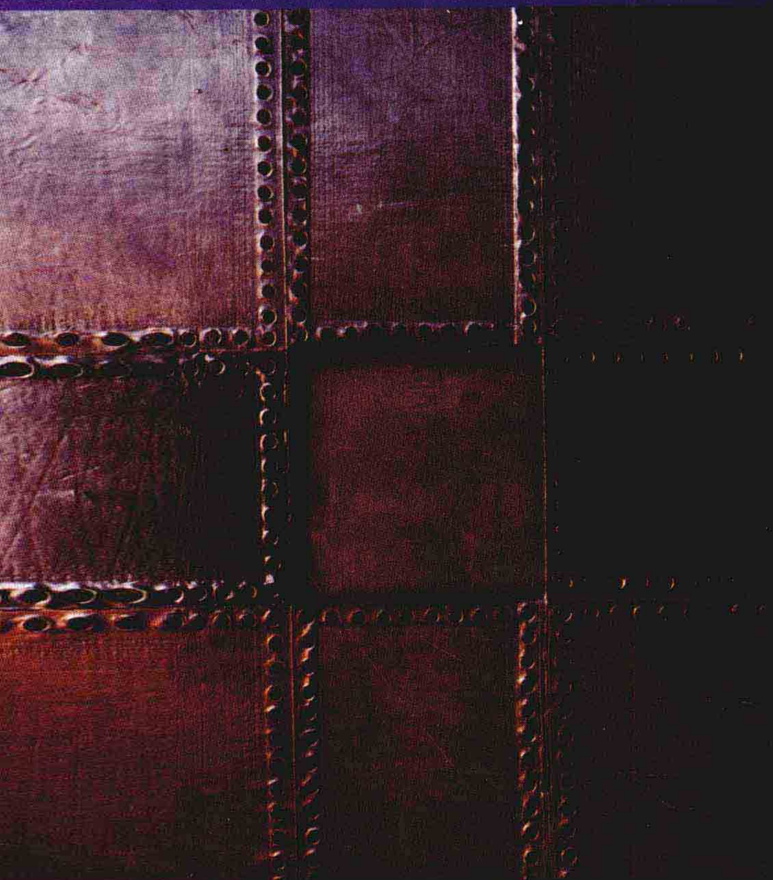

INTRODUCTORY DC/AC ELECTRONICS

FOURTH EDITION

NIGEL P. COOK

Introductory
DC/AC Electronics
Fourth Edition

Nigel P. Cook

PRENTICE HALL
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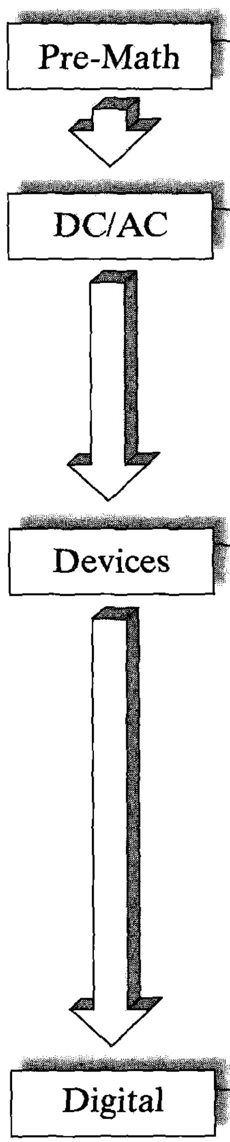
To Dawn, Candy, and Jon

Titles by Nigel P. Cook



Introductory Mathematics, 2/e
7 Math Chapters

Practical Electricity
15 DC/AC Chapters

Introductory DC/AC Circuits, 4/e
17 DC/AC Chapters

Introductory DC/AC Electronics, 4/e
17 DC/AC Chapters, 6 Devices Chapters

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For more information on any of the other textbooks by Nigel Cook, see his web page at: www.prenhall.com/cook or ask your local Prentice Hall representative.

Preface

TO THE STUDENT

The early pioneers in electronics were intrigued by the mystery and wonder of a newly discovered science, whereas people today are attracted by its ability to lend its hand to any application and accomplish almost anything imaginable. If you analyze exactly how you feel at this stage, you will probably discover that you have mixed emotions about the journey ahead. On one hand, imagination, curiosity, and excitement are driving you on, while apprehension and reservations may be slowing you down. Your enthusiasm will overcome any indecision you have once you become actively involved in electronics and realize that it is as exciting as you ever expected it to be.

ORGANIZATION OF THE TEXTBOOK

This textbook has been divided into four basic parts. Chapters 1 through 5 introduce you to the world of electronics and the fundamentals of electricity. Chapters 6 through 9 cover direct current, or DC, circuits; Chapters 10 through 17 cover alternating current, or AC, circuits; and Chapters 18 through 23 cover semiconductor principles, devices, and circuits.

PART I The Fundamentals of Electricity

- Chapter 1 The World of Electronics
- Chapter 2 Voltage and Current
- Chapter 3 Resistance and Power
- Chapter 4 Resistors
- Chapter 5 Experimenting in the Lab

PART II Direct-Current Electronics

- Chapter 6 Direct Current (DC)
- Chapter 7 Series DC Circuits
- Chapter 8 Parallel DC Circuits
- Chapter 9 Series–Parallel DC Circuits

PART III Alternating-Current Electronics

- Chapter 10 Alternating Current (AC)

Chapter 11 Experimenting in the Lab with AC
Chapter 12 Capacitance and Capacitors
Chapter 13 Capacitive Circuits, Testing, and Applications
Chapter 14 Electromagnetism and Electromagnetic Induction
Chapter 15 Inductance and Inductors
Chapter 16 Transformers
Chapter 17 Resistive, Inductive, and Capacitive (*RLC*) Circuits

PART IV Semiconductor Devices and Circuits
Chapter 18 Semiconductor Principles
Chapter 19 Junction Diodes
Chapter 20 Diode Power Supply Circuits
Chapter 21 Bipolar Junction Transistors (BJTs)
Chapter 22 Field Effect Transistors (FETs)
Chapter 23 Operational Amplifiers

The material covered in this book has been logically divided and sequenced to provide a gradual progression from the known to the unknown, and from the simple to the complex.

