electricity is a form of energy, where energy refers to the ability to do work. More specifically, electrical energy refers to the energy associated with electric charges.

1–1 Self-Review

Answers at the end of the chapter.

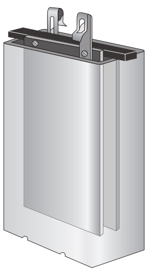
a. Is the charge of an electron positive or negative?
b Is the charge of a proton positive or negative?
c. Is it true or false that the neutral condition means equal positive and negative charges?

1–2 Electrons and Protons in the Atom

Although there are any number of possible methods by which electrons and protons might be grouped, they assemble in specific atomic combinations for a stable arrangement. (An **atom** is the smallest particle of the basic elements which forms

Multisim Icons, identify circuits for which there is a Multisim activity. Multisim files can be found on the Instructor Resources section for Connect.

MultiSim Figure 1–8 Chemical cell as a voltage source. (*a*) Voltage output is the potential difference between the two terminals. (*b*) Schematic symbol of any DC voltage source with constant polarity. Longer line indicates positive side.



(*a*)

then, is a voltage source, or a source of electromotive force (emf). The schematic symbol for a battery or DC voltage source is shown in Fig. 1–8*b*.

Sometimes the symbol E is used for emf, but the standard symbol V represents any potential difference. This applies either to the voltage generated by a source or to the voltage drop across a passive component such as a resistor.

It may be helpful to think of voltage as an electrical pressure or force. The higher the voltage, the more electrical pressure or force. The electrical pressure of voltage is in the form of the attraction and repulsion of an electric charge, such as an electron.

The general equation for any voltage can be stated as

$$V = \frac{W}{Q} \qquad \textbf{(1–1)}$$

where V is the voltage in volts, W is the work or energy in joules, and Q is the charge in coulombs.

Let's take a look at an example.

Example 1-5

What is the output voltage of a battery that expends 3.6 J of energy in moving 0.5 C of charge?

ANSWER Use equation 1–1.

$$V = \frac{W}{Q}$$

After you've read . . .

Real-world **applications** bring to life the concepts covered in a specific chapter.

Application of Ohm's Law and Power Formulas

HOME APPLIANCES

Every electrical appliance in our home has a ***nameplate*** attached to it. The nameplate provides important information about the appliance such as its make and model, its electrical specifications and the Underwriters Laboratories (UL) listing mark. The nameplate is usually located on the bottom or rear-side of the appliance. The electrical specifications listed are usually its power and voltage ratings. The voltage rating is the voltage at which the appliance is designed to operate. The power rating is the power dissipation of the appliance when the rated voltage is applied. With the rated voltage and power ratings listed on the nameplate, we can calculate the current drawn from the appliance when it's being used. To calculate the current (I) simply divide the power rating (P) in watts by the voltage rating (V) in volts. As an example, suppose you want to know how much current your toaster draws when it's toasting your bread. To find the answer you will probably need to turn your toaster rating of 120 V and a power rating of 850 W, the current drawn by the toaster is calculated as follows;

$$I = \frac{P}{V} = \frac{850\ W}{120\ V} = 7.083\ A$$

Some appliances in our homes have a voltage rating of 240 V rather than 120 V. These are typically the appliances with very high power ratings. Some examples include: electric stoves, electric clothes dryers, electric water heaters, and air conditioning units. These appliances may have power ratings as high as 7.2 kW or more. The reason the higher power appliances have a higher voltage rating is simple. At twice the voltage you only need half the current to obtain the desired power. With half as much current, the size of the conductors connecting the appliance to the power line can be kept much smaller. This is important because a smaller diameter wire costs less and is physically much easier to handle.

Each chapter concludes with a **Summary,** a comprehensive recap of the major points and takeaways.

Summary

- Electricity is present in all matter in the form of electrons and protons.
- The electron is the basic particle of negative charge, and the proton is the basic particle of positive charge.
- A conductor is a material in which electrons can move easily from one atom to the next.
- An insulator is a material in which electrons tend to stay in their own orbit. Another name for insulator is dielectric.
- The atomic number of an element gives the number of protons in the nucleus of the atom, balanced by an
- One coulomb (C) of charge is a quantity of electricity corresponding to 6.25×10^{18} electrons or protons. The symbol for charge is Q.
- Potential difference or voltage is an electrical pressure or force that exists between two points. The unit of potential difference is the volt (V). $1\ V = \frac{1\ J}{1\ C}$. In general, $V = \frac{W}{Q}$.
- Current is the rate of movement of electric charge. The symbol for current is I, and the basic unit of measure is the ampere (A). $1\ A = \frac{1\ C}{1\ s}$. In general, $I = \frac{Q}{T}$.
- An electric circuit is a closed path for current flow. A voltage must be connected across a circuit to produce current flow. In the external circuit outside the voltage source, electrons flow from the negative terminal toward the positive terminal.
- A motion of positive charges, in the opposite direction of electron flow, is considered conventional current.
- Voltage can exist without current, but current cannot exist without voltage.
- Direct current has just one direction because a DC voltage source has

Related Formulas are a quick, easy way to locate the important formulas from the chapter.

Related Formulas

$1\ C = 6.25 \times 10^{18}$ electrons

$V = \frac{W}{Q}$

$I = Q/T$

$Q = I \times T$

$R = 1/G$

$G = 1/R$

Multiple-Choice Self-Tests at the end of every chapter allow for quick learning assessment.

Self-Test

Answers at the back of the book.

1. The most basic particle of negative charge is the
a. coulomb.
b. electron.
c. proton.
d. neutron.

2. The coulomb is a unit of
a. electric charge.
b. potential difference.
c. current.
d. voltage.

4. The electron valence of a neutral copper atom is
a. +1.
b. 0.
c. ±4.
d. −1.

5. The unit of potential difference is the
a. volt.
b. ampere.
c. siemens.
d. coulomb.

7. In a metal conductor, such as a copper wire,
a. positive ions are the moving charges that provide current.
b. free electrons are the moving charges that provide current.
c. there are no free electrons.
d. none of the above.

8. A 100-Ω resistor has a conductance, *G*, of
a. 0.01 S.
b. 0.1 S.
c. 0.001 S.

Essay Questions

1. Name two good conductors, two good insulators, and two semiconductors.
2. In a metal conductor, what is a free electron?
3. What is the smallest unit of a compound with the same chemical characteristics?
4. Define the term ion.
5. How does the resistance of a conductor compare to that of an insulator?
6. Explain why potential difference is necessary to produce current in a circuit.
7. List three important characteristics of an electric circuit.
8. Describe the difference between an open circuit and a short circuit.
9. Is the power line voltage available in our homes a DC or an AC voltage?
10. What is the mathematical relationship between resistance and conductance?
11. Briefly describe the electric field of a static charge.

The **Essay Questions** at the end of each chapter are great ways to spark classroom discussion, and they make great homework assignments.

End-of-Chapter Problems, organized by chapter section, provide another opportunity for students to check their understanding, and for instructors to hone in on key concepts.

Problems

SECTION 1–4 THE COULOMB UNIT OF ELECTRIC CHARGE

1–1 If 31.25×10^{18} electrons are removed from a neutral dielectric, how much charge is stored in coulombs?

1–2 If 18.75×10^{18} electrons are added to a neutral dielectric, how much charge is stored in coulombs?

1–3 A dielectric with a positive charge of +5 C has 18.75×10^{18} electrons added to it. What is the net charge of the dielectric in coulombs?

1–4 If 93.75×10^{18} electrons are removed from a neutral dielectric, how much charge is stored in coulombs?

1–5 If 37.5×10^{18} electrons are added to a neutral dielectric, how much charge is stored in coulombs?

SECTION 1–5 THE VOLT UNIT OF POTENTIAL DIFFERENCE

1–6 What is the output voltage of a battery if 10 J of energy is expended in moving 1.25 C of charge?

1–7 What is the output voltage of a battery if 6 J of energy is expended in moving 1 C of charge?

1–8 What is the output voltage of a battery if 12 J of energy is expended in moving 1 C of charge?

1–9 How much is the potential difference between two points if 0.5 J of energy is required to move 0.4 C of charge between the two points?

1–10 How much energy is expended, in joules, if a voltage of 12 V moves 1.25 C of charge between two points?

SECTION 1–6 CHARGE IN MOTION IS CURRENT

1–11 A charge of 2 C moves past a given point every 0.5 s. How much is the current?