DEVELOPMENT, CLASS TESTING, AND REVIEWING

The first phase of development for this manuscript was conducted in the classroom with students and instructors as critics. Each topic was class-tested by videotaping each lesson, and the results were then evaluated and implemented. This invaluable feedback enabled me to fine-tune my presentation of topics and instill understanding and confidence in the students.

The second phase of development was to forward a copy of the revised manuscript to several instructors at schools throughout the country. Their technical and topical critiques helped to mold the text into a more accurate form.

The third and final phase was to class-test the final revised manuscript and then commission the last technical review in the final stages of production.

CIRCUIT SIMULATION USING THE ELECTRONICS WORKBENCH® CD-ROM

In the back of this book is a CD-ROM containing the circuit simulation software *Electronics Workbench® (EWB)*. Using the demo on this CD, you can simulate fifteen circuits taken directly from this text. The EWB icon shown here in the margin indicates which circuits in this text have been prebuilt and stored on the CD ready for simulation.

In addition to the EWB demo, the CD also contains an EWB tutorial, a complete locked version of EWB student version 5, and a circuit-set file containing over 150 circuits from Cook's dc/ac, devices, and digital texts.

ANCILLARIES ACCOMPANYING THIS TEXT

- A comprehensive **lab manual,** co-authored by Nigel Cook and Gary Lancaster, contains numerous experiments that are designed to translate all of the textbook's theory into practical experimentation.
- A **CD-ROM** is included in the back of this text containing a fully functional **Electronics Workbench® demo** and an **EWB tutorial.**
- An **Electronics Workbench® circuits file** is also included on the CD-ROM in the back of this book. This file contains many of this text's circuits pre-built and ready for simulation.
- An **MS PowerPoint® data disk** containing text figures can be used for overhead projection in the classroom.
- A **test item file manual** includes additional questions for tests and examinations. These questions are also available on a **test item file disk** that will operate with the Prentice Hall custom test generator.
- An **instructor's solutions manual** includes the full worked-out answers to all self-test review and end-of-chapter questions.
- A **companion www site** located at http://www.prenhall.com/cook that includes numerous interactive study questions designed to reinforce the concepts of the book.

ACKNOWLEDGMENTS

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Secondly, a special thank you goes to my marketing director, Debbie Yarnell, for her special efforts with all my books, and my production editors Martha Beyerlein and Rex Davidson.

My appreciation and thanks are extended also to the following instructors who have reviewed and contributed greatly to the development of this textbook: Wade Jung, ITT Technical Institute; Joe Gryniuk, Jr., Lake Washington Technical College; Dr. Lee Rosenthal, Fairleigh Dickinson University; James W. Roberts, West Georgia Tech.; Dr. Robert Powell, Oakland Community College; Dr. Michael Chier, Milwaukee School of Engineering; Dr. Mauro Caputi, Hofstra University; Tony Hearn, Community College of Philadelphia; Doug Fuller, Humber College.

Nigel P. Cook

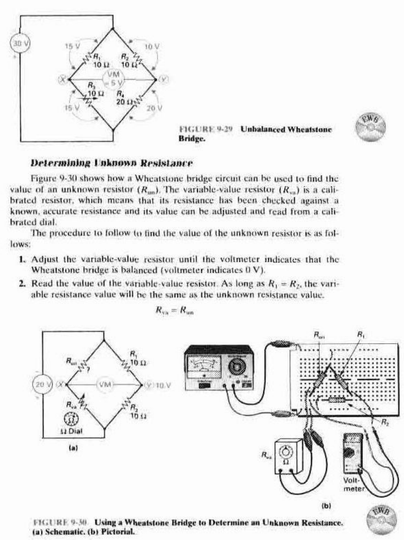


FIGURE 9-29 **Unbalanced Wheatstone Bridge.**

Determining Unknown Resistance

Figure 9-30 shows how a Wheatstone bridge circuit can be used to find the value of an unknown resistor (R_{un}). The variable-value resistor (R_{va}) is a calibrated resistor, which means that its resistance has been checked against a known, accurate resistance and its value can be adjusted and read from a calibrated dial.

The procedure to follow to find the value of the unknown resistor is as follows:

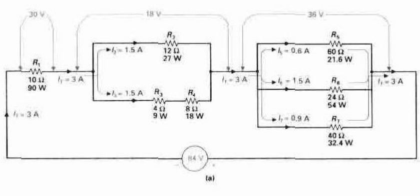
1. Adjust the variable-value resistor until the voltmeter indicates that the Wheatstone bridge is balanced (voltmeter indicates 0 V).
2. Read the value of the variable-value resistor. As long as $R_1 = R_2$, the variable resistance value will be the same as the unknown resistance value.

$$R_{va} = R_{un}$$

FIGURE 9-30 **Using a Wheatstone Bridge to Determine an Unknown Resistance. (a) Schematic. (b) Pictorial.**

SEC. 9-7 / SERIES-PARALLEL CIRCUITS 333

The CD-ROM in the back of this text contains the circuit simulation software *Electronics Workbench*®. Circuit simulation icons have been included in the margin to indicate which of the text's circuits have been prebuilt and included on the CD for simulation.



CIRCUIT ANALYSIS TABLE

Resistance $R = V/I$	Voltage $V = I \times R$	Current $I = V/R$	Power $P = V \times I$
$R_1 = 10\ \Omega$	$V = 30$ V	$I_1 = 3$ A	$P_1 = 90$ W
$R_2 = 12\ \Omega$	$V = 18$ V	$I_2 = 1.5$ A	$P_2 = 27$ W
$R_3 = 4\ \Omega$	$V = 6$ V	$I_3 = 1.5$ A	$P_3 = 9$ W
$R_4 = 8\ \Omega$	$V = 12$ V	$I_4 = 1.5$ A	$P_4 = 18$ W
$R_5 = 60\ \Omega$	$V = 36$ V	$I_5 = 0.6$ A	$P_5 = 21.6$ W
$R_6 = 24\ \Omega$	$V = 36$ V	$I_6 = 1.5$ A	$P_6 = 54$ W
$R_7 = 40\ \Omega$	$V = 36$ V	$I_7 = 0.9$ A	$P_7 = 32.4$ W
$R_T = 28\ \Omega$	$V_T = V_S = 84$ V	$I_T = 3$ A	$P_T = 252$ W

(b)

FIGURE 9-18 **Series–Parallel Circuit Example with All Information Inserted. (a) Schematic. (b) Circuit Analysis Table.**

Solving for Resistance, Voltage, Current, and Power in a Series–Parallel Circuit

STEP 1 Determine the circuit's total resistance.