1–12 A charge of 1 C moves past a given point every 0.1 s. How much is the current?

1–13 A charge of 0.05 C moves past a given point every 0.1 s. How much is the current?

1–14 A charge of 6 C moves past a given point every 0.3 s. How much is the current?

1–15 A charge of 0.1 C moves past a given point every 0.01 s. How much is the current?

1–16 If a current of 1.5 A charges a dielectric for 5 s, how much charge is stored in the dielectric?

1–17 If a current of 500 mA charges a dielectric for 2 s, how much charge is stored in the dielectric?

1–18 If a current of 200 μA charges a dielectric for 20 s, how much charge is stored in the dielectric?

SECTION 1–7 RESISTANCE IS OPPOSITION TO CURRENT

1–19 Calculate the resistance value in ohms for the following conductance values: (a) 0.001 S (b) 0.01 S (c) 0.1 S (d) 1 S.

1–20 Calculate the resistance value in ohms for the following conductance values: (a) 0.002 S (b) 0.004 S (c) 0.00833 S (d) 0.25 S.

1–21 Calculate the conductance value in siemens for each of the following resistance values: (a) 200 Ω (b) 100 Ω (c) 50 Ω (d) 25 Ω.

1–22 Calculate the conductance value in siemens for each of the following resistance values: (a) 1 Ω (b) 10 kΩ (c) 40 Ω (d) 0.5 Ω.

Critical Thinking Problems for each chapter provide students with more challenging problems, allowing them to polish critical skills needed on the job.

Critical Thinking

1–23 Suppose that 1000 electrons are removed from a neutral dielectric. How much charge, in coulombs, is stored in the dielectric?

1–24 How long will it take an insulator that has a charge of +5 C to charge to +30 C if the charging current is 2 A?

1–25 Assume that 6.25×10^{15} electrons flow past a given point in a conductor every 10 s. Calculate the current *I* in amperes.

1–26 The conductance of a wire at 100°C is one-tenth its value at 25°C. If the wire resistance equals 10 Ω at 25°C calculate the resistance of the wire at 100°C.

Laboratory Application Assignment

In your first lab application assignment you will use a DMM to measure the voltage, current, and resistance in Fig. 1–22. Refer to Section 1–12, "The Digital Multimeter," if necessary.

Equipment: Obtain the following items from your instructor.

- Variable dc power supply
- 1-kΩ, ½-W resistor
- DMM
- Connecting leads

Measuring Voltage

Set the DMM to measure DC voltage. Be sure the meter leads are inserted into the correct jacks (red lead in the VΩ jack and the black lead in the COM jack). Also, be sure the voltmeter range exceeds the voltage being measured. Connect the DMM test leads to the variable DC power supply as shown in Fig. 1–22*a*. Adjust the variable DC power supply voltage to any value between 5 and 15 V. Record your measured voltage. $V =$ ____________ Note: Keep the power supply voltage set to this value when measuring the current in Fig. 1–22*c*.

Measuring Resistance

Disconnect the meter leads from the power supply terminals. Set the DMM to measure resistance. Keep the meter leads in the same jacks you used for measuring voltage. Connect the DMM test leads to the leads of the 1 kΩ resistor, as shown in Fig. 1–22*b*. Record your measured resistance.

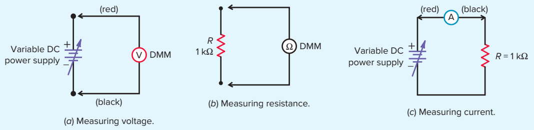
$R =$ ____________ (The measured resistance will most likely be displayed as a decimal fraction in kΩ.)

Measuring Current

Set the DMM to measure DC current. Also, move the red test lead to the appropriate jack for measuring small DC currents (usually labeled mA). Turn off the variable DC power supply. Connect the red test lead of the DMM to the positive (+) terminal of the variable DC power supply as shown in Fig. 1–22*c*. Also, connect the black test lead of the DMM to one lead of the 1 kΩ resistor as shown. Finally, connect the other lead of the resistor to the negative (−) terminal of the variable DC power supply. Turn on the variable DC power supply. Record your measured current.

$I =$ ____________

Figure 1–22 Measuring electrical quantities. (*a*) Measuring voltage. (*b*) Measuring resistance. (*c*) Measuring current.