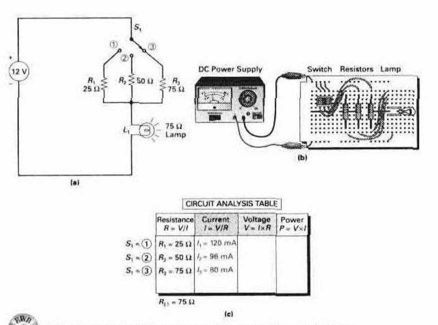
Step A Solve for series-connected resistors in all parallel combinations.

Step B Solve for all parallel combinations.

Step C Solve for remaining series resistances.

324 CHAPTER 9 / SERIES-PARALLEL DC CIRCUITS

Circuit analysis tables train the student to collect circuit facts in an easy-to-read table that enables the student to clearly see total and individual current, voltage, resistance, and power values and relationships.



CIRCUIT ANALYSIS TABLE

	Resistance $R = V/I$	Current $I = V/R$	Voltage $V = I \times R$	Power $P = V \times I$
S_1 = ①	$R_1 = 25\ \Omega$	$I_1 = 120$ mA		
S_1 = ②	$R_2 = 50\ \Omega$	$I_2 = 96$ mA		
S_1 = ③	$R_3 = 75\ \Omega$	$I_3 = 80$ mA		

$R_{L1} = 75\ \Omega$

(c)

FIGURE 7-8 **Three-Position Switch Controlling Lamp Brightness. (a) Schematic (b) Protoboard Circuit (c) Circuit Analysis Table.**

Position 2: $R_T = R_2 + R_{lamp} = 50\ \Omega + 75\ \Omega = 125\ \Omega$

$$I_T = \frac{V_T}{R_T} = \frac{12\ \text{V}}{125\ \Omega} = 96\ \text{mA}$$

Position 3: $R_T = R_3 + R_{lamp} = 75\ \Omega + 75\ \Omega = 150\ \Omega$

$$I_T = \frac{V_T}{R_T} = \frac{12\ \text{V}}{150\ \Omega} = 80\ \text{mA}$$

The details of this circuit are summarized in the analysis table shown in Figure 7-8(c).

SELF-TEST REVIEW QUESTIONS FOR SECTION 7-3

1. State the total resistance formula for a series circuit.
2. Calculate R_T if $R_1 = 2\ \text{k}\Omega$, $R_2 = 3\ \text{k}\Omega$, and $R_3 = 4700\ \Omega$.

238 CHAPTER 7 / SERIES DC CIRCUITS

Protoboard pictorials help the beginning student make the transition from circuit schematic on paper to constructed circuit on a protoboard.

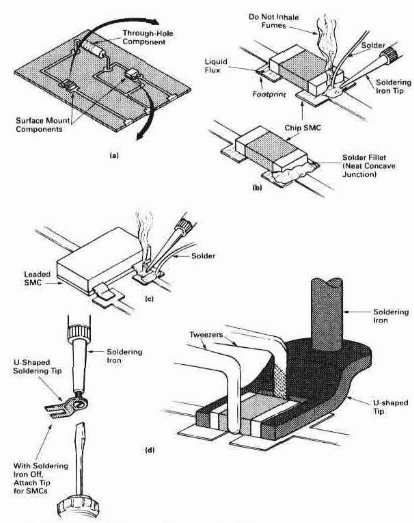
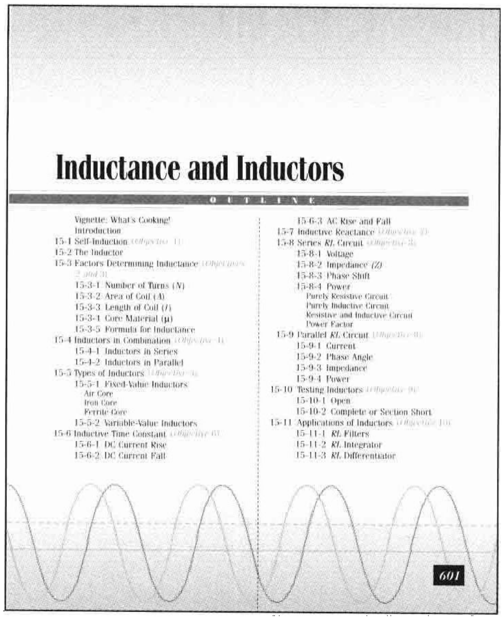


FIGURE 5-28 **Soldering Surface Mount Components (SMCs).**

SEC. 5-4 / SOLDERING TOOLS AND TECHNIQUES 187

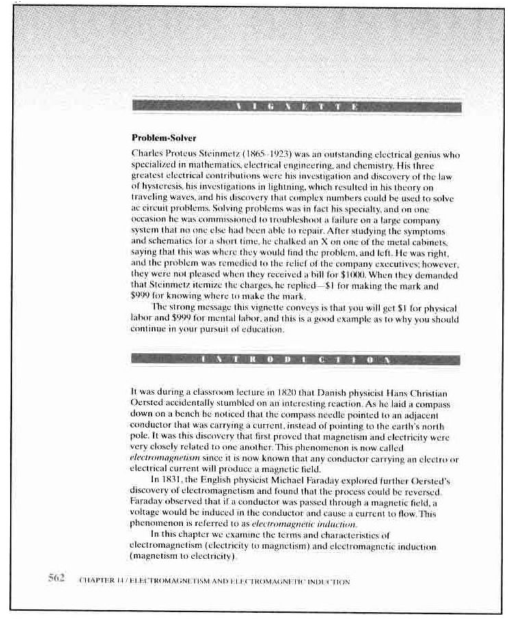
New technology topics have been added, such as how to solder and desolder surface mount components (SMCs).


Inductance and Inductors

OUTLINE

601

Each chapter opening lists performance-based objectives, with each objective directly correlated to a chapter section on the following page.


VIGNETTE

Problem-Solver

Charles Proteus Steinmetz (1865–1923) was an outstanding electrical genius who specialized in mathematics, electrical engineering, and chemistry. His three greatest electrical contributions were his investigation and discovery of the law of hysteresis, his investigations in lightning, which resulted in his theory on traveling waves, and his discovery that complex numbers could be used to solve ac circuit problems. Solving problems was in fact his specialty, and on one occasion he was commissioned to troubleshoot a failure on a large company system that no one else had been able to repair. After studying the symptoms and schematics for a short time, he chalked an X on one of the metal cabinets, saying that this was where they would find the problem, and left. He was right, and the problem was remedied to the relief of the company executives; however, they were not pleased when they received a bill for $1000. When they demanded that Steinmetz itemize the charges, he replied—$1 for making the mark and $999 for knowing where to make the mark.

The strong message this vignette conveys is that you will get $1 for physical labor and $999 for mental labor, and this is a good example as to why you should continue in your pursuit of education.

INTRODUCTION

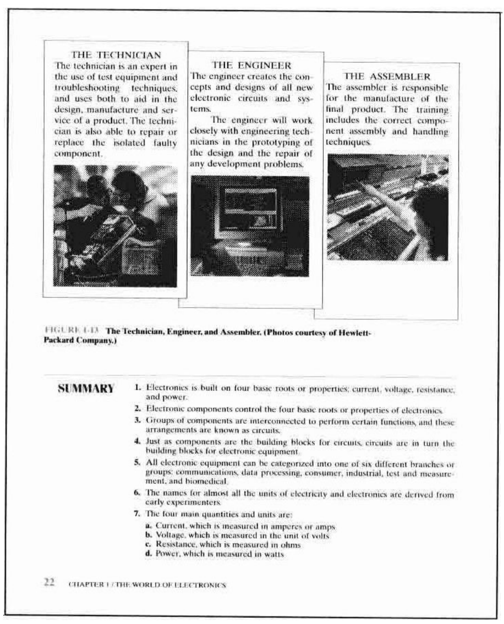
It was during a classroom lecture in 1820 that Danish physicist Hans Christian Oersted accidentally stumbled on an interesting reaction. As he laid a compass down on a bench he noticed that the compass needle pointed to an adjacent conductor that was carrying a current, instead of pointing to the earth's north pole. It was this discovery that first proved that magnetism and electricity were very closely related to one another. This phenomenon is now called *electromagnetism* since it is now known that any conductor carrying an electric or electrical current will produce a magnetic field.

In 1831, the English physicist Michael Faraday explored further Oersted's discovery of electromagnetism and found that the process could be reversed. Faraday observed that if a conductor was passed through a magnetic field, a voltage would be induced in the conductor and cause a current to flow. This phenomenon is referred to as *electromagnetic induction*.

In this chapter we examine the terms and characteristics of electromagnetism (electricity to magnetism) and electromagnetic induction (magnetism to electricity).

562 CHAPTER 11 / ELECTROMAGNETISM AND ELECTROMAGNETIC INDUCTION

Motivational stories detail the people behind the electronics industry, and a conversational introduction reviews what has been previously covered and what is about to be covered.


THE TECHNICIAN
The technician is an expert in the use of test equipment and troubleshooting techniques, and uses both to aid in the design, manufacture and service of a product. The technician is also able to repair or replace the isolated faulty component.

THE ENGINEER
The engineer creates the concepts and designs of all new electronic circuits and systems.
The engineer will work closely with engineering technicians in the prototyping of the design and the repair of any development problems.

THE ASSEMBLER
The assembler is responsible for the manufacture of the final product. The training includes the correct component assembly and handling techniques.

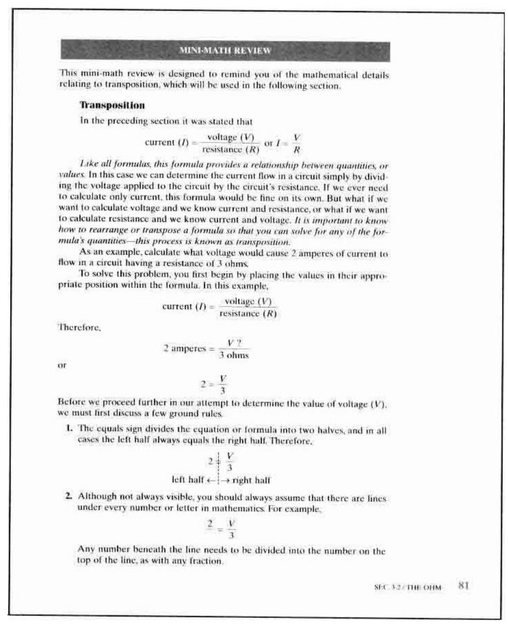
FIGURE 1-13 The Technician, Engineer, and Assembler. (Photos courtesy of Hewlett-Packard Company.)

SUMMARY

1. Electronics is built on four basic roots or properties: current, voltage, resistance, and power.
2. Electronic components control the four basic roots or properties of electronics.
3. Groups of components are interconnected to perform certain functions, and these arrangements are known as circuits.
4. Just as components are the building blocks for circuits, circuits are in turn the building blocks for electronic equipment.
5. All electronic equipment can be categorized into one of six different branches or groups: communications, data processing, consumer, industrial, test and measurement, and biomedical.
6. The names for almost all the units of electricity and electronics are derived from early experimenters.
7. The four main quantities and units are:
   a. Current, which is measured in amperes or amps
   b. Voltage, which is measured in the unit of volts
   c. Resistance, which is measured in ohms
   d. Power, which is measured in watts

22 CHAPTER 1 / THE WORLD OF ELECTRONICS

Chapter 1 includes extensive information about the world of electronics and career opportunities for the electronics technician, providing interest in and motivation for the material which follows.


MINI-MATH REVIEW

This mini-math review is designed to remind you of the mathematical details relating to transposition, which will be used in the following section.