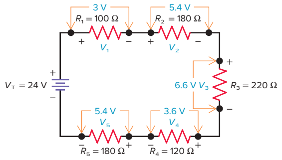


Laboratory Application Assignments, reinforce one or more of the chapter's main topics by asking students to build and test circuits in a laboratory environment.

Troubleshooting Challenge

Table 4–1 shows voltage measurements taken in Fig. 4–50. The first row shows the normal values that exist when the circuit is operating properly. Rows 2 to 15 are voltage measurements taken when one component in the circuit has failed. For each row, identify which component is defective and determine the type of defect that has occurred in the component.

Figure 4–50 Circuit diagram for Troubleshooting Challenge. Normal values for V_1, V_2, V_3, V_4, and V_5 are shown on schematic.



Troubleshooting Challenges appear in selected chapters to give students a feel for troubleshooting real circuits, again providing real-world applications of chapter content.

About the Author

Mitchel E. Schultz is an instructor at Western Technical College in La Crosse, Wisconsin, where he has taught electronics for the past 31 years. Prior to teaching at Western, he taught electronics for 8 years at Riverland Community College in Austin, Minnesota. He has also provided training for a variety of different electronic industries over the past 39 years.

Before he began teaching, Mitchel worked for several years as an electronic technician. His primary work experience was in the field of electronic communication, which included designing, testing, and troubleshooting rf communications systems. Mitchel graduated in 1978 from Minnesota State, Southeast Technical College, where he earned an Associate's Degree in Electronics Technology. He also attended Winona State University, Mankato State University, and the University of Minnesota. He is an ISCET Certified Electronics Technician and also holds his Extra Class Amateur Radio License.

Mitchel has authored and/or co-authored several other electronic textbooks which include Problems Manual for use with Grob's Basic Electronics, Electric Circuits: A Text and Software Problems Manual, Electronic Devices: A Text and Software Problems Manual, Basic Mathematics for Electricity and Electronics, *and* Shaum's Outline of Theory and Problems of Electronic Communication.

Electric Shock—Dangers, Precautions, and First Aid

Electricity is a form of energy that provides an endless number of useful functions in our daily lives. However, no matter how useful electricity may be, it can also be very dangerous. Perhaps the greatest danger is from an electric shock. If a person comes into contact with a "live" conductor or circuit, it only takes a small amount of current through the human body to paralyze the victim, making it impossible for him or her to let go. A current in excessive of about $\frac{1}{100}$ of an Ampere (A), which is the basic unit of current, is about all it takes. If the current approaches $\frac{1}{10}$ of an Ampere, or more, the shock can be fatal. The danger of electric shock increases with higher voltages because a higher voltage can produce more current through the skin and internal organs. Lower voltages, such as those associated with AA or AAA batteries, for example, can be handled with little or no danger because the resistance of human skin is normally high enough to keep the current well below the threshold of sensation. However, when a person's skin is moist or cut, the resistance to the flow of current decreases drastically. When this happens, even moderate voltages can produce an electric shock. Therefore, safe practices must always be followed when working in and around electric circuits to avoid accidental electric shock, fires, and explosions.

Guideline of Safe Practices

The following is a list of ***safe practices*** that will help protect you and your fellow classmates while performing experiments in the laboratory. These same rules apply to those individuals working in industry. It is a good idea to review these safe practices from time to time so that you are reminded of their importance.

1. Never work on electrical equipment and/or machinery if you are under the influence of either drugs or alcohol.
2. Never work on electrical equipment and/or machinery if the lighting is poor or insufficient.
3. Never work on electrical equipment and/or machinery if your shoes and/or clothing are wet.
4. Wear rubber-soled shoes or stand on an insulated mat when working on electrical equipment.
5. If possible, never work alone.
6. Avoid wearing any metal objects such as bracelets, rings, necklaces, etc., when working in and around electric circuits.
7. Never assume that the power applied to a circuit is off! Either unplug the equipment you are working on or use a known-good meter to check for power.
8. Measure voltages with one hand in your pocket or behind your back when possible.
9. Do not remove safety grounds on three-prong power plugs and never use AC adapters to defeat the ground connection on any electrical equipment.
10. Power cords should always be checked before use. If the insulation is cracked or cut, they should not be used until they are properly repaired.