Transposition

In the preceding section it was stated that

$$\text{current } (I) = \frac{\text{voltage } (V)}{\text{resistance } (R)} \quad \text{or} \quad I = \frac{V}{R}$$

Like all formulas, this formula provides a relationship between quantities, or values. In this case we can determine the current flow in a circuit simply by dividing the voltage applied to the circuit by the circuit's resistance. If we ever need to calculate only current, this formula would be fine on its own. But what if we want to calculate voltage and we know current and resistance, or what if we want to calculate resistance and we know current and voltage. *It is important to know how to rearrange or transpose a formula so that you can solve for any of the formula's quantities—this process is known as transposition.*

As an example, calculate what voltage would cause 2 amperes of current to flow in a circuit having a resistance of 3 ohms.

To solve this problem, you first begin by placing the values in their appropriate position within the formula. In this example,

$$\text{current } (I) = \frac{\text{voltage } (V)}{\text{resistance } (R)}$$

Therefore,

$$2 \text{ amperes} = \frac{V\,?}{3 \text{ ohms}}$$

or

$$2 = \frac{V}{3}$$

Before we proceed further in our attempt to determine the value of voltage (V), we must first discuss a few ground rules.

1. The equals sign divides the equation or formula into two halves, and in all cases the left half always equals the right half. Therefore,

$$2 = \frac{V}{3}$$

left half ← → right half

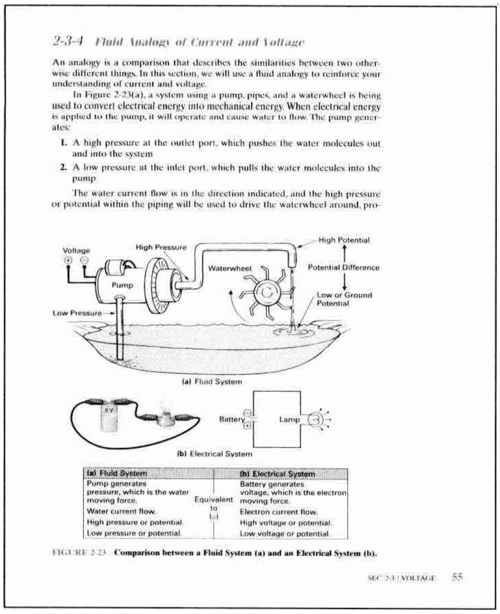
2. Although not always visible, you should always assume that there are lines under every number or letter in mathematics. For example,

$$\frac{2}{1} = \frac{V}{3}$$

Any number beneath the line needs to be divided into the number on the top of the line, as with any fraction.

SEC. 3-2 / THE OHM 81

Mini-Math Reviews are included in appropriate places to review the necessary mathematics needed for the discussion at hand.



2-3-4 *Fluid Analogy of Current and Voltage*

An analogy is a comparison that describes the similarities between two otherwise different things. In this section, we will use a fluid analogy to reinforce your understanding of current and voltage.

In Figure 2-23(a), a system using a pump, pipes, and a waterwheel is being used to convert electrical energy into mechanical energy. When electrical energy is applied to the pump, it will operate and cause water to flow. The pump generates:

1. A high pressure at the outlet port, which pushes the water molecules out and into the system
2. A low pressure at the inlet port, which pulls the water molecules into the pump

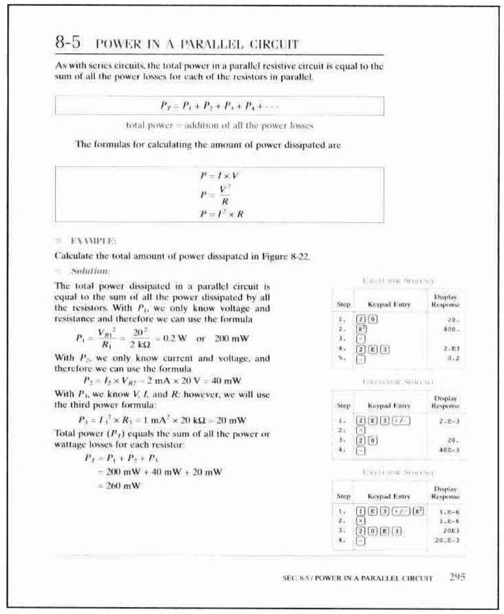
The water current flow is in the direction indicated, and the high pressure or potential within the piping will be used to drive the waterwheel around, pro-

(a) Fluid System		(b) Electrical System
Pump generates pressure, which is the water moving force.	Equivalent to (≡)	Battery generates voltage, which is the electron moving force.
Water current flow.		Electron current flow.
High pressure or potential.		High voltage or potential.
Low pressure or potential.		Low voltage or potential.

FIGURE 2-23 **Comparison between a Fluid System (a) and an Electrical System (b).**

SEC 2-3 / VOLTAGE 55

Concept analogies are used throughout the text to take the student from the known to the unknown.



8-5 POWER IN A PARALLEL CIRCUIT

As with series circuits, the total power in a parallel resistive circuit is equal to the sum of all the power losses for each of the resistors in parallel.

$$P_T = P_1 + P_2 + P_3 + P_4 + \cdots$$

total power = addition of all the power losses

The formulas for calculating the amount of power dissipated are

$$P = I \times V \qquad P = \frac{V^2}{R} \qquad P = I^2 \times R$$

EXAMPLE:

Calculate the total amount of power dissipated in Figure 8-22.

Solution:

The total power dissipated in a parallel circuit is equal to the sum of all the power dissipated by all the resistors. With P_1, we only know voltage and resistance and therefore we can use the formula

$$P_1 = \frac{V_{R1}^2}{R_1} = \frac{20^2}{2\ k\Omega} = 0.2\ W \quad \text{or} \quad 200\ mW$$

With P_2, we only know current and voltage, and therefore we can use the formula

$$P_2 = I_2 \times V_{R2} = 2\ mA \times 20\ V = 40\ mW$$

With P_3, we know V, I, and R; however, we will use the third power formula:

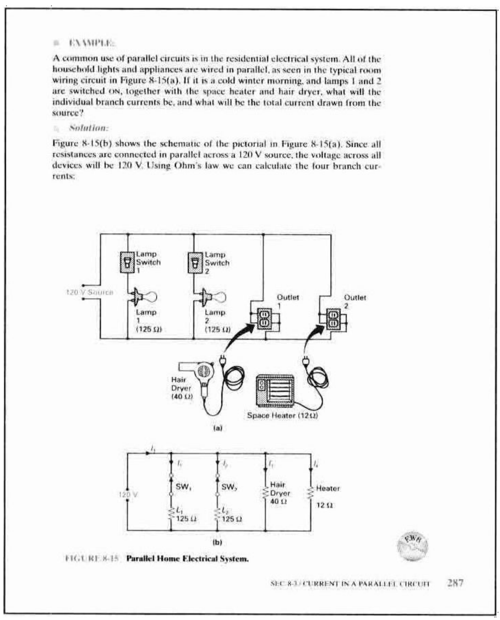
$$P_3 = I_3^2 \times R_3 = 1\ mA^2 \times 20\ k\Omega = 20\ mW$$

Total power (P_T) equals the sum of all the power or wattage losses for each resistor:

$$P_T = P_1 + P_2 + P_3 = 200\ mW + 40\ mW + 20\ mW = 260\ mW$$

SEC 8-5 / POWER IN A PARALLEL CIRCUIT 295

Calculator sequences are included in all examples that introduce new mathematical procedures, and a running glossary defines all new terms in the margin of the text.



EXAMPLE:

A common use of parallel circuits is in the residential electrical system. All of the household lights and appliances are wired in parallel, as seen in the typical room wiring circuit in Figure 8-15(a). If it is a cold winter morning, and lamps 1 and 2 are switched ON, together with the space heater and hair dryer, what will the individual branch currents be, and what will be the total current drawn from the source?

Solution:

Figure 8-15(b) shows the schematic of the pictorial in Figure 8-15(a). Since all resistances are connected in parallel across a 120 V source, the voltage across all devices will be 120 V. Using Ohm's law we can calculate the four branch currents:

FIGURE 8-15 **Parallel Home Electrical System.**

SEC 8-3 / CURRENT IN A PARALLEL CIRCUIT 287

Actual circuit examples are included to help the student connect a topic to the real world.

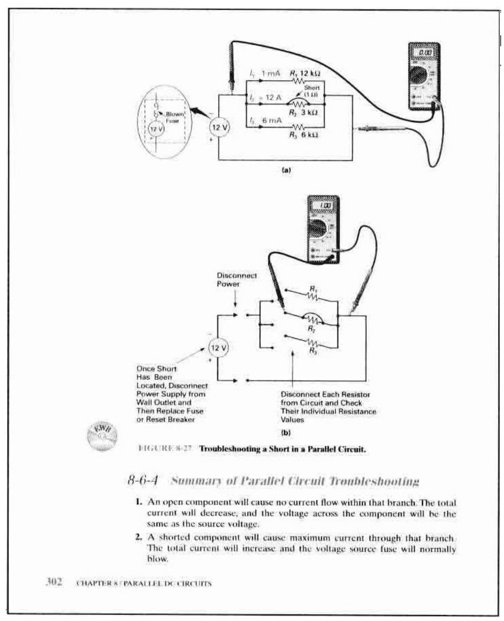


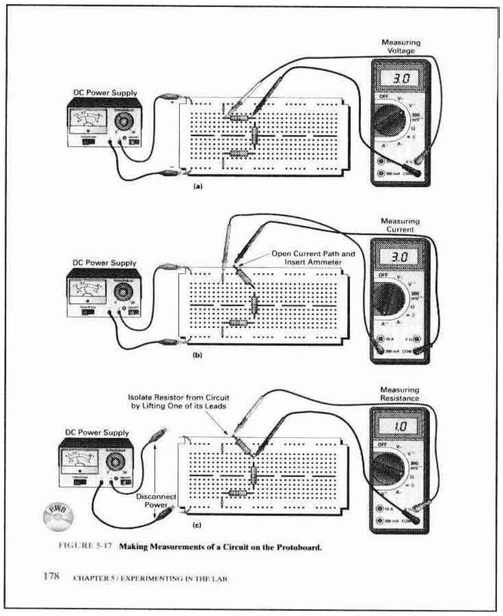
FIGURE 8-27 **Troubleshooting a Short in a Parallel Circuit.**

8-6-4 *Summary of Parallel Circuit Troubleshooting*

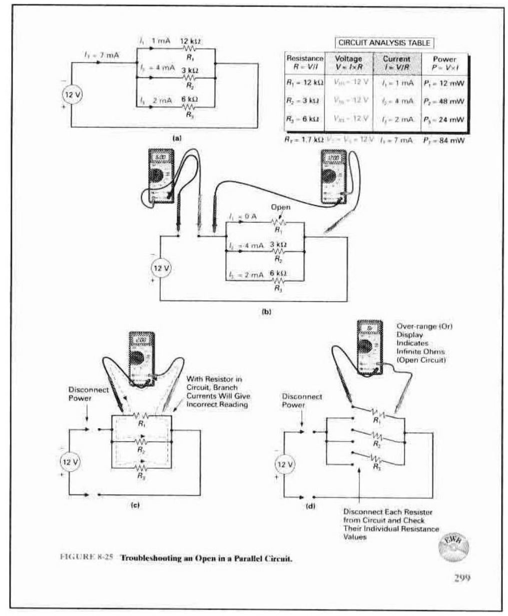
1. An open component will cause no current flow within that branch. The total current will decrease, and the voltage across the component will be the same as the source voltage.
2. A shorted component will cause maximum current through that branch. The total current will increase and the voltage source fuse will normally blow.

302 CHAPTER 8 / PARALLEL DC CIRCUITS

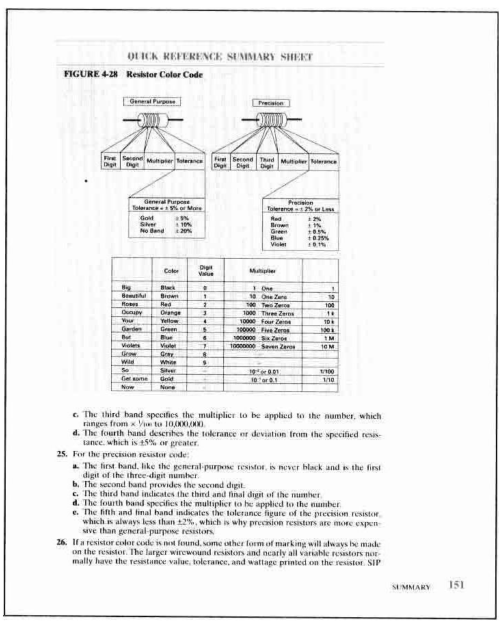
A strong testing, test equipment, and troubleshooting emphasis prepares the student for the working world.



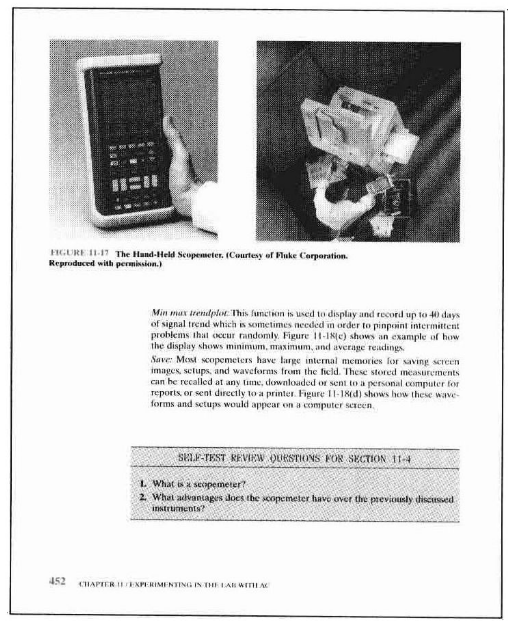
Chapter 5 introduces the student to experimenting in the lab by covering safety, test equipment, protoboards, and soldering tools and techniques.



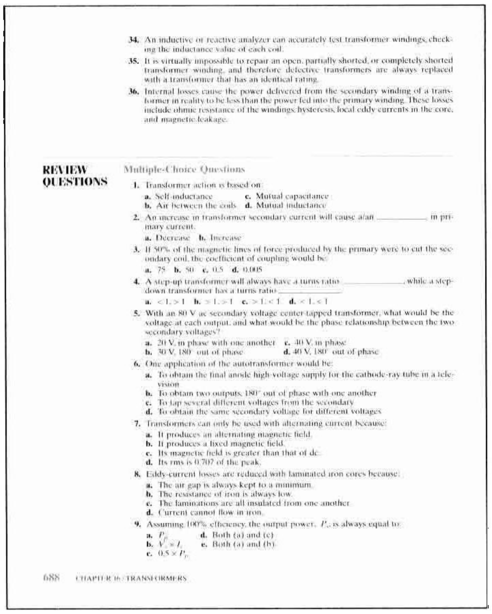
Unique diagrams and tables, coupled with the textbook's conversational writing style, make even traditionally difficult topics easily accessible.



Quick Reference Summary Sheets within the end-of-chapter summary provide a visual reference to all key facts, symbols, circuits, and formulas.



Many new photos have been included to help student recognition.


34. An inductive or reactive analyzer can accurately test transformer windings, checking the inductance value of each coil.

35. It is virtually impossible to repair an open, partially shorted, or completely shorted transformer winding, and therefore defective transformers are always replaced with a transformer that has an identical rating.

36. Internal losses cause the power delivered from the secondary winding of a transformer in reality to be less than the power fed into the primary winding. These losses include ohmic resistance of the windings, hysteresis, local eddy currents in the core, and magnetic leakage.

REVIEW QUESTIONS

Multiple-Choice Questions

1. Transformer action is based on:
   a. Self-inductance c. Mutual capacitance
   b. Air between the coils d. Mutual inductance
2. An increase in transformer secondary current will cause a/an ________ in primary current.
   a. Decrease b. Increase
3. If 50% of the magnetic lines of force produced by the primary were to cut the secondary coil, the coefficient of coupling would be:
   a. 75 b. 50 c. 0.5 d. 0.005
4. A step-up transformer will always have a turns ratio ________, while a step-down transformer has a turns ratio ________.
   a. < 1, > 1 b. > 1, > 1 c. > 1, < 1 d. < 1, < 1
5. With an 80 V ac secondary voltage center-tapped transformer, what would be the voltage at each output, and what would be the phase relationship between the two secondary voltages?
   a. 20 V, in phase with one another c. 40 V, in phase
   b. 30 V, 180° out of phase d. 40 V, 180° out of phase
6. One application of the autotransformer would be:
   a. To obtain the final anode high-voltage supply for the cathode-ray tube in a television
   b. To obtain two outputs, 180° out of phase with one another
   c. To tap several different voltages from the secondary
   d. To obtain the same secondary voltage for different voltages
7. Transformers can only be used with alternating current because:
   a. It produces an alternating magnetic field.
   b. It produces a fixed magnetic field.
   c. Its magnetic field is greater than that of dc.
   d. Its rms is 0.707 of the peak.
8. Eddy-current losses are reduced with laminated iron cores because:
   a. The air gap is always kept to a minimum.
   b. The resistance of iron is always low.
   c. The laminations are all insulated from one another.
   d. Current cannot flow in iron.
9. Assuming 100% efficiency, the output power, P_s, is always equal to:
   a. P_p d. Both (a) and (c)
   b. $V_s \times I_s$ e. Both (a) and (b)
   c. $0.5 \times P_p$

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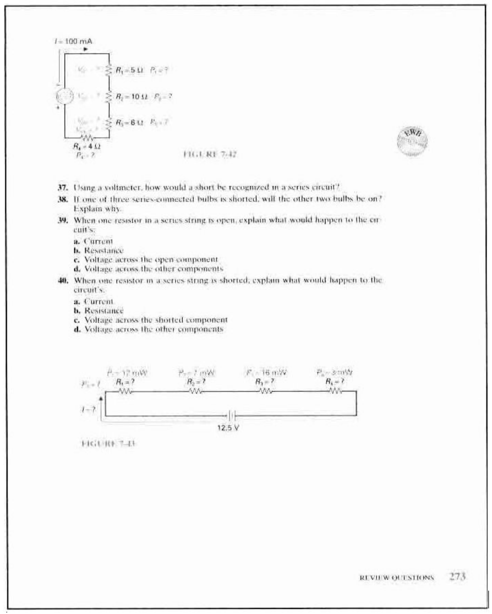


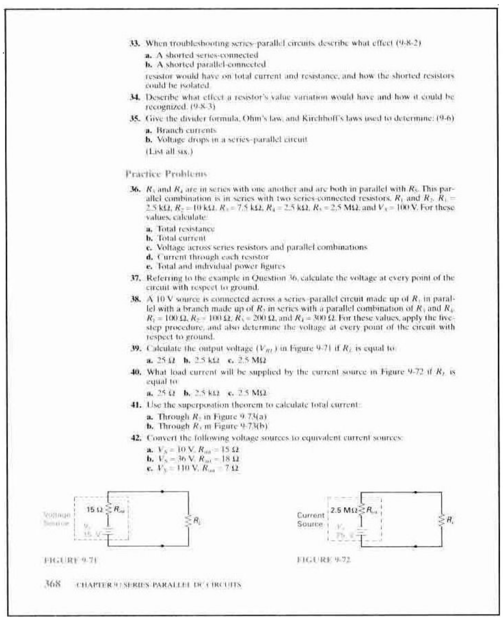
FIGURE 7-42

37. Using a voltmeter, how would a short be recognized in a series circuit?
38. If one of three series-connected bulbs is shorted, will the other two bulbs be on? Explain why.
39. When one resistor in a series string is open, explain what would happen to the circuit's:
   a. Current
   b. Resistance
   c. Voltage across the open component
   d. Voltage across the other components
40. When one resistor in a series string is shorted, explain what would happen to the circuit's:
   a. Current
   b. Resistance
   c. Voltage across the shorted component
   d. Voltage across the other components

FIGURE 7-43

REVIEW QUESTIONS 273

An extensive end-of-chapter test bank tests the student's understanding with multiple-choice questions, essay questions, practice problems, and troubleshooting questions.


33. When troubleshooting series-parallel circuits describe what effect (9-8-2)
   a. A shorted series-connected
   b. A shorted parallel-connected
   resistor would have on total current and resistance, and how the shorted resistors could be isolated.
34. Describe what effect a resistor's value variation would have and how it could be recognized. (9-8-3)
35. Give the divider formula, Ohm's law, and Kirchhoff's laws used to determine: (9-6)
   a. Branch currents
   b. Voltage drops in a series-parallel circuit
   (List all six.)

Practice Problems

36. R_3 and R_4 are in series with one another and are both in parallel with R_5. This parallel combination is in series with two series-connected resistors, R_1 and R_2. R_1 = 2.5 kΩ, R_2 = 10 kΩ, R_3 = 7.5 kΩ, R_4 = 2.5 kΩ, R_5 = 2.5 MΩ, and V_S = 100 V. For these values, calculate:
   a. Total resistance
   b. Total current
   c. Voltage across series resistors and parallel combinations
   d. Current through each resistor
   e. Total and individual power figures
37. Referring to the example in Question 36, calculate the voltage at every point of the circuit with respect to ground.
38. A 10 V source is connected across a series-parallel circuit made up of R_1 in parallel with a branch made up of R_2 in series with a parallel combination of R_3 and R_4. R_1 = 100 Ω, R_2 = 100 Ω, R_3 = 200 Ω, and R_4 = 300 Ω. For these values, apply the five-step procedure, and also determine the voltage at every point of the circuit with respect to ground.
39. Calculate the output voltage (V_{RL}) in Figure 9-71 if R_L is equal to:
   a. 25 Ω b. 2.5 kΩ c. 2.5 MΩ
40. What load current will be supplied by the current source in Figure 9-72 if R_L is equal to:
   a. 25 Ω b. 2.5 kΩ c. 2.5 MΩ
41. Use the superposition theorem to calculate total current:
   a. Through R_2 in Figure 9-73(a)
   b. Through R_3 in Figure 9-73(b)
42. Convert the following voltage sources to equivalent current sources:
   a. V_S = 10 V, R_{int} = 15 Ω
   b. V_S = 36 V, R_{int} = 18 Ω
   c. V_S = 110 V, R_{int} = 7 Ω

FIGURE 9-71 FIGURE 9-72

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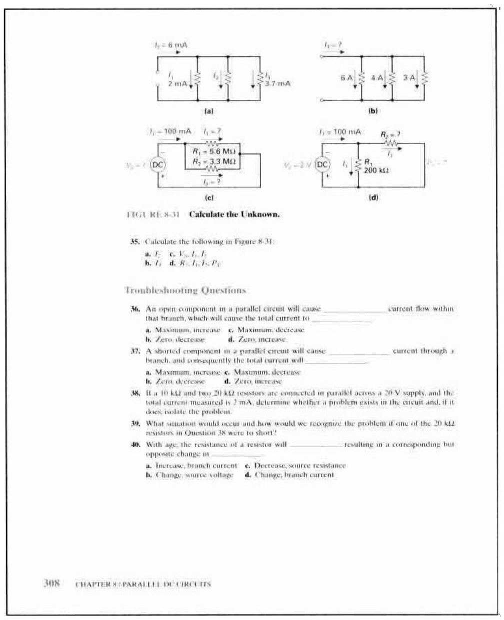

FIGURE 8-31 **Calculate the Unknown.**

35. Calculate the following in Figure 8-31:
   a. I_2 c. V_S, I_1, I_2
   b. I_T d. R_2, I_1, I_2, P_T

Troubleshooting Questions

36. An open component in a parallel circuit will cause ________ current flow within that branch, which will cause the total current to ________.
   a. Maximum, increase c. Maximum, decrease
   b. Zero, decrease d. Zero, increase
37. A shorted component in a parallel circuit will cause ________ current through a branch, and consequently the total current will ________.
   a. Maximum, increase c. Maximum, decrease
   b. Zero, decrease d. Zero, increase
38. If a 10 kΩ and two 20 kΩ resistors are connected in parallel across a 20 V supply, and the total current measured is 2 mA, determine whether a problem exists in the circuit and, if it does, isolate the problem.
39. What situation would occur and how would we recognize the problem if one of the 20 kΩ resistors in Question 38 were to short?
40. With age, the resistance of a resistor will ________ resulting in a corresponding but opposite change in ________.
   a. Increase, branch current c. Decrease, source resistance
   b. Change, source voltage d. Change, branch current

